ANNUAL REPORT

IISc 2020-2021

INDIAN INSTITUTE OF SCIENCE

VISITOR
The President of India

PRESIDENT OF THE COURT
N Chandrasekaran

CHAIRMAN OF THE COUNCIL
A S Kiran Kumar

DIRECTOR
G Rangarajan

DEANS
SCIENCE: A G Samuelson
ENGINEERING: Y N Srikant
UG PROGRAMME: Balaji Jagirdar

REGISTRAR
Capt. Sridhar Warrier (Retd.)

IISc ranked India's Top University

In 2016, 2017, and before 2018 IISc was ranked No.1 among universities by the National Institutional Ranking Framework (NIRF) under the auspices of the Ministry of Human Resource Development. Again in 2020 IISc was ranked No.1 among universities and second in the overall category by NIRF. This year IISc ranked fourth under the category of Government funded institutions by Atal Ranking of Institutions on Innovation Achievements (ARIIA).

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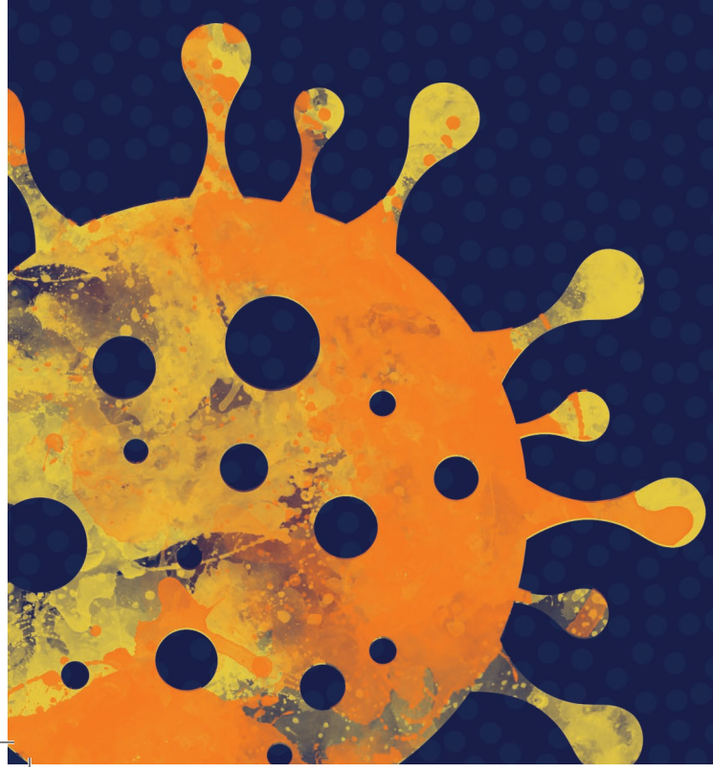
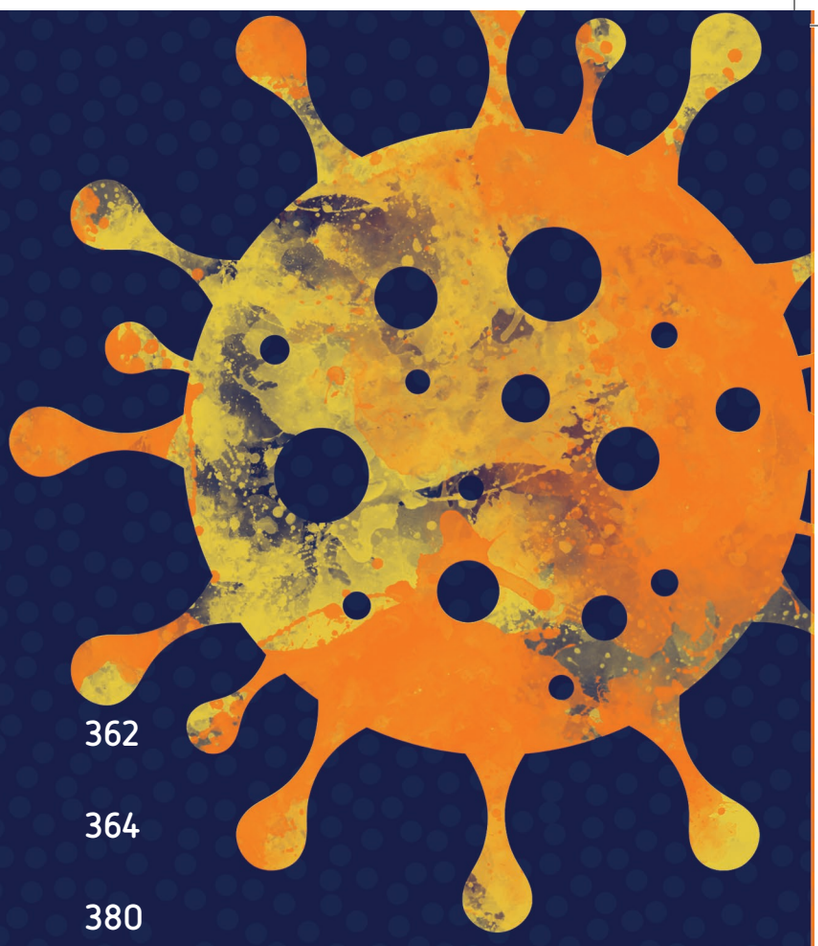




Foreword

I am honoured to present the 2020-21 Annual Report of the Indian Institute of Science (IISc).

In May 2020, IISc completed 111 years of existence. Over the last century, the Institute has established itself firmly as India's premier destination for original research and higher education in science and engineering. In keeping with its mandate to "provide for advanced instruction and to conduct original investigations in all branches of knowledge as are likely to promote the material and industrial welfare of India," the Institute has always strived to strike a balance between the pursuit of basic knowledge and applying its research for industrial and social benefit.

From March 2020, our lives have been dominated by the deadly COVID-19 pandemic that has wreaked havoc across the world. Since then, IISc researchers – like their counterparts around the globe – have been racing against time to develop solutions to tackle this crisis. Examples of their efforts include affordable and accurate electrochemical and RT-PCR diagnostic tests, low-cost indigenous ventilators and nasal cannulas for hospitals, a contact tracing app, and oxygen concentrators and generators. Researchers have also carried out fundamental studies on virus evolution, host response and treatment approaches. A 'warm' vaccine candidate that can be stored at room temperature – ideal for transportation to remote regions – is being developed by a team from IISc and IISc-incubated start-up Mynvax. It has been shown to trigger a strong immune response in animal models and appears to be effective against all current variants of concern. One of the formulations is being rapidly moved to clinical development.

At IISc, a COVID-19 test centre and a facility to evaluate vaccines and antivirals have also been established with support from the Government of Karnataka and the Department of Biotechnology's Biotechnology Industry Research Assistance Council (DBT-BIRAC). IISc also collaborated with other Indian institutions to create an online platform called CovidGyan, which provided scientifically-validated resources for scientists, journalists, and lay people on COVID-19.

During 2020-21, the IISc community also responded to the crisis remarkably. All classes, interviews and exams shifted online, and faculty members and students adapted quickly to this new mode of teaching. Staff members continued to keep the administration machinery running through the many lockdowns imposed. Our frontline workers – doctors, nurses, security personnel, janitorial staff – toiled round the clock to keep our campus community safe and healthy. Despite the lockdowns and restrictions, research has continued; in this report, you will find glimpses of high-quality work carried out at IISc this past year by our

faculty members and students, with the help of the technical and administrative personnel, and financial support from various funding agencies.

The COVID-19 crisis has underscored the importance of investing in interdisciplinary medical research that can drive the development of next-generation healthcare technologies and approaches, in order to prepare for pandemics of the future. Towards this end, IISc plans to embark on a highly ambitious endeavour – establishing a post-graduate medical school and a not-for-profit 490-bed multispecialty research hospital. The IISc Medical School will leverage the Institute's existing strengths in science and engineering and nurture cross-disciplinary research training programmes through the seamless integration of basic sciences, clinical sciences, applied engineering and clinical practice. Graduate programmes (MD/MS) in select disciplines will be launched, along with a unique dual degree MD-PhD (MS-PhD) research programme. New specialisations such as Digital Health, Precision Medicine, and Medical Informatics will also be initiated. After a century of excellence in science and engineering, the 'IISc Medical School' will add a third dimension to the Institute's legacy.

Even as we responded to the pandemic in many constructive ways, we have tried to ensure that new initiatives do not suffer. IISc has established the AI and Robotics Technology Park (ARTPARK), an innovation hub that aims to address socio-economic problems using mission mode approaches to developing and leveraging cutting-edge technology. Its star attraction is Asha, a robotic avatar nurse, who made her debut at the Bengaluru Tech Summit in November 2020.

With support from the Ministry of Electronics and Information Technology, a new Centre for Excellence in Quantum Technology (CEQT) has been created by leveraging IISc's inherent strengths in physics, nanotechnology and computer science. Quantum technology is expected to become one of the most exciting areas of research in the coming years.

IISc's Knowledge E-Learning Network (I-KEN) has also been set up to provide state-of-the-art infrastructure that will enable faculty members to create rich multimedia content for online delivery of courses. As part of this initiative, three studios have already come up in the Institute. A new MTech (Online) degree programme for working scientists and professionals has also been launched in three areas.

IISc has also continued its engagement with other universities and organisations. It has signed its first joint PhD agreement with the University of Melbourne in Australia, and renewed its partnership with the Defence Research and Development Organisation (DRDO) of the Government of India to expand the scope and objective of the existing Joint Advanced Technology Programme (JATP). This will enable directed basic and applied research on indigenous state-of-the-art technologies in strategic areas.

While funding from the government continues to remain critical for IISc's operations, support from non-government sources has also played an important role in the Institute's advancement in the last few years. Endowments and grants from generous donors have not only enabled the Institute to modernise its infrastructure and provide enhanced travel and scholarship support for its students, but also helped our faculty members to pursue ground-breaking research.

The increasing vaccination numbers across the country and the world promise a more hopeful year ahead. We will continue our pursuit of excellence in research and teaching, and contribute to nation-building activities. We also extend our gratitude to the Chair and Members of the Council of the Institute for their valuable support and guidance in all our endeavours.

G. Rangarajan

DIRECTOR
SEPTEMBER 2021

IISc at a glance 2020-21

ACADEMIC STRUCTURE

Division of Biological Sciences

BC	Biochemistry
CAF	Central Animal Facility
CES	Centre for Ecological Sciences
CIDR	Centre for Infectious Disease Research
CNS	Centre for Neuroscience
MCB	Microbiology and Cell Biology
MBU	Molecular Biophysics Unit
MRDG	Molecular Reproduction, Development and Genetics

Division of Chemical Sciences

IPC	Inorganic and Physical Chemistry Materials
MRC	Research Centre
NRC	NMR Research Centre
OC	Organic Chemistry
SSCU	Solid State and Structural Chemistry Unit

Division of Electrical, Electronics, and Computer Sciences

CSA	Computer Science and Automation
ECE	Electrical Communication Engineering
EE	Electrical Engineering
ESE	Electronic Systems Engineering

Division of Interdisciplinary Research

BSSE	Centre for BioSystems Science and Engineering
CCS	Centre for Contemporary Studies
CISTUP	Centre for Infrastructure, Sustainable Transportation and Urban Planning
CENSE	Centre for Nano Science and Engineering
CDS	Computational and Data Sciences
MS	Management Studies
ICER	Interdisciplinary Centre for Energy Research
ICWAR	Interdisciplinary Centre for Water Research
RBCCPS	Robert Bosch Centre for Cyber Physical Systems
SERC	Supercomputer Education and Research Centre

Division of Mechanical Sciences

AE	Aerospace Engineering
CPDM	Centre for Product Design and Manufacturing
CE	Chemical Engineering
MT	Materials Engineering
ME	Mechanical Engineering
CIE	Civil Engineering
CEAS	Centre for Earth Sciences
CAOS	Centre for Atmospheric and Oceanic Sciences
CST	Centre for Sustainable Technologies
DCCC	Divecha Centre for Climate Change

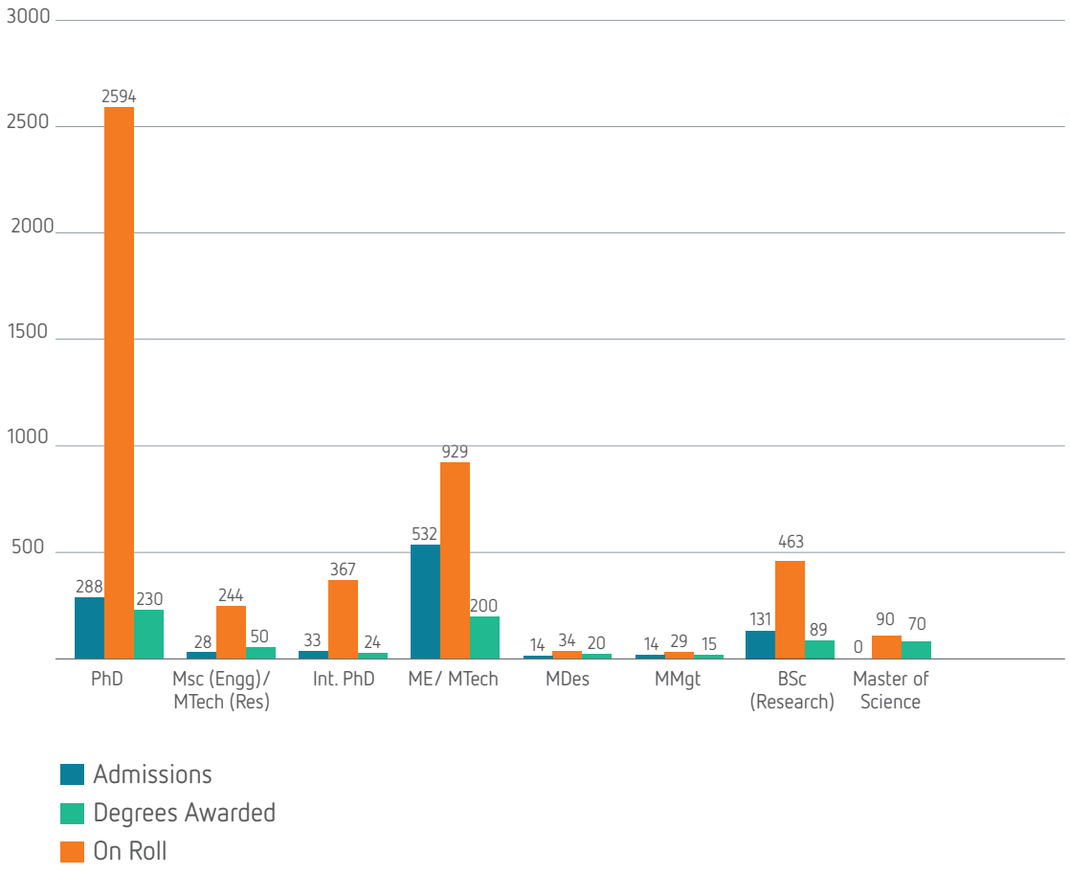
Division of Physical and Mathematical Sciences

CCT	Centre for Cryogenic Technology
CHEP	Centre for High Energy Physics
IAP	Instrumentation and Applied Physics
MA	Mathematics
PHY	Physics

Centres under the Director

LIB	JRD Tata Memorial Library
OOC	Office of Communications
OIR	Office of International Relations
CCE	Centre for Continuing Education
CSSP	Centre for Sponsored Schemes & Projects
ODAA	Office of Development and Alumni Affairs
IPTEL	Office of Intellectual Property and Technology Licensing
CC	Challakere Campus
CSIC	Centre for Scientific and Industrial Consultancy
DIGITS	Digital Campus and IT Services Office
SID	Society for Innovation and Development
CBR	Centre for Brain Research
KVPY	Kishore Vaigyanik Protsahan Yojana
KSCST	Karnataka State Council for Science and Technology
ORG	Office of Research Grants
OCCAP	Office of Career Counselling and Placement

STUDENTS



Hostels	2825
Men	2077
Women	748
Messes	4

Continuing Education	816
QIP Degree program	23
QIP Short Term Courses	0
CCE Proficience	407
Industry sponsored courses	386

Scholarships/Fellowships	2624
IISc	2303
Others	321

FACULTY 2020-21

Staff (820)	SC/ST	OBC	GN
Academic, Scientific & Technical (558)			
Academic	14	12	439
Scientific	28	2	36
Technical	15	0	12
Support (262)			
Officers	11	6	17
Administrative	48	8	38
Technical	12	1	18
Maintenance	40	3	57
Others	1	0	2

Awards and Distinctions	(220)
JC Bose Fellowship	1
Indian Academy of Sciences	2
Awards, Honours and Recognition	217

Interactions	
On Campus	
Institute Lectures	2
Conferences	125

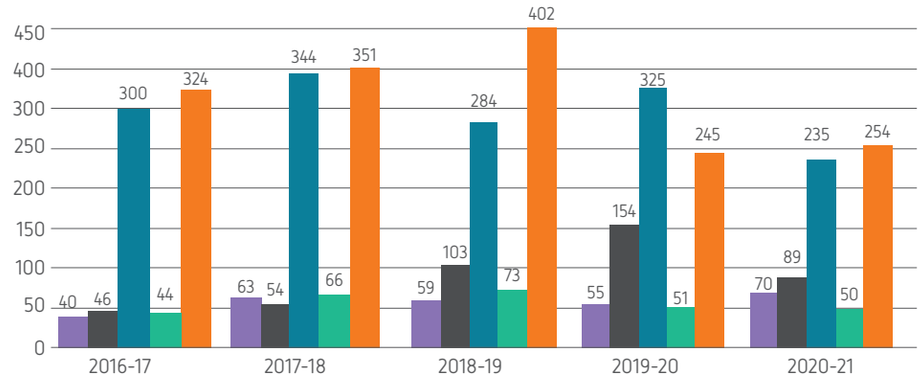
Academic Divisions: 6	Departments: 42
Biological Sciences	8
Chemical Sciences	5
Electrical, Electronics, and Computer Sciences	4
Mechanical Sciences	10
Physical & Mathematical Sciences	5
Interdisciplinary Sciences	10

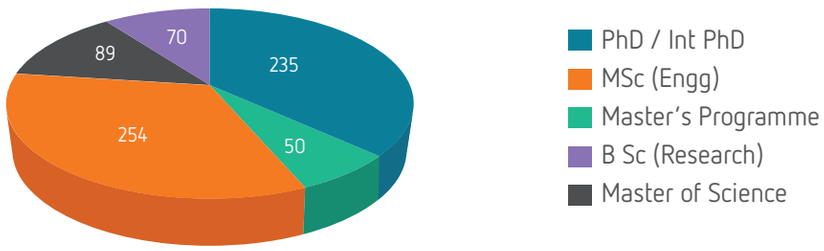
Indian Institute of Science Publications data (Jan-Dec 2020) - Division wise break up as updated in August 2021

Division	Journal Art	Conf. Proc	Book Chap	Total
Biological Sciences	339	0	1	340
Chemical Sciences	374	7	4	385
Electrical Sciences	238	329	2	569
Interdisciplinary Sciences	248	102	4	354
Mechanical Sciences	642	128	12	782
Physical & Mathematical Sciences	457	35	5	497
Autonomous Society/centre	8	4	0	12
Centres under Director	5	2	0	7
UG Studies	17	2	0	19
Total	2328	609	28	2965

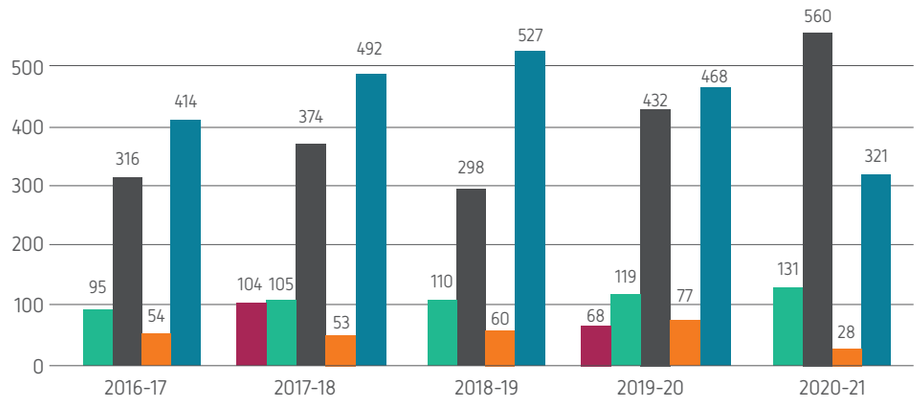
STUDENTS DEGREES AWARDED 2020-21, ADMISSIONS AND ON ROLL

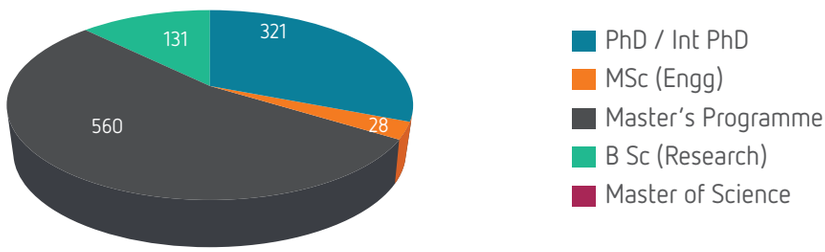
Degrees Awarded 2020-21



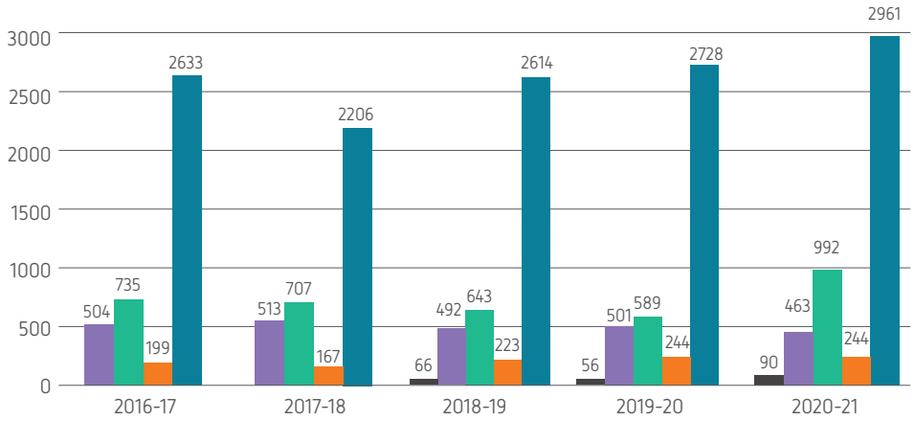


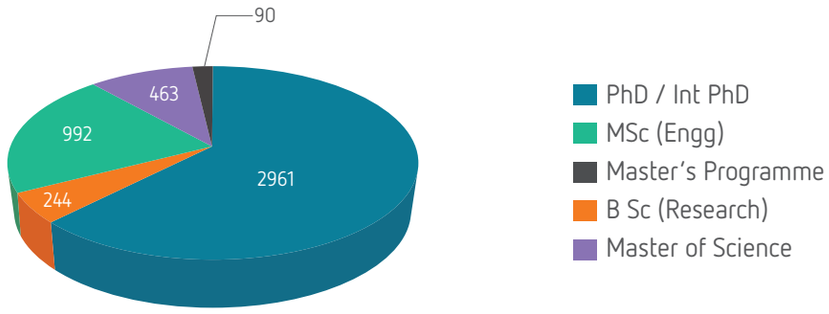
Admissions



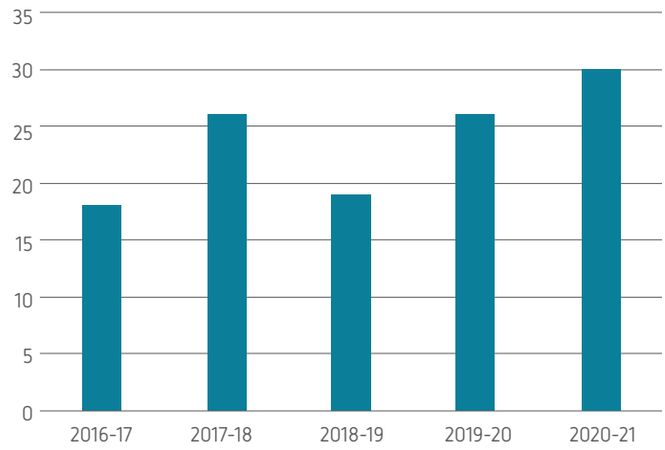


On Roll from 2016 to 2021

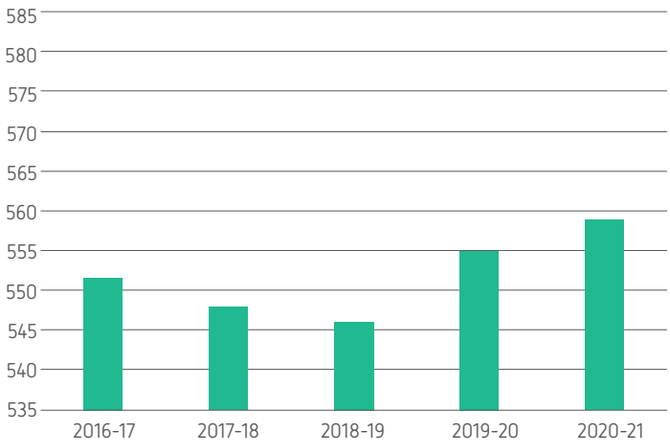




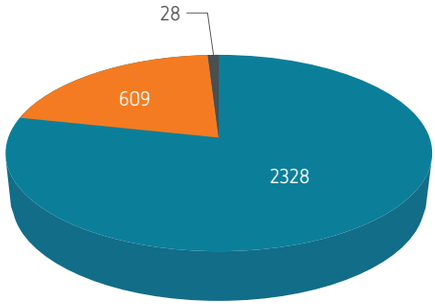
New Faculty Inducted during 2016-2021



Academic, Scientific and Technical Staff On Roll from 2016-2021

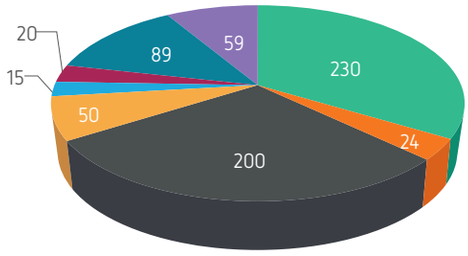


Publications 2020-21



- Journal Publications
- Conference Publications
- Book Chapters

Degrees Awarded 2020-2021



- PhD
- Int. PhD
- M.tech/ME
- MSc (Engg.)
- MMgt
- MDes
- BSc (Research)
- Master of Science

PROGRAMMES

Research

PhD ● Int. PhD ● MTech(Res) ● BSc(Res) ●

Science		
Biochemistry	●	●
Ecological Sciences	●	●
Microbiology and Cell Biology	●	●
Molecular Biophysics	●	●
Molecular Reproduction Development and Genetics	●	●
Neurosciences	●	●
Inorganic and Physical Chemistry	●	●
Materials Research	●	●
Organic Chemistry	●	●
Solid State and Structural Chemistry	●	●
Mathematics	●	●
Physics	●	●
Astronomy and Astrophysics	●	●
High Energy Physics	●	●
Interdisciplinary Programme - IMI	●	
Undergraduate Programme		●

Course / Research

PhD ● M Tech(Res) ● M Tech ● M Des ● M Mgt ●

Engineering					
Civil Engineering	●	●	●		
Earth Sciences	●	●	●		
Computer Science and Automation	●	●	●		
Electrical Engineering	●	●	●		
Electrical Communication Engineering	●	●	●		
Electronic Systems Engineering	●	●	●		
Aerospace Engineering	●	●	●		
Chemical Engineering	●	●	●		
Mechanical Engineering	●	●	●		
Materials Engineering	●	●	●		
Product Design and Manufacturing	●	●	●	●	
Atmospheric and Oceanic Sciences	●	●	●		
Instrumentation	●	●	●		
Computational and Data Science	●	●	●		
Nanoscience and Engineering	●		●		
Energy Research	●				
Management Studies	●				●
BioSystems Science and Engineering	●				
Water Research	●				
Sustainable Technologies	●	●			
Cyber Physical Systems	●				
Climate Change	●				

Courses Offered

Division	100 level	200 level	300 level	400 level	No Level	Total
Biological Sciences	1	20	9			30
chemical sciences		5	17		1	23
Physical & Mathematical Sciences		23	23			46
Electrical Sciences		52	9			61
Mechanical Sciences		76	9	2		87
Centres /IDP	1	25	11			37
Undergraduate (BS)	10	11	11	3		35
Total	**12**	**212**	**89**	**5**	**1**	**319**

1 The Institute

The Indian Institute of Science is an institution of higher learning and research established in 1909 under the Charitable Endowments Act 1890. With the establishment of the University Grants Commission in 1956, the Institute came under its purview as a Deemed University. The principal authority governing the Institute is the Council, which is advised by the Court in the formulation of policies. The Director is the Chief Executive of the Institute and is assisted in its management by the Senate and the Faculties of Science and Engineering.

1.1 THE COURT

The membership of the Court is drawn from different cross sections of the country such as Industry, Universities, Scientific Institutions, etc. In addition to eminent persons of science, learning and industry, it also contains the nominees of the Government of India, the Government of Karnataka and the Tata Trusts. The Professors of the Institute and the members of the Council are also ex-officio members of the Court. The following are the members of the Court:

N CHANDRASEKARAN
President of the Court
Chairman, Tata Sons Ltd

PRAHLADA RAMARAO
Formerly Distinguished Scientist
and Chief Controller, DRDO, New Delhi
Adjunct Faculty,
Dept of Management Studies,
IISc and NIAS

ANIL D SAHASRABUDHE
Chairman, The All India Council for
Technical Education

KAMINI CHAUHAN RATAN
Joint Secretary (HE), MoE
Department of Higher Education,
GoI

PRADEEP P
Commissioner
Department of Collegiate Education

R K KRISHNA KUMAR
Former Director, Tata Sons Ltd

PANKAJ R PATEL
President, FICCI & Chairman
& Managing Director
Cadila Healthcare Ltd.

S N AGARWAL
Chairman, Bhoruka Power
Corporation Ltd.

VIJAY PADATE
Director General,
The Employers Federation of India

SHEKHAR C MANDE
Director General, Council
of Scientific & Industrial Res.

R S BAWA
Vice Chancellor, Chandigarh University

SANDEEP SANCHETI
Vice Chancellor
SRM Institute of Science & Technology

RAKESH BHATNAGAR
Vice Chancellor
Banaras Hindu University

SOUVIK BHATTACHARYA
Vice Chancellor
Birla Institute of Technology & Science

KRIS GOPALAKRISHNAN
Former Co-Chairman
Infosys Limited

K S RAJANANDAM
President, IISc. Alumni Association

GOVINDAN RANGARAJAN
Director (Ex-officio)

ALL PROFESSORS OF THE INSTITUTE
(Ex-officio)

ALL MEMBERS OF THE COUNCIL
(Ex-officio)

CAPT. SRIDHAR WARRIER (REGISTRAR)
Registrar (Ex-officio Secretary)

Every year Court meets once in March.

1.2 THE COUNCIL

The Council is the principal governing authority of the Institute and its membership includes the Nominees of the Court, Parliament, Government of India, Government of Karnataka, Tata Trusts, Representatives of Indian Universities, University Grants Commission and Scientific bodies. The following are the members of the Council.

A S KIRAN KUMAR
Chairman of the Council
Former Secretary
Department of Space

AMIT KHARE
Secretary, MoE
Dept. of Higher Education,
Govt. of India

RAKESH RANJAN
Additional Secretary
Ministry of Education
Government of India

G KUMAR NAIK
Principal Secretary, Higher
Education Dept.
Government of Karnataka

I S N PRASAD
Additional Chief Secretary
Finance Dept.,
Govt. of Karnataka

J J IRANI
Director, Tata Sons Ltd.

RANENDRA SEN

RAJENDRA PRASAD
Director, Amity Institute of
Biotechnology, Amity Univ.

P C MOHAN
Hon'ble Member of Parliament (LS)

L S TEJASVI SURYA
Hon'ble Member of Parliament (LS)

NARENDRA JADHAV
Hon'ble Member of Parliament (RS)

R S BAWA
Vice Chancellor,
Chandigarh University

SANDEEP SANCHETI
Vice Chancellor, SRM Institute of
Science & Technology

ANIL D. SAHASRABUDHE
Chairman, The All India Council
for Technical Education

SHEKHAR C MANDE
Director General,
Council of Scientific & Industrial Res.

GOVINDAN RANGARAJAN
Director (Ex-officio)

A G SAMUELSON
(Ex-officio)
Dean, Science Faculty

Y N SRIKANT
(Ex-officio)
Dean, Engineering Faculty

CAPT. SRIDHAR WARRIER (RETD.)
Registrar (Ex-officio Secretary)

The Council met quarterly on 12 May 2020, 27 June 2020, 19 September 2020, 19 December 2020 and 27 March 2021

1.3 FINANCE COMMITTEE

The following are the members of the Finance Committee.

A S KIRAN KUMAR
Chairman of the Council (Ex-officio)
Former Secretary, Department of Space,

DARSHANA M DABRAL
Joint Secretary & Financial Adviser
Dept. of Higher Education, MHRD
GOI (Nom. GOI)

RAKESH RANJAN
Additional Secretary
Dept. of Higher Education, Ministry of Education, GOI

CHANDRASHEKHAR NAYAK L
Deputy Secretary (Budget & Resources),
Finance Department

R F SAVAKSHA
Secretary & Chief Financial Officer
Sir Dorabji Tata Trust, Mumbai

ASHISH W DESHPANDE
Secretary & Chief Financial Officer
Sir Ratan Tata Trust, Mumbai

R NARESH
Pr. Accountant General (A&E)
Karnataka, Bangalore

GOVINDAN RANGARAJAN
Director (Ex-officio)

CAPT. SRIDHAR WARRIER (RETD.)
Registrar (Ex-officio Secretary)

The Finance Committee met quarterly on 08 May 2020, 26 June 2020; 18 September 2020; 18 December 2020 and 25 March 2021

1.4 THE SENATE

The Senate is one of the authorities of the Institute that consists of the Director as the Chairman, all Professors and Associate Professors, one elected representative (Assistant Professor) from each of the Faculties, the Librarian, and the Registrar (Secretary). The Senate meets at least once a term.

This principal academic body functions to (a) plan and coordinate the research activities of the Institute, (b) regulate and organise courses of instruction and study, admission of students, examinations, etc., (c) formulate conditions for the award of Degrees of the Institute, and (d) recommend names to the Council for the award of Degrees.

During the year, the Senate met on June 5, 2020; Aug 25, 2020; Nov 19, 2020, and Feb 19, 2021.

The Senate recommended the award of various degrees as follows:

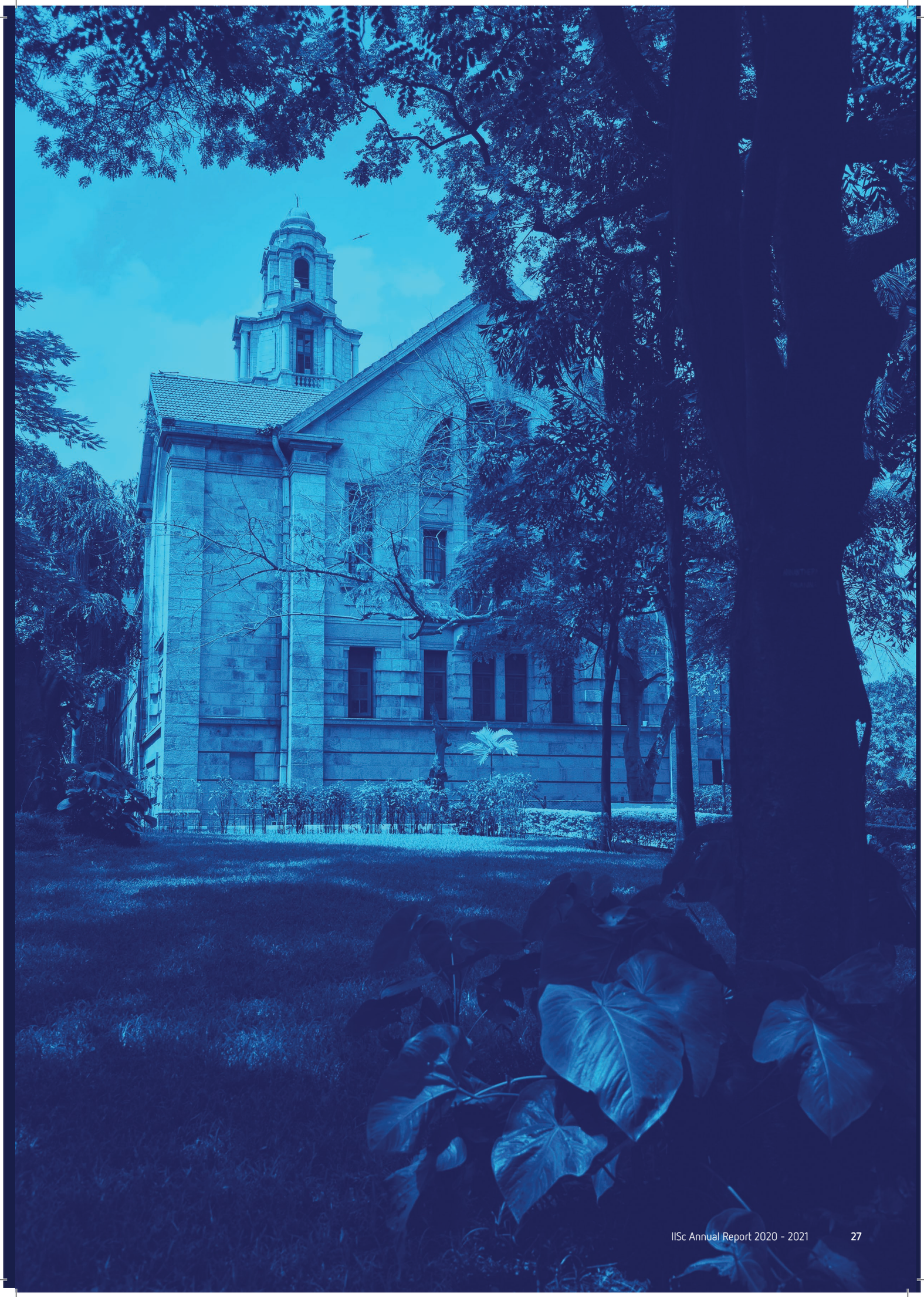
• PhD	230
• Int. PhD	24
• MSc (Engg)	50
• ME/MTech	200
• MDes	20
• MMgt	15
• BSc (Research)	89
• Master of Science	70
Total	698

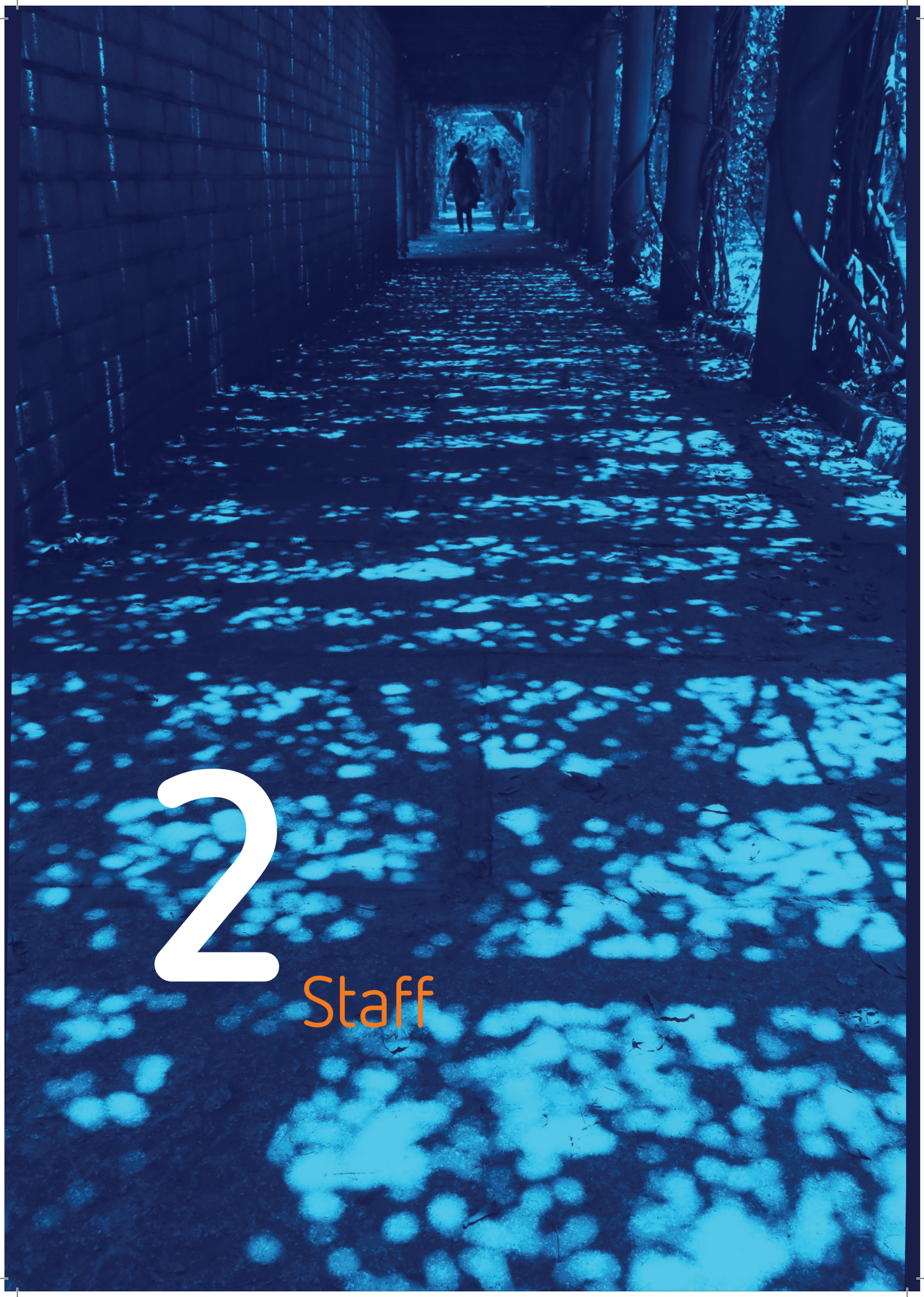
1.5 FACULTIES

The faculties act as advisory bodies to the Senate and assist in the discharge of its duties. Each Faculty consists of the respective Dean as Chairman, all Professors, Associate Professors, Chief Research Scientists, Principal Research Scientists, Assistant Professors and Senior Scientific Officers as members and the Assistant Registrar as the Secretary.

The Science Faculty, Engineering Faculty and Joint Faculties Held At 2.30pm On 21 October 2020.

No separate meeting for Science & Engineering Faculty was held and it was clubbed with joint faculty meeting





2 Staff

Director: Govindan Rangarajan

Dean (Science)
AG Samuelson

Dean (Engineering)
YN Srikant

Dean (Planning and Infrastructure)
SK Satheesh

Dean (Administration and Finance)
PS Anil Kumar

Dean, Division of Biological Sciences
Usha Vijayraghavan

Dean, Division of Chemical Sciences
G Mugesh

Dean, Division of Electrical, Electronics, and Computer Sciences
Y Narahari

Dean, Division of Interdisciplinary Sciences
Navakanta Bhat

Dean, Division of Mechanical Sciences
Vikram Jayaram

Dean, Division of Physical & Mathematical Sciences
Kaushal Verma

Dean UG Programme: Balaji Jagirdar

Registrar
Capt. Sridhar Warrier (Retd.)
MBA

Financial Controller
Indumati Srinivasan, PGDPPM

Joint Registrar (Finance)
M Krishna Murthy, PhD
(Bangalore)
Deputy Registrar
V Nagaraja, MA
M C Jayaprakash, MBA
Rajeev Kumar, MBA
Veeranna Kammar, MSc
(Bangalore)

Assistant Registrars
Aparna Kandi, BE
B N Sreedhar, MBA
P Selva Kumar, MA
Krishna Kant Kumar, MA
Rajan Babu Lankapalli, MCom
Sreenivasaiah V, MA
Mithun Nair, MBA
Vasanthan A A, MBA
Anoop Yadav, MBA
Nitin Anand, MBA
C.T Nagaraja, MA

Assistant Registrar (Security & Hostels)
Jayaraj K, MBA

Sr. Hindi Officer
V Thilagam, PhD

Internal Auditor
Gurumurthy, M. Com

HEALTHCARE

Officer-In-Charge
C Sathish Rao, MBBS

Medical Officers
Aditya Malladi, MBBS
R Nirmala, MBBS
Neethi Raveendran MBBS

CAMPUS MANAGEMENT & DEVELOPMENT

Project Engineer-cum-Estate Officer
Col. Arun Sharma, M Tech

Deputy Project Engineer
Lenin Ram K, M Tech

Assistant Project Engineer
Radhika Muthukumar, BE

Assistant Executive Engineers
G Lohithesh Kumar, MTech
Manjunath S, BE

Technical Officers
G Radhaswamy, BE (Elec)
B Sridhar MSc (Hort)

Gymkhana President
Ambedkar Dukkipati, PhD (IISc)

STUDENT AFFAIRS

Chair, Council of Hostel Wardens
Dipshikha Chakravortty, PhD

Wardens
Kaushik Chatterjee, PhD
Kavita Isvaran, PhD
Navin Kashyap, PhD
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Suryasarathi Bose, PhD
Susheela Devi Visweswariah, PhD

Student Advisors
Satish V Kailas, PhD (IISc)

Student Counsellors
Vishwesha Guttal, PhD (Ohio State)
Ambedkar Dukkipati, PhD (IISc)
Prabal K Maiti, PhD (IIT/K)
Partha Pratim Mondal, PhD (IISc)
Ravishankar Narayan, PhD (IISc)
Annapoorni Rangarajan, PhD (NCBS)
Abha Misra, PhD (IIT Bombay)


3
Divisions

3.1

Division of Biological Sciences

IN NUMBERS

- 74 FACULTY MEMBERS
- 360 PhD STUDENTS
- 51 INTEGRATED PhD STUDENTS

The Division of Biological Sciences forges important links between basic science and innovative research. It is committed to enhancing frontline studies in almost all aspects of modern biology: Neuroscience in health and disease, Infectious Disease, Structural Biology, Oncology, DNA Repair and Genomic Stability, Systems Biology and Bioinformatics, Immunology, Enzymology, Reproductive and Developmental Biology, Diverse Ecological Studies and more.

THEMES

Investigators in the Division focus on numerous processes central to the understanding of life, emphasising on areas with considerable translational potential, namely, Cognition and Neuronal Reprogramming, Infectious Diseases, Drug and Molecular Design, Diagnostics and Therapeutics in Cancer, Gene Targeting, Genetic Disorders and Genetic Diversity.

RESEARCH HIGHLIGHTS

The Division of Biological Sciences consists of the Departments of Biochemistry, Microbiology & Cell Biology, Molecular Reproduction, Development & Genetics, Molecular Biophysics Unit, Ecological Sciences, Centre for Neuroscience, Centre for Infectious Disease Research and Central Animal Facility including Primate Research Laboratory

DEPARTMENTS | CENTRES | UNITS

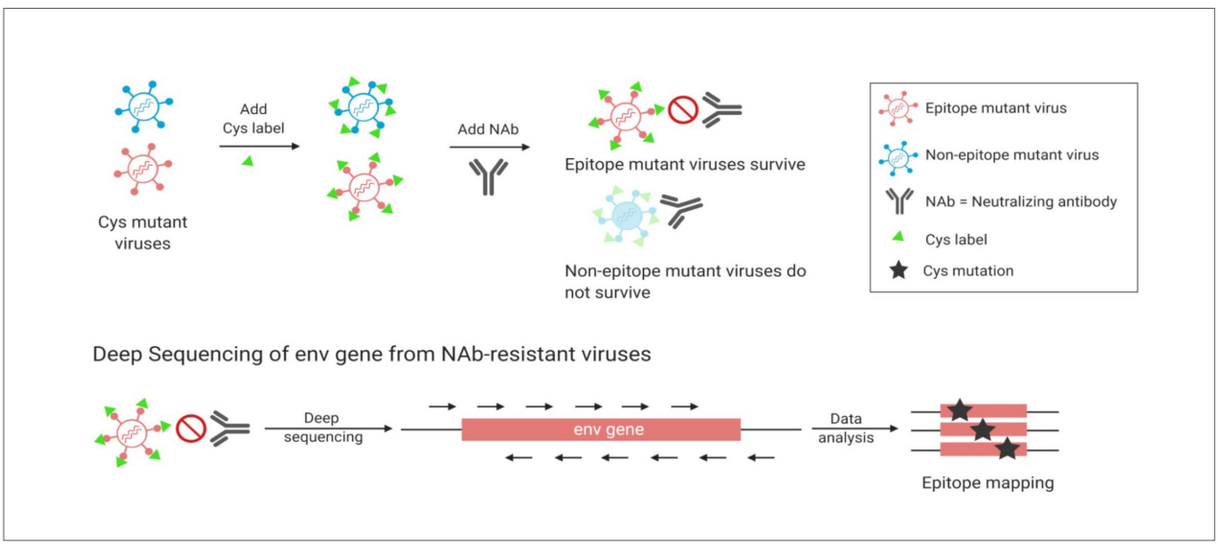
- BIOCHEMISTRY
- CENTRAL ANIMAL FACILITY
- CENTRE FOR ECOLOGICAL SCIENCES
- CENTRE FOR INFECTIOUS DISEASE RESEARCH
- CENTRE FOR NEUROSCIENCE
- MICROBIOLOGY AND CELL BIOLOGY
- MOLECULAR BIOPHYSICS UNIT
- MOLECULAR REPRODUCTION, DEVELOPMENT AND GENETICS

2020-21

Research Snapshots

RAGHAVAN VARADARAJAN (MBU)

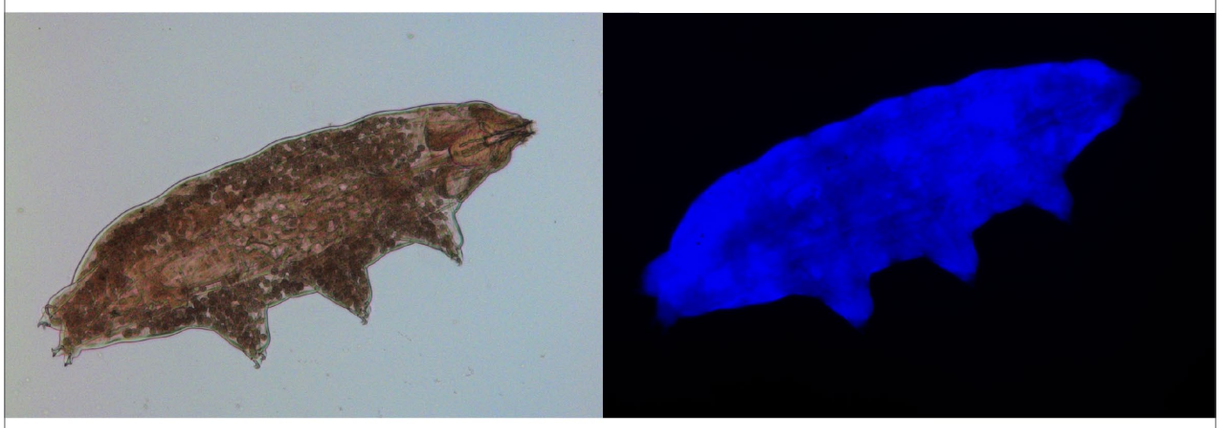
A new study from the Molecular Biophysics Unit reports a new method to rapidly identify specific regions on the HIV envelope protein that are targeted by neutralising antibodies, which can help design effective vaccines. The approach involves mutating the virus to produce cysteine on the surface of the envelope protein, then adding a chemical label that sticks to these cysteine molecules, and treating the virus with neutralising antibodies. If the antibodies could not bind to crucial sites because they were blocked by the cysteine label, the virus could survive and cause infection. These sites were then identified in one shot by sequencing the genes of the surviving mutant viruses.



Reference: Datta R, Chowdhury RR, Manjunath K, Hanna LE, **Varadarajan R,** A facile method of mapping HIV-1 neutralizing epitopes using chemically masked cysteines and deep sequencing, *Proceedings of the National Academy of Sciences (2020).*

SANDEEP ESWARAPPA (BC)

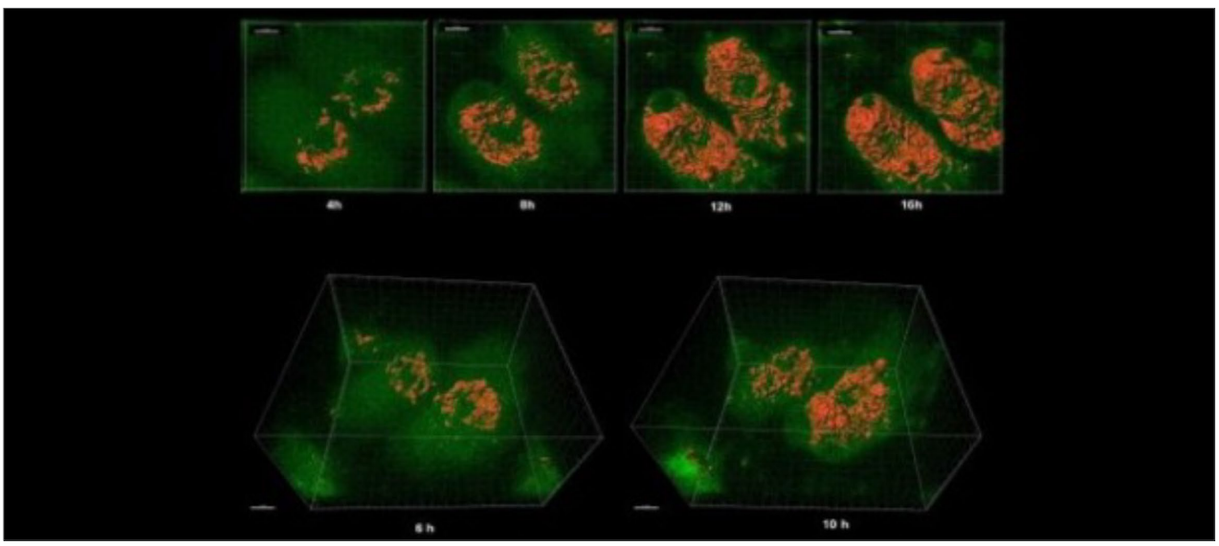
Tardigrades are tiny animals known for their ability to tolerate extreme physical stresses such as high temperature and pressure, ionising radiation, osmotic stress, and even the vacuum of space at low Earth orbit. In a recent study, researchers from the Department of Biochemistry have isolated a new species of tardigrade on the IISc campus that can protect itself from harmful UV radiation. It uses a fluorescent shield which absorbs the radiation and emits harmless blue light. The team was also able to transfer this UV tolerance property to another tardigrade and a worm, which are otherwise sensitive to UV radiation.



Reference: Suma HR, Prakash S, **Eswarappa SM,** Naturally occurring fluorescence protects the eutardigrade Paramacrobiotus sp. from ultraviolet radiation, *Biology Letters (2020).*

SHASHANK TRIPATHI (CIDR)

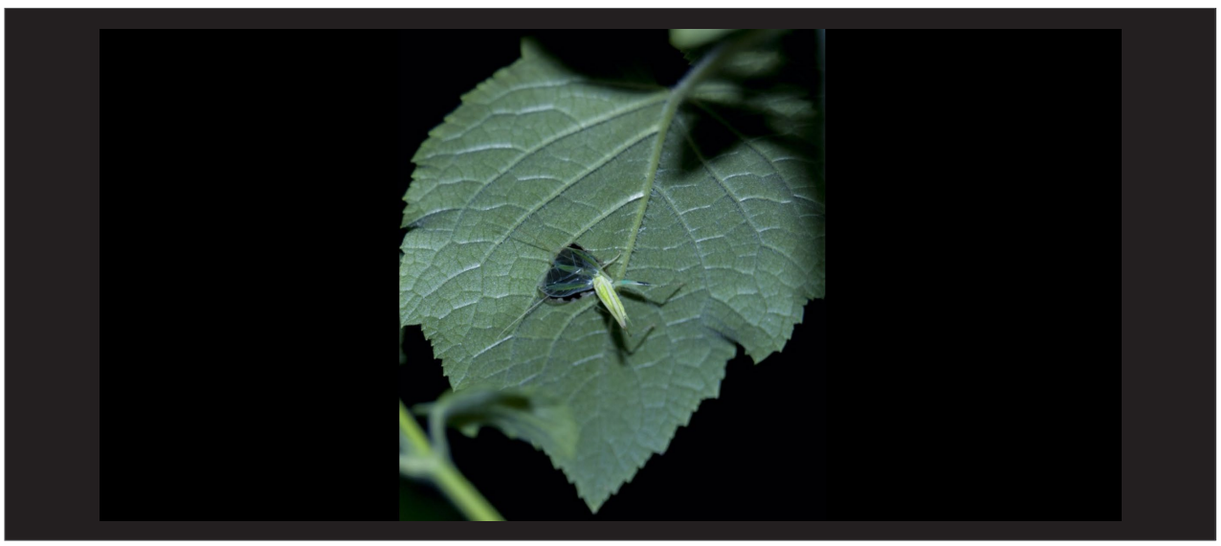
Subtypes of Influenza A viruses cause the 'flu' in birds and some mammals, including humans. Influenza hemagglutinin (HA) is a glycoprotein on the surface of these viruses that binds to the host cell membrane to enable viral entry. However, little is known about how HA moves through the network of organelles inside the host cell and reaches the host cell membrane. Researchers at the Centre for Infectious Diseases Research, along with international collaborators, have developed a new method to visualise the HA protein in infected cells. It involves engineering a recombinant virus with a tetra cysteine tag that emits fluorescence in the presence of biarsenic dyes, and can be rapidly detected.



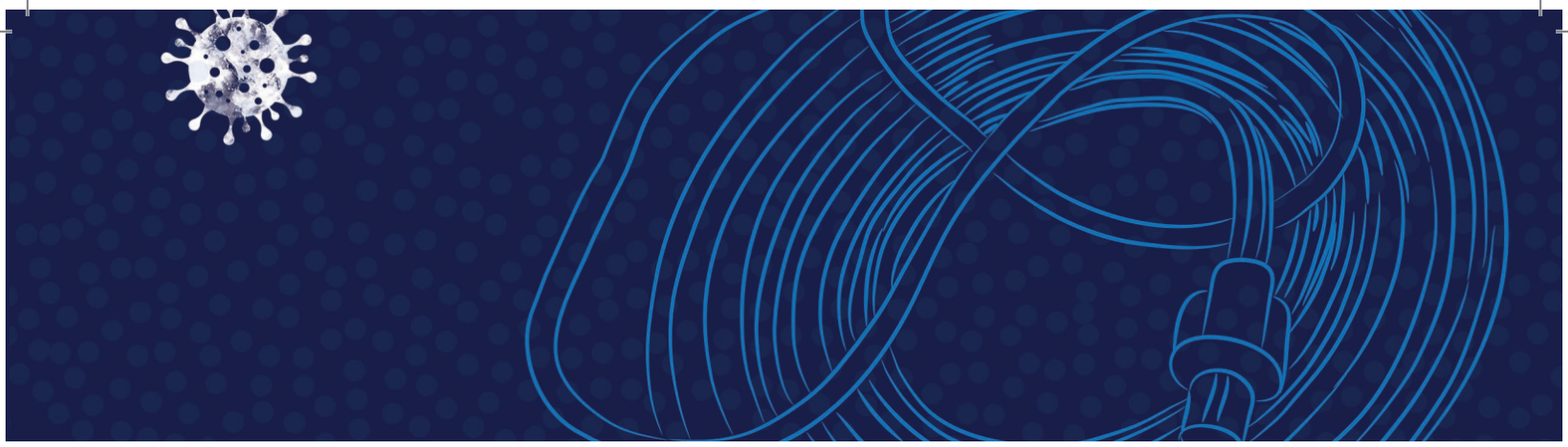
Reference: dos Anjos Borges LG, Pisanelli G, Khatun O, García-Sastre A, **Tripathi S,** Live Visualization of hemagglutinin dynamics during infection by using a novel reporter influenza A virus, *Viruses (2020).*

ROHINI BALAKRISHNAN (CES)

Tree cricket males that are smaller and not as loud as their peers cannot attract as many mates. However, these males have adopted an ingenious strategy to make themselves appear more attractive to females, a new study from the Centre for Ecological Sciences has found. Smaller and quieter males have been found to construct 'baffles' by chewing holes in large leaves which can make their voices twice as loud, effectively drowning out the competition from non-baffling males. Interestingly, being louder also causes females to mate with smaller males for longer than usual, giving these baffle-constructing males a two-fold advantage.

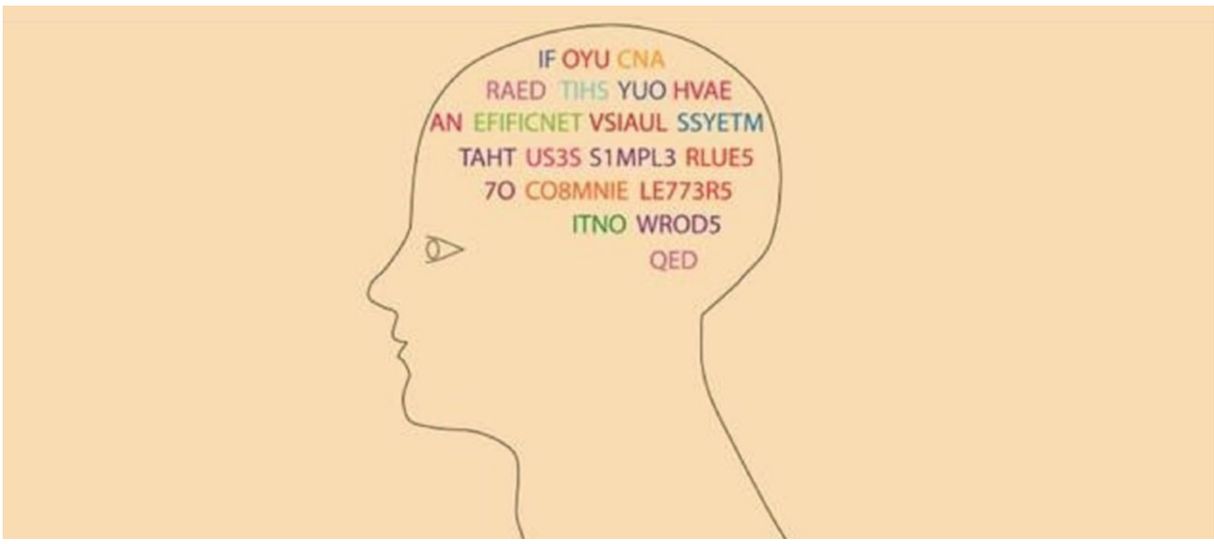


Reference: Deb R, Modak S, **Balakrishnan R,** Baffling: a condition-dependent alternative mate attraction strategy using self-made tools in tree crickets, *Proceedings of the Royal Society B (2020).*



SP ARUN (CNS) & KVS HARI (ECE)

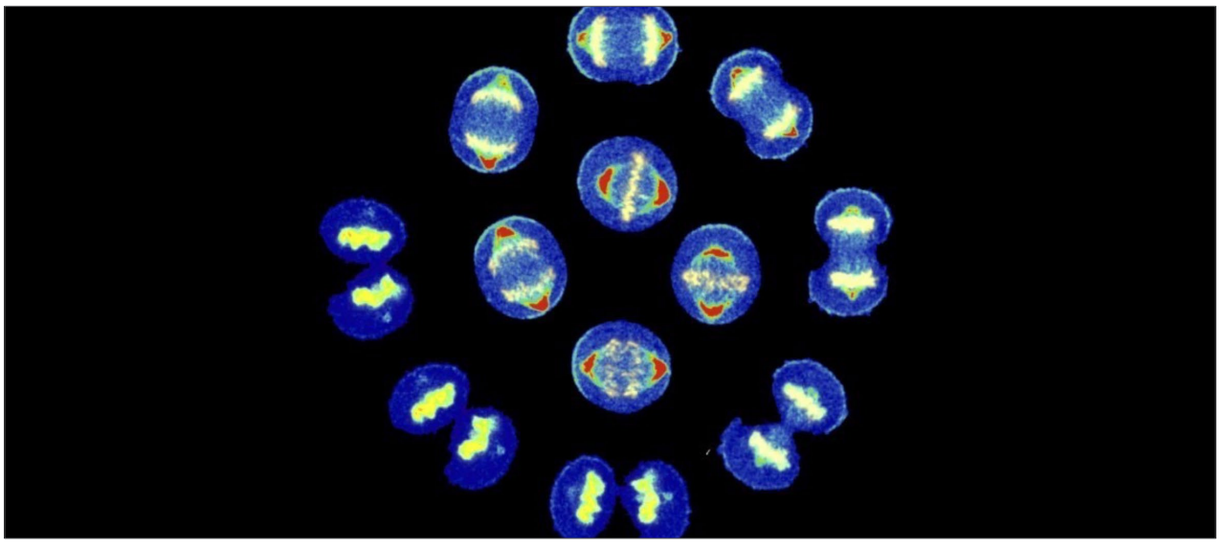
Reading a word involves both visual processing of letter and word shapes, as well as associated sounds, phonemes, syllables and its meaning. How does our brain read jumbled words efficiently? Researchers in the Centre for Neuroscience and Department of Electrical Communication Engineering devised a model in which neurons respond to single letter shapes, and obtained their responses to longer strings by adding up their responses to individual letters. They show that seeing a string of letters activates a visual representation in the higher visual cortex of the brain, which is then matched to stored words in the visual word form area.



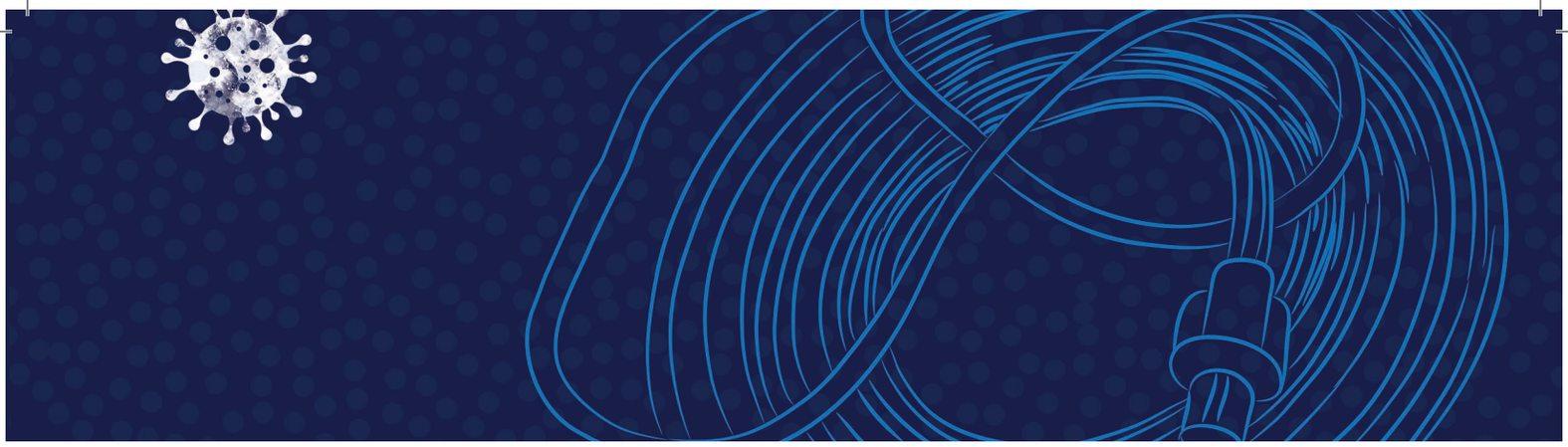
Reference: Agrawal A, **Hari KVS, Arun SP,** A compositional neural code in high-level visual cortex can explain jumbled word reading, *eLife (2020).*

SACHIN KOTAK (MCB)

When eukaryotic cells divide, thread-like structures called spindle fibres help pull a copy of the replicated chromosomes into each daughter cell. In animal cells, a protein called NuMA plays an integral role in this process. Cells regulate such proteins by adding or removing phosphate groups. Researchers from the Department of Microbiology and Cell Biology have now identified and characterised the subunit (B55γ) of an enzyme called PP2A responsible for dephosphorylating NuMA at a specific spot. A tug-of-war between PP2A-B55γ and another enzyme called Cdk1 regulates cortical NuMA levels. As low levels of B55γ are linked to prostate cancer, future research will attempt to unravel the role of spindle formation in cancer progression.

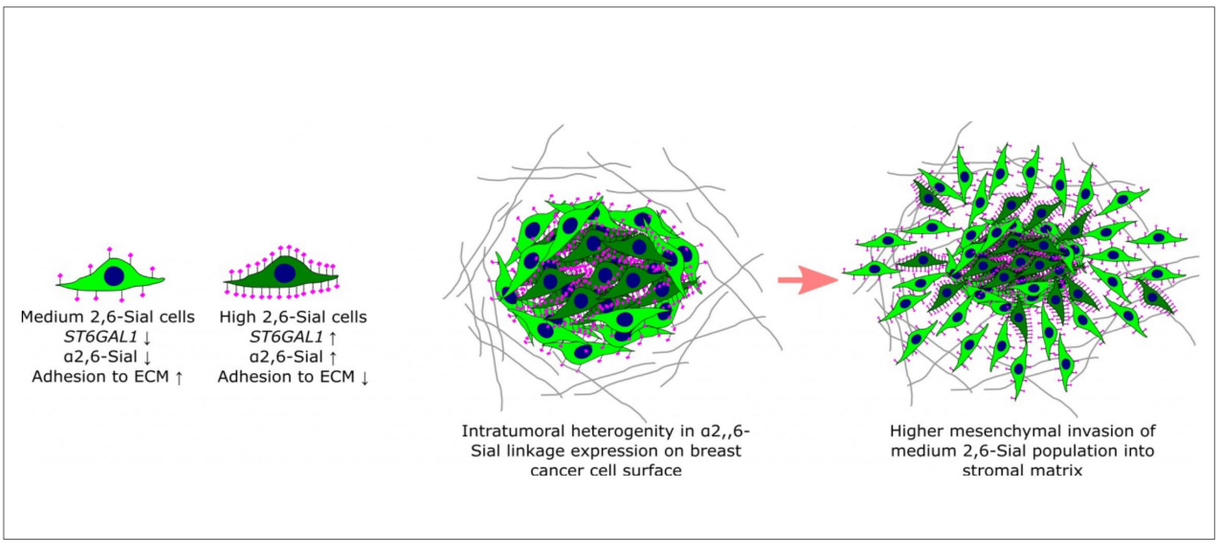


Reference: Keshri R, Rajeevan A, **Kotak S,** PP2A-B55γ counteracts Cdk1 and regulates proper spindle orientation through the cortical dynein adaptor NuMA, *Journal of Cell Science (2020).*



RAMRAY BHAT (MRDG)

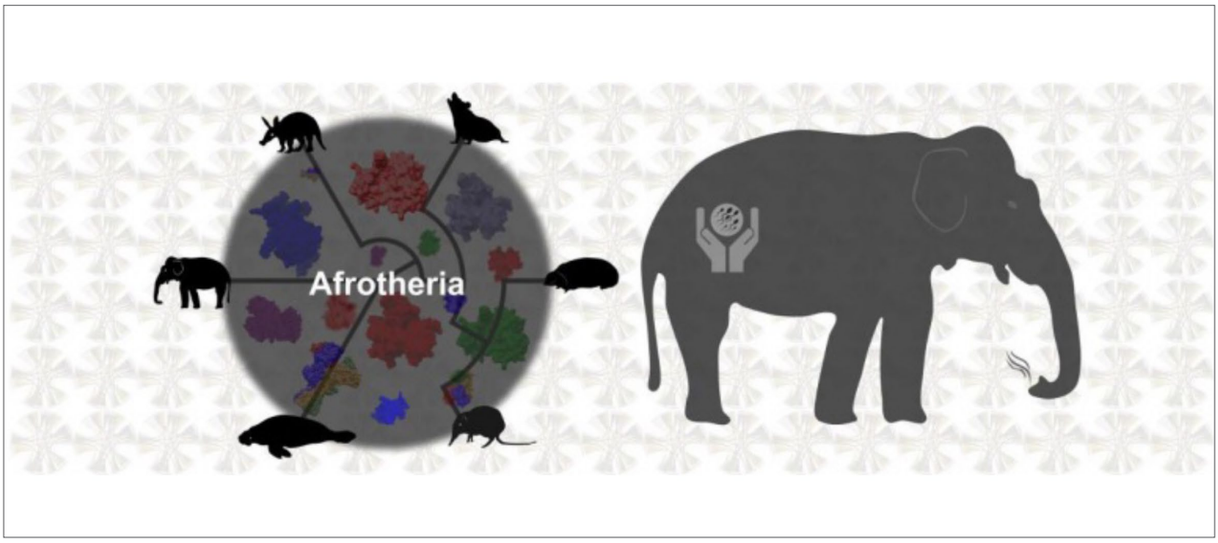
Malignant tumours are increasingly being understood as heterogenous – a patchwork of cells that cooperate or compete with each other as the cancer spreads. A recent study from the Department of Molecular Reproduction, Development and Genetics shows that a specific sugar called 2,6-Sial is expressed to different levels on the surface of different breast cancer cells. Cells with higher levels stick less strongly to their surroundings and are less likely to invade, while those with moderate levels stick strongly and invade more efficiently. Computer models also showed that having a slow-moving central bulk boosts the efficiency with which fast moving cancer cells can 'unjam' and spread outwards in a circular fashion, thereby justifying the need for heterogeneity.



Reference: Pally D, Pramanik D, Hussain S, Verma S, Srinivas A, Kumar RV, Everest-Dass A, **Bhat R,** Heterogeneity in 2,6-linked sialic acids potentiates invasion of breast cancer epithelia, *ACS Central Science (2021).*

N SRINIVASAN (MBU)

A new study from the Molecular Biophysics Unit has probed the proteomes – the entire set of functional proteins – of a group of mammals collectively called Afrotheria. The authors found that a large number of ribosomal proteins and olfactory receptors – linked to stress regulation and a heightened sense of smell respectively – were hallmarks of Afrotherian proteomes. Although Afrotherian proteomes are almost 99% similar, comparisons on a finer scale reveal that elephants have branched out extensively from their Afrotherian relatives. Elephants were also found to have an unusually high number of sperm-protecting proteins, possibly because with low reproductive rates and fewer offspring, it is critical for them to produce high-quality eggs and sperm.



Reference: Yazhini A, **Srinivasan N,** Sandhya S, Signatures of conserved and unique molecular features in Afrotheria, *Scientific Reports (2021).*

The Department of Biochemistry, started in 1921, is celebrating its Centenary this year. There are 14 faculty members, 3 Honorary Professors, 3 Emeritus Scientists, 91 PhD students, 24 PDF/DST Young Scientists/UGC Kothari Fellows, administrative staff, 3 permanent helpers and 32 temporary staff members in the department.

CURRENT RESEARCH

PROTEINS – STRUCTURE AND FUNCTION:

(i) The enzymes involved in the restriction-modification system in *Heliobacter pylori* and the mismatch repair system from *Neisseria gonorrhoea*

(ii) Transcriptional and post-transcriptional regulation of carbon metabolism of *Pichia pastoris*

(iii) Mitochondrial protein translocation, biogenesis and turnover with regard to various pathophysiological conditions

(iv) The roles of heat shock proteins (HSPs) and mechanisms regulating gametocytogenesis in malaria are

CORE RESEARCH

Proteins, Natural products and metabolic engineering, DNA repair, RNA transactions and genomic stability, biology of chaperones, immunobiology

3.1.1 Biochemistry

CHAIRPERSON
PN RANGARAJAN

being investigated. In addition, neglected infectious diseases are being studied to improve diagnosis and treatment strategies.

GENOME BIOLOGY:

(i) The molecular mechanisms underlying chromosome synapsis, homologous recombination, DNA repair and genomic stability

(ii) Studies on RAD51 paralogs in mammalian DNA damage responses, genome stability and tumour suppression

(iii) The roles of the Structural Maintenance of Chromosomes (SMC) complexes that mediate higher order chromatin organisation

(iv) The roles of RAG proteins in genomic instability, understanding mechanism of non-homologous end joining (NHEJ) and identification of compounds with anti-cancer properties

(v) Understanding the basis of mRNA fate decisions with a specific focus on translation and mRNA decay

(vi) Mechanism and physiological significance of stop codon readthrough in mammalian systems

(vii) Investigations of macromolecular interactions that help in 3D genome organisation using single-molecule and super-resolution imaging technologies

SYSTEMS BIOLOGY, BIOINFORMATICS AND METABOLIC ENGINEERING:

(i) Mathematical and computational models of biological systems are being studied to understand control structures in biochemical pathways, metabolic and regulatory networks, insights from which are being used to understand key perturbations in disease and or biomarker and drug discovery as well as precision medicine.

(ii) Investigations of secondary metabolites with anti-cancer as well as anti-thrombotic activity from endophytic fungi of *Datura metel, Casia fistula, Catharanthus roseus* and *Mapia foetida*

CELL BIOLOGY AND IMMUNOLOGY:

(i) The host response during infection is an important area of research. In this regard, two aspects – thymic atrophy and sepsis during infections – are being investigated

(ii) Investigation of host response to tuberculosis using an integrated systems biology approach

(iii) Investigation of cytoskeletal forces generated through actomyosin ring machinery during cell division

(iv) Signalling role of inositol phosphates in plants

(v) Role of intracellular RNA sensing mechanisms in inflammatory cell death.

FACT FILE

Established: 1921
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Degree Programmes offered: PhD and Int PhD

IN NUMBERS

14 Academic staff
72 PhD students
19 Int PhD students
139 Publications
2 Int PhD conferments
16 PhD conferments

FACULTY & STAFF

PN RANGARAJAN | PhD (IISc), Professor
UTPAL S TATU | PhD (IISc), Professor
DIPANKAR NANDI | PhD (California-Berkeley), Professor
PATRICK D'SILVA | PhD (IIT Bombay), Professor
SATHEES C RAGHAVAN | PhD (BHU), Professor
NAGASUMA CHANDRA | PhD (Bristol), Professor
SHIKHA LALORAYA | PhD (Wisconsin), Professor
GANESH NAGARAJU | PhD (IISc), Associate Professor
SANDEEP M ESWARAPPA | PhD (IISc), Associate Professor
PURUSHARTH RAJYAGURU | PhD (CCMB), Associate Professor
SARAVANAN PALANI | PhD (University of Heidelberg), Assistant Professor
DEBABRATA LAHA | PhD (University of Tübingen), Assistant Professor
KESAVARDANA SANNULA | PhD (IISc), Assistant Professor
MAHIPAL GANJI | PhD (TU Delft), Assistant Professor

HONORARY PROFESSORS

K MUNIYAPPA | PhD (IISc)
C JAYABASKARAN | PhD (IISc)
D NARASIMHA RAO | PhD (IISc)

EMERITUS PROFESSORS

G PADMANABAN | PhD (IISc)
H S SAVITHRI | PhD (IISc)

The Central Animal Facility (CAF) breeds, maintains and supplies pure and inbred strains of experimental animals for biomedical research activities at the Institute. The animal species includes New Zealand white rabbits, hamsters, Wistar rats, Sprague Dawley rats and several strains of mice (nude mice, Swiss albino, BALB/c, FVB/N, CD1, C57BL/6, C3HeJ) including knockout mice (IFNg, KO, INoS KO, etc.).

3.1.2 Central Animal Facility

CHAIRPERSON
SATHEES C RAGHAVAN

CORE RESEARCH

Experimental animals are provided to several investigators who are using animals for research activities in the Division of Biological Sciences (Biochemistry, Microbiology and Cell Biology, Molecular Reproduction, Development and Genetics; Molecular Biophysics Unit and Centre for Neuroscience) and other departments such as the Department of Mechanical Engineering, Materials Research Centre, Materials Engineering, Inorganic and Physical Chemistry and Centre for Nanoscience and Engineering. Researchers from outside organisations also benefit from CAF in various ways.

FACULTY & STAFF

SATHEES C RAGHAVAN | PhD (BHU), Professor
RAVINDRANATH H ALADAKATTI | PhD (Karnatak University), Principal Research Scientist
DHANUSHA G | Junior Research Scientist (Veterinarian)
ROSA JOHN SAMUEL | PhD, Supervisor (Project Assistant)
VEENA B K | Microbiologist (Project Assistant)
SHALINI R | Administrative Assistant
GUNDAPPA | Multi-tasking Staff
RAMACHANDRA S G | PhD (UAS), Chief Research Scientist (on lien)

FACT FILE

Established: 1971
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URL: http://caf.iisc.ac.in
Degree programmes offered: Nil

The Centre for Ecological Sciences (CES) conducts cutting-edge research in diverse areas of ecology, behaviour and evolutionary biology. We study a range of taxa, from insects, herpetofauna and birds to the largest land mammal, the Asian elephant. We employ diverse tools from field-based research to molecular ecology to mathematical modelling of ecosystems.

CURRENT RESEARCH

CES has continued to carry out cutting-edge research in the field of ecology, evolution and behaviour, which we summarise below.

Biogeographical variation in the venoms of the spectacled cobra (*Naja naja*) and Russell's viper (*Daboia russelii*), the two most important medically-relevant snake species in India, and the impact of this variation on the preclinical effectiveness of Indian antivenoms were demonstrated (Laxme et al., *PLoS Neglected Tropical Diseases).* In collaboration with the Serum Institute of India, the second generation of antivenoms were produced and their preclinical effectiveness is being tested. Similar collaborations have been initiated with VINS Biopharma to improve the efficacy of antivenoms for treatment of bites in India and sub-Saharan

FACT FILE

Established: 1983
Phone: +91-80-2293 2506, 23600985
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URL: ces.iisc.ac.in
Degree programmes offered: PhD and Int PhD

IN NUMBERS

10 Academic staff
1 Scientific staff
42 PhD students
2 Int PhD students
63 Publications
15 PhD student conferments
2 Honorary Professors

3.1.3 Centre for Ecological Sciences

CHAIRPERSON
K PRAVEEN KARANTH

Africa. A new species of medically important krait has been discovered in Karnataka, and the impact of phylogenetic crypsis and molecular mechanisms in diversifying the venoms of medically-important snakes were highlighted. The origin and diversification of defensive venoms were demonstrated in funnel-web spiders from Australia.

We contributed to the Oxford Dictionary contribution entitled Predator-Prey Interactions, which is a comprehensive review and synthesis of the field. We also had two major papers on this topic, one in the *Journal of Animal Ecology* that critically evaluates the impact of non-consumptive effects of predators on prey populations, and another in the *Proceedings of the Royal Society* with empirical data on the predator-prey space race. The second research focus was on animal communication, in which we published two papers on multi-species communication strategies in the *Proceedings of the Royal Society and Integrative Organismal Biology.*

We completed a series of outdoor enclosure experiments examining predator-prey interactions between bats and their katydid prey species to examine the risk posed by different behaviours for male and female katydids. We examined the predation risk posed by different signalling and search (movement) behaviours, including acoustic and vibrational signalling, walking and flying. We found that vibrational signalling posed essentially no risk, whereas acoustic signalling resulted in moderate levels of predator approaches. As expected, flight posed the maximum levels of risk for both males and females; however, we unexpectedly found that walking was not risky for either males or females. These results, with free, untethered predators and prey, offer novel insights into both the level of risk posed by different behaviours for prey as well as possible cues that predators may be paying attention to.

The research group on evolutionary ecology and biogeography of terrestrial and marine systems published a global collaborative review paper on mixed species groups *(Biological Reviews),* described several new species of frogs and snakes, and initiated two new research programmes on marine biology and herpetofauna. The Marine Integrated Science for the Tropics (MIST) project funded by IISc engages experts from ecology, oceanography, computational

CORE RESEARCH

CES carries out research in animal behaviour, behavioural ecology, bioacoustics, biogeography, chemical ecology, climate change, community ecology, ecosystem ecology, forest and grassland dynamics, macroecology, marine ecology, mathematical ecology and modelling, movement ecology, nutrient cycling, molecular ecology, venom evolution, phylogenetics, phylogeography, plant–animal interactions, predator–prey interactions, sensory ecology and stress physiology.

sciences and conservation biology, to develop a broad understanding of marine ecosystems in the islands. In addition, we have also deployed 'Autonomous Reef Monitoring Structures', a programme pioneered by the Smithsonian Institution, in collaboration with Hong Kong University. Additionally, the group is also leading a national project on long-term monitoring of herpetofauna as part of the MoEFCC and Long-Term Ecological Observatories Programme, with collaborators from multiple institutions.

We studied the role of age in non-reproductive division of labour in the tropical primitively eusocial wasp, *Ropalidia cyathiformis* and compared it with *Ropalidia marginata,* a congeneric species that exhibits relatively strong age polyethism. Age had a significant effect on the first performance of the four tasks studied; tasks were initiated in the sequence: feed larva, build, bring food and bring building material. We measured task performance as the absolute frequency of tasks performed (FTP) and the probability of performing a task relative to other tasks (PTP). FTP varied significantly with both absolute and relative age, although absolute age explained more variance. PTP varied significantly with absolute age but not always with relative age. This is contrary to R. marginata, where more variation is explained by relative age than by absolute age. We conclude that age polyethism is weak and less flexible in *R. cyathiformis* compared to that in *R. marginata.*

We have also undertaken studies in the areas of biogeography, phylogeography and molecular systematics. In this regard, papers dealing with the taxonomy of Himalayan langurs, origin and diversification of Indian Ceropegieae, historical biogeography of the freshwater gastropod and patterns of phylogenetic diversity across climatic zones of Western Ghats were published. Further, two online workshops on molecular phylogenetics were organised.

With the help of diverse systems ranging from figs and fig wasps to nematodes and nocturnal bees, we have shown how vision and/or chemoreception interact with physiology to influence ecology and evolution of multitrophic interactions. New topics studied are sensory biology of oviposition in galler, parasitoid fig wasps and ecology of sensilla; passive drift in air currents versus active anemotaxis in pollinating fig wasps and how that affects the diversity of fig wasps within microcosms; and sensory ecology of flower scent and colour patterns in plants. Other areas include sequencing the whole genome of the pollinator of Ficus racemosa and characterising its olfactory receptors, interfacing with civil engineers to understand construction of termite mounds and how this phenotype of termites achieve high structural strength, examining the respiration and energetics of individual fig syconia to model the nutrient flux within microcosm, and measuring thermal environments within natural microcosms and thermal tolerances of insects.

We have seen collective motion in birds, mammals, fish, insects, microbes, and so on, all of which exhibit fascinating patterns. Each individual has only limited local information about their surroundings. So, a question that many of us are interested in is: What types of interactions produce these spectacular visuals? This has been a question involving substantial work over the last few decades, and we provide fundamentally new insights here. Our work involved experiments of fish schools, data analysis, mathematical theory and computer simulations. The first insight from our work is that the fish use a much simpler rule — copy a random neighbour — than the more complicated rules popular in the literature. The second major insight is that stochasticity, arising from the fact that animal groups contain a finite number of individuals, plays the counter-intuitive role of enhancing order in fish schools. We also worked on the dynamics of forest-savanna transitions.

A paper was published on the interactive effects of land use change and climate change on the population dynamics of birds in the Eastern Himalayas in the journal *Ecology.*

Studies on topics related to the carbon cycle and ecosystem functions were also undertaken. This spans a wide spectrum of ecological and biophysical interactions. At one end of the spectrum are the functional roles played by microbial decomposers in soil that metabolise organic matter inputs from soil. Here, we studied how microbial functions and

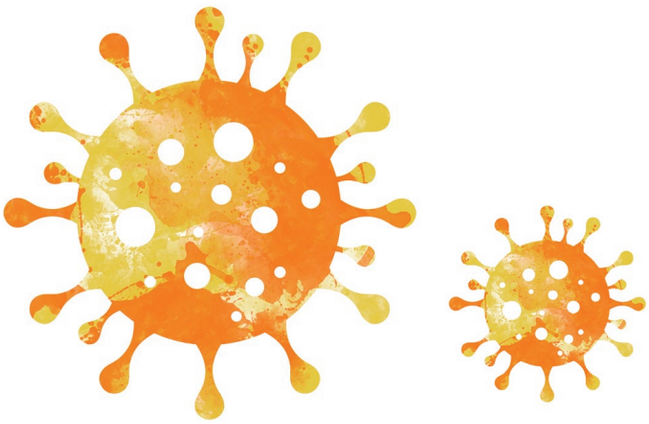
their functional diversity respond to human land use change. At the other end of the spectrum, scaling up to the whole planet, is the balance between microbial release of carbon from soil versus detrital inputs from vegetation. Here, we studied how the balance between influx and efflux of carbon responds to decadal-scale variability in temperature and precipitation.

Another area of research we undertake is the ecology and evolution of behaviour and life histories, and the application of behavioural approaches towards conservation. In our study of sexual selection in a wild population of the rock lizard, Psammophilus dorsalis, we tracked individually-identified males and females over their lifetime and carried out field experiments to assess a poorly understood research topic, namely how females signal to potential mates. In a project on behavioural and life-history strategies of mosquitoes belonging to *Aedes sp.,* which are vectors for dengue and other pathogens, we show that females experience variable selection pressures in the wild, which can shape their egg-laying strategies. In a second applied project on grassland butterflies, we show that butterflies pay attention to resource distribution at multiple spatial scales and balance acquiring multiple resources when deciding how to use space.

Physiological stress has the potential to influence animal population persistence. It is important to understand how the elephant's stress levels are influenced by socio-ecological factors when not directly exposed to human-induced threats, and to use this understanding to improve conservation and management strategies. In this study, we assessed the stress status (by measuring faecal glucocorticoid metabolites as a proxy of stress) in adult female elephants in the forests of Karnataka, India (Bandipur and Nagarahole National Parks). We found that the adult females in a herd with more calves and lesser adult females showed higher stress levels than the herd with lesser number of calves and more adult females. Additionally, adult females which were lactating have higher stress levels than those which were not. These findings suggest that herd size, lactation, presence of experienced (adult) and inexperienced individuals (calf) significantly influence the physiology of elephants.

FACULTY & STAFF

SUMANTA BAGCHI | PhD (Syracuse), Associate Professor
ROHINI BALAKRISHNAN | PhD (TIFR), Professor
RENEE M BORGES | PhD (Miami), FASc, FNA, Professor
RAGHAVENDRA GADAGKAR | PhD (IISc), FASc, FNA, FTWAS, International member, US Natl Acad Sci, Honorary Professor
VISHWESHA GUTTAL | PhD (Ohio), Associate Professor
KAVITA ISVARAN | PhD (Florida), Associate Professor
PRAVEEN KARANTH | PhD (SUNY, Albany), Professor
T V RAMACHANDRA | PhD (IISc), Scientific Officer
KARTIK SHANKER | PhD (IISc), Professor
UMESH SRINIVASAN | PhD (NCBS), Assistant Professor
RAMAN SUKUMAR | PhD (IISc), FASc, FNA, FTWAS, Professor
KARTIK SUNAGAR | PhD (Portugal), Assistant Professor
MARIA THAKER | PhD (Indiana State), Associate Professor



3.1.4 Centre for Infectious Disease Research

CONVENER
BALAJI K N

The main goal of the Centre for Infectious Disease Research (CIDR) is to integrate research activities in the area of infectious diseases with interactions and collaborations, and provide avenues for multidisciplinary activities with translational outcomes. CIDR hosts fellows with a fully equipped and functional laboratory and a state-of-the-art Bio Safety Level-3 (BSL-3) facility to perform their research. A dedicated viral BSL-3 has also started operations where research on emerging viral pathogens will be carried out. Research activities in CIDR are spearheaded by faculty members from Biological Sciences or scientists with senior level fellowships such as DBT-Wellcome Trust, Ramalingaswami, Ramanujan and so on, through which competitive grants have been procured for studies related to infectious disease research. In addition, CIDR received generous funding from the Infosys Foundation in January 2016.

CURRENT RESEARCH

RESEARCH ON *MYCOBACTERIUM TUBERCULOSIS:*

An important area of study is understanding the mechanisms by which *Mycobacterium tuberculosis* evades immunity. A comparative analysis of some 5000 whole genome sequences of *Mycobacterium tuberculosis* isolates curated from India identified precise amino acids that are recognised by CD4+ T cells, resulting in

FACT FILE

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the bacterium escaping immune recognition. These studies can potentially have significant impact on TB vaccine design. This work, along with a highly detailed analysis of the immune response induced by BCG vaccination — the only licensed vaccine in the fight against TB — has provided fresh insight into the potential efficacy of BCG revaccination in a TB-endemic country like India. In addition, key markers have been identified in chronically activated CD4+ T cells during *Mycobacterium tuberculosis* infection. The second area of investigation is potentiating the activity of anti-TB drugs by modulating host immune response to eradicate tuberculosis. Here, we performed a mid-throughput screening to identify small molecules that potentiate host immunity to target *Mycobacterium tuberculosis*. Our study points to the critical role of host and pathogen heterogeneity in tolerating antibiotics, and targeting the RIG pathway could be one of the strategies to increase the efficacy of anti-TB drugs in vivo.

RESEARCH ON EMERGING RNA VIRUSES

In the Infosys wing of CIDR, the Emerging Viral Pathogens laboratory was setup in 2019. The major focus of the lab is human RNA viruses, which are primary contributors of new pandemics and epidemics. On the influenza virus front, we are trying to develop novel broad-spectrum vaccines and antivirals. For SARS-CoV-2, we have developed cell culture and animal models to study virus biology and pathogenesis. These have been used to identify novel antivirals and test vaccine candidates. In

CORE RESEARCH

Ongoing work is directed towards understanding and targeting drug tolerance in *Mycobacterium tuberculosis* and application of network biology to identify new drug combinations. Another area of research is focused on the principal immune mechanisms that contribute to reactivation of tuberculosis in the context of HIV infection and affiliated research on the mechanisms of action of BCG vaccination and its efficacy in preventing TB. Another newly developed area of research is virus-host interactions of emerging RNA viral pathogens including SARS-CoV-2, and viruses that cause influenza and dengue. The overall aim is to understand the molecular basis of viral pathogenesis and translate the knowledge to novel antivirals and improved vaccine candidates.

addition, we have conducted research to identify a reliable gene expression signature for accurate prognosis of COVID-19 in nasal swabs. For dengue and other mosquito-borne flaviviruses, we are studying their interactions with the *Aedes aegypti* host, with the aim of developing CRISPR-based gene drives to abrogate viral transmission by the mosquito vector.

COVID-19 DIAGNOSTIC LAB

To meet the urgent need for scaling up diagnostic capacity in the wake of the COVID-19 pandemic, CIDR faculty members, with support from the IISc administration, have set up a dedicated COVID-19 diagnostic facility in the Infosys wing of CIDR. It became operational in early May 2020 and has already screened more than 1,00,000 samples so far from different collection centres across Bangalore and neighbouring cities.

VIRAL BSL-3 FACILITY

In the year 2020-21, a new BSL-3 facility has been established to conduct research on highly pathogenic viruses such as SARS-CoV-2, Avian Influenza and Coxsackievirus. The construction of the facility has been supported by the DBT-IISc partnership fund and its augmentation with advanced equipment has been supported by DBT-BIRAC. Currently, the facility is being used for development and testing of antiviral vaccines, drugs and materials against SARS-CoV-2. In the future, this facility will serve as a hub for pandemic preparedness and research on other emerging viruses of BSL-3 category.

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Understanding the structure, function and development of the brain in health and disease requires studying the brain across different levels of organisation using molecular, cellular, systems, cognitive, and computational approaches. These are the main focus areas of the Centre for Neuroscience (CNS). It recruits faculty across wide-ranging disciplines to establish a strong programme in basic neuroscience and builds links to existing expertise in IISc as well as with clinical centres to develop translational research. The department currently has 10 faculty members, one Honorary Professor, one Wellcome-DBT India Alliance Intermediate Fellow, two Ramalingaswami Fellows and one INSPIRE faculty fellow.

CURRENT RESEARCH

We recorded brain signals from awake monkeys using both microelectrodes and electrocorticogram (ECoG) electrodes and found that both signals have similar stimulus preferences (Dubey and Ray, *Scientific Reports)* and natural images can be better encoded and decoded using ECoG signals than any other signal (Kanth and Ray, *Journal of Neuroscience).* We also studied steady-state visually evoked potential (SSVEP) responses in monkeys and found that multiple SSVEP tags interact with each other in an orientation and

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31 Publications
6 Int PhD students
2 PhD conferments

3.1.5 Centre for Neuroscience

CHAIRPERSON
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frequency-dependent manner (Salelkar and Ray, *Scientific Reports).* Finally, in a large-scale EEG study on a healthy elderly population, we found that gamma oscillations, as well as SSVEPs, weaken with age.

Multiple neurons contribute to a common computation on a single trial, rather than a single neuron contributing to a computation across multiple trials. Using measures of within trial regularity, we showed using a combination of simulations and empirical data, that changes in the spiking regularity on single trials could be observed during movement planning and observed that the reaction time of the animal was faster when the neural spiking regularity within trials was lower. Taken together, our results provide further constraints on how changes in spiking statistics help neurons optimally encode information and its implication on behaviour.

In the last year, we have obtained several new insights into how the brain performs object recognition. First, we have studied how the brain processes jumbled words (Agrawal, Hari & Arun, 2020, *eLife).* Our main finding is that when we read a string of multiple letters, our brain creates a letter-based visual representation that is matched to items in memory. Second, we have performed a systematic comparison of object representations in brains and machines (Pramod & Arun, 2020, *IEEE Transactions in Pattern Analysis and Machine Intelligence).* Our main finding is that there are systematic biases between machine vision algorithms and brains, and fixing these biases can improve machine vision. In other work, we have shown that global and local processing can be explained using systematic representational rules (Jacob & Arun, 2020, *Journal of Vision)* and that perceptual priming shows different trends with age (Zhivago et al, 2020, *Frontiers in Aging Neuroscience).* Finally, we have reported a number of qualitative and quantitative dissimilarities between brains and deep neural networks (Jacob et al, 2021, *Nature Communications).*

Memories of lifetime events, once acquired, are consolidated over time and these memories acquire the ability to be retrieved independent of original brain structure where it was formed. During this process, our brain is thought to acquire representation that encapsulates the common features of related memories. However, little is known about how these memories are represented at the neuronal scale and if that representation has functional bearing during retrieval. Our research has shown that knowledge structure acquired through past experience not only enhances the cognitive capacity for encoding new related memories but

CORE RESEARCH

Movement and cognitive control, neurobiology of disease, neural mechanisms of selective attention, neuronal differentiation and development, neurobiology of learning and memory, molecular organisation of synapse, visual perception and recognition, interactions between emotion, motivation and cognition; molecular mechanisms of pain and itch, neural signal processing and oscillations.

also promotes emergence of novel context-relevant response in the animals. Results from our laboratory's research show that higher order associations develop during the remote retrieval, and through in vivo imaging, we tracked and showed that not just the numbers but spatial reorganisation can store these memory representations.

Astrocytes are the major glial cells in the central nervous system (CNS) and respond to CNS infection, injury or disease by undergoing a spectrum of gene expression, morphological and physiological changes in a process termed reactive astrogliosis. Reactive astrocytes can be protective or harmful for the normal functioning of the brain. We have identified the transcription factor, serum response factor (SRF), as critical for the maintenance of astrocytes in a non-reactive state (Jain et al., 2021). These SRF mutant mice exhibited better neuroprotection follow excitotoxicity and protected dopaminergic neurons in a mouse model of Parkinson's disease. Our findings indicate that SRF-dependent transcription is critical for the conversion of astrocytes to a neuroprotective state. Studies are ongoing to identify genes and pathways upregulated in these astrocytes that can serve as novel therapeutic targets to aid in neuroprotection following injury and in neurodegenerative disorders.

New areas of research included the following: 1) Development of a live super-resolution imaging microscope with a combination of radial fluctuation and stochastic labelling to image organelles in live cells. 2) Development of a paradigm for objective characterisation of nanoscale organization of F-actin in excitatory synapses imaged with Single Molecule Localisation Microscopy. 3) Understanding molecular determinants that control real-time nanoscale localisation and regulation of amyloidogenic processing of APP in the synapses of excitatory neurons. 4) Development of novel strategies for tRNA labelling to map translation events in sub-compartments of individual neurons.

We demonstrated that task-specific cognitive states can be reliably decoded by quantifying slow, directed functional interactions in the human brain, using Granger Causality (GC) and functional MRI scans (Ajmera et al, *eNeuro,* 2020). Secondly, we showed that "brain-age", a marker for the state of the brain's health, can be reliably predicted from an individual's structural connectome, estimated using diffusion MRI scans and tractography (Guruprasath et al, *Med-NeurIPS,* 2020). Thirdly, we showed that activity in the prefrontal and visual cortex encode fundamental components of attention with distinct neural codes (Chandrasekaran et al, *Cosyne,* 2021). In collaboration with Google Research, we also developed novel methods to improve anomaly detection with a popular class of deep generative models — variational autoencoders — with potential applications to diagnostic medical imaging (Chauhan et al, *arXiv,* 2021).

We set up the Emotion and Cognition lab at the Centre for Neuroscience, and initiated behavioural and brain imaging (functional MRI) research on interactions between reward and emotional processing.

We have used the model system *C. elegans* to study aspects of chemosensation and alcohol sensitivity. We have recently identified two receptors, SRX-97 and EXP-1 that are involved in sensing odours at different concentrations (Kadam et al., *eNeuro,* 2021 and Pandey et al., eNeuro, 2021). We have also shown that increased levels of dopamine make the animal very sensitive to ethanol. Our work has delineated the circuit through which dopamine functions to allow for increased ethanol sensitivity in *C. elegans* (Pandey et al., *PLoS Genetics,* 2021).

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The Molecular Biophysics Unit (MBU) is engaged in frontline research in contemporary areas of biophysics, structural biology and physiology. Research activities in the Unit focus on the structure, conformation and interactions of biomolecules and their functions, with the main objective of understanding biological activity in molecular terms.

CURRENT RESEARCH

Research investigations are focussed on biophysical, structural, and computational studies of biomolecules with the goal of understanding biological phenomenon at the molecular level.

Current research in theoretical and computational membrane biophysics seeks to understand the evolutionary advantage of maintaining the complex lipid diversity in biological membranes. We are trying to address a few fundamental questions in the field of membrane spatiotemporal organisation that arise due to the complexity in the lipid constitutions. Towards that end, a theory-based framework is being developed to rigorously characterise nanoscale domains in the membrane with liquid-liquid phase co-

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3.1.6 Molecular Biophysics Unit

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existence and explore the functional implications of membrane heterogeneity in terms of processes such as preferential localisation, insertion and assembly of peptides and peripheral/intrinsic membrane proteins.

Another area of exploration in the membrane biophysics field is related to extracting protein and membrane intermediates in vesicular trafficking pathways using multiscale modeling. Experimentally probing the short-lived and highly localised conformational changes in the membrane lipids, proteins and assembly intermediates during the membrane remodeling processes is non-trivial even with the most advanced high-resolution microscopy/imaging methods. Decoupling the role of individual motifs of the intricate protein machinery, where different components work in concert to tightly regulate vesicular trafficking, is one of the biggest challenges towards mechanistic understanding of the underlying processes. With dynamin and EHD proteins as our model systems for multi-scale simulations, we aim to understand the molecular basis behind the fission intermediates, ATP/GTP activity of these machineries and their interactions of membrane that leads to membrane curvature formation and fission.

Extensive analysis of 3D structures of protein-protein complexes has highlighted the importance of proximal interactions among sequentially-related residues for the stability of protein-protein

CORE RESEARCH

Research areas include inter alia protein folding and dynamics, protein-protein interactions, protein-DNA/RNA interactions, lectin-carbohydrate interactions, peptide synthesis and design, solution NMR studies of proteins and nucleic acids, X-ray crystallography of proteins, Cryo-EM studies of biomolecular complexes, computational modelling and dynamics of biological molecules, theoretical studies on the conformation of peptides, proteins, and nucleic acids, unusual nucleic acid structures and control of transcription, ionophores and drugs and their interaction with membranes, genome organisation, synthetic protein and vaccine design, ion channels and electrophysiology, neurophysiology and computational neuroscience.

complexes. Extensive computational analysis of toxin-antitoxin systems in *Mycobacterium tuberculosis* has enabled the identification of novel systems and the potential for cross-regulation among this important class of proteins. A protocol has been designed for repurposing clinically-approved drugs for use in infectious diseases as well as cancer.

High-throughput in vitro and in silico analyses have been carried out to understand the influence of flanking sequences outside the cognate sites in binding of three transcription factor (TF) families in vertebrates. It is found that local structural features of flanking sequences are instrumental in determining the binding affinity of TFs for their core consensus motifs.

Neurotransmitter transporters are vital for the control of neural communication and serve as targets for anti-depressants, addictive drugs and drugs to treat chronic pain. In this context, recently, the X-ray structure of a neurotransmitter transporter in complex with medication popularly used to treat neuropathic pain and fibromyalgia was elucidated. Antimicrobial efflux is a mechanism leading to multi-drug resistant pathogens. Recent work on a proton-driven antibacterial efflux transporter, QacA, has provided insights into the promiscuous substrate recognition observed in efflux transporters.

Novel inhibitors of the human alpha7 and alpha3beta4 nicotinic acetylcholine receptor subtypes have been characterised from the natural peptide libraries found in the venom of the marine cone snail Conus zonatus. Characterisation of the structure and function of the peptide and its variants show that cis-trans conformation about X-Pro amide bonds is crucial for nicotinic acetylcholine receptor subtype selectivity.

While the genetic basis for a number of neuropsychiatric disorders afflicting millions is increasingly being appreciated, for the first time, a link between immunity and obsessive-compulsive disorder (OCD) was established by demonstrating incursion of TH17 cells in the thalamic and brain stem circuit of the brain.

Models of medial entorhinal cortical stellate neurons exhibited degeneracy, whereby models with disparate channel combinations were endowed with similar physiological characteristics. The generation of dendritic spikes and the consequent sharp tuning of neuronal responses are together attainable even when iso-feature synapses are randomly dispersed across the dendritic arbour. Targeted synaptic plasticity converts silent cells to place cells for specific place fields in models with disparate channel combinations that receive dispersed synaptic inputs from multiple locations. The research demonstrated a unique convergence of cellular- and network-scale degeneracy in the emergence of channel decorrelation in the dentate gyrus, whereby disparate forms of local and afferent heterogeneities could synergistically drive input discriminability. It unveiled a pivotal role for dendritic voltage-gated ion channels in actively amplifying or suppressing biochemical signals and their spatiotemporal spread.

Studies were carried out on the sensitivity of the longer isoform of human brain TREK1 leak potassium ion channel to hypoxia, which has a neuroprotective role, using single-ion channel molecule patch clamp recordings on excised inside-out patches of hTREK-1 channels expressed in HEK293 cells. They indicate an increase in the activity of hTREK-1 channel during hypoxic conditions. Polymodal regulation by ischemic factors like pH and lactate are being investigated. The role of lactate whose concentration in the brain rises during epileptic activity is being investigated for its neuroprotective role in hippocampal subicular neurons and identifying the ion channel mechanisms. In vitro brain slice experiments are being conducted on the medial entorhinal cortex stellate cells (that show grid cell firing in vivo), subjected to in vivo-like stochastic synaptic activity through the dynamic clamp, to understand mapping between the speed-direction modulated excitatory inputs, and firing rate modulation.

Metal ions such as copper and iron are essential for many cellular functions and play a critical role in stabilising conformations that ensures storage and propagation of genetic information. Metals are

essential for the normal functioning of DNA and are also capable of producing errors in information transfer when in excess. There is compelling evidence that copper and iron bind directly to DNA, induce DNA damage and alter DNA structure and function, and play a role in the pathogenesis of Alzheimer's disease. Spectroscopic studies of the effect that metals have on conformational properties of GC-rich DNA sequences have revealed several dramatic effects of metal ions on the structure and function of nucleic acids.

Efforts are also underway to study amyloidogeneis in the Human islet amyloid polypeptide (h-IAPP, also known as Amylin). Amylin is a peptide hormone which is co-packaged and co-secreted with insulin by the pancreatic beta cells. In its normal physiological role, it is associated with glucose homeostasis, control of gastric emptying, suppression of glucagon release and satiety regulation. The secreted amylin has the propensity to form membrane-toxic oligomers which causes it to aggregate into dense insoluble fibrillar deposits (amyloid deposits) that accumulate in the pancreas. Deposits have been postulated to be one of the main contributors to impaired insulin secretion and pancreatic β-cell death in approximately 90% of Type-II diabetic patients and eventually lead to cell dysfunction and apoptosis. Recent evidence also suggests that amylin accumulates in the brain of AD patients, may interact with Aβ peptides and can contribute to the neurodegenerative process. Studies are underway to improve our understanding of the mechanism of aggregation of peptide-metal complex and identification of novel compounds that prevent cytotoxic polypeptide self-assembly and amyloidogenesis.

Two new research areas on understanding the molecular mechanism behind the mammalian circadian rhythms and metamorphic proteins have been initiated.

Maintenance of telomere DNA has implications in cellular aging and cancer. Several proteins and telomere repeat containing non-coding RNA, TERRA, play roles in this process. Recently, it was shown that the RGG-box in hnRNPA1 specifically recognises the telomere DNA and RNA G-quadruplex structures and helps the adjacent UP1 domain to unfold DNA G-quadruple efficiently. Bacterial toxin-antitoxin (TA) systems play roles in bacterial persister cell formation, phage resistance, and antibiotic tolerance. Structures of type II (HigBA) and type III (toxin) TA complexes from *E. coli* revealed the assembly mechanism of these TA complexes.

Research is underway towards characterisation of large multi-protein complexes that mediate intra-cellular RNA levels in *Staphylococci.* Furthermore, the molecular mechanism(s) that link environmental conditions with transcription regulation in *Mycobacteria* are under investigation. A recent prominent finding was that RNA degradation mechanisms are directly regulated by other information pathways in bacteria.

UV cross-linking experiments and ITC revealed that the association of 32P azido-labeled ppGpp with RNAP was weaker without the ω subunit. Altered distribution of RNA polymerase lacking the omega subunit was found within the prophages along the *E. coli* genome. ChIP-chip analysis of wild-type and rpoZ-defective mutant strains elucidated the functional role of the omega subunit. Substrate-induced domain movement in a bifunctional protein, DcpA, regulates cyclic-do-GMP turnover. C-di-GMP homeostasis in M. smegmatis is supported by DcpA, a bifunctional protein. FRET experiments were used to gain insight into how interactions and movement among these three domains affect the DcpA activity.

Structural studies on mycobacterial proteins involved in maintaining genomic integrity and mycobacterial and archeal lectins were carried out. The mode of action of second single-stranded DNA binding proteins, RecGwed and MutT2, has been elucidated. A major long-range collaborative programme on the design of inhibitors against selected TB proteins has been initiated.

A novel therapeutic approach targeting both a metabolic pathway in *Mtb* essential for its survival and the host machinery crucial for its survival in the host was developed. The compound targets an allosteric

site in the essential enzyme ArgJ of *Mtb* not found in humans or their commensals sparing the humans from the harmful effects of currently used therapy.

Derivatives of the receptor binding domain of the spike protein of the novel SARS-CoV-2 virus were designed and characterised, and shown to be highly thermotolerant and immunogenic in small animals. These are being further developed as potential vaccine candidates. In other studies, a HIV-1 gp120 derived fragment was expressed on the surface of proteinaceous nanoparticles and was exposed to different immunogen combinations to elicit neutralising antibodies. Diverse protein engineering strategies were used to design and test derivatives of the outer domain of HIV-1 gp120 as potential immunogens. Immunogens derived from the conserved stem of the influenza virus surface protein, hemagglutinin, were designed. Using the methodology of yeast surface display, the immunogen libraries were screened to isolate a derivative that was thermally stabilised over previous design by about 24°C. This will be tested in future vaccine studies.

The crystal structures of the coiled-coil region of nonstructural protein 4 (NSP4), from two strains of the rotavirus as two novel antiparallel tetrameric forms were determined. The study demonstrates the structural diversity of the protein under different conditions. DNA damage-inducible 1 (Ddi1) is a multidomain protein with one of the domains being retropepsin-like. HIV-1 protease inhibitors were found to reduce opportunistic infections caused by pathogens like *Leishmania* and *Plasmodium,* and some of them were shown to inhibit the growth of these parasites. The crystal structure of the retropepsin-like domain of Ddi1 from *Leishmania major* was determined and its binding with one of the HIV-1 protease inhibitors was characterised in solution.

The structural basis for the coupled binding-induced folding of the intrinsically disorderd Viral Protein genome-linked (VPg) has been determined using solution NMR methods. Crucial aromatic pi-pi interactions and CH-pi interactions drive this coupled folding upon binding and are necessary for the structural stability of the complex. These results provide an important basis for predicting the binding and folding of other intrinsically disordered proteins.

Incorporation of thioamide into the peptide backbone of a cyclic peptide results in enhanced local rigidity. The increased local rigidity translates into global rigidity of the peptide backbone. This increased rigidity results in extremely well-defined conformation of the peptide that could be used to pre-design the orientation of pharmacophores for target recognition. This was utilised to develop cyclic peptides that have very high affinity to integrins in cellulo. The structural rigidity also results in increased metabolic stability of the peptides in human serum ex vivo. The results have been extended to develop orally bioavailable model cyclic peptides and sub-cutaneously administered somatostatin agonists that show long-term growth hormone inhibition in rats. This demonstrates the promise of the single atom substitution (O to S) onto the peptide backbone to improve the pharmacokinetic and pharmacodynamic properties of macrocyclic peptides.

Structural studies of polyketide synthase, pore-forming toxin bacterial secretion system, bacterial ion channels and GPCRs are underway using cryo-electron microscopy. Cryo-EM techniques are used to characterise the protein structure, conformational changes and dynamics of very small (100 kDa) protein complexes to extremely large biological macromolecules (2.6 Mda). Furthermore, cryo-EM was used to characterise SARS-CoV-2 spike protein, which helped to characterise vaccine designs against SARS-CoV-2.

Abundant n / p* interactions between adjacent backbone carbonyl groups, identified by statistical analysis of protein structures, are predicted to play an important role in dictating the structure of proteins. However, experimentally testing the prediction in proteins has been challenging due to the weak nature of this interaction. By amplifying the strength of the n / p* interaction via amino acid substitution and thioamide incorporation at a solvent exposed b-turn within the GB1 proteins and Pin 1 WW domain, we demonstrate that an n / p* interaction increases the

structural stability of proteins by restricting the f torsion angle. Our results also suggest that amino acid side-chain identity and its rotameric conformation play an important and decisive role in dictating the strength of an n / p* interaction.

An important component of the research programme in one of the labs is to further our understanding of intra- and extra-cellular events that govern persistence or virulence in bacteria. Understanding this molecular mechanism can potentially impact our understanding of host-pathogen interactions and influence therapeutic intervention. We use *Staphylococcus aureus* as a model system for these studies. Recently, we could extend the scope of this study to evaluate the role of RNA-mediated intra-cellular signalling in the context of the phenotypic switch. The focus was on RNase J enzymes that are involved in RNA maturation, RNA recycling and gene expression in bacteria. These metallo-hydrolases catalyse both exo-nuclease and endo-nuclease activity. The catalytic activity of RNase J was seen to be regulated by multiple mechanisms which include oligomerization, conformational changes to aid substrate recognition and the metal cofactor at the active site.

Recent contributions include the following: 1) Quantitatively defined efficiency of spatial encoding in hippocampal place cells and demonsted that efficient phase coding can be achieved through several disparate routes. 2) Demonstrated the expression of significant heterogeneities in the intrinsic properties of granule cells in the hippocampus. 3) Demonstrated degeneracy in the emergence of spike-triggered averages, an important measure of the features that a neuron encodes, in hippocampal pyramidal neurons. 4) Demonstrated that the robust emergence of sharply tuned place cell responses in hippocampal neurons does not require precision in structural or ion-channel properties, but can emerge even in the presence of heterogeneities.

A facile method of mapping HIV-1 neutralising epitopes using chemically-masked cysteines and deep sequencing was developed. Env, the major surface protein of HIV-1, is the primary target of the immune response elicited against HIV-1, and is therefore an important candidate for vaccine design. Vaccines confer protective immunity by eliciting neutralising antibodies that not only bind to a virus, but also prevent further infection. The knowledge of target sites (epitopes) of neutralising antibodies on the viral surface is therefore a prerequisite for the design of effective vaccines. We have devised a high-throughput methodology to rapidly identify epitopes of monoclonal and polyclonal neutralising HIV-1 antibodies on Env, at single residue resolution. The methodology is useful for both design and testing of HIV-1 vaccines and can be readily extended to identify neutralising epitopes in emerging viral infections *(PNAS,* 2020).

We have calculated the structure of an excited state in equilibrium with the intrinsically disordered state of the transcriptional repressor protein CytR. The structure is a three-helix bundle that is very similar to the structure of DNA-bound functional form of CytR. Secondly, we discovered an aberrant DNA binding characteristic of the Cas12a endonuclease through SPR experiments. We have localised the binding to the RuvC domain of this enzyme. Thirdly, we have developed a new method for calibrating weak radiofrequency fields for CEST experiments using features in off-resonance nutation profiles of small molecules. The method is very sensitive to the value of the B1 field with errors of the order of 0.1-1%. We have verified the accuracy of the B1 values by cross-validating against the values obtained from a standard on-resonance nutation experiment. Fourthly, we have shown that the PAS-B domain of PER2 forms large oligomers in solution that are disrupted by a phosphomimetic S478D mutation.

1) Phase boundary fluctuation spectra in membranes with the nanoscale organisation: We employed a highly automated supervised machine learning technique (Support Vector Machine) to quantify the phase boundary and its fluctuations in several different biological membrane systems exhibiting co-existing fluid phases. 2) Intrinsically disordered patterns in the nanoscale membrane organisation: The central question we are addressing in this work is the possibility of degeneracy in the nanoscale membrane

organisation for a membrane with in vivo composition. We use ideas from energy landscape theory and statistical mechanics to answer the question. (3) Lipid packing defects and implications on membrane association of peripheral protein: Here, we explore the implications of membrane packing defects on processes such as peptide folding/insertion in the membrane.

The function and structure of novel single disulfide conotoxins as allosteric nicotinic acetyl choline receptor antagonists have been demonstrated. The importance of aromatic interactions on the coupled folding and binding of intrinsically disordered proteins was also studied.

The interests of our laboratory lie in understanding protein-nucleic acid interactions that play roles in telomere DNA/chromatin remodelling, non-coding RNA recognition, and bacterial toxin-antitoxin system assembly and functions. We employ biophysical methods that include solution-state NMR, CD, fluorescence spectroscopy, X-ray crystallography, isothermal calorimetry, computational analysis, and biochemical assays in our work. Recently we have shown that an intrinsically disordered, arginine and glycine-rich domain (RGG-box) of hnRNPA1 specifically recognises the higher-order telomere DNA and TERRA RNA G-quadruplex structures, but not the single-stranded DNA or RNA. This helps the adjacent UP1 domain in hnRNPA1 to unfold G-quadruplex structures more efficiently. The lab is currently pursuing the understanding of the role of arginine methylation in the structure of the RGG-box.

The stellate cells (SCs) of the medial entorhinal cortex (MEC) are important for spatial navigation and learning as well as theta and gamma brain oscillations. Using brain slice preparations and a dynamic clamp, a systematic assessment of synaptic theta modulation of subthreshold resonance properties due to HCN channels to control suprathreshold neuronal firing motifs was done. The study has important implications in understanding the computations in the medial entorhinal cortex in vivo for executing complex behaviours. In a different study, we showed cell type-specific acetylcholine receptor-independent shift in resonance frequency by partially inhibiting HCN current during high cholinergic inputs in the subiculum showing the direct modulation of a voltage gated ion channel by acetylcholine. Such interaction can modulate hippocampal output.

We elucidated the structural basis of noradrenaline recognition and the ability of neurotransmitter transporters to distinguish between dopamine and norepinephrine. The work allowed us to understand the basis of specificity of chronic pain inhibitors towards the norepinephrine transporter. The findings would allow us to design improved inhibitors against neurotransmitter transporters. We also have developed technology to isolate single domain camelid antibodies and are using them to study multi-drug efflux transporters. As an extension of this study, we have recently solved the structure of a multi-drug efflux transporter in complex with a camelid antibody that block transport through a bottle-cork mechanism. SARS-CoV-2, the causative agent of COVID-19, employs the spike (S) glycoprotein to interact with the human Ace2 receptor (hAce2) and for subsequent pathogenesis. Three major conformations of the S glycoprotein were observed, 1-RBD up open, 2-RBD up open and 3 RBD down close conformations, although 2-RBD up open conformation was not widely visible. The open conformation of the spike protein is mainly responsible for binding with hAce2. However, there are no specific studies that indicate any intermediate conformations of open and close spike protein. Also, previously, several studies indicted that the spike protein has significant conformational changes at various pH levels. Therefore, in this study, we implemented cryo-EM-based structural analyses to identify several intermediate conformations of the spike protein.

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SARASWATHI VISHVESHWARA | PhD (New York), Professor

The origin of the Department of Microbiology and Cell Biology (MCB) traces back to the Pharmacology Laboratory and the Fermentation Technology Laboratory, both established in the early 1940s, which were amalgamated in 1968. MCB has 17 faculty members: 6 Professors, 5 Associate Professors, 5 Assistant Professors and 1 Honorary Professor. The major research activities include investigations on microbial pathogenesis, and eukaryotic cellular and developmental processes.

CURRENT RESEARCH

PATHOGENESIS AND GENOME BIOLOGY OF HUMAN PATHOGENS

One of the mechanisms by which the human pathogen *Salmonella enterica* causes infection is by surviving inside dendritic cells (DCs) and suppressing antigen presentation. Mechanistic studies revealed that Salmonella infection induces a host epigenetic modulator SIRT2, which produces nitric oxide (NO) in amounts required to inhibit the T cell response. This inhibition of T cell via SIRT2-mediated NO production impairs antigen presentation, facilitating the establishment of Salmonella infection. Similarly, examination of host-pathogen interaction in the context of tuberculosis (TB)-causing bacteria *(Mycobacterium tuberculosis [Mtb])* identified an epigenetic mechanism coordinated by c-ABI-TWIST1 to deregulate inflammatory response during *Mtb* infection. This study proposes to use c-ABI inhibitors in potentiating innate immune response against TB infection. Further investigation on *Mtb* revealed a crucial role for a protein called WhiB4 in protecting the

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IN NUMBERS

18 Academic staff
3 Scientific staff
90 PhD students
10 Int PhD students
52 Publications
3 Int PhD conferments
9 PhD conferments

3.1.7 Microbiology and Cell Biology

CHAIRPERSON
KUMAR SOMASUNDARAM

TB bacteria from oxidative stress by condensing the DNA. Compacted DNA has a reduced surface area and hence lower vulnerability to oxidative stress. Modulating the levels of WhiB4 attenuated the ability of *Mtb* to survive inside macrophages and in animal models of experimental TB. Asymmetric cell division and heterogeneity in cell length also modulate the mycobacterial stress response. It was shown that mycobacteria secrete diadenosine polyphosphates (Ap) to induce variations in the length of mycobacterial cells during cell division. In the context of protein translation, studies have identified the evolutionary lineages of initiator and elongator methionine tRNAs. This study led to the identification of a single mutant tRNA capable of initiating and elongating protein synthesis in bacteria, thus indicating that initiator and elongator methionine tRNAs might have originated from a single 'dual function' tRNA. Using *Mycobacterium smegmatis* as a model system, it has been demonstrated that modulation of DNA gyrase expression has a widespread influence on cell division, nucleoid structure, chromosome condensation, and gene expression. Knocking down DNA gyrase also led to increased susceptibility of bacteria towards clinically relevant anti-TB drugs.

VIRAL PATHOGENESIS AND VACCINE DESIGN

Hepatitis C Virus (HCV) is a liver-specific pathogen which manipulates the host machinery to establish chronic infection. Studies have identified the role of a host factor, Human antigen-R (HuR), and a micro-RNA (miR-125b) in mediating HCV replication. Furthermore, a long non-coding RNA, Highly Upregulated in Liver Carcinoma (HULC), was found to increase the number and the size of lipid droplets (LDs), which enhanced the association of the viral core protein with LDs and facilitated the release of the virus particles. Human RNA viruses are the primary cause of frequent outbreaks, epidemics, and global pandemics. Among them, respiratory RNA viruses like Influenza and SARS-CoV-2 have caused catastrophic pandemics. Current research in the department is focused on identifying the molecular basis of viral pathogenesis and strain-specific differences in virulence. This knowledge is being translated towards the development of new vaccine candidates and identifying host-directed antivirals. For COVID-19, a gene signature has been identified in the nasal swab of patients, which can accurately predict the status of the diseases. For Influenza, a nanoparticle-based vaccine candidate is being formulated, which covers the conserved and immunodominant regions of the viral proteome for broad-spectrum protection. A virus-like particle-based vaccine candidate is in development for COVID-19. Furthermore, research on antiviral innate immunity in the context of interferons and beyond that in non-canonical forms is being conducted to identify novel antiviral mechanisms. Finally, viral engineering, especially for Influenza and SARS-CoV-2, using reverse genetics approaches, is being

CORE RESEARCH

Some areas where MCB has a long tradition of excellence are host-pathogen interaction, gene regulation, cancer and cell biology, vaccine and drug development, and plant biology. Some newer areas where we are expanding include systems biology, molecular virology, microbial ecology, and cardiovascular and muscle research.

undertaken to develop reporter viruses that can be used for studying various aspects of the viral life cycle and screening antivirals and vaccines.

CELLULAR PROCESSES, CELL DIVISION, AND CANCER BIOLOGY

Correct orientation of the mitotic spindle during metaphase is fundamental for dictating the future plane of the cell division axis. It is well known that the evolutionarily conserved dynein adaptor protein NuMA regulates the correct spindle orientation. Further studies discovered that Polo-like kinase 1 (Plk1) directly phosphorylates NuMA and regulates proper spindle orientation by orchestrating the cortical localisation of NuMA/dynein. Inhibition of Plk1 in metaphase robustly enriches NuMA and dynein at the cell cortex, which affected spindle orientation on cells grown on the L-shape micro-patterns. In humans, several lysosomal disorders are mediated by alterations in the mechanisms of cargo segregation, vesicle biogenesis and transport, and vesicle fusion. Work in this direction identified a major role for Rab22A in recycling endosome biogenesis and Rab4A in organising cargo-specific domains on sorting endosomes. Efforts are also ongoing to understand microRNA (miRNA) metabolism in Caenorhabditis elegans *(C. elegans),* primarily how these regulatory RNAs themselves get regulated by the turnover pathway. In cancer biology, genetic and epigenetic landscapes were identified during glioma (adult brain tumor) development. It was discovered that RNA methylase METTL3 and m6A modification are essential for glioma stem cell growth. Furthermore, it was found that GBMs with Calcitonin receptor (CALCR) mutations define a subtype with a poor prognosis. To launch an effective immune response against a solid tumour, immune cells such as cytotoxic T cells (CTLs) must traffic to the tumour and precisely recognise and react to tumour cell-derived biochemical signals ('antigens') within the tumour microenvironment. However, immunosuppressive microenvironments within tumours inhibit T cell infiltration and function. Despite intense research into the tumour factors that drive immunosuppression, our understanding of precisely how these mechanisms alter a T cell's anti-tumour function is still limited. We aim to address this mechanistic gap by investigating the fundamental mechanisms in T cells that sense and transduce the tumour antigen contexts, using cell biological approaches. We will explore the molecular and biophysical mechanisms that either block T cell infiltration into solid tumours or prevent tumour recognition by infiltrating cytotoxic lymphocytes and characterise the unconventional immune cell types known to have potent anti-tumour activity. This research will further our understanding of tumour-specific factors that suppress the immune system leading to tumour progression. This knowledge will also help solve outstanding questions in existing tumour immunotherapies and lead to new, more potent, safer, and cost-effective therapies targeting solid tumours. In addition to the membrane-bound organelles like nucleus and mitochondria, the cellular microenvironment is further compartmentalised by biomolecular condensates of RNA binding proteins (RBPs) and RNA, like nuclear splicing speckles, nuclear stress granules, and cytoplasmic stress granules. These condensates form by a physicochemical process known as liquid-liquid phase separation, which makes them dynamic, enabling them to exchange components with the surroundings and behave like liquid droplets. Importantly, changes in phase behaviour of condensates result in pathological neurodegenerative conditions like Amyotrophic Lateral Sclerosis (ALS) and Frontotemporal Dementia. We focus on understanding the role of RNA interaction in the formation and function of biomolecular condensates. More specifically, we are studying phase behaviour of ALS implicated RBPs from the perspective of pathological repeat RNA and oxidised RNA found in ALS, which will provide novel insight into the physiological relevance of RNA and mechanism of RBP aggregation in ALS and other proteinopathies where LLPS-prone RBPs aggregate.

GENE REGULATION, DEVELOPMENT, AND LIFESTYLE DISEASES

Fundamental mechanisms underlying cardiovascular diseases and pathologies are not entirely understood. The lack of essential tools to study heart failure in vitro and in vivo is a stumbling block for development. A simple and cost-effective method was developed for culturing cardiomyocytes using keratin derived from human hair to study cardiac hypertrophy. This resulted in elucidating the role of SIRT2 deacetylase in the development of heart failure. The SIRT2 deficiency hyperactivated NFAT signalling pathway in the heart, thus inducing spontaneous pathological cardiac

hypertrophy. Another SIRT family member, SIRT6, played an essential role in causing metabolic shift associated with the remodelling of the failing heart. *Myxococcus xanthus* is a gram-negative bacterium that cooperatively forms spore-filled multicellular fruiting bodies upon starvation. Repeated bottlenecks during lab evolution experiments resulted in the emergence of a genotype with superior developmental phenotype in *M. xanthus* populations. Since repeated population bottlenecks can limit diversity and increase kinship, our further experiments demonstrated that lower diversity in such populations is the primary reason for the evolution of cooperation during development. Finally, we show trade-offs between the quantity of spores produced during development and their quality and between spore quantity and predation in *M. xanthus.* These results uncover previously unknown trade-off patterns in *M. xanthus.* In plant developmental biology, genome-wide datasets of OsMADS1 transcription factor-chromatin interactions and comparative gene expression generated snapshots of two temporal gene regulatory networks. One of its indirectly downstream targets, a transcription factor OsbZIP47, was shown to partner with OsMADS1, thus establishing a regulatory loop between these factors that likely control floral development. Intron splicing is an essential step in the post-transcriptional fine-tuning of eukaryotic gene expression to give functional mRNA. The role of a critical RNA helicase in intron context-specific splicing and centromere heterochromatin formation was uncovered in yeast.

The timing of the transition to flowering in plants is crucial for their reproductive success. Two transcription factors, VASCULAR PLANT ONE–ZINC-FINGER1 (VOZ1) and VOZ2 were found to promote flowering in Arabidopsis by modulating the activity of flower-promoting transcription factor, CONTANS. At the level of cellular morphogenesis in plants, the molecular control of cell shape in the epidermis, especially trichomes, is not clear. Studies show that the CIN-TCP transcription factors suppress trichome branching in Arabidopsis by direct transcriptional activation of the GLABROUS INFLORESCENCE STEMS transcription factor, a known negative regulator of trichome branching.

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Research in the Department of Molecular Reproduction, Development and Genetics (MRDG) is diverse and ranges from molecular to organismal scales. Groups within the department conduct research in bacterial and human genetics, signal transduction, mammalian reproduction, endocrinology, cell and developmental biology, ageing and metabolic disease, cancer, stem cells and cryo-electron microscopic analysis of large macromolecular complexes.

CURRENT RESEARCH

The following are the important ongoing research projects with recent progress in MRDG.

SIGNAL TRANSDUCTION, INFECTION AND TRANSGENIC MOUSE MODELS TO STUDY GASTROINTESTINAL FUNCTION

A novel transgenic mouse has been characterised, harbouring an activating mutation in the receptor guanylyl cyclase C that appears to mimic some of the features seen in patients with familial diarrhoeal syndrome. These changes include an altered gut microbiome and increased faecal water content and gut transit. The role of a universal stress protein in modulating biofilm formation in *Mycobacterium smegmatis* has been shown, and the role of a novel phosphodiesterase in mycobacteria that has profound effects in cell physiology and membrane properties has also been characterised. We also identified a novel protein in mycobacteria that condenses DNA and binds RNA. We investigated the consequences of expression of

3.1.8 Molecular Reproduction, Development and Genetics

CHAIRPERSON
POLANI B SESHAGIRI

hyperactive receptor guanylyl cyclase C in the gut, and identified changes that include alterations in the microbiome and intestinal gene expression.

CELLULAR SIGNALLING AND INFLAMMATION

Towards understanding aging and inflammation, research is focused on a class of receptors known as G protein-coupled receptors (GPCRs) and their roles in the cascade of events that occur when cells grow old or 'aged'. Receptors, however, do not work in isolation, and research is keenly being pursued on the mechanisms by which GPCRs and receptors of other classes cross paths, a phenomenon known as 'cross-talk'. The ramifications of such cross-talk in the context of cellular responses in aged cells are being studied, using live imaging, pharmacological and gene inactivation and metabolomics profiling approaches. Similar to eukaryotic cells, prokaryotic bacterial cells also possess an extensive internal network of connections that direct specific responses to specific stimuli. In this area, studies are carried out on two-component signalling (TCS) cascades and we recently reported the presence of intricate networking amongst TCS systems in *Mtb.* A Raman spectroscopy-based bacterial identification and viability assessment platform has been developed. In the field of bacterial signalling, the role of carbon metabolism in modelling the signal transduction pathways has been established.

STRUCTURAL BIOLOGY OF TRANSLATION

Scd6 is a highly conserved protein and functions to repress translation by binding to eIF4G. However, there is no clear understanding of the interaction between the two proteins and how this repressor protein is regulated. In order to study the interaction between the Scd6 and eIF4F, recombinant His-eIF4G protein was expressed and purified. 100nM eIF4G was incubated with increasing concentration of recombinantly purified Scd6. Native PAGE analysis showed binding of Scd6 with eIF4G at 1:1 and 1:2 ratio but not at higher concentration of Scd6. Purified Scd6 undergoes oligomerisation as analysed by native PAGE and the oligomerisation is driven by the RGG motif. Results suggests that Scd6 forms higher oligomers whereas Scd6-without-RGG and mutant Scd6 remain as monomer. Thus, self-association of RGG motifs seems to regulate the translation repressor protein, Scd6.

CORE RESEARCH

The core research areas of the department are as follows: gene regulation in prokaryotes and eukaryotes, host-pathogen interactions, human genetics, X-inactivation, signal transduction, developmental biology and ageing, adipocyte differentiation and metabolic disease, morphogenesis, mouse embryo development, stem cells and differentiation, reproductive biology, endocrinology, cancer biology and cancer stem cells, and protein translation and its regulation.

During protein synthesis in eukaryotes, the eIF4 group of factors plays a role in recruiting mRNA to the ribosome. In order to study mRNA recruitment by eIF4 factors on the 40S ribosome, reconstitution of yeast 40S-eIF4B complex was standardised using sucrose density gradient centrifugation assays. This complex was subjected to cryogenic electron microscopy, and we were able to observe an extra density protruding from the ribosomal protein rps20, which may belong to a part of eIF4B. However, the resolution of the map needs to be improved to assign the density to eIF4B unambiguously. Further, efforts were also made to optimise the purification of complex eIF4 factors. In a separate effort, we have performed molecular screening of the FDA-approved drug library towards a SARS-CoV-2 protein. The top hits were subjected to molecular dynamics simulation analysis, and their stability was monitored throughout the simulation. Efforts were made to characterise the interaction of drug molecules.

HOST-MICROBE INTERACTION

Research focused on understanding how sensing/perception in a complex environment shapes adaptation in prokaryotes and eukaryotes, ensuring their survival. A genetically tractable eukaryotic model, Caenorhabditis elegans, has been utilised to understand how sensory neurons and G-protein coupled receptors allow sensing of microbes in the environment leading to adaptation in the worm's behaviour or its physiology, to optimise its survival. It was found that *C. elegans* uses olfaction as the means to distinguish between some species of bacteria. Volatiles that are perceived as threats allow worms to run away (flight response), lay their eggs far away from threat cues and allow them to mount a defensive physiological response. Also, Pseudomonas aeruginosa, a Gram-negative bacterium, has been utilised to understand how its large genomic repertoire of two-component sensors and response regulators (136 genes) regulates quorum-dependent processes, namely swarming motility and biofilm formation.
Research also focused on identifying 18 two-component systems in Pseudomonas aeruginosa as regulators of biofilm formation on endotracheal tubes. This sheds lights on genes which affect disease pathology in patients suffering from ventilator-associated pneumonia. Studies were also carried out on identification of an olfactory G Protein-Coupled Receptor STR-2 as a regulator of lipid metabolism and longevity in *C. elegans,* and lipid breakdown as fuel for facilitating innate immune response of *C. elegans* to bacterial and fungal pathogens of medical importance.

REPRODUCTIVE BIOLOGY AND EARLY MAMMALIAN DEVELOPMENT

Early mammalian development is fundamental to the procreation of mammals. The genesis of mammalian life begins with the fusion of functional male and female gametes, leading to a series of mitotic cleavage divisions and formation of the first differentiated embryonic entity which is the blastocyst that contains an inner pluripotent stem cells mass and an outer single layer of trophectodermal cells. The laboratory has been addressing the above critical early developmental event, particularly the phenomenon of blastocyst hatching, at the cellular and molecular levels, by judiciously employing rodents (mice and hamsters) and spent medium from cultured human embryos (from IVC clinics).

Studies on the cellular and molecular regulation of blastocyst hatching and pluripotent stem cell (PSC) differentiation are in progress. Molecular regulators responsible for rodent blastocyst development and hatching have been investigated. Expression and function of blastocyst-derived hatching enabling factors were identified and characterised. A non-invasive approach to measure human embryo-viability biomarkers was carried out. Our in-house derived and established mouse embryonic stem cells (GS-2 ESCs) and induced pluripotent stem cells (N9 iPSCs) were employed as cellular platforms to achieve cell lineage commitment and differentiation toward cardiovascular progenitors and their enrichment and expansion, for potential use in cell transplantation.

In the last year, rodent development data showed that the development and hatching of blastocysts are improved by supplementation of cytokines, particularly interleukin Î²1 (IL-1Î²). We also showed that the blastocyst-derived zona-lysins, for example, cathepsins (hamsters) and ISPs (mouse), are

responsible for hatching. Besides, human embryo-derived spent medium had measurable quantities of HLA-G, the levels of which positively correlated with the progression of embryo development and live births post-ET in the human (a retrospective correlative analysis).

In addition, reproductive and stress status in free-ranging Asian elephant have been assessed by measuring faecal progesterone and glucocorticoid metabolites and they were correlated with the wellbeing of free-ranging elephants in the wild versus human-dominated landscapes.

EPIGENETICS OF DEVELOPMENT

Recently, a unique form of X-chromosome dosage compensation has been demonstrated in human preimplantation embryos, which happens through the dampening of X-linked gene expression from both X-chromosomes. Subsequently, X-chromosome dampening has also been demonstrated in female human pluripotent stem cells (hPSCs) during the transition from primed to naïve state. However, the existence of dampened X-chromosomes remains controversial in both embryos and hPSCs. Specifically, in preimplantation embryos, it has been shown that there is inactivation of X-chromosome instead of dampening. Allelic analysis of X-linked genes was performed at the single cell level in hPSCs and it was found that there was a partial reactivation of the inactive X-chromosome instead of chromosome-wide dampening upon conversion from primed to naïve state. In addition, analysis suggested that the reduced X-linked gene expression in naïve hPSCs might be the consequence of erasure of active X-chromosome upregulation.

A unique form of X chromosome dosage compensation was recently demonstrated in human preimplantation embryos and pluripotent stem cells (hPSCs), which happens through the dampening of X-linked gene expression. However, the existence of dampened X chromosomes in both embryos and hPSCs remained controversial. We discovered that the reduced X-linked gene expression in naïve hPSCs originates from the erasure of active X chromosome upregulation, not because of dampening. Moreover, we have given insight that in preimplantation embryos, there is no dampening but rather X-inactivation. Our studies shift the paradigm of the X chromosome states of early human development. In addition, the origin of dynamic random monoallelic expression of autosomal genes (aRME) remains poorly understood. Our studies showed that dynamic aRME originates from the allelic transcriptional bursting. We provide significant insight into the origin of cell-to-cell expression heterogeneity during development.

MUSCLE DEVELOPMENT

The LIM domain, constituted by two tandem C2H2 zinc finger motif proteins, regulates several biological processes. They are usually found associated with various functional domains like Homeodomain, kinase domain and other protein-binding domains. LIM proteins that are devoid of other domains are called LIM only proteins (LMO). LMO proteins were first identified in humans and are implicated in development and oncogenesis. A novel role for LIM only protein Beadex (LMO2) has been identified in the development of crystal cell blood formation in Drosophila melanogaster.

It is shown that the Drosophila gene CG9650 is involved in muscle patterning through regulation of Notch and Wingless pathways (Saroj Jawkar PhD thesis). It was also shown that Croton tiglium L. which has been used in Ayurvedic and Chinese herbal medicinal formulations from ancient times can cause genotoxicity (Yumnamcha et al., 2020).

MOLECULAR REPROGRAMING OF ADIPOCYTE DIFFERENTIATION

In general, white adipose tissue (WAT) expands massively during obesity and aging with lipid overload. Conversely, brown fat, a distinct tissue, dissipates energy in the form of heat through uncoupled respiration, and increasing the activity of brown adipose tissue (BAT) is considered an attractive therapeutic strategy to help reduce obesity and associated metabolic disease. In one study, a small molecule (SML) has been identified as an inducer of brown adipose function. Unlike genetic manipulation, small molecules that can induce BAT function are safer and attractive therapeutic targets to develop anti-obesity regimens. Therefore, the effect of SML

on adipose tissue and whole body energy metabolism has been examined. Interestingly, SML treatment led to enhanced BAT activity and browning of WAT, which protected mice against high fat diet-induced obesity. Further mechanistic studies in myoblast cells revealed that SML suppresses myogenic differentiation and thereby promotes brown adipogenesis.
Most importantly, the lipid composition is indispensable to maintain quantity, quality, and function. Therefore, quantitative lipidomics has been employed to probe the mitochondrial lipidome of adipose tissues. The mitochondrial lipidome reveals that Î²3-adrenergic stimulation and aging drastically altered the levels of phosphatidylcholine (PC)/ phosphatidylethanolamine (PE) ratio and acyl chain desaturation. While aging increased lysoPC species in white adipose tissue (WAT) mitochondria, CL-316,243 administration reduced lysoPC species and increased lyso-PE18:1 and 18:2 content during WAT browning. Also, non-thermogenic mitochondria accumulate sphingomyelin (SM), phosphatidylserine (PS), phosphatidic acid (PA) and ether-linked PC (ePC). Further, it was uncovered that EBF2 directly binds onto several lipid biosynthesis genes, including the master regulator of lipid metabolism, Srebf1, to maintain the mitochondrial lipidome. The lipidome of Ebf2-KO cells mirrored the profile of aged and/or WAT mitochondria.

GENETICS OF HUMAN DISEASE

Wilson disease (WD) is an autosomal recessive disorder, characterised by excessive deposition of copper in various parts of the body, mainly in the liver and brain. It is caused by mutations in the ATP7B gene. We report the genetic analysis of 102 WD families from a South Indian population. Thirty-six different ATP7B mutations, including 13 novel ones, were identified in 76/102 families. The haplotype analysis suggested that all the 14 recurrent mutations have founder effects. Interestingly, the mutation analysis of affected individuals in two families identified two different homozygous mutations in each family, and thus each affected individual from these families harboured two mutations in each ATP7B allele. These studies further increased the mutational landscape of ATP7B with a total number of 758 mutations. The present study will be advantageous in genetic diagnosis and genetic counselling in WD.

Cohen syndrome (CS) is an autosomal recessive congenital disorder, which is characterised by hypotonia, intellectual disability, developmental delay, microcephaly, progressive retinopathy, neutropenia, truncal obesity, joint laxity, characteristic facial, ophthalmic, oral and appendage abnormalities, and over-friendly behaviour. CS has been linked to mutations in the VPS13B gene. The main purpose of this study was to determine the genetic cause of CS in an Indian family. Whole exome sequencing (WES) analysis was used to identify the genetic cause of CS in the family. The WES analysis identified a homozygous novel duplication mutation c.5272dupG in the VPS13B gene, leading to the formation of a truncating protein. The present study will be advantageous in genetic diagnosis and genetic counselling in CS. The study also increases the mutational spectrum of this gene.

CANCER STEM CELLS

Metastasis, the spread of tumour from the primary site to distant organs, is the major cause of cancer-associated deaths. Two key processes that aid in this are the epithelial-to-mesenchymal transformation that enables cancer cells to become more migratory and invasive, and anoikis resistance which enables cancer cells to death triggered by matrix-detachment. Work done so far has identified a key role for the cellular energy sensor, AMP-activated protein kinase (AMPK) in both these processes. AMPK activation causes metabolic re-wiring by activating catabolic and inhibiting anabolic processes. By identifying AMPK as a key switch in metastasis, the work highlights metabolic vulnerabilities of metastatic cancer cells, which can be targeted.

Hypoxia is a hall mark of solid tumour microenvironment and contributes to tumour progression and therapy failure. The developmentally important Notch pathway is implicated in the maintenance of cancer stem/progenitor cells in tumour hypoxia. Yet, the mechanisms that lead to Notch activation under hypoxia are not fully understood. Hypoxia is also a stimulus for AMP-activated protein kinase (AMPK), a major cellular energy sensor. In this study, we show that pharmacological as well as hypoxia-triggered AMPK activation led to stabilisation of intracellular Notch1

via Fyn kinase. AMPK inhibition under hypoxia affected self-renewal and drug resistance adversely, suggesting that hypoxia-induced AMPK activation might potentiate breast cancer aggressiveness through the Notch pathway.

CANCER GLYCOBIOLOGY

The relationship between cancer (breast and ovarian) cells and their tissue microenvironments in the context of invasion and metastasis is being investigated using approaches including experimentation and computation, to understand changes in glycans that contribute to cell and tissue structure, and how they are aberrantly regulated and in turn affect cancer cell phenotypes. The lab's publications (2019) highlight the complexity of the tumour microenvironment in governing the invasion of breast and ovarian cancer epithelia and the manner of their migration.
The group has strived to uncover the role of glycans at distinct scales: evolutionarily shaping the primary structure of a protein by evolving residue neighbourhoods distinct from disordered stretches (Goutham et al, *Scientific Reports,* 2020) and conferring negative charge through sialic acids to the local ECM neighbourhoods around cancer cells with implications both for immune cell interactions and theragnostic applications.

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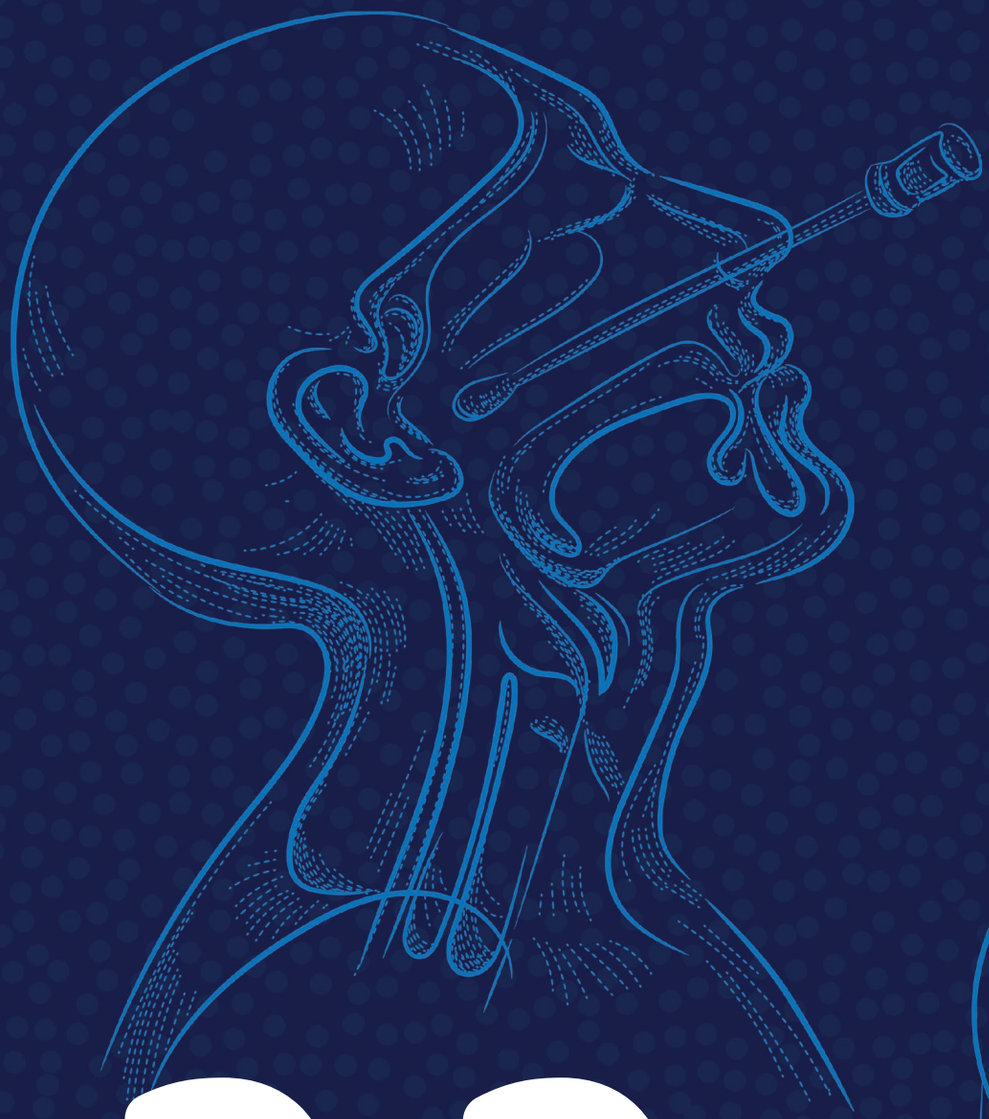
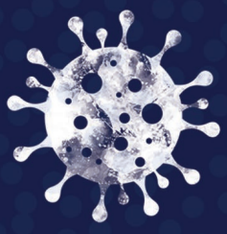
IN NUMBERS

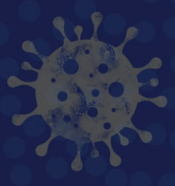
12 Academic staff
56 PhD students
11 Int PhD students
62 Publications
1 Int PhD conferment





3.2

Division of Chemical Sciences



IN NUMBERS

- 53 FACULTY MEMBERS
- 261 PhD STUDENTS
- 61 INT PhD STUDENT

The faculty members of the Division work on all contemporary topics in chemistry, including Chemical Synthesis, Drug Design, Chemical Biology, Materials Chemistry, Surface and Interface Science, Nanochemistry, Molecular Spectroscopy, Ultrafast Chemical Dynamics, Computational and Theoretical Chemistry, Solid State Chemistry and Nuclear Magnetic Resonance spectroscopy.

THEMES

The Division of Chemical Sciences has consistently maintained its position among the top 50 chemistry departments in world rankings over the past decade. It is a globally competitive Division with clear focus on top quality research in specific current areas such as bio-inorganic chemistry and chemical biology of drugs with a particular aim on disease control and cure, ultrafast spectroscopy and dynamics of molecules.

RESEARCH HIGHLIGHTS

The Division of Chemical Sciences comprises the Department of Inorganic and Physical Chemistry, Department of Organic Chemistry, Solid State & Structural Chemistry Unit, Materials Research Centre and NMR Research Centre

DEPARTMENTS | CENTRES | UNITS

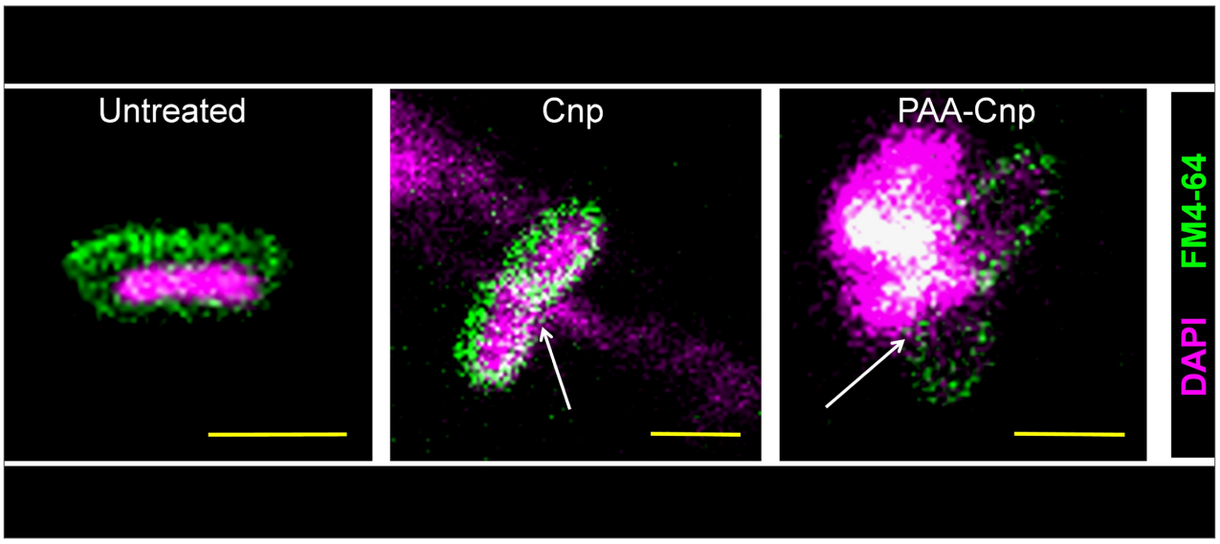
- INORGANIC AND PHYSICAL CHEMISTRY
- MATERIALS RESEARCH CENTRE
- NMR RESEARCH CENTRE
- ORGANIC CHEMISTRY
- SOLID STATE AND STRUCTURAL CHEMISTRY UNIT

2020-21

Research Snapshots

G MUGESH (IPC) & DIPSHIKHA CHAKRAVORTTY (MCB)

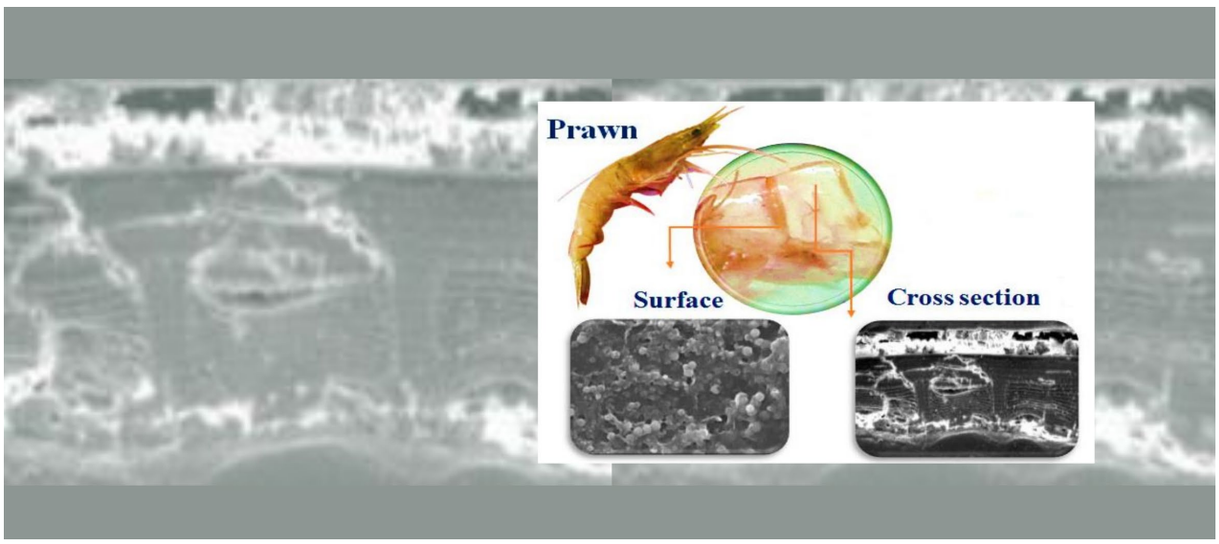
Researchers from the departments of Inorganic and Physical Chemistry & Microbiology and Cell Biology have synthesised a nanomaterial that mimics an enzyme ('nanozyme') and can disintegrate the cell membranes of a range of disease-causing bacteria. They synthesised the nanozyme from cerium oxide using a chemical co-precipitation method and coated the nanoparticles with polymers. It was then tested in the lab on several potentially pathogenic bacteria. It stopped their growth and subsequently inhibited the formation of biofilm – a densely packed community of bacteria. The researchers also tested the nanozyme on urinary catheters and found that it greatly reduced biofilm formation inside these medical devices.



Reference: Khulbe K, Karmakar K, Ghosh S, Chandra K, **Chakravortty D, Mugesh G,** Nanoceria-based phospholipase-mimetic cell membrane disruptive anti-biofilm agents, *ACS Applied Bio Materials (2020).*

BIKRAMJIT BASU (MRC)

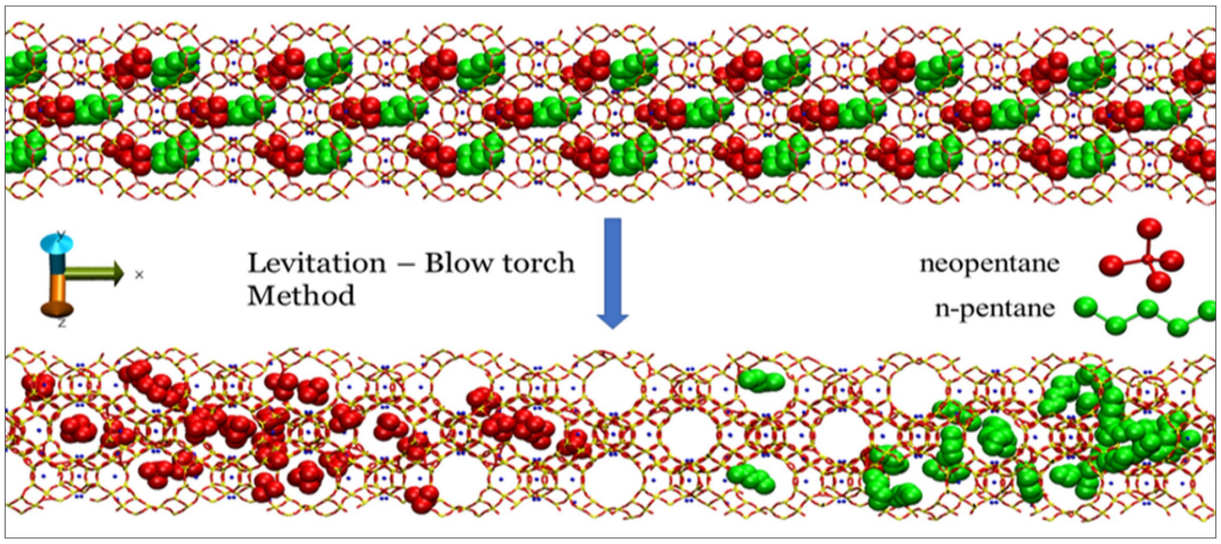
Amino acids with a central aromatic ring can absorb UV radiation and can potentially replace harmful chemicals in commercial sunscreen products. A research team from the Materials Research Centre has identified a natural source for these amino acids: the prawn's exoskeleton, the external shell that covers its entire body. They collected shells of the Arabian Sea prawn, cleaned and dried them, and examined their chemical composition using X-ray and UV-visible spectroscopy. The analysis confirmed the presence of amino acids with a central aromatic ring. These amino acids are able to absorb the entire range (200-400 nm) of UV radiation and can hence serve as excellent sunscreen filters.



Reference: Hadagalli K, Kumar R, Mandal S, **Basu B,** Structural, compositional and spectral investigation of prawn exoskeleton nanocomposite: UV protection from mycosporine-like amino acids, *Materials Chemistry and Physics (2020).*

S YASHONATH (SSCU), PRABAL K MAITI (PHY) & G ANANTHAKRISHNA (MRC)

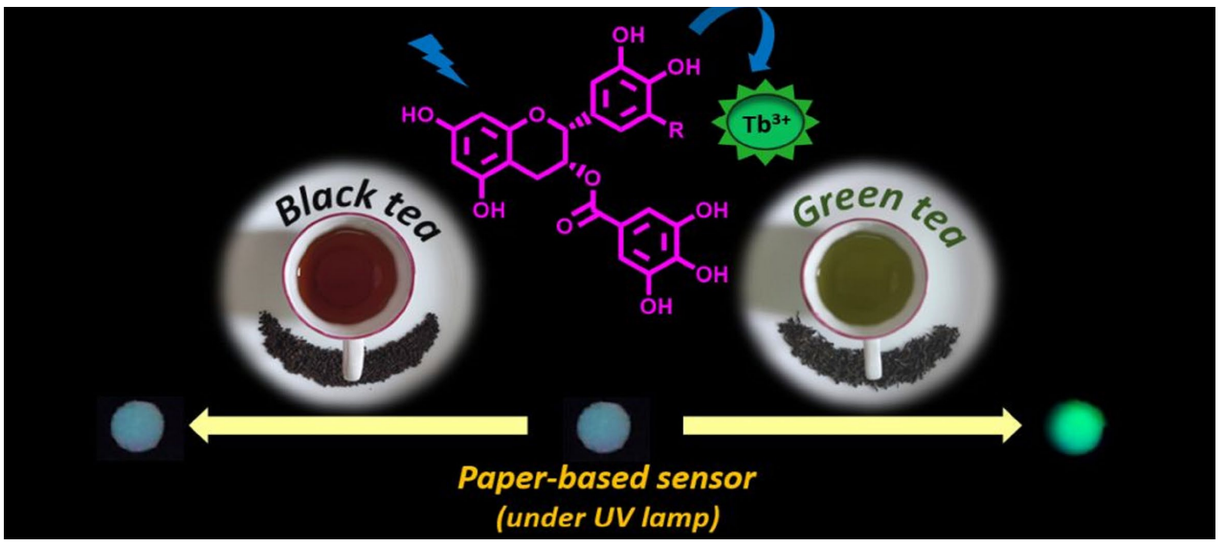
A novel method has been proposed by researchers in the Solid State and Structural Chemistry Unit and Department of Physics to separate molecular mixtures to very high purity. Existing methods separate the components of a mixture by driving them to move at different speeds along the same direction in a column of porous solid such as zeolite. They usually lead to an impurity of 1 molecule in 100. The proposed new method causes movement of different types of molecules to opposite ends of the column, resulting in better than 1 in 10^{10} separation. The method requires very low energy compared to existing methods, making it environment-friendly.



Reference: Nag S, **Ananthakrishna G, Maiti PK, Yashonath S,** Separating hydrocarbon mixtures by driving the components in opposite directions: High degree of separation factor and energy efficiency, *Physical Review Letters (2020).*

UDAY MAITRA (OC)

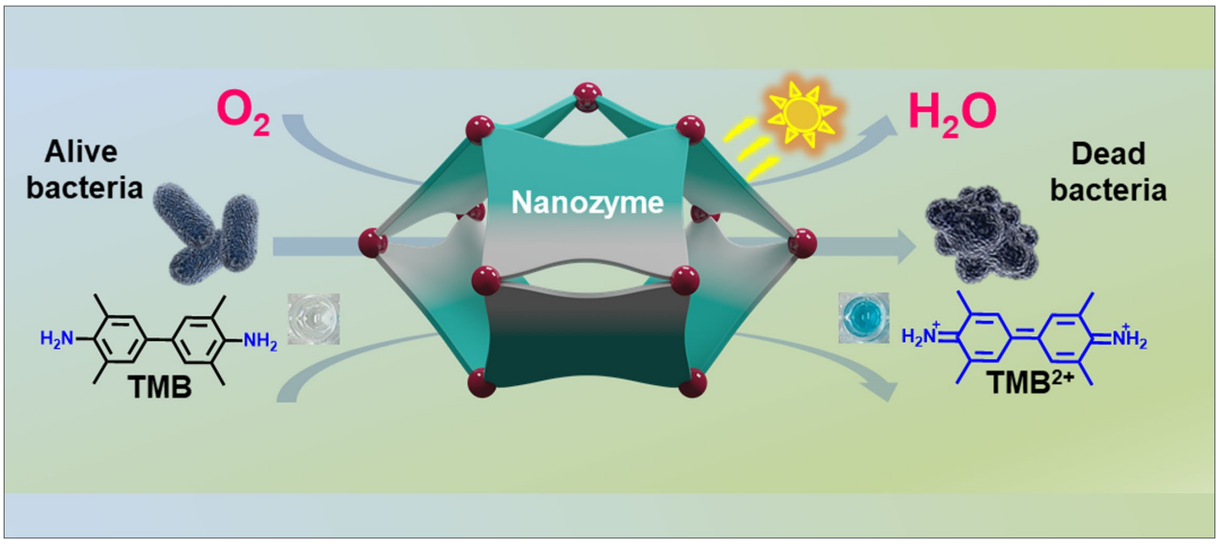
Green tea has gained worldwide attention for its multiple health benefits, because of its antioxidant properties. Its therapeutic effects are mainly due to the gallate-derived polyphenols present in them. Their content in a green tea sample directly reflects the quality of tea. Researchers in the Department of Organic Chemistry have developed a simple photoluminescent paper sensor that exhibits green colour emission on the addition of gallate polyphenols (samples as small as 5 µL). The method developed is highly selective, has low detection limits (sub-micromolar range), and is cost-effective (Rs 0.13/sensor disc), making it a reliable, inexpensive test for determining the quality of green tea samples.



Reference: Gorai T, Sakthivel S, **Maitra U,** An inexpensive paper-based photoluminescent sensor for gallate derived green tea polyphenols, *Chemistry (2020).*

PS MUKHERJEE (IPC) & MRINMOY DE (OC)

Researchers from the departments of Inorganic and Physical Chemistry & Organic Chemistry have synthesised molecular architectures that can kill pathogenic bacteria in water, including the infamous methicillin-resistant *Staphylococcus aureus.* They fashioned these molecules to mimic natural enzymes found in living organisms. The team designed a 'molecular cage' through the self-assembly of a benzothiadiazole-based ligand and platinum-based units. The ligand absorbs light and produces reactive molecules that can break up bacterial cell membranes. They also developed water-soluble cage-like structures based on benzothiadiazole and palladium that can kill bacteria present in water, and can therefore potentially be used as disinfectants.

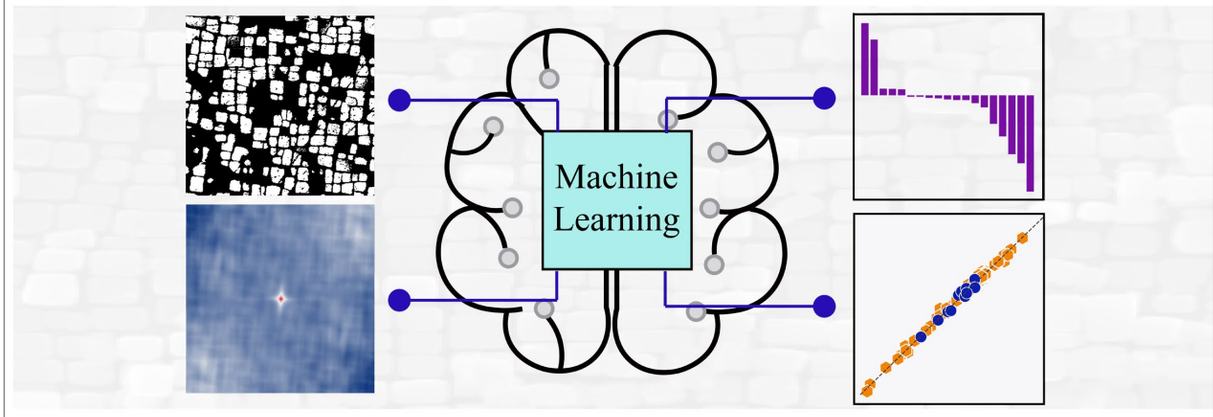


Reference: Bhattacharyya S, Venkateswarulu M, Sahoo J, Zangrando E, **De M, Mukherjee PS,** Self-assembled PtII8 metallosupramolecular tubular cage as dual warhead antibacterial agent in water, *Inorganic Chemistry (2020).*

Bhattacharyya S, Ali SKR, Venkateswarulu M, Howlader P, Zangrando E, **De M, Mukherjee PS,** Self-assembled Pd12 coordination cage as photoregulated oxidase-like nanozyme, *Journal of the American Chemical Society (2020).*

ABHISHEK KUMAR SINGH (MRC)

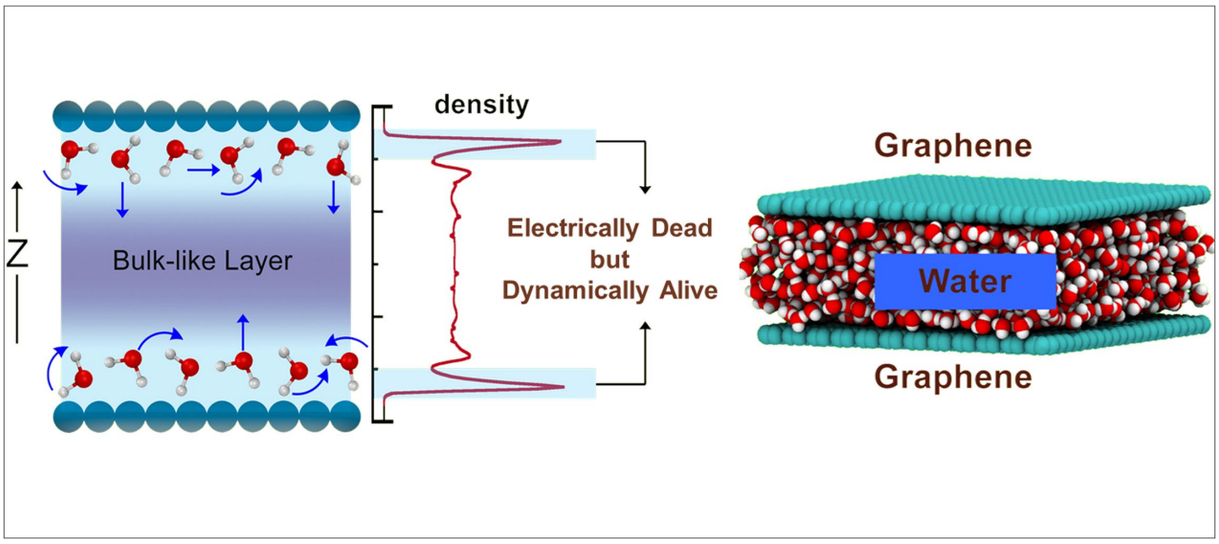
Researchers at the Materials Research Centre have developed highly accurate machine learning models to predict the Vickers hardness – an important material property – of nickel and cobalt-based superalloys. A database of microstructures, compositions and Vickers hardness of several cobalt and nickel-based superalloys was first generated. Scanning electron microscopy images were processed to obtain binary microstructures, which were then used to calculate statistically derived parameters called 2-point correlations, on which principal component analysis was performed. These PCA-derived correlations along with composition of the superalloys were used as descriptors for building the models. This approach can be applied for any material property.



Reference: Khatavkar N, Swetlana S, **Singh AK,** Accelerated prediction of Vickers hardness of Co- and Ni-based superalloys from microstructure and composition using advanced image processing techniques and machine learning, *Acta Materialia (2020).*

BIMAN BAGCHI (SSCU)

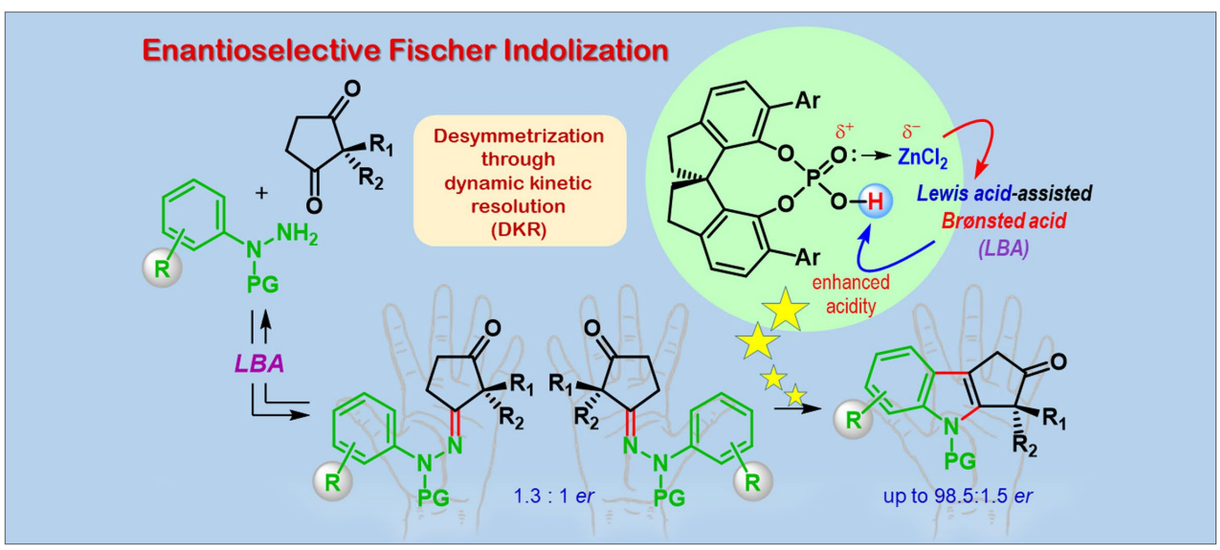
Water confined between parallel graphene sheets exhibits several interesting anomalies, one of which is a low static dielectric constant. Researchers in the Solid State and Structural Chemistry Unit have unravelled the origin of this anomaly. They found that water layers at the interfaces between the liquid and sheets, with a substantially weakened dielectric permittivity, make a disproportionately large contribution, reducing the effective value of dielectric constant of the entire system. The team also studied the dynamics of water molecules residing in these so-called "electrically dead" layers, and found that they align in the same orientation and yet remain dynamically active, residing only for a short time in the layer.



Reference: Mondal S, **Bagchi B,** Water layer at hydrophobic surface: electrically dead but dynamically alive? *Nano Letters (2020).*

SANTANU MUKHERJEE (OC)

Researchers from the Department of Organic Chemistry have developed an efficient method to synthesise cyclopenta[b] indolones – an important class of indole derivatives. These molecules are 'chiral' in nature; they can exist in two distinct forms whose 3D structures are non-superimposable mirror images of each other, called enantiomers. It is extremely difficult to selectively synthesise just one of them individually in the lab. The IISc team has overcome this hurdle using a catalyst which is also chiral in nature, and by carrying out a modified version of a century-old reaction called Fischer indolization. Computational studies through Density Functional Theory calculations helped in shedding light on the reaction mechanism.



Reference: Ghosh B, Balhara R, Jindal G and **Mukherjee S,** Catalytic enantioselective desymmetrizing Fischer indolization through dynamic kinetic resolution, *Angewandte Chemie International Edition (2020).*

Established more than a century ago in 1909, when the Institute was founded, the Inorganic and Physical Chemistry Department (IPC) has excelled in both fundamental and applied research.

CURRENT RESEARCH

BIO AND MEDICINAL INORGANIC CHEMISTRY

On this topic the following research areas are being undertaken by the department faculty, outlined below. Direct delivery of therapeutic agents into cells has been an emerging area of research at IPC. Introduction of iodine atoms into small molecules remarkably enhances the cellular uptake, representing an interesting

CORE RESEARCH

Currently, the department has 20 faculty members working in rich and diverse areas of chemistry including molecular spectroscopy, magnetic resonance spectroscopy, chemical dynamics, bio photonics, molecular electronics and spintronics, analytical and computational theory, electrochemistry, polymer chemistry, transition metal and non-metal chemistry, bio-inorganic and biophysical chemistry, chemical biology, and functional materials.

3.2.1

Inorganic and Physical Chemistry

CHAIRPERSON
ELANGANNAN ARUNAN

strategy for the transport of fluorescent probes and therapeutic agents. For the iodine-containing small molecules, the formation of a halogen bond with the thyroid hormone-specific transporter, MCT8, has been shown to be responsible for the improvement in the membrane transport. The halogen bonding strategy can also be used to transport larger molecules such as proteins. Work done at IPC has showed that a single atom change, from hydrogen to iodine, enhances the cellular uptake of green fluorescent proteins (GFPs).

Curcumin-based metal complexes as photochemotherapeutic agents have been developed and the compounds show significant photo-induced cytotoxicity in visible light, while being minimally toxic in dark. BODIPY-Copper conjugates are reported to show mitochondrial localization with singlet oxygen mediated visible light-induced apoptotic cell death.

Metal oxide nanomaterials that are capable of mimicking all the three major cellular metalloenzymes have been shown to control the level of reactive oxygen species (ROS) inside cells. The nanomaterials appear promising candidates for therapeutic applications against oxidative stress-induced neurological disorders, particularly Parkinson's. Hypoxia, which is caused by an inadequate oxygen supply, is an important feature of various diseases, including cancer, cardiopathy, ischemia, and vascular diseases. Therefore, hypoxia-specific molecular probes would be useful as diagnostic agents. We have recently developed molecules with unique characteristics such as cytotoxicity in longer incubation time and luminescence in lower incubation time. Thus, these compounds can be used in theragnostic applications, meaning that one can use them for diagnosis (imaging) and therapy (killing cells) for cancer. As expected under hypoxia conditions, cells with these compounds showed 4-fold and 5-fold stronger luminescence, respectively, as compared with cells under normoxia conditions. Thus, these compounds could be used as imaging agents to differentiate cells in normoxia and hypoxia conditions.

The red blood cell programmed death or erythrocyte apoptosis (eryptosis) is generally mediated by oxidative stress, energy depletion, heavy metals exposure or xenobiotics. As erythrocytes are a major target for oxidative stress due to their primary function as O_2-carrying cells, they possess an efficient antioxidant defense system consisting of glutathione peroxidase (GPx), superoxide dismutase (SOD), catalase (CAT) and peroxiredoxin 2 (Prx2). The oxidative stress-mediated activation of Ca^{2+} permeable cation channel results in Ca^{2+} entry into the cells and subsequent cell death. For the first time, selenium compounds having intramolecular diselenide or selenenyl sulfide moieties have been shown to prevent the oxidative stress-induced eryptosis by exhibiting an unusual Prx2-like redox activity even when the cellular Prx2 and CAT enzymes are inhibited.

FACT FILE

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IN NUMBERS

20 Academic staff
2 Scientific staff
102 PhD students
37 Int PhD students
63 Publications
4 Int PhD conferments
9 PhD conferments
2 M.S. conferments

Metalloenzymes play a crucial role in hydrocarbon biosynthesis in nature. Membrane bound metalloenzymes that are responsible for biosynthesis of alkanes in plants are being investigated. The reaction mechanism, activity and kinetics of the enzymes are being explored. Bioremediation of toxic organometallic compounds by metalloenzymes and their potential to develop whole-cell biocatalyst to detoxify environmental pollutants are being investigated.

Investigation on novel glycoside hydrolase enzymes having biofilm dispersion properties has been carried out. Preliminary data shows that certain glycoside hydrolase enzymes show excellent activity against biofilms, which might lead to the development of first-in-kind enzyme therapy in the future for effective treatment of biofilm-associated infections in human.

CHEMICAL DYNAMICS AND SPECTROSCOPY

Several faculty members of the department work in this area.

The IPC department has been at the forefront in experimental physical chemistry. Home-built experimental facilities, such as a pulsed nozzle Fourier transform microwave spectrometer and single pulse shock tubes have been used to solve both fundamental and applied problems. During this year, microwave spectra of various complexes such as $Ar\text{-}(H_2O)_2$ and $H_2O\text{-}(H_2S)_2$ have been solved. Studies on these complexes help us understand intermolecular bonds, which is an evolving field. Our department has made crucial contributions in this field over the last decade, leading to the new definition of hydrogen bond by IUPAC in 2011 and the discovery of the carbon bond in 2013. Now, intermolecular bonding involving all the group elements in periodic table have been proposed with names for each group. This year, a comprehensive analysis of all such bonds led us to propose a simple classification of intermolecular bonds closely paralleling intramolecular bonds. This was presented in the International Conference on Non-Covalent Interactions (ICNI) organized by the University of Strasbourg. A perspective article written for *Physical Chemistry, Chemical Physics* will be published based on this talk.

Though the microwave spectrum of benzene-water was published three decades ago, the assignment of some excited state transitions, which were assigned based on a free internal-rotor model, remained unsatisfactory. Several other complexes had similar spectra and all these were assigned based on the free internal-rotor model and had poor assignments. During this year, we showed that the Coriolis interactions explained all the observed transitions for benzene-water and related complexes, solving a three-decade old mystery.

Single pulse shock tube facility was used to study pyrolysis of isopropyl cyclohexane and hydrindane, both being hydrocarbons found in fuels.
Ultrafast surface reactions are being studied, including catalytic oxidation of CO monoxide, desorption of CO and CO_2 on transition metal and metal oxide nanoparticle surfaces. Ultrafast initial steps in the laser ignition of energetic molecules like propellants and plasticizes are also being investigated. Steps are being taken towards development of X-Ray spectroscopy. Theoretical studies in attochemistry are also done.

Light-matter interactions are classified into weak and strong coupling regimes depending on the nature of resonance energy exchange between the matter and the confined photons (electromagnetic field). Under weak coupling, the radiative decay rates and intensity of the emitter are altered, while under strong coupling, light and matter exchange energy at Rabi frequency, resulting in the formation of two new hybrid states of light and matter known as the polaritonic states. Light-matter strong coupling, especially the vibrational strong coupling (VSC) has a large impact on the chemical reactivity landscape, and it is evolving as a physical technique to control chemical reactivity through selective vibrations. Research on light-matter hybrid states have been initiated in the IPC department. The initial experiments are aimed at understanding the role of VSC on the hydrolysis of tert-butyl chloride when the C-Cl vibrational mode is strongly coupled. Parallel to this, the group investigates the photoinduced electron transfer in methylene blue-benzoquinone system by strongly coupling the electronic transition of methylene blue.

Characterisation of nanoparticle protein corona in solution has gained tremendous importance lately. The parameters which quantitatively establish a specific nanoparticle-protein interaction need to be measured accurately since good quality data is necessary for the elucidation of the underlying mechanism, and to make computer simulation parameters more effective. We have employed surface sensitive second harmonic light scattering (SHLS) for investigating the adsorption of a series of commonly available proteins on functionalised nanoparticle surfaces in aqueous buffers. We have extracted the binding constant, number of protein molecules bound per nanoparticle, free energy change (ΔG°), enthalpy change (ΔH°) and entropy change (ΔS°) in the adsorption process at nanomolar concentrations of both the nanoparticle and the protein, where other techniques fall short. All these data point out the nature of forces involved in adsorption between a specific pair of the nanoparticle and the protein and also the underlying mechanism of adhesion. We have, thus far, used gold and carbon nanoparticles since they are biocompatible and have tremendous application potential.

THEORETICAL CHEMISTRY

On this topic the following research activities were undertaken by the department faculty:
Optical response from molecular junctions is being investigated using theoretical methods. A perturbative technique has been proposed recently to explain experimentally observed electroluminescence signal from molecular junctions. Theoretical methods are being developed to compute ionization times in molecules. In recent work it has been shown how the ionization time is affected due to disorder in nuclear configuration in the gas phase. In addition to this, quantum mode-coupling models and path-integral molecular dynamics simulation are being used to study dynamics in supercooled quantum liquids. Theoretical studies have been carried out on vibronic structure and dynamics of different systems. For aniline, the quantum dynamics of NH dissociation using a three surface model potential have been studied, exploring how the system's evolution changes with different initial conditions. We have also begun exploring the dynamics of 2-amino pyridine, specially focussing on electron-coupled proton transfer dynamics leading to the generation of charge transfer states. In other work, we have completed the computation of vibrational eigenstates of catecholate, with a view to understand multidimensional quantum tunnelling in this molecule; this system has not been previously explored. Manuscripts for the above are under preparation. Efforts towards vibrational tunnelling and IVR dynamics in this system are also ongoing. Finally, we are developing a model surface for 2-X-ethanols towards quantum RPMD dynamics.

An understanding of vibronic dynamics in the gas and solution phases via theory is being developed. Theoretical work towards understanding photodynamics on the excited state of aniline was carried out. The multi-coordinate, multi-surface potential surface for this was developed and the dynamical evolution was carried out using the Chebyshev propagation method with in-house codes. The dynamical results are now being analysed, and we hope to learn about the ultrafast photoprocesses in this molecule as a function of initial vibrational excitation. We have also developed a full-dimensional Empirical Valence Bond potential surface for H-atom tunnelling dynamics in catecholate. We computed up to four coordinate eigenstates in order to see the trends and mode dependence in the ground and excited vibrational state tunneling splittings. We hope to understand how different modes enhance or suppress tunneling. Other studies using ring polymer dynamics and surface hopping trajectory dynamics are also being carried out.

Path integral techniques have been used to test the validity of various fluctuation theorems in a model system consisting of a Brownian particle evolving stochastically in two dimensions under the influence of an asymmetric harmonic potential, and in the presence of thermal reservoirs of different temperatures located along the x and y axes. The validation of some of the fluctuation theorems was found to require the existence of an effective temperature that depended on the temperatures along the two Cartesian axes.

A model of the dynamics of concentrated polymer solutions was developed, which was based on

a generalized Langevin equation and that did invoke the notion of a tube. The model achieved semi-quantitative fits to experimental data on the decay curves of entangled DNA solutions stretched hydrodynamically by external flow fields and then allowed to relax to equilibrium following the cessation of flow.

It was shown that in a model system based on the dynamics of a one-dimensional Brownian particle making random transitions between two different coupled harmonic potentials the effects of reactivity (as represented by the inter-state transitions) could strongly influence the particle's effective diffusion coefficient.

POLYMER CHEMISTRY

Liquid crystalline (LC) polymers require the presence of rigid anisotropic units, termed mesogens, to be either incorporated within the polymer backbone or side chain; and the formation of the LC phase requires the organisation/ordering of the mesogens, which in turn would coerce the polymer backbone to adopt some conformation that can accommodate this ordering. We turned the problem around and asked the question: whether the polymer architecture could direct the organisation/ordering of the mesogens, thereby control the type of mesophase formed. Based on our earlier studies on chain folding in periodically grafted amphiphilic copolymers (PGACs), we designed LCPs that carry either biphenyl or azobenzene based mesogens within the polymer backbone or side chain; we then showed that the zigzag folding of the chain leads to a lamellar organisation of the mesogens and consequently, in many systems, a smectic (layered) type mesophase is stabilised.

Likewise, in LCPs carrying two types of mesogens (azobenzene and biphenyl), one within the backbone and the other in the side-chain, we showed that chain-folding enables the two mesogens to segregate and occupy alternate layers in a smectic-type ordering; an important fallout of this finding is that this idea could, in principle, be used to segregate different types of functional units, such as electron donor and electron acceptors, at subnanometer-scale distances within a polymeric material, which could have important ramifications in organic electronics.

ORGANOMETALLIC AND COORDINATION CHEMISTRY

In this sub-discipline, the departmental faculty members have contributed to the following:
Rutheinum NHC complexes were used as precursors to generate nanoparticles and their catalytic activity was explored. Very efficient hydroborylation of alkenes and alkynes have been studied. Further, NHC complexes of iridium were synthesised in chiral and achiral NHC ligands to probe hydrosilylation of imines.
An efficient NHC-supported cobalt-catalyst for the borylation of aryl chloride and vinyl arenes affording the aryl and alkyl boronates, which are important synthetic intermediates in organic synthesis were developed. An inexpensive iron-based catalyst for the hydroboration of carbonyl compounds and the first scandium-based Lewis acid catalyst for the hydroboration of alkynes and alkenes were also developed.

In continuing efforts on the activation of unreactive chemical bonds in small molecules, certain unusual iridium complexes bearing pincer motif have been developed. These complexes have the ability to bring about the oxidative addition of molecular hydrogen under very mild conditions. Activation of the H—H bond using these complexes is dependent on the H2 gas pressure thus making it possible to map the reaction coordinate for the oxidative addition of H_2 to a metal centre. This has significant implications in homogeneous hydrogenation catalysis. In addition, iridium based pincer complexes for hydrogenation of CO_2, carbonyl and certain imine substrates have been developed. These catalysts are quite active and efficient over several cycles. Further, air-stable Fe-Co nanostructured alloys have been prepared and characterised. They exhibit interesting magnetic behaviour.

Metalloorganic complexes possessing switchable (on/off) second order nonlinear optical (NLO) properties triggered by external stimuli are important for designing molecular devices in the area of optoelectronics. By switching the second order nonlinearity (β) of a multimetallic metallorganic complex by electrochemical oxidation/reduction of the metal centres sequentially, in a series of ruthenium

and iron complexes, we have shown that the metal oxidation states provide a handle for such a switching application. In fact, the electron rich metal centre along with the surrounding ligands acts as a "donor" while an electron deficient metal centre behaves as an "acceptor". Electrochemical switching of the donor/acceptor nature of the metal is what is responsible for the NLO signal switching. It is also demonstrated that such a switching of β values is possible to induce by ligand oxidation/reduction. With multiple metal-containing complexes, a three-state switching pattern is also seen.

Iridium NHC complexes were used as catalysts for catalytic hydrosilylation. The very efficient room temperature hydrosilylation of imines and other unsaturated substrates have been studied. Further, chiral NHC complexes of iridium were synthesised using chiral amino acids as starting materials. Asymmetric hydrosilylation of imines was carried out. The chiral ligands could carry out the reduction of both enantiomers using two different amino acid precursors.

A Cobalt-based water oxidation catalyst has been developed. We have shown that CoOx catalysts show highly enhanced activity with the addition of Cr. Such enhancement originates from Cr stabilising lower oxidation states of Co. Using in situ Raman Spectroscopy we have shown that the catalyst develops in situ and the formation of Co^{4+} species is suppressed using Cr. The catalysts were shown to have an AuOOH intermediate which decomposed to release O_2.

Certain new sigma-complexes of iridium have been prepared and characterised. They exhibit excellent catalytic activity for hydrogenation of olefins. An extremely important question in hydrogenation catalysis that has remained unanswered for decades is: "at what stage in the reaction coordinate could the H-H bond be considered to be broken?". Some preliminary work towards addressing this question has been carried out and certain novel findings have been obtained. It was found that there is an influence of the hydrogen gas pressure on this reaction. On the other hand, certain Pd-Zn bimetallic nanoparticles and their catalytic activities have been explored. Additionally, a novel observation of digestive ripening of polydisperse Au nanoparticles into nearly monodisperse nanoparticles in ionic liquid medium was made.

SUPRAMOLECULAR CHEMISTRY/CATALYSIS

Pd(II) and Pt(II) cages and molecular barrels were synthesised and their confined space was used for studying chemistry of photochromic molecules. Newly designed organic cages were used as templates for nucleation of Au nanoparticles and used as photocatalysts.

Synthesis of enantiopure metallo-cages and their chiral recognition of a specific enantiomer from a racemic mixture of enantiomers have been carried out. A new strategy was also developed to obtain enantiopure chiral cages without using chiral building blocks and without chiral resolution just by a chiral seeding. A complex dynamic mixture of stereoisomers of a chiral cage was readily converted to an enantiopure cage by using an enantiopure guest. Water soluble Pd and Pt based molecular cages incorporating building blocks that can generate reactive oxygen have also been reported. Finally, such cages were used for killing bacteria in water upon photo-irradiation.

MAIN GROUP CHEMISTRY

In this area, the following contributions have been made.

Development of cost effective, earth abundant, less toxic base metal catalysts or main group catalysts for the synthesis of organoboranes, which are important synthetic intermediates in pharmaceuticals and organic light-emitting diodes as exemplified by the Suzuki-Miyaura cross-coupling reaction has been carried out. Considerable effort has been committed to the preparation of organoboranes using precious metals (such as Pd, Rh, Ir, etc.) and more recently, using non-precious metals (Cu, Ni, Fe). High cost, human toxicity, and limited natural abundance are few drawbacks associated with precious metals. These drawbacks have sparked interest for the development of cost effective earth abundant, less toxic metals or

even metal free catalytic systems to promote selective synthesis of organoboranes efficiently. Recently, an efficient catalyst system based on Co(II)-NHC complex for the borylation of aryl halides was developed.

The design and synthesis of new molecules/materials containing Boron for the potential application in the field of Catalysis, Molecular Electronics (OLEDs, TFTs and solar cells), and Chemosensory materials are parts of the ongoing research at IPC. Also, research on the Lewis acidity of tri-coordinated boron for the development of boron- based proteasome inhibitors (BPI) and understanding the differences in the catalytic activity of multiple proteolytic sites in both eukaryotic and bacteria proteasomes are going on.

ELECTROCHEMISTRY, SURFACES AND INTERFACES

Rechargeable Li- and Zn- based batteries have been developed. High capacity behaviour of Cu_3PS_4 towards lithium storage has been understood using in situ Raman spectro-electrochemistry. High rate, rechargeable Mg batteries have been studied using organic electrode materials based on vat orange. Fundamental studies on mixed layered chalcogenides towards understanding their catalytic and optoelectronic properties have been carried out based on isomeric combinations. These studies reveal the reasons for high stability observed in mixed chalcogenides. Sensors and field effect transistors have been developed using ternary layered, semiconductors, MoSSe, MoSeTe, MPX3 (X=S,Se,Te). Plasma electrolytic oxidation – based coatings have been developed for aerospace applications. Co-polymers have been used to develop anodes for rechargeable multi-metal ion batteries.

Electrochemical general of hydrogen from water is one of the central challenges towards implementing a sustainable energy and material ecosystem. Cobalt oxides are a benchmark system in this context. Work towards understanding the limitations of this system and developing new cobalt based mixed metal oxide catalysts is being carried out. A catalyst was reported, which is electrochemically promoted by Cr specifically Co{Cr}Ox/Au showing significantly improved performance. The study uses in situ Raman Spectroscopy to track the progression of novel catalyst material besides benchmark compounds such as CoOx.

New catalysts were discovered for high temperature electrochemical CO_2 reduction to fuels. Such cells are based on zirconia based high temperature oxide ion conductors. In this context specific cells capable of doing in situ spectroscopy at 800 °C on button cell architectures along with online mass spectrometry have been developed. Ceramic membranes capable of using protons instead of oxide ions to access lower temperature reactions in the temperature range of 400-600 °C are being developed.

Formic acid is one of the best energy carriers of the future due to its ease of conversion to CO_2 and back to formic acid, and its ease of handling. Theoretical insights were obtained into formic acid oxidation reaction using density and new catalyst materials were developed in this context.

Single molecular electronics and Spintronics research direction has been initiated at the IPC department. Following instruments are currently being built at the IPC department.

1. Mechanically Controllable Break Junction (MCBJ) setup with Ultra-low current Measurement Capability and Large Dynamic Current Measurement Range

2. Ultra-Sensitive Electrochemical STM- based break Junction (EC-STM BJ) setup

This custom-built equipment will have unique single molecule conductance measurement capabilities and only few groups across the world have comparable capability in terms of measurable current range and modes of single molecule conductance measurement.

COMPUTATIONAL CHEMISTRY

Computing photoionization times of molecules is currently an emerging area of research. Attosecond laser pulses are being developed to study the ionization time and related dynamics. We investigated the ionisation time of C_2H_4 molecule as a model for Ï€-conjugated molecular systems. Analytical results were obtained using the Wigner phase delay, which was

compared with energy-streaking measurements. We showed that the nuclear configuration can lead to qualitative changes in the ionization time scales. In a separate work, we proposed a perturbative scheme to compute spectroscopic signals from a current carrying molecular junction. We applied this method to study electroluminescence from a molecular junction which allowed us to interpret recent experimental observations.

Aromaticity is traditionally attributed to the delocalisation of 4n+2 electrons in pi molecular orbitals involving p-orbitals. We had suggested in 2013 that sigma* orbitals of pi symmetry (named as pseudo-pi* orbitals) could also support aromatic delocalisation. In collaboration with an experimental group, we have designed, synthesised, and characterised a three-membered two pi-aromatic disila-borirane derivative involving two pseudo-pi*MOs and a p orbital. We showed that comparison of reactions across the periodic table brings out novel concepts and that Bi cations are good Lewis acid catalysts.

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BINNY J CHERAYIL | PhD (U Chicago), Professor
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P K DAS | PhD (Columbia U), FASc, Professor
K GEETHARANI | PhD (IIT Madras), Assistant Professor
UPENDRA HARBOLA | PhD (JNU), Associate Professor
BALAJI R JAGIRDAR | PhD (Kansas State U), FASc, Professor
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G MUGESH | PhD (IIT Bombay), FASc, FNASc, FNA, Professor
PARTHA SARATHI MUKHERJEE | PhD (Jadavpur U), Professor
M NETHAJI | PhD (Madras), Chief Research Scientist
SANJAY PRASAD | MTech (Anna), Scientific Officer
S RAMAKRISHNAN | PhD (U Massachusetts), FASc, Professor
SAI G RAMESH | PhD (U Wisconsin), Associate Professor
C RANJAN | PhD (Muelheim Ruhr), Assistant Professor
S SAMPATH | PhD (IIT Madras), FASc, FNA, Professor
AG SAMUELSON | PhD (Cornell U), Professor
S SANDYA | PhD (Kerala), Scientific Officer
P THILAGAR | PhD (IIT Kanpur), Associate Professor
S UMAPATHY | PhD (U Otago), FASc, FNASc, FRSC Professor (On lien)

HONORARY/EMERITUS FACULTY

AR CHAKRAVARTY | PhD (U Calcutta), FASc, FNA, Honorary Professor
ED JEMMIS | PhD (Princeton U), FASc, FNA, Honorary Professor
S VASUDEVAN | PhD (IIT Kanpur), FASc, FNA, Honorary Professor
KL SEBASTIAN | PhD (IISc), FASc, FNA, Emeritus Professor
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The Materials Research Centre (MRC) was established in 1978, to foster interdisciplinary research in different areas of materials science and technology with an emphasis on electronic and functional materials. Over the last decade, MRC has been pursing extensive research in the emerging areas of biomaterials, multiscale simulation and properties of nanomaterials. The slogan of the centre, "From basic science to device prototypes," would aptly sum up its research efforts.

CURRENT RESEARCH

ENERGY HARVESTING MATERIALS

Faculty at the centre are involved in addressing the challenges associated with the development of efficient energy harvesting materials using state-of-the-art density functional theory-based methods. An extensive study is in progress to develop guidelines for designing high ZT thermoelectric materials and ambient condition efficient hydrogen and Li storage materials. Nanostructurisation of transition metal silicides is carried out for high temperature thermoelectric applications.

FACT FILE

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IN NUMBERS

8 Faculty members
1 INSA Faculty members
80 Graduate students
47 PhD students
6 Int PhD students
100 Publications

3.2.2 Materials Research Centre

CHAIRPERSON

KK NANDA

2D MATERIALS AND METAMATERIALS

Faculty of the centre are working on 2D materials for next generation devices. In order to use 2D materials as building blocks in electronic, optical, and sensing applications, their electronic properties need to be modified. A focussed effort aiming towards gaining the ability to modify the band gaps of these materials in a controlled and non-invasive way in currently underway. Meta-structure based on Vanadium oxide phase change materials for perfect absorbers at IR and microwave frequencies is demonstrated.

WHITE LIGHT-EMITTING-DIODES FOR GREEN ENERGY

The LED project evolved for this initiative dealt with "White" LEDs, typically blue LEDs working in conjunction with yttrium aluminium garnet (YAG) phosphor, used for lighting applications. A commercial white LED produces 110 lm/W at an injection current of 700 mA, exemplifies the state-of-the-art in solid-state lighting. The work at MRC developed highly efficient white LEDs, more so than commercially available LEDs in three phases over the last 6 years in collaboration with an industry.

ORGANIC LIGHT EMITTING DIODES FOR FLEXIBLE DISPLAYS

MRC faculty are also involved in various organic materials development, such as light emitting, electron transporting, and host materials for OLED application. Main focus is on solution-processed device fabrication for cost-effective OLED displays and lightings.

BIOMATERIALS FOR MUSCULOSKELETAL RECONSTRUCTION AND REGENERATIVE ENGINEERING

MRC has been pursuing interdisciplinary research at the cross-roads of Engineering Science, Biological Science and Medicine. A research group has aptly used the principles and tools of these disciplines to develop next generation implants and

CORE RESEARCH

The efforts of the faculty of the centre covers the following broad areas of research: Semiconducting materials for blue LEDs, phosphors for white light applications, OLEDs for flexible displays, infra-red and UV detection, gas sensing, etc. Biomaterials for musculoskeletal applications, catalytic materials for water splitting, water purification, energy harvesting and storage materials for thermoelectric, Li-ion/Na-ion battery, and hydrogen storage, fuel cells, etc., and thermoelectrics and meta-materials are pursued at the centre.

bioengineering solutions to address unmet clinical needs for musculoskeletal, dental, and neurosurgical applications. Over the years, the researchers have created interactive and intensive collaborations with over 20 clinicians, one MNC and 7 MSMEs/ start-ups to accelerate biomaterials science to biomedical device prototype development. Encompassing experimental discovery, theoretical predictions, computational analysis, and clinical translational research, this research group has laid the foundation for biomechanically-compliant design of implants, 3D binderjet printing of biomaterials, science of biocompatibility and bioengineering strategies. These advances in the field of biomaterials science and regenerative engineering have impacts on human healthcare.

NANOSTRUCTURED MATERIALS FOR ENERGY AND ENVIRONMENT APPLICATIONS

Faculty of our centre are involved in designing nanostructured based catalysts for water splitting, water purification, batteries and fuel cells. Few faculties are associated with the development of materials for gas sensing applications at room temperature, infra-red and UV detection.

Our research group recently published a bioengineering strategy to switch EF-mediated differentiation of human mesenchymal stem cells (hMSCs) between neuronal and glial pathways, using tailored functional properties of the biomaterial substrate. We examined the combinatorial effect of substrate functionalities (conductivity, electroactivity, and topography) on the EF-mediated stem cell differentiation on polyvinylidine difluoride (PVDF) nanocomposites in vitro, without any biochemical inducers. This work critically unveils complex yet synergistic interaction of substrate functional properties to direct EF-mediated differentiation toward neuron-like and glial-like cells, with distinguishable electrophysiological responses.

Using bonding characteristics driven structural attributes along with the Seebeck coefficient and electrical conductivity as descriptors, we developed a highly accurate machine learning model to predict the lattice thermal conductivity. We demonstrated chemical bond hierarchy hosted distinct rattlers in a noncaged oxychalcogenide AgBiTeO, causing an ultralow Î°l of 0.9 W/m-K at room temperature. To develop a model on a highly variable database, we propose a localised regression based patchwork kriging approach for capturing most of the complex details in the data. Using bonding characteristics driven structural attributes along with the Seebeck coefficient and electrical conductivity as descriptors, we developed a highly accurate machine learning model to predict the lattice thermal conductivity. We discover ultralow thermal conductivity and high thermoelectric figure of merit in mixed valence In5X5Br (X = S, and Se) compounds.

A synthesis lab has been set up. A method for synthesising oxide thin films at the air-water interface was developed. SnO2 films produced using this method display excellent gas sensing characteristics. A method for synthesising radial-axial heterostructures of Bi2T3/PbTe/Te using wet chemical synthesis was developed. This architecture shows interesting transport characteristics.

We have demonstrated alkali metal fluorphosphate (AMPO4F, A = Li/Na, M = 3d metals) as versatile cathode materials for secondary batteries. They can be useful as high energy density cathode materials in aqueous as well as non-aqueous sodium-ion batteries. In addition, it is possible to use them as efficient bifunctional electrocatalysts to realize oxygen evolution and reduction (OER and ORR) reaction thereby enabling their usage in metal-air batteries. The combustion synthesis, structure, magnetic and electrochemical performance of these fluorophosphate cathodes have been investigated using computational and experimental tools.

Our group has made outstanding and fundamental contributions to the technologically important fields of non-precious catalysts having relevance to our country's energy sectors and sensing materials for environmental monitoring. We have also developed materials for photodetection as well as multifunctional catalysis.

FACULTY & STAFF

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N RAVISHANKAR | PhD (IISc Bangalore, India), Professor
BALARAM SAHOO | PhD (University of Duisburg, Germany), Associate Professor
ABHISHEK KUMAR SINGH | (Tohoku University, Sendai, Japan), Associate Professor

The primary focus of the NMR Research Centre is the development of new Nuclear Magnetic Resonance spectroscopic methods and their application to important and challenging problems in Chemistry and Biology.

CURRENT RESEARCH

NMR based identification and quantification of metabolites allows direct mapping of related biological pathways and helps in understanding their flux in the cell. However, this requires recording data on a large number of samples to arrive at statistically relevant information, which increases the time required for data collection. We develop new techniques, which allows one to significantly reduce the time required for acquiring multidimensional NMR data. We have also developed methods for automated data analysis, which address the important problem of rapidly identifying metabolites from NMR spectra and mapping them to metabolic pathways. We have applied these methods for finding biomarkers in human in-vitro fertilization (IVF) and for studying cancer cell metabolism.

A simple ternary ion-pair complexation protocol has been developed for rapid testing of enantiopurity and the assignment of absolute configurations of various acids and ester derivatives employing 1,1′-[binaphthalene]-2,2′-diamine (BINAM) as a novel chiral solvating agent (CSA) in the presence of trifluoromethanesulfonic acid (TFMS) as a third ingredient. The protocol also permits the unambiguous assignment of stereospecific configurations of different acids and ester derivatives. NMR spectroscopic studies revealed the occurrence of bifurcated intramolecular hydrogen bond in the dibenzoyl oxalamide derivatives. Orchestrated approaches

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IN NUMBERS

6 students
1 Academic staff
30 Publications

3.2.3 NMR Research Centre

CHAIRPERSON
N SURYAPRAKASH

have been developed using pure shift NMR for the extraction of spectral parameters, ultra-high resolution, and sensitivity enhancement.

Weak Molecular Interactions: A series of synthesised N-bezoylanthranilamide derivatives have been investigated by one- and two- dimensional NMR experimental techniques to ascertain the presence of weak molecular interactions, if any, that direct the stable conformations of the molecules. The in-depth investigation reveals the existence of very weak hydrogen bond interaction. Clean-PE-SERF: A novel pulse sequence is reported, which completely eliminates the uninformative zero frequency axial peaks while preventing the evolution of undesired couplings, thereby aiding the accurate determination of all the scalar couplings to a selectively excited proton in a perfect echo selective refocusing sequence.

CORE RESEARCH

NMR Spectroscopy, Elucidation of molecular structures, Chiral Analysis, Weak Molecular Interactions, Metabolomics, Structural Biology, Bionanomaterials

The Department of Organic Chemistry (OC) is one of the oldest departments in IISc, which started in the year 1911. Core strength of the Department relies on the broad areas of organic chemistry, covering all aspects of organic synthesis and application of organic chemistry principles at the interface of biological and materials chemistry.

CURRENT RESEARCH

Polymer-dendrimer composite membranes are developed to address the influence of dendrimer generations on the membrane CO_2 permselectivities. Poly(vinyl alcohol) (PVA) – poly(ethylene glycol) (PEG), cross-linked with glutaraldehyde (GA), and further incorporated with amine-rich poly(ether imine) (PETIM) dendrimer generations 1 – 3 membrane systems are studied. Studies demonstrate that the third-generation dendrimer containing membranes approach the Robeson trade boundary curve very closely. The associated permselectivities are CO_2 permeance and CO_2/N_2 selectivity of 6.2 x 10^{-9} mol m^{-2} s^{-1} Pa^{-1} and 56, respectively, at a feed pressure of 2 x10^5 Pa and the temperature of 30˚C.

The covalent glycovesicles, constituted with diacetylene monomers of varying ligand densities at their surfaces, are prepared through photo-polymerisation. Vesicles imbedded with sparsely populated ligands engage a lectin interaction, leading to a dense cross-linked multimeric complex formation. Whereas vesicles having the most or complete ligand constitution switch the lectin interaction to form a fully soluble monomeric complex, without a cross-linking. Nanomolar dissociation constants govern these interactions, as assessed by a ligand displacement assay.

NS3/4A protease of hepatitis C virus (HCV) plays an important role in viral RNA replication. Synthesis of phyllanthin (1,4-diphenylbutanedicarboxylic acid) congeners by chemical methods show that one of the congeners, annotated as D8, is a novel and potent inhibitor of the HCV-NS3/4A protease activity in vitro. Oral administration of D8 in BALB/c mice proved its better tolerability and bioavailability, as compared to

3.2.4 Organic Chemistry

CHAIRPERSON
N JAYARAMAN

native phyllanthin. Taken together, this study reveals a promising candidate for developing anti-HCV therapeutics to control HCV induced liver diseases. A compilation covering synthetic methodology development for carbohydrate conjugation onto biomolecular and biomacromolecular scaffolds was reviewed. Importance of such glycoconjugations on the functional properties was also covered.

Among the unstabilised enolates used as nucleophiles in iridium-catalyzed asymmetric allylic alkylation reactions, amide enolates are the least explored. We have employed vinyl azides as amide enolate surrogates for the first time in Ir-catalyzed asymmetric allylic alkylation. Competing reaction pathways are suppressed through the systematic tuning of the steric and electronic properties of vinyl azide to bring about the alpha-allylic alkylation of secondary acetamides with high atom economy, exclusive branched selectivity, and mostly excellent enantioselectivity. In addition, we have developed the first catalytic enantioselective allylic alkylation of an olefinic C(sp2)–H bond – that of an α,β-unsaturated carbonyl compound, namely coumalate ester. Cooperatively catalyzed by cinchonidine and an in situ generated cyclometalated Ir(I)/phosphoramidite complex, this reaction makes use of the latent enolate character of coumalate ester to introduce an allyl group at its α-position in a branched-selective manner with good to excellent enantioselectivity. Apart from the Ir-catalyzed allylic alkylation reactions mentioned above, we have developed

CORE RESEARCH

Organic Synthesis; Peptides; Enantioselective Catalysis; Synthetic Methodologies; Asymmetric Synthesis; Transition Metal Catalysis; Total Synthesis of Natural Products; Medicinal Chemistry; Chemical Biology; C-H Activation and Functionalization; Hydrogen Economy; Cross Dehydrogenative Coupling Reactions; Green Chemistry; Carbohydrate Chemistry; Macromolecular Chemistry; Biophysical Chemistry; Organocatalysis; N-Heterocyclic Carbenes; Aryne Chemistry; Asymmetric Catalysis; Material Chemistry; a-Helical Turn Mimics; Helix Folding; Amyloidogenesis; Supramolecular Chemistry; Lanthanide Photoluminescence; Enzyme Sensing; Hydrogels; Applied Supramolecular Chemistry; Analytical Chemistry

the first catalytic enantioselective desymmetrizing Fischer indolization of prochiral diketones containing enantiotopic carbonyl groups, namely 2,2-disubstituted cyclopentane-1,3-diones. This reaction is catalysed by a spirocyclic chiral phosphoric acid in the presence of $ZnCl_2$ as the co-catalyst, possibly by Lewis acid assisted enhancement of Bronsted acidity and shown to proceed through dynamic kinetic resolution (DKR) of the initially formed enantiomeric hydrazones. The products of this reaction - cyclopenta[b]indolones, bearing an all-carbon quaternary stereocenter, are formed in moderate yields and with good to excellent enantioselectivities.

Natural tripeptide capped pH-sensitive gold nanoparticles have been developed for the efficacious doxorubicin delivery both in vitro and in vivo. A fluorescent supramolecular host for urea has been synthesized. A thermo-responsive supramolecular hydrogel that senses Cholera Toxin B via a colour-changing response has been developed. A two-component charge-transfer hydrogel with excellent sensitivity towards micro-environment has been developed as a responsive platform for biogenic thiol detection. Specific stabilisation of promoter G-Quadruplex DNA by 2, 6-disubstituted amidoanthracene-9, 10-dione based dimeric distamycin analogues and their selective cancer cell cytotoxicity has been achieved. A transparent, flexible MAPbI3 type perovskite microwire array passivated with ultra-hydrophobic supramolecular assembly has been developed for stable and high-performance photo-detection. Encapsulation of CsPbBr3 Nanocrystals by a Tripodal Amine has been shown to markedly improve the photo-luminescence and stability concomitantly via anion defect elimination. In advances in polymer technology, synthesized functional glycopolymers for biomedical applications have been reviewed.

In the synthesis of natural products, total synthesis of panaginsene, a sesquiterpene natural product containing an angularly fused tricyclic moiety, has been accomplished in 11 linear steps starting from methyl 3,3-dimethyl-5-oxocyclopent-1-ene-1-carboxylate. The key steps are the Sharpless asymmetric epoxidation and our Ti(III)-mediated reductive epoxide opening-radical cyclization to construct the chiral quaternary carbon stereocenter followed by a very challenging HWE olefination reaction on an 1,3-keto aldehyde and a late stage McMurry olefination using low valent titanium to construct the highly constrained angular tetrasubstituted olefin in a five-membered ring. In sugar amino acid related work, we achieved the synthesis, NMR based conformational studies and in silico analysis of tetrahydrofuran amino acid (TAA) based 15-membered cyclic tetrapeptides containing hydroxamic acid side chain as potential HDAC inhibitors. NMR studies revealed that these macrocycles are stabilised by 10-membered β-turn as well as a 7-membered γ-turn. This type of fused structures within the same macrocycle is not frequently sighted. In silico docking results indicated that the hydroxamic acid appended cyclic tetrapeptides show promising binding with the class-1 HDACs. Moreover, some of these cyclic tetrapeptides with hydroxamic acid side chain exhibited an induction of acetylation of histones on preliminary cell-based experiments. Our initial results provide an insight into the development of HDAC inhibitors based on these cyclic tetrapeptides with novel $\beta\gamma$ fused turns which have not been explored yet.

The research in our group revolves around the use of computational methods to gain a better understanding of carbene transfer reactions catalysed by small molecules as well as engineered enzymes. We are particularly interested in delineating the mechanistic features and selectivity of C-H insertion reactions. The carbene species generated via diazo precursors has become an indispensable synthetic tool to construct C-X bonds (where X=O, S, C, N, Si, B). These reactions are typically catalysed by precious metal catalysts such as Rh, Ir, Ru, Au and Pd. Rh paddlewheel complexes, either with chiral ligands or chiral Brønsted acids and have witnessed tremendous success in achieving regio-, chemo-, and stereocontrol. Recent efforts have focussed on developing cheap and less toxic Fe based catalysts for carbene transfer reactions. A significant advancement in this field has been the use of suitably engineered heme containing enzymes to catalyse these non-natural reactions. Even though, Fe complexes have emerged as a good alternative to

precious metals, there are still unmet challenges in terms of reactivity and particularly enantioselectivity. While there have been several reports delineating the mechanistic features of Rh and Cu catalysed transformations, the study of Fe catalysed reactions and the potential intermediates involved is largely unexplored. A major disadvantage of using Fe catalysts has been the modest selectivities obtained for reactions that proceed via an initial nucleophilic attack on the electrophilic carbene. Computational studies can act as a cornerstone in understanding the mechanism and selectivity of these complex reactions. In the context of nucleophilic attack, only Fe catalysed N-H insertion reaction has been studied where lowest energy pathway proceeds via the formation of an ylide and a free enol. A major problem in carbene transfer reactions catalysed by Fe complexes is the multiple mechanistic possibilities and it often becomes difficult to extrapolate the knowledge of one reaction to another. The mechanism can significantly vary on changing the metal, substrates as well as ligands. In addition, the possibilities of different spin states further complicate the mechanism. We use Density Functional Theory methods to gain a better understanding of the mechanism and the stereochemical model of these reactions. A clear picture of the mechanism would help in developing reactions with better selectivity and yield. We show that the lowest energy pathway involves the formation of a metal free enol. We propose the formation of weakly coordinated metal-enol complexes that explain the low selectivity. In addition, the substituents on carbenes play a significant role in strength of the metal-enol complex which could be used as a guiding factor to achieve higher selectivities. In another Ir catalysed reaction, a quinoid carbene is generated which inserts into sp3 C-H bonds. A radical mechanism which is unique for Ir chemistry was initially proposed for this reaction. Using our calculations, we show that the reaction proceeds via the typical concerted C-H insertion pathway and does not involve radicals.

Our research continues to be in the area of asymmetric total synthesis of natural products of medicinal significance. We have accomplished the total synthesis of pyrone containing natural products monticolides A and B. A four-step synthesis of the alkaloids eupochoccine and aldaline was achieved. We have also developed a procedure for the addition of dithioketene acetals from acetone to the sulfinimnes. The resultant products were used to synthesise chiral amines containing heterocycles such as pyrazoles and oxazoles. We have also initiated studies directed toward the synthesis of the alkaloid daphenylline, and the total synthesis of macrolatone natural product arenicolide C.

Development of paper based, photoluminescent sensors for hydrogen peroxide, hypochlorite, acetylcholine esterase, chymotrypsin. Development of an analytical method for the detection of small amounts of water in common organic solvents. Development of an analytical method for the detection of sub-micromolar quantities of lanthanides terbium (III) and Europium (III).

Catalytic, enantioselective C2-functionalization of 3-aminobenzofurans using N-heterocyclic carbenes (NHCs) has been demonstrated and the reaction proceeds via chiral α, β-unsaturated acylazoliums. We have also disclosed the enantioselective synthesis of tricyclic β-lactones by NHC-catalysed desymmetrization of cyclic 1,3-diketones. A conceptually new NHC-catalysed desymmetrisation of N-aryl maleimides leading to the atroposelective synthesis of N-aryl succinimides featuring an axially chiral C-N bonds has been reported. A rapid synthesis of zwitterionic phosphonium benzoates was demonstrated by a three-component coupling involving phosphines, arynes and CO_2. 5. Using thiophenols as the protic nucleophilic triggers in aryne three-component coupling, a transition-metal-free synthesis of 2-arylthio benzyl alcohol derivatives was developed.

The structure activity relationship of the bacterial quorum sensing agents – namely N-acylhomoserine lactones (AHLs) – have been explored. The presence of weak inter-carbonyl charge $\rightarrow \pi^*$ interactions in the AHLs have also been discovered. The influence of neighboring group electrostatic interactions on the lactone ring stabilities of AHLs has been elucidated, by studying carbamate, amide and thioamide variants of the AHLs. A synthetic protocol has been developed for incorporating 1,3-thaizine isosteres in the middle

of oligopeptides; the method involves the selective realization of a 6-exo cyclization reaction whose rates are faster than that of a competing 5-exo cyclization. Thioamide and thiazine containing peptides have been synthesised as diffusers and fragmentors of pre-formed amyloid fibrils in vitro and in FUS and TDP mutated yeast cells. The first flat helical peptidomimics have been synthesised by incorporating endo-pseudo-double bond within 13-membered peptidomimetic rings; the ring size and sequences of the cyclic peptides are optimised so that the side chains of all residues are long the same face of the flat helix, conducive for organo-catalytic anchoring of functional groups. Anti-parallel β-sheet analogues constrained through circularisation with covalent H-bond surrogates (HBS) at both ends, have been designed and synthesised; the role of intra-, rather than inter-strand weak interactions on sheet conformational preferences has been studied using 2-D NMR methods. The presence of generic charge $\rightarrow \pi^*$ O $\rightarrow$ C interactions at esters and carbamates, that govern their stereoelectronic properties, are elucidated using extensive NMR and FT-IR analyses of designed analogues.

Developed functionalised 2D materials for application in antimicrobial agents, sensing and phot-catalysts for organic transformation. Development of lipid nanoparticles in drug delivery.

The primary focus is using redox chemistry in transition metal and equivalent non-metallic catalyst systems to achieve efficient transformations. Initiated a program to develop highly selective oxidation methods, similar to those found in nature, for the direct installation of oxygen, nitrogen, and carbon functionalities into aliphatic C-H bonds of organic molecules and their intermediates. Work involves C-H functionalisation, C-C bond forming reactions, and functional group transformations. The core work of the laboratory lies in designing sustainable methods.

In the area of NHC organocatalysis, we have developed the enantioselective synthesis of functionalized 3-amino benzofurans/benzothiophenes, tricyclic β-lactones and N-aryl succinimides featuring an axially chiral C-N bond. Moreover, we have summarized the similarities of α,β-unsaturated iminiums and acylazoliums in organocatalysis, synthetic potential of aldimines in NHC catalysis, and the carbene catalysis using aliphatic aldehydes.

In the area of aryne chemistry, we have demonstrated the role of thiophenols as nucleophiles in aryne three component reactions, and a facile method for the synthesis of zwitterionic phosphonium benzoates has been uncovered using phosphines, arynes and CO2.

Core-shell CdS/CdSe quantum rods (QR) made from a highly thermally stable Cd precursor were co-assembled in supramolecular nanofibres of organo and hydrogels derived from bile salts. Such materials are promising hybrid nanostructures with anisotropic optical or electronic properties. Porous MnO2 nanoflowers with remarkably high surface area were made using a bile salt mediated technique and was used for efficient removal of cationic organic dyes, and for the oxidation of organic compounds. An inexpensive and sensitive photoluminescence protocol was developed for sensing formaldehyde, a biologically important molecule. A simple method was also worked out for sensing gallate derived green tea polyphenols. The low-cost and ease of detection make these protocols attractive for developing practical devices for the rapid detection of such analytes.

As part of our ongoing program on enantioselective catalysis, we are constantly looking to develop new catalytic enantioselective transformations. One of our research highlights is as follows: -

Among the unstabilized enolates used as nucleophiles in iridium-catalyzed asymmetric allylic alkylation reactions, amide enolates are the least explored. We have employed vinyl azides as amide enolate surrogates for the first time in Ir-catalysed asymmetric allylic alkylation. Competing reaction pathways are suppressed through the systematic tuning of the steric and electronic properties of vinyl azide to affect the alpha-allylic alkylation of secondary acetamides with high atom economy, exclusive branched selectivity, and mostly excellent enantioselectivity.

Carbohydrate-protein interactions occurring at the cell surface mimics, namely, glycovesicles were

investigated, in order to identify the factors governing cis- and trans- nature of these interactions. A fine sugar density dependence on protein recognitions for these cis- and trans-interactions. In collaboration with biologists and computations, small molecule inhibition of hepatitis C virus (HCV) by diarylbutane derivatives are identified as most potent inhibitors of HCV in in vivo and ex vivo conditions, thereby establishing a new chemical entity for HCV inhibition in mammalian systems. Mesomorphic polydiacetylene-based covalent polymers were synthesised and their thermotropic liquid crystalline property established. In a study involving Chemical Engineering and Computational Physics research groups, the ability to reach the Robeson boundary having the most permselectivities in PETIM dendrimer-based membranes for isolation of CO_2 gas from a mixture of gases was established.

We introduced a H-bond surrogate model that can be placed in unstructured tetrapeptides without excising any of its residues, to bias them into remarkably stable single Î±-helical turns in varying solvents, pH values, and temperatures. Spectral and computational analyses reveal that the number of spÂ² atoms in the backbone influences single turn Î±-helicity (STÎ±H) and rigidity. A solution phase trimodular synthetic (SPS) method was introduced for the rapid, large-scale, low-cost synthesis of libraries of STÎ±H and Extended Î±-helices in high yields. Î±-helical turn is found to guide the Ï• torsion of the residue succeeding it, exclusively into either a predominantly populated entropically favored Î±-helical (Î±-Ï•) state or a scarcely populated random coil (RC-Ï•) state; (ii) the Î±-Ï• state of Gly in turn favors the stability of the preceding Î±-helical turn, while the RC-Ï• state disrupts it. These findings provide first predictable efficient access to single Î±-helical turns in industrial scales.

1. A Computational Investigation on the Role of Metals and Axial Ligands in C-H Insertion Reaction Catalysed by Heme Proteins: Manuscript Submitted 2. Converging the Reaction Mechanisms of Indole C-H Alkylation by Heme, Non-Heme and Enzyme Catalysts: Manuscript Under Preparation 3. Understanding the Origin of Stereodivergence in CALB Catalyzed Transesterification reaction 4. Enantiodivergence in Heme Protein Catalysed C-H Insertion 5. Reaction Mechanism of Fumarate Hydration by Fumarse using a QM Cluster Approach (Collaborative work) 6. Catalytic Enantioselective Desymmetrizing Fischer Indolization through Dynamic Kinetic Resolution (Collaborative work, manuscript submitted)

Our Research interest continues to be in the area of asymmetric total synthesis of natural products of medicinal significance. We have accomplished the total synthesis of sphingolipids, pyrrolidine, piperidine alkaloids and alkaloids such as lycorane, stemoamide. Also, the synthesis of oxygenated natural products such as palmerolide C, cryptofolione, ratjadone, diospongin A and monticolides A and B was accomplished. The synthesis of C9-C22 fragment of polio containing natural product such pentamycin was achieved.

Our studies to delineate the minimal diguanosinyl motif towards RNA G-quadruplex like structure in solution led to the development of an amide-linked diguanosinyl compound that formed G-quadruplex like structure in solution in presence of K+ ion. Various linear guanosine amino acid dimers were synthesized with linkers of different chain lengths to investigate the optimum flexibility required to form such structures. In the area of peptides, linear dodecameric cationic antimicrobial peptides showed slightly better antimicrobial activities than their tetra and octameric congeners, but no activity against *MTB* for which octapeptides exhibited by far the best results implying that antibacterial activities are dependent on the length of these linear peptides. The study helped to derive the optimal length of this series of linear peptides and select potential leads in the development of novel cationic peptide-based antibiotics.

Developed functionalised 2D materials for application in sensing explosives, antimicrobial agents and phot-catalysts for organic transformation.

FACULTY & STAFF

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INSA HONORARY PROFESSOR

S CHANDRASEKARAN

IN NUMBERS

11 Academic staff
56 PhD students
6 Int PhD students
73 Publications
1 Int PhD conferment
10 PhD conferments

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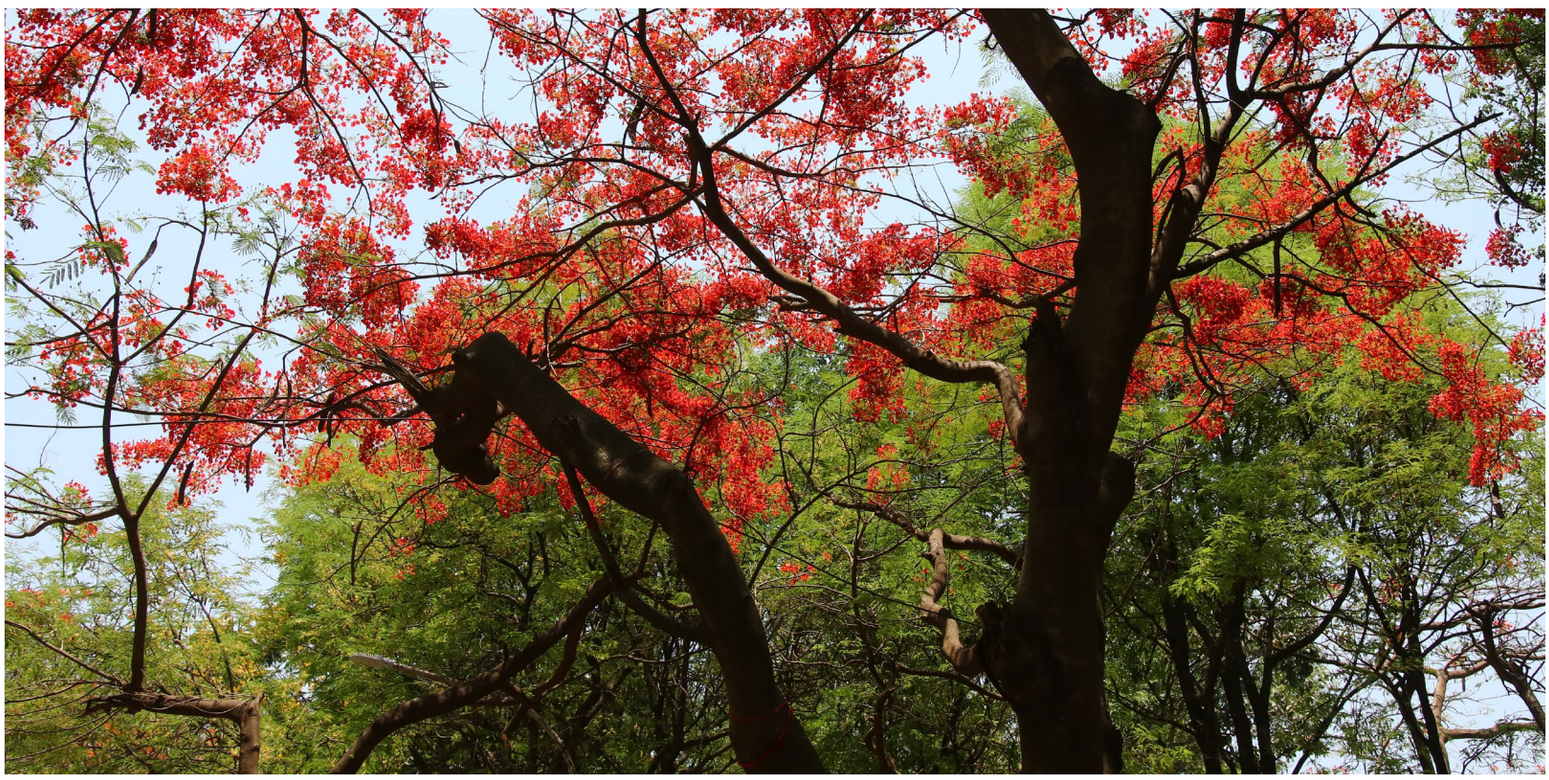
URL: orgchem.iisc.ac.in/



The Solid State and Structural Chemistry Unit (SSCU) was founded in November 1976. The unit has provided a major thrust to the frontier areas of Chemistry. Besides developing its research and teaching programs, unit members interact closely with other departments of the Institute. The unit is a premier research centre of global repute in the areas of solid state and physical chemistry. Our faculty and students work in inter-disciplinary areas at the intersection of chemistry, physics, and materials science.

CURRENT RESEARCH

Experimental and theoretical research pursued in the unit aims at understanding diverse phenomena associated with solids and condensed phases at varying length scales as well as liquids at the fundamental level. There is also significant emphasis on research activities aimed at the development of prototypes for commercialisation. Some on-going cutting-edge research areas pursued in the Unit are as follows:

SYNTHESIS, STRUCTURE, ELECTRONIC AND MAGNETIC PROPERTIES OF OXIDES

Inorganic-organic hybrid framework compounds have been studied over the years with a primary focus on understanding the structure and properties. In the course of this study, it has been found that new anions such as sulfates, thiosulfates, borates can be incorporated as part of the framework leading to interesting new families of compounds. The use of organic acids along with nitrogen-containing ligands led to new compounds that exhibit proton conductivity, (photo)catalysis, heterogeneous catalysis. Some of the

3.2.5 Solid State and Structural Chemistry Unit

CHAIRPERSON
SATISH PATIL

framework solids have shown great potential in alkali metal-ion and metal-sulfur battery chemistries and hydrogen storage.

MOLECULAR MATERIALS FOR OPTOELECTRONIC DEVICES

Synthesis of a new class of π-conjugated polymers, and correlating their structure and properties, has been pursued in great detail. A new class of conjugated polymers by various chemical routes, which control the polymer chain conformations, intermolecular interactions, and disorder by rational design were initiated and utilised to fabricate optoelectronic devices. The synthetic design principles helped in developing a new class of n-type conjugated polymers, which exhibit enhancement of electron charge carrier mobility. Examples of this type are rare in the literature. The conjugated polymers exhibit band-like transport, which demonstrates the effectiveness of the rational molecular design and generate the potential for a new class of optoelectronic devices. Understanding the photophysical properties of such systems would lead to new and efficient photovoltaic materials.

SYNTHESIS, STRUCTURE AND ELECTRONIC PROPERTIES OF SEMICONDUCTORS

The main activity centres on exploring novel properties of a range of materials with an emphasis on their electronic, magnetic, dielectric, and optical properties. Besides seeking new materials and properties, a major thrust is in trying to understand the origin of such novel and interesting properties, based on advanced experimental techniques and state-of-the-art theoretical approaches. Some specific highlights of the research in such directions are (a) crystal structure engineering by fine-tuning the surface energy in II-VI nanocrystals e.g. /CdSe, (b) tuning of dielectric properties and magnetism of oxide materials (c) discovery of multiglass properties in partially-disordered La2NiMnO6 (d) Magnetism in Fe/Cu Co-doped ZnO nanocrystals (e) discovery of effective mass driven structural

CORE RESEARCH

The work of the faculty of the Unit broadly focuses on Solid State Materials Chemistry and Physics, Physical Chemistry, and Theoretical Chemistry with specific emphasis on: Inorganic and Organic Materials Design and Synthesis for Energy, Nanostructured materials, Molecular Magnetic Materials and Switches, Statistical Phenomena of Biophysical Systems, Soft Matter, Quantum Chemistry and Electronic Structure, Multidimensional Femtosecond Microscopy, Crystallography, and Structural Chemistry, Electronics Device Design and Engineering.

transition in Mn-doped ZnS nanoplatelet (f) the very first demonstration of ultra-narrow and widely tunable Mn2+ emission from single nanocrystals of ZnS-CdS alloy (g) resolving the age-old controversy regarding NiS and proving it to be an unusual self-doped, nearly compensated antiferromagnetic metal (h) the pioneering work to demonstrate the feasibility of obtaining emission across the entire visible range from an atomic transition in doped quantum dots by strain engineering and (i) a microscopic description of how the local structure, distinct from the global average structure determined by XRD, evolves in to the global structure with an increasing length scale of the description and its consequence on the widely used concept of a chemical pressure in solid solutions. Other studies on this front have demonstrated the occurrence of ground state charge transfer between quantum dots. This leads to the emergence of strong electrostatic forces between quantum dots, leading to the formation of a quantum dot solid. These solids exhibit chemical properties such as stoichiometry and bear a strong resemblance to ionic compounds except that the building blocks are hundreds of times larger. In another study, possible routes to low threshold quantum dot lasers have been proposed, and novel, low threshold continuous wave quantum dot-based lasers have been developed. Other studies include the development of novel synthetic methods that enable copying the morphology of a nanostructure as well as the synthesis and spectroscopy of solar energy-relevant quantum dots composed entirely of earth-abundant, non-toxic elements.

MATERIALS ELECTROCHEMISTRY FOR RENEWABLE ENERGY

In this area, faculty members focus on the synthesis of electrode and electrolyte materials for various battery chemistries, configurations and supercapacitors. Critical understanding of materials properties, their correlation with structure and function is the primary focus. Many of these studies have also involved the utilisation of synchrotron facilities. The synthesis involved the development of multifunctional high-performance soft materials, inorganic nanomaterials, conjugated systems along with networked gel polymer electrolytes based on organic materials that have been investigated as potential candidates for various rechargeable battery chemistries.

CRYSTAL ENGINEERING, CHARGE DENSITY AND RELATED ASPECTS

The application of crystal engineering in the development of pharmaceutical solids is the main topic of research here. The main objective of crystal engineering is to design functional molecular solids with tunable properties based on intermolecular interactions. The concept of supramolecular synthon or the recognition of molecules through intermolecular interactions plays a crucial role to correlate the structure and property of crystalline solids. A wide variety of weak interactions including hydrogen bonding, π-π, halogen-halogen interactions present in single component as well as multi-component molecular crystals or cocrystals have been studied. The understanding of molecular interactions aids in the design of pharmaceutical cocrystal with improved physicochemical properties.

THEORETICAL STUDIES OF ELECTRONIC AND MAGNETIC PROPERTIES OF ORGANIC MATERIALS

Studies on the electronic and magnetic properties of strongly correlated low-dimensional systems and conjugated Entanglement entropy as a handle to study quantum phase transitions in frustrated spin chains were established. The scope of Valence Bond (VB) method by using new symmetries of symmetrically substituted donor-acceptor systems in polyenes and polyacenes to carry out ED studies on systems spanning nearly a billion- dimensional Hilbert space was extended. This method was employed to study excited state tuning in substitute polyenes and Tetracene. In addition, systems such as fused azulenes can be in magnetic ground states due to intrinsic bond frustration in electron delocalisation were also established.

STATISTICAL MECHANICS CONDENSED MATTER AND BIOLOGICAL SYSTEMS

The problems of protein folding and aggregation have important implications in several neurodegenerative diseases such as Alzheimer's and Parkinson's. Our faculty have recently addressed a fundamental problem in the area of protein collapse. Single domain proteins are finite-sized heteropolymers and behave like random coils at high denaturant concentrations, and fold into specific three-dimensional structures at low denaturant concentrations to perform their

functions. An interesting fundamental question is whether proteins akin to polymers undergo a coil-to globule collapse transition during the initial stages of folding (burst-phase) organic molecules have been carried out. During the course of this study, a new time-dependent density matrix renormalization group (DMRG) algorithm was developed to study the effect of long-range correlations on spin charge separation in polyene chains. The studies, shown through entanglement entropy studies, reveal why the DMRG method is accurate for models with long range interactions. The DMRG method was extended to study Bethe lattices and dendrimers. On the exact diagonalization (ED) front, for the first time how to exploit both spatial and spin symmetries of systems belonging to non-Abelian point groups was shown, as the conditions are made conducive for folding. The collapse transition in proteins is generally studied using single molecule fluorescence resonance energy transfer (FRET), and small angle X-ray scattering (SAXS) experiments. The FRET and SAXS experiments disagreed on whether Protein L, a model protein used to study protein folding, collapses during the burst-phase of folding. We studied the burst-phase of folding for Protein L using a coarse-grained protein model and molecular dynamics simulations to understand the impact of various approximations used in these methods to resolve the controversy between the FRET and SAXS experiments. We found that FRET experiments overestimated Rg of the protein due to the application of Gaussian polymer chain end-to-end distribution to extract Rg from the FRET efficiency and thereby suggesting pronounced compaction in the protein dimensions in the burst-phase. We further found that the decrease in Rg is close to the statistical uncertainties of the Rg data measured from SAXS experiments, which suggested no compaction, leading to a disagreement with the FRET experiments.

MOLECULAR SIMULATION AND THEORETICAL MODEL STUDIES

A detailed theory of the effects of intermediate metastable phases on the nucleation and growth of the thermodynamically stable phase has been developed. This theory explains such novel phenomena like the role of LDL phase in the nucleation of ice from supercooled water. A theory of surface tension under the same free energy conditions was developed. Studies on protein unfolding dynamics in aqueous binary mixtures demonstrated that while DMSO preferentially melts helices, urea does the same to beta sheets. The former was not known before this work. A theory of pair hydrophobicity in mixed solvents was developed. Studies on the origin of hydrophobic force law between two hydrophobic surfaces were initiated. In another front, the first theory of the role of vitamin D in the human immune response is being developed.

MAGNETIC MATERIALS AND SWITCHES

The world of digital information storage has been run mainly by bulk magnets, which have brought a significant reduction in size together with enhanced storage capacity. Yet much improvement could be brought, both in terms of size and storage space, by opting for molecular magnets that have potential applications in the field of data storage, sensors, spintronics, quantum computing, etc. Molecular systems are at par owing to their several advantages such as the chemical and structural versatility, low density, solubility towards conventional solvents making them fit for various device-level applications. Research activities of the group are directed towards rational design, synthesis, and details physical characterisation of new molecular magnetic materials (organic, inorganic, and nanoscale). The research being conducted is interdisciplinary in nature covering wide aspects of academically driven fundamentals of magnetism and challenges of the applicative world. Highlights of group activities are Electron-transfer systems, Spin-State Switching systems, Single Molecule Magnets, Single Chain Magnets, Magnetic Nanoparticles, Quantum Dots, Switchable Metal-Organic Frameworks, Magnetic Liquid Crystals, etc. We are also developing various multi-functional materials where our interest lies in studying the details of (Photo)magnetism, Photoluminescence, Photo- and Thermo-induced electron transfer, Magnetocaloric effect, Magneto-Optical properties, etc. The switchable materials being synthesised are also studied for their applications in various MEMS devices and sensors. Detailed theoretical investigations are also being carried out to enhance the present systems and design new materials.

MULTIDIMENSIONAL FEMTOSECOND SPECTRO-IMAGING

Multidimensional Femtosecond Spectroscopy coherently excites a manifold of vibronic states and resolves the ensuing coherent dynamics with conventionally high temporal and spectral resolution. Such information has provided valuable insight into the nature of System and Bath Hamiltonians for a number of systems spanning from proteins, organic photovoltaic polymers, singlet fission materials and perovskites.

The broad impetus of the group is to develop state-of-the-art multidimensional spectroscopic tools to probe matter through controlled interactions with femtosecond pulses and apply such tools to gain a better understanding of the fundamental physics of energy and charge transfer on femtosecond timescales. Such tools will integrate sub-micron spatial resolution with the conventional femtosecond temporal resolution and high spectral resolution of multidimensional spectroscopies. This will enable the investigation of fundamental processes ranging from electronic and nuclear interactions among a network of chromophores packed tightly inside a photosynthetic cell, to bridging the gap between the morphology of photovoltaic thin films and device performance by correlating morphology with sub-100 fs exciton delocalisation physics.

FACULTY & STAFF

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C SHIVAKUMARA | Ph.D. (IISc)

SENIOR SCIENTIFIC OFFICER

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R SATHISHKUMAR | MTech (Madras)

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M. S. HEGDE | PhD (IIT Kanpur), FASc

IN NUMBERS

12 Academic staff
5 Scientific staff
64 PhD students
22 Int PhD students
95 Publications
4 Int PhD conferments
13 PhD conferments

FACT FILE

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Degree Programs offered: PhD and Int PhD

3.3

Division of Electrical, Electronics, and Computer Sciences

IN NUMBERS

- 101 FACULTY MEMBERS
- 300 PhD STUDENTS
- 369 MASTER'S STUDENTS

The Division is assiduously seeking fundamental advances in the following core areas: Signal Processing, Communications, Networks, Microelectronics and Devices, Photonics, Theoretical Computer Science, Computer Systems and Software, Artificial Intelligence and Machine Learning, Control and Optimisation, Power Systems, Power Electronics and High Voltage Engineering.

THEMES

A feature of the Division's R&D activities is its focus on rigorous innovation in contemporary, interdisciplinary themes: Cyber Physical Systems, Big Data Analytics, 5G Technologies, Devices for Healthcare, Electronics for Strategic Sector, Network Science, Cybersecurity, Neuromorphic computing, Image and Video Processing, and Smart Grids.

RESEARCH HIGHLIGHTS

The Division of Electrical, Electronics, and Computer Sciences comprises four Departments: Computer Science and Automation; Electrical Communication Engineering; Electrical Engineering; and Electronic Systems Engineering. A feature of the Division's R&D activities is its forays into contemporary, inter-disciplinary, and nationally relevant themes including Cyberphysical Systems, Cybersecurity, Data Science, and Neurocomputing. The Division is also actively participating in Institute level programmes on Smart Energy, Smart Water, Smart Cities, and Devices for Healthcare, and Electronics for the Strategic Sector

DEPARTMENTS | CENTRES | UNITS

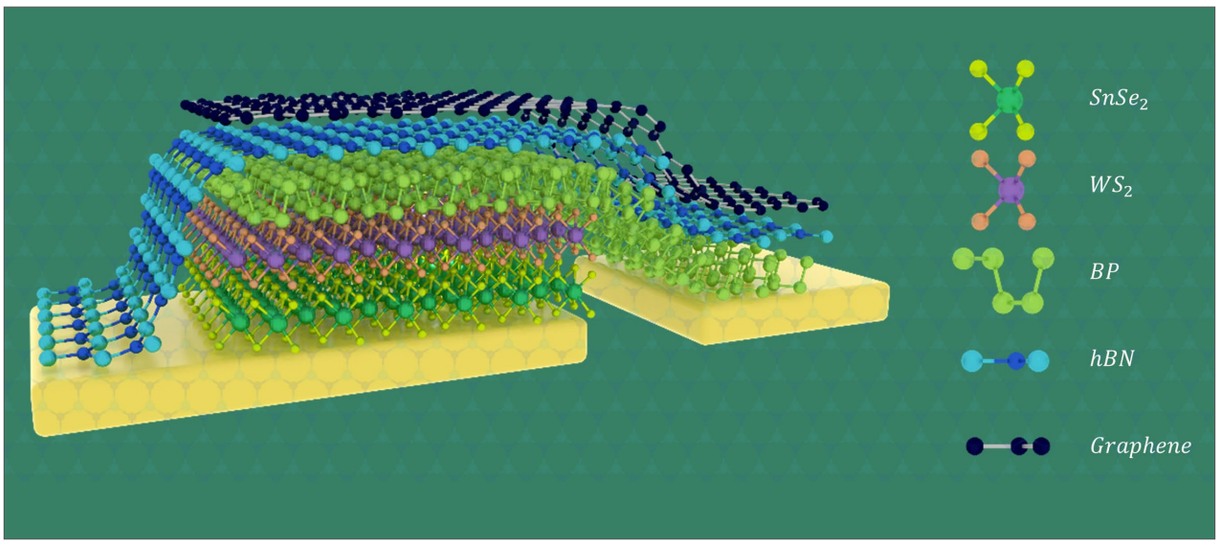
- COMPUTER SCIENCE AND AUTOMATION
- ELECTRICAL COMMUNICATION ENGINEERING
- ELECTRICAL ENGINEERING
- ELECTRONIC SYSTEMS ENGINEERING

2020-21

Research Snapshots

KAUSIK MAJUMDAR (ECE)

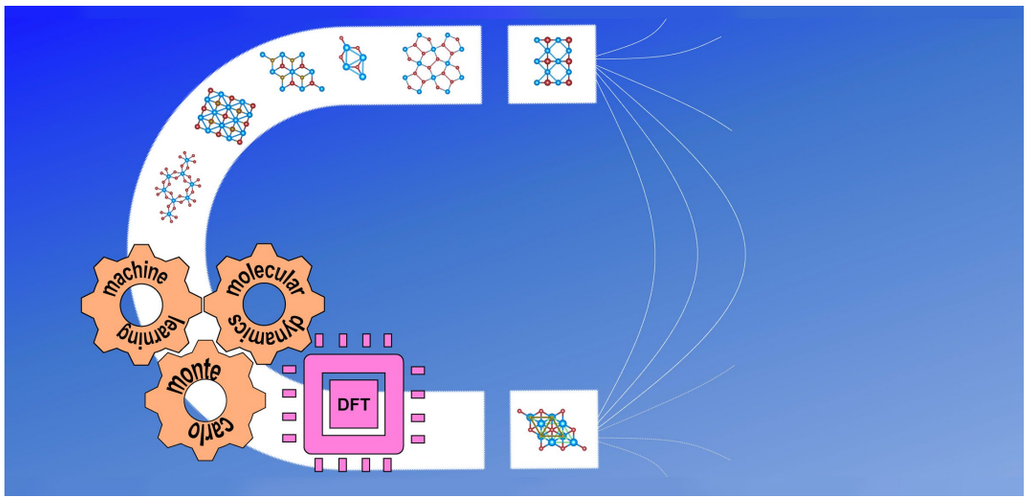
The Esaki tunnel diode, a landmark discovery in the semiconductor industry, is now a key element in electronic circuits. Researchers from the Department of Electrical Communication Engineering have designed a highly versatile form of this tunnel diode, where the active layers are separated by just a few tenths of a nanometre.
The team transformed this diode into both a voltage-controlled oscillator and a memory cell. The oscillator can be easily integrated onto a chip. The memory cell consumes very less energy, and is suitable for high density memory applications. The proposed tunnel diode also retains its versatile operation at very low temperatures (-269°C), making it suitable for cryogenic electronics.



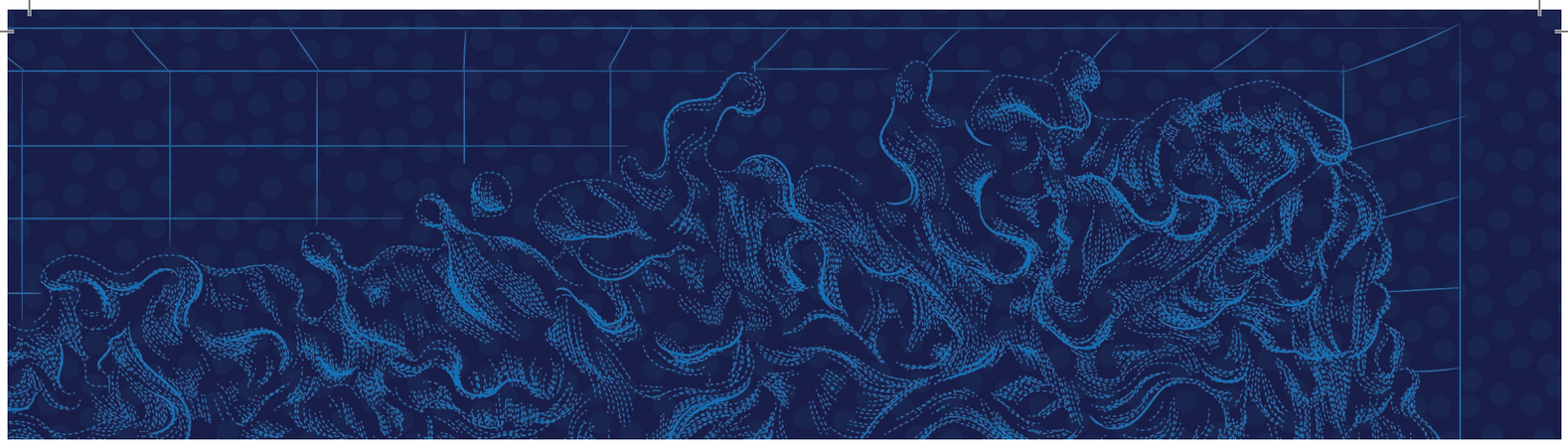
Reference: Abraham N, Murali K, Watanabe K, Taniguchi T, and **Majumdar K,** Astability versus bistability in van der Waals Tunnel diode for voltage controlled oscillator and memory applications, *ACS Nano (2020).*

SANTANU MAHAPATRA (ESE)

2D materials are atomically thin, single-layered films arranged in a crystal structure, with potential applications in next-generation electronics. As the temperature increases, the magnetic order in these materials gets disturbed. The temperature at which they lose their ferromagnetic properties is known as the Curie point. Determining the Curie point involves very complex calculations. Researchers from the Department of Electronic Systems Engineering have developed an open-source computer code to estimate Curie temperatures from the crystal structures of materials. They were able to identify 26 high temperature 2D ferromagnetic materials from large open-source databases, which could be ideal for use in high temperature devices.



Reference: Kabiraj A, Kumar M, **Mahapatra S,** High-throughput discovery of high Curie point two-dimensional ferromagnetic materials, *npj Computational Materials (2020).*



SOMA BISWAS (EE)

Cross-modal retrieval tasks with image-text, sketch-image, and so on are gaining increasing importance due to abundance of data from multiple modalities, as well as applications like e-commerce, security, and so on. For example, given an image query, it is often required to retrieve relevant textual documents from the database. In a recent study, researchers from the Department of Electrical Engineering developed a novel approach which seamlessly handles both labelled and unlabelled data for this task, thus reducing manual intervention significantly. In another study, they addressed the problem of retrieving previously unseen data, since new categories are discovered dynamically in the real world.

Data stored in multiple modalities, thus requiring cross-modal matching

Text-image matching [Ref 1]

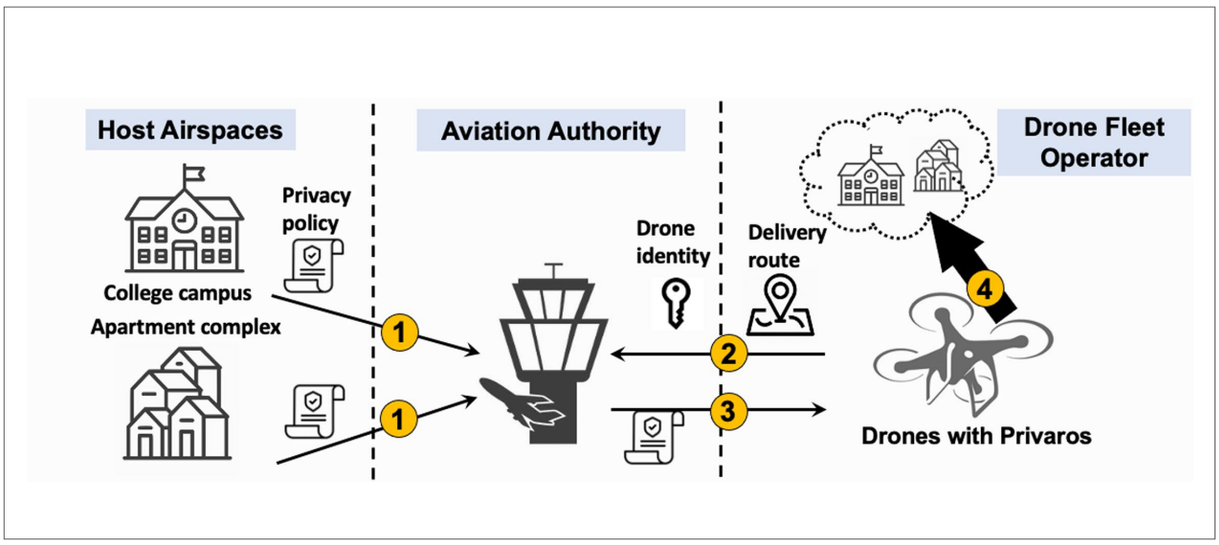
Sketch-image matching [Ref 2]

Reference: Mandal D, Rao P, **Biswas S,** Semi-supervised cross-modal retrieval with label prediction, *IEEE Transactions on Multimedia (2020).*

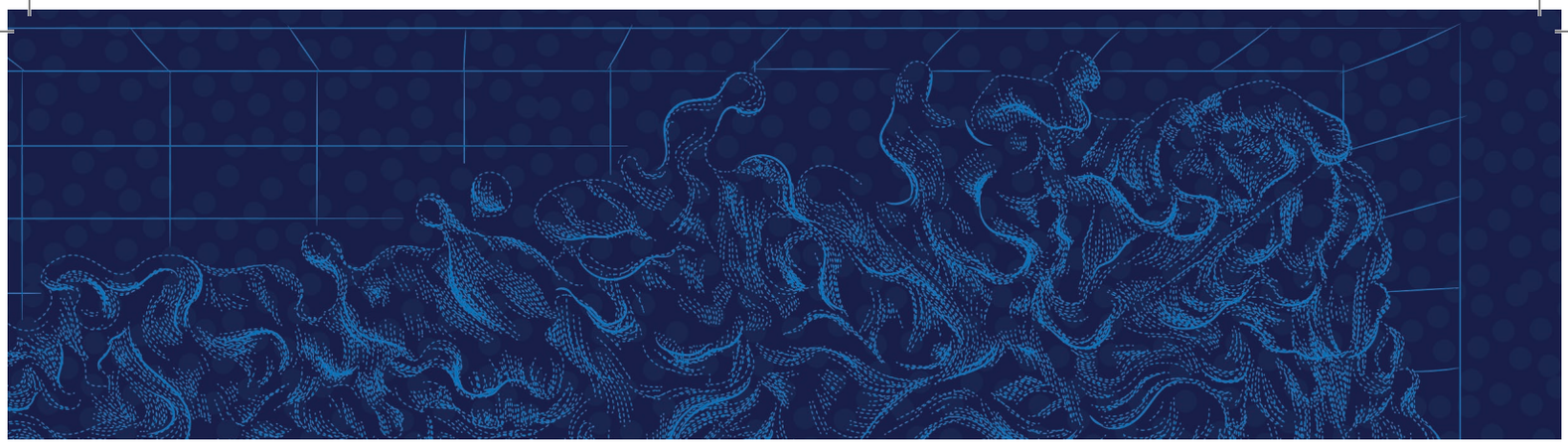
Dutta T, Singh A, **Biswas S,** Adaptive margin diversity regularizer for handling data imbalance in Zero-Shot SBIR, *European Conference on Computer Vision (2020).*

VINOD GANAPATHY (CSA)

Researchers in the Department of Computer Science and Automation have developed "Privaros", a set of enhancements to the drone software stack, which allows "host airspaces" such as an apartment complex, a university campus, or a city municipality to ensure that "guest" delivery drones visiting the airspace are privacy-compliant. Privaros incorporates new mechanisms into the drone software stack that allow such host-specified policies on board the drone. Trusted hardware on board can be used to prove to the host airspace that the guest drone is in compliance with its policies. This work also shows how Privaros can be integrated with upcoming policy frameworks, such as India's Digital Sky framework.

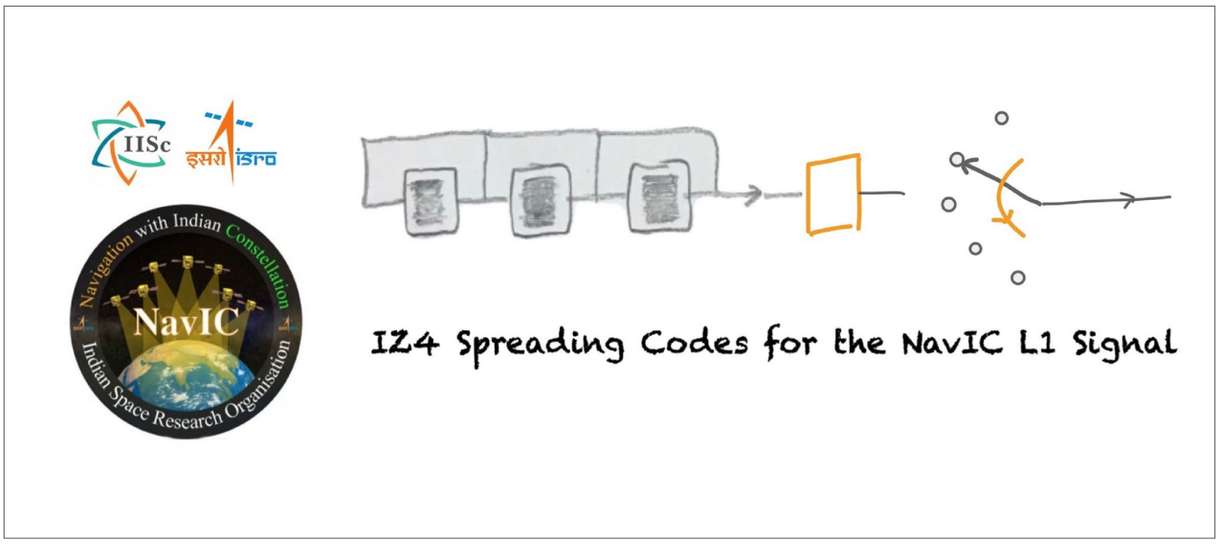


Reference: Beck RR, Vijeev A, **Ganapathy V,** Privaros: A framework for privacy-compliant delivery drones, *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security (2020).*



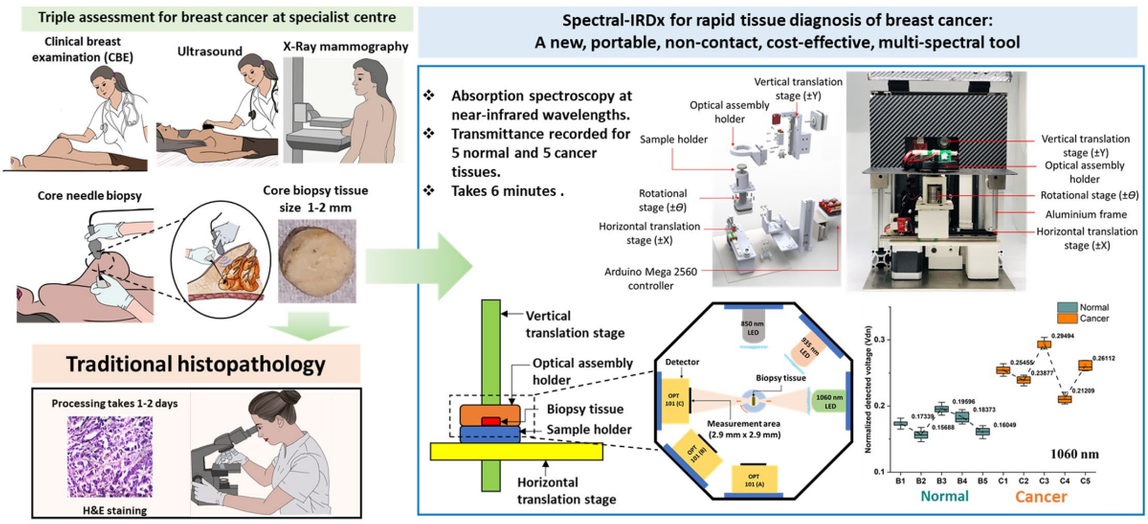
P VIJAY KUMAR (ECE)

To carry out satellite acquisition and ranging tasks, global navigation satellite systems use spreading codes, which have period related to the frequency 10.23 MHz of the onboard atomic clock. Operations in the L1 frequency band of the Global Positioning System and BeiDou Navigation Satellite System employ spreading code having length 10230, achieved by padding and truncating, respectively, a family of Weil sequences having period that is a prime number, either 10223 or 10243. IISc and ISRO scientists adopted a different approach, and interleaved 5, Z4-linear sequences of period 2046 to achieve period 10230, resulting in the IZ4 family of spreading codes. ISRO will incorporate these spreading codes in the new civilian L1 signal of NavIC (Navigation with Indian Constellation).

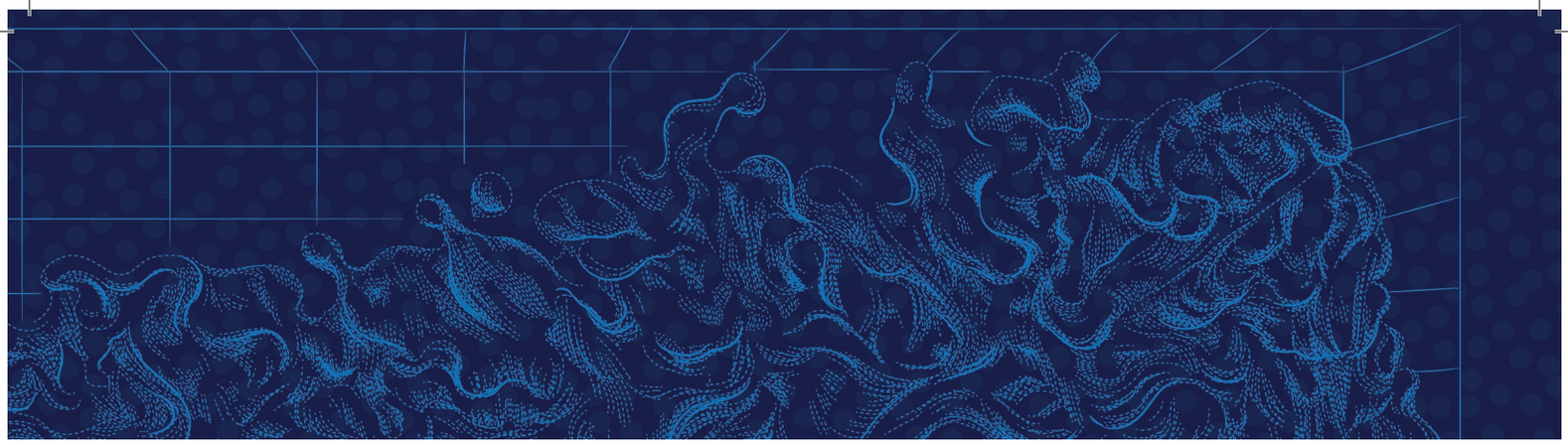


HARDIK PANDYA (ESE)

Breast cancer accounts for 11.6% of cases amongst all cancers, out of which it accounts for 6.6% of deaths globally. Early screening and diagnosis help in effectively treating it, increasing the survival rate of the patient. Currently, breast cancer is diagnosed using histopathology, which is labour-intensive and requires skilled doctors. To aid pathologists, researchers in the Department of Electronic Systems Engineering, in collaboration with University College London and Assam Medical College, have developed a portable, non-contact, multi-spectral, affordable breast cancer diagnostic tool. The cancer is diagnosed based on the infrared absorption characteristics of normal and cancerous tissues with respect to different operating wavelengths (850 nm, 940 nm and 1060 nm).

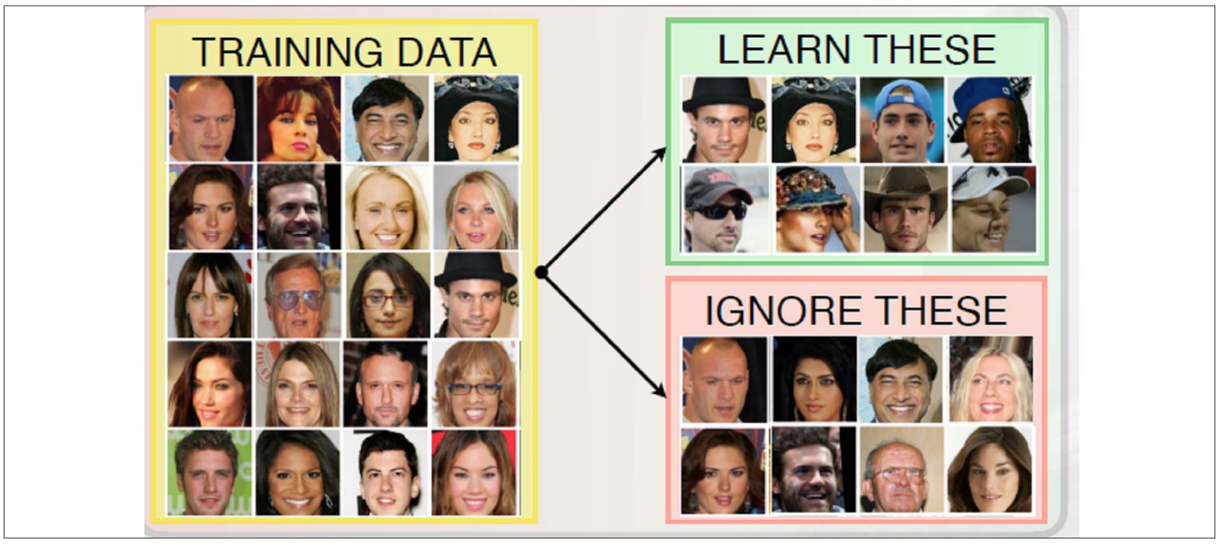


Reference: Pal UM, Vishnu AGK, Rila S, Shroff S, Gokul AM, Baruah D, Vaidya JS, Gogoi G, and **Pandya HJ,** Portable near-infrared spectroscopy tool using multi-spectral non-contact probes to delineate normal and cancerous breast tissue, *IEEE TBioCAS (2020).*



CHANDRA SEKHAR SEELAMANTULA (EE)

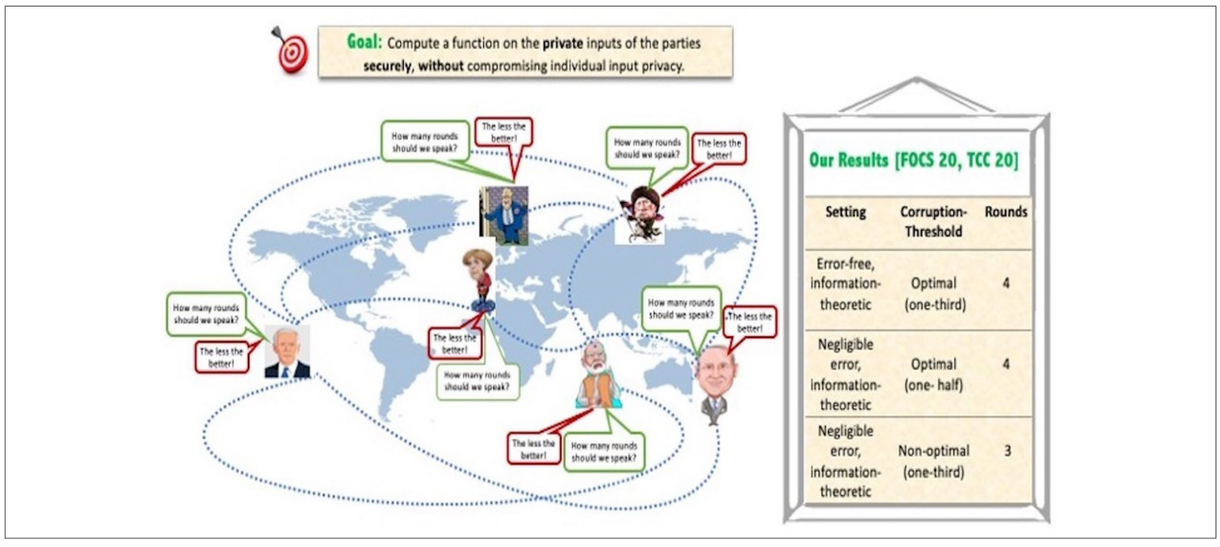
Semi-supervised generative adversarial networks (GANs) consist of neural networks tasked with learning the underlying distributions of each class of a target dataset, usually images. In a new study, researchers approached the GAN learning problem from a novel perspective, one that is motivated by the famous Persian poet Rumi, who said, "The art of knowing is knowing what to ignore." They provided the GAN with both positive data that it must learn to model, and negative samples that it must learn to avoid. The proposed formulation is able to generate realistic high-resolution images on datasets with positive to negative class ratios as low as 1:50.



Reference: Asokan S, **Seelamantula CS,** Teaching a GAN what not to learn, *Advances in Neural Information Processing Systems (2020).*

ARPITA PATRA (CSA)

Ben-Or, Goldwasser and Wigderson (BGW) established an important milestone in cryptography by showing that every function can be computed with perfect (information-theoretic and error-free) security, tolerating an active (byzantine or malicious) adversary that controls up to one-third of the total number of parties. A study from the Department of Computer Science and Automation explored the round complexity of general multi-party computation (MPC) in the classic BGW model, and showed that every function can be computed securely in only four rounds of interaction, and that some functions cannot be computed in three rounds. This resolves a long line of research. Follow-up work also settles questions related to statistical (information-theoretic with negligible error) security.



Reference: Applebaum B, Kachlon E, **Patra A,** The round complexity of perfect MPC with active security and optimal resiliency, *61st Annual IEEE Symposium on Foundations of Computer Science (2020).*

Applebaum B, Kachlon E, **Patra A, T**he resiliency of MPC with low interaction: the benefit of making errors, *18th Theory of Cryptography Conference (2020).*

The Department, originally called the School of Automation, was founded in 1969. In 1986, it was renamed as the Department of Computer Science and Automation. The department is recognised as a Centre of Excellence. The faculty and students of this department are engaged in cutting edge research covering the entire gamut of computer science.

Research activities of the Department of Computer Science and Automation (CSA) can be classified broadly into three streams: Theoretical Computer Science; Computer Systems and Software, and Intelligent Systems.

CURRENT RESEARCH

THEORETICAL COMPUTER SCIENCE

Research in Theoretical Computer Science has been in areas including algorithms, graph theory, complexity theory and cryptography.

In the area of algorithms, we have developed efficient online algorithms for the secretary problem, knapsack problem and generalised assignment problem. For the forest augmentation problem in survivable-network-design, we have developed a 7/4-approximation algorithm for the special case of matching input. We have developed approximation algorithms for partially colorable graphs. We have developed efficient approximation schemes for fair division of rent, cake and indivisible goods. We have developed a topology-aware distance measure between two bivariate functions that supports feature-aware comparison and plays an important role in multifield data visualisation. We have developed new interactive designs for visual

3.3.1 Computer Science and Automation

CHAIRPERSON
CHIRANJIB BHATTACHARYYA

display and interaction of a topological structure called the merge tree. In the area of graph theory, we have shown that to prove the celebrated Hadwiger's conjecture in general it is sufficient to prove it for all graphs which can be expressed as the square of some other graph. Also we showed that the Hadwiger's conjecture is true for the squares of 2-trees. We have proved special cases of k=4 and k-girth on a conjecture which states that a triangle free graph of chromatic number k will always have a rainbow path on k vertices with respect to any proper colouring. We have shown structural and algorithmic results on a game-based variant of vertex cover problem. We have develolped a new method called HyperGCN for training graph convolutional networks on hypergraphs. In the area of cryptography, we settle the round complexity of fair and robust MPC tolerating dynamic and boundary adversaries. We have presented a practically efficient MPC protocol with small number of parties and demonstrated its practical performance. We have developed a set of protocols for privacy-preserving machine learning inference and demonstrated their

CORE RESEARCH

Theoretical Computer Science: Algorithms and Complexity Theory, Combinatorial and Computational Geometry, Cryptography, Distributed Computing, Game Theory, and Graph Theory.

Computer Systems and Software: Programming languages, Software engineering, High-performance computing, Compilers, Computer architecture, Operating Systems, Databases, Systems Security, and Scientific visualisation.

Intelligent Systems: Machine Learning, Reinforcement Learning, Game Theory and Mechanism Design, Stochastic Approximation Algorithms, Stochastic Optimisation and Control, Computational Biology, Data Analytics in Computer Systems, Robotic Systems, and Data-Driven Safety.

practical efficiency. On pairing-based cryptography, we have proposed new Subset Predicate Encryption (SPE) schemes where the predicate function evaluates simple access-control mechanisms like subset containment. In the context of digital signature we have proposed randomisable signature schemes based on standard assumption. On privacy amplification, we have developed a new approach using non-malleable codes for building amplification protocols with optimal entropy loss as well as constant round complexity.

COMPUTER SYSTEMS AND SOFTWARE

Visualisation: Designed a distance measure for comparing individual topological features within or across different scalar fields that represent scientific data. Applications of the measure include symmetry identification, feature tracking, and fine-grained analysis of time-varying data. Developed a topology-aware distance measure between two bivariate functions that supports feature-aware comparison and plays an important role in multifield data visualisation. Developed new interactive designs for visual display and interaction using a topological structure called the merge tree.

Computer Systems and Security: Research was conducted on privacy for delivery drones in public airspaces (published in HotMobile 2019). Research was also conducted on programming support for cloud-based trusted execution environments (Intel SGX). Other topics investigated include securing mobile payment schemes as well as model stealing adversarial machine learning attacks. We designed the secure Diffie-Hellman key establishment protocol without the use of a trusted third party. This protocol attempts to take advantage of the fact that the adversary may not be able to compromise multiple channels at the same time. Based on this assumption, a secure Diffie-Hellman key establishment is proposed, and a probabilistic evaluation of the same has been carried out. DESA: A Dynamic Encryption Scheme with Authentication using Symmetric Block Cipher: For secure communication, it is required that each message is encrypted and authenticated before it is transmitted. Besides, the encryption schemes must produce indistinguishable ciphers, and the resulting secure communication must be free from various types of attacks such as replay attacks. Most existing encryption schemes do not satisfy all these requirements together. In this work, we have proposed dynamic encryption scheme with authentication that can potentially satisfy all these requirements together. Research on memory management especially on kernel object placement in NUMA machines and fault tolerant RCU has also been conducted. We also looked at the problem of detecting heap-based vulnerabilities at code level and detecting vulnerabilities in payment systems and gave suitable solution approaches.

Programming Languages and Verification: Designed, implemented, and evaluated a novel approach to perform formal verification of distributed systems using data flow analysis. The approach solves a hitherto unsolved computer science problem. The evaluation on a set of real benchmarks shows good promise of practicality. Completed the development and implementation of an approach and tool to verify observation purity of a given recursive function that uses persistent state internally across calls to it. Observational purity means the function always returns the same result for the same argument. Completed the design and implementation of an approach for automated testing of C programs to find buffer over-run and integer overflow vulnerabilities. This approach uncovers vulnerabilities several times faster than current baseline approaches. We developed effective techniques for sound and efficient static analysis for race detection in embedded software.

High Performance Computing: One of the faculty, while on sabbatical at Google, was a founding team member of the MLIR project and was a co-developer of the early infrastructure, especially, the polyhedral/mid-level analysis and optimisation infrastructure. It was open-sourced in April 2019, and is currently a major open-source project with significant industry traction. The MLIR project was initiated to deliver the next generation optimising compiler infrastructure with a focus on serving the computational demands of AI and machine learning programming models. MLIR is a new intermediate representation designed to provide a unified, modular, and extensible infrastructure to progressively lower dataflow compute graphs, through loop nests potentially, to high-performance target-specific code. We have also been working on a new compiler-based approach to do high-level synthesis

of hardware, an approach to do GPU code generation using MLIR, and new scalable techniques for loop fusion in the polyhedral framework.

INTELLIGENT SYSTEMS

Unsupervised Learning remains a new frontier in Machine Learning. For the problem of learning a latent k polytope from perturbed samples, it was shown that there exists an algorithm which has time complexity linear in input sparsity and which can recover the model using polynomial number in k and the dimension where the polytope resides. This immediately suggests an input sparsity time algorithm for Topic models which was not known earlier. Another important question in this domain is the number of samples needed to recover an unsupervised model. If d denotes the dimension, it was shown that kd number of samples are sufficient if a latent k polytope problem satisfies certain assumptions. This result is also useful in determining optimal sample complexity for topic models.

A new project on exploring the use of non-humanoid robots for providing interventions to autistic children has been initiated. It was demonstrated that the children react well with robotic toys, thus eliminating the need for humanoids. This project is useful especially in Indian settings where the humanoid robots are expensive and their use is impractical.

In the area of machine learning in the low data regime, several contributions were made. A deep learning model called skip residual network for one short learning was developed and it has set benchmark results. Further for domain adaptation, a state-of-the-art model called Contra-distinguisher was developed.

The notion of fairness in multiarmed bandit learning was introduced, the well-known upper confidence bounds algorithm was extended to the new model, and regret bounds were derived. This marks an important contribution to fair online learning. A novel extension to multiarmed bandits was proposed by proposing ballooning bandits. This model has powerful applications in posting high quality content in question-answer forums and online discussion forums.

In the context of web-crawling, two online algorithms were proposed to estimate the rates at which different webpages change. These algorithms are based on the principles of the law of large numbers and stochastic approximation theory. Theoretical guarantees and simulations demonstrate their efficacy vis-a-vis the offline schemes.

We analysed, for the first time, convergence of two-timescale stochastic approximation algorithms where both recursions have non-ergodic controlled Markov noise in them and the driving vector field in both recursions is set-valued. This setting is most often encountered while analysing reinforcement learning algorithms involving online updates under partial observations. We further devised a reset-mechanism for stochastic recursions with set-valued maps that examines the iterates at increasing time instants and resets them to the boundaries of a region should the iterate sequence escape the region. This provided for a means to ensure convergence of stochastic recursions even when stability of the iterates are not guaranteed. In the area of reinforcement learning, we developed a Q-learning based algorithm that we proved is convergent to the fix-point of the scheme despite the fact that the update step is an off-policy recursion by approximating the greedy max operation in update step.

The role of centrality and diversity in various pattern recognition, machine learning and artificial intelligence tasks was examined. The importance of outliers and their characterisation and detection was examined in detail. Embedding nodes in a network in the presence of outliers was also analysed. Further, machine learning techniques in evolutionary algorithms and database robust query processing were investigated.

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47 MTech (Res)

107 MTech

88 Publications

9 MSc (Engg) Conferments

16 PhD Conferments

CORE RESEARCH

Information Theory, Communications, Communication Networking, Signal Processing, Machine Learning, Photonics, Electromagnetics, Nanoelectronic Devices and VLSI

CURRENT RESEARCH

Communication, Networking, Internet of Things and Information Theory, Signal Processing, Machine Learning

Research on several topics of 5G, autonomous vehicle transmission, Internet-of-things, compressed sensing, sparse signal processing, sensor array signal processing, neuroscience are in progress such as device-to-device communications, full-duplex radios, vehicle-to-infrastructure transmission, and mmWave communications. A new multiple access protocol to leverage the full-duplex capability envisaged for next generation access points in wireless local area networks was proposed. A computationally-efficient and resource-efficient allocation algorithm for device-to-device communications in 5G networks was developed. Improved energy-efficiency of green energy harvesting wireless sensor networks, a new ordered transmission technique that reduces the average number of sensor nodes while ensuring the same error rates as the conventional scheme, and optimised new censoring schemes with channel strength aware transmission were also developed.

The transmission rate allocation problem in a cache-enabled power constrained wireless access system with a fixed probability of local cache hit was modelled as an average file request backlog minimisation problem in a two-phase local/remote quasi-birth-death process. A computational method for determining the rates

3.3.2 Electrical Communication Engineering

CHAIRPERSON

KJ VINOY

based on the approach of showing strong duality for the problem, using analytically derived recursive Karush-Kuhn-Tucker optimality equations for the rates is being developed. Information-constrained statistics and learning: goal has been to study statistics and machine learning algorithms with communication and privacy constraints placed on the input data to provide optimal algorithms. A "resource-centric" view of information-theoretic cryptography for the design and implementation of city-scale engineering systems that involves distributed control over a communication network was developed.

The sample complexity of sparse support recovery was analysed, leading to matching upper and lower bounds. A rigorous convergence of a Bayesian algorithm for dictionary learning (DL) has been carried out; such convergence results are not available in the literature, even though DL has been an active area of research for over two decades. A new area of research, namely, linear dynamical systems under sparsity constraints, has been initiated, where the classical notions of observability, controllability, stability have been revisited under sparsity constraints.

A modulation scheme `Orthogonal Time Frequency Space (OTFS) modulation' was investigated. It is well-suited for communication over high-Doppler channels encountered in high-mobility environments and in mmWave frequencies. We analysed the diversity order achieved by OTFS and the PAPR characteristics of OTFS, proposed low-complexity schemes for OTFS signal detection and channel estimation, and studied MIMO and multiuser OTFS systems. A Modulation scheme for wireless communications in rich scattering environments called 'media based modulation' was analysed. We initiated investigations on the use of deep neural networks (DNN) for the design and optimisation of next generation wireless communication systems.

A new data exchange framework was developed, which is now undergoing standardisation in BIS. The framework allows publishers of IoT data to connect with consumers and allows publishers to setup access control policies to ensure privacy. APIs will allow developers to create new applications easily. An open source reference implementation has been created and deployed in Pune Smart City. Low-cost gas sensors and the algorithms for their calibration were developed. A quadruped walking platform and techniques for training robot arms were developed. Coding for probabilistic forwarding over networks, using tools from percolation theory to analyse probabilistic forwarding on grids was developed. We developed dynamic-programming based upper and lower bounds on the capacity of finite-state channels. We developed a range of Markov chain Monte Carlo methods for sampling from high-dimensional probability distributions on lattices. Convolutional neural networks were used for classifying skin lesions. A method was developed for designing a Home

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IN NUMBERS

27 Academic Staff 27
116 PhD students
14 M Tech (Res) students
57 M Tech students
185 Publications

Automation Control System (HACK) using a Virtual Assistant and a Mobile Application.

Codes for reliable, low-latency communication were designed for vehicle-to-infrastructure communication in the direction of autonomous vehicles, multiplayer augmented and virtual reality, telesurgery. In the area of index coding, optimal broadcast rates for two-sender index coding were characterised for linear index codes and a special case of the general case. Also for a class of generalised index coding problems, error correcting index codes were found and a discrete polymatroidal framework was developed for differential error correcting index codes. For coding caching problems, optimal error correcting delivery schemes were found for a well-known prefetching scheme called symmetric batch prefetching.

Several topics on image and video processing topics have been explored for low light image enhancement, quality assessment of image stitching algorithms and user experience models for rate adaptation in video streaming. Low light image restoration using deep convolutional neural networks showed that learning subbands of multiscale decompositions can lead to much better performance while using deep CNNs to learn to restore low light images. Prediction of discomfort due to egomotion in virtual reality was done. We conducted a subjective study to evaluate the naturalness of predicted videos and benchmarked popular naturalness assessment measures.

RF, MICROWAVES, VLSI, PHOTONICS, CYBER PHYSICAL SYSTEMS

A millimetre wave antenna array with active beam steering capability was designed and characterised, along with support hardware and software platforms for analogue beam steering. Beam shaping and beam steering approaches were developed to reduce the impact of quantisation. With the goal of developing an intelligent surface, the performance of an electronically reconfigurable meta surface to validate media-based modulation and its effectiveness in a scatter-rich environment were evaluated. Computational EM capabilities were enhanced by incorporating spatial variation of uncertainties in EM problems and were solved using FEM where both intrusive and non-intrusive approaches were attempted. Integrated circuits for wireless communication and sensing, including radars-on-chip were developed. Beam steering for visible light communication for indoor applications was investigated. A hybrid 2D-3D fast electromagnetic analysis aided by pattern recognition was developed for signal integrity analysis. Methods were developed to model Vcc in feed through noise in microprocessors with fully integrated voltage regulators. This included a distributed formulation and led to EMI/EMC IC immunity.

Photonic Integrated Circuits: A large group velocity dispersion of hybrid modes in a Lithium Niobate-on-insulator multimode rib waveguide was reported. A novel slot formed, to achieve Zero Birefringence, when a sub-micron rib waveguide is slit with vertical symmetry resulting in L shaped rails was analysed. Single photon sources for quantum communications: We proposed an on-chip nonlinear optics based correlated and higher dimensional state photon source using silicon hybrid materials.

VLSI: First demonstration of (a) strong luminescence from metallic 2H-TaSe2 and (b) fast vertical trion switch through exciton-trion coherent coupling was reported. Experimental studies of nonlinear optical effects in novel material platforms were carried out: Resonant enhancement of nonlinear optical and fluorescence processes utilising dielectric, 2D materials and dielectric-2D material hybrid systems was shown and we developed super-resolution techniques for nonlinear optical microscopy. Demonstrated (a) high responsivity and ultra-low NEP, while maintaining high speed of operation in graphene-absorption based photodetector (b) intrinsic limit of exciton linewidth in monolayer semiconductor and (c) large single-photon and two-photon luminescence enhancement through FRET in MoS2/SnSe2 layered heterojunction.

Ubiquitous sensing enabled by cyber-physical systems: For applications such as smart metering, health monitoring devices, cameras, manufacturing, etc., it enables reduced cost, improved operations, and safety. Our research was motivated by the following questions: How do individuals take to technology and adapt their behaviour? How can we make IoT with AI algorithms effective when people are in the

loop? How do we build communication networks that enable fast decision making and feedback? With these broad questions in mind, we studied problems involving: (a) information design for enabling change in behaviour for reduced energy consumption, (b) providing incentives to stake holders to share ubiquitously sensed but privately held data, (c) camera and AI enabled real-time feedback to drivers for enabling safer driving, (d) sensing and communication infrastructure for a smart factory, and (e) real time sensing-enabled fatigue monitoring of factory workers.

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The Department of Electrical Engineering was started in 1911 (then known as the Department of Electro-Technics and subsequently changed to the Department of Electrical Engineering in 1913), just two years after the founding of Indian Institute of Science. Initially, students were admitted for a postgraduate diploma, known as the Diploma of the Indian Institute of Science (DIISc). Subsequently, the diploma programme was replaced by ME degree programme, which is a post-BE programme, and which has been named as MTech programme recently. The doctoral programme began in the 1950s. In 1970s, the MSc (Engineering) degree, a Master's programme by research was introduced to supplement the research activities. The MSc (Engineering) programme was recently renamed MTech (Research).

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IN NUMBERS

23 Academic staff

1 Scientific staff

83 PhD students

51 MTech (EE) students

33 MTech (SP) students

30 MTech (AI) students

18 MTech (Res) students

187 Publications

5 MTech (Res) conferments

16 PhDs conferments

3.3.3 Electrical Engineering

CHAIRPERSON

UDAYA KUMAR

CURRENT RESEARCH

Power Systems: An open-source, heterogeneous, resource-constrained hardware platform is developed for edge computing applications research in smart grid using a unique hardware platform called Parallella which hosts a Zynq SoC (dual-core ARM + FPGA) and a 16 core co-processor called Epiphany. A custom I/O board and an analogue sensing board with three voltage and four current channels using a synchronous 16-bit ADC synchronised to PPS time clock of a GPS. The raw waveform data is sent to a cloud server over a bandwidth-limited communication channel using a custom anomaly aware data compression algorithm implemented on the ARM. Phasor measurement algorithms are implemented on the FPGA. A parallel power quality measurement algorithm is implemented on the Epiphany. The obtained measurements are found to be comparable to a commercial power analyser.

A single-step method based on the properties of Foster equivalent circuit is proposed to directly fit an R-L equivalent circuit to the frequency response of modal impedances of a transmission line. The positive peaks, negative peaks and the positive zero crossings of the slope change plot of the frequency response are found to provide a good approximation of zeros, poles and the flat region locations of the frequency response. Accurate fitting is achieved using the proposed method with fewer passive elements than Vector Fitting.

A systematic procedure for the development of an experimental scaled-down 220 V lumped parameter frequency dependent transmission line model of a 230 kV transmission line has been developed. The developed experimental line properly captured important features such as smoother wave shape during energisation, traveling time, currents, and voltage magnitudes during the fault and after the fault removal.

In the area of power system protection, a simple linear programming algorithm running in the central master controller to co-ordinate the relays using three different IEEE standard curves is developed.

CORE RESEARCH

Research work of the Department of Electrical Engineering falls into two major fields, namely i) Power and ii) Systems and Signal Processing. The area of Power includes Power Systems, Power Electronics and High Voltage Engineering. The Systems and Signal Processing research area includes Machine Learning, Real-Time Systems, Medical Imaging, Image and Video Processing, Medical Signal Processing, Digital Health, and Speech and Audio Signal Processing.

Power Electronics: Power electronic converters that can transform single phase power to three phase power is highly beneficial in many applications. A new power electronic converter topology, termed Auxiliary Capacitor based Active Phase Converter (AC-APC), which converts single-phase AC to three-phase AC has been developed. Tests on the converter show a significant reduction of up to 60% in the semiconductor power rating and more than 50% reduction in power loss in the power converter. Such a converter can be very useful in agriculture, small industries and for rural electrification.

A new method of control of power electronic converters called dual comparison one cycle control has been established based on the research carried out in the laboratory. This control is shown to be simple and can be implemented using simple analogue circuits. The control exhibits superior performance, in terms of current ripple, dc offset and overall stability under a wide range of loading conditions.

Novel pulse width modulation (PWM) techniques are developed for two-level and three-level inverter-fed induction motor drives. These novel techniques help reduce the harmonic distortion in motor current and pulsations in the motor torque in switching-frequency-constrained inverter fed motor drives. Research has also been carried out to better understand and compensate the effect of inverter dead time on the motor applied voltage. Improved rotor position sensing technique for slip-ring induction motor was also proposed and demonstrated.

Significant research effort has been directed towards various aspects of high-speed switched reluctance (SR) machine-based generation system. A 5-kW, 10000-rpm SR machine has been developed indigenously and tested successfully. Other highlights include silicon carbide (SiC) devices-based power converter for SR machine, a novel protection circuit for power devices, and control methods for motoring and generating at low and high speeds.

Asymmetrical six-phase induction machine (ASIM) is one of the most common multi-phase machines, which is preferred in high power drives and safety-critical fault-tolerant applications, like, electric-ship propulsion, electric aircraft, etc. Interestingly, harmonic voltages applied for OVM operation of ASIM do not create any torque ripple, but they cause copper loss in the machine, and hence reduce the efficiency. A set of optimal OVM PWM techniques are proposed that minimise the copper loss.

Fast switching transient of SiC MOSFET reduces switching loss but may induce prolonged oscillations, spurious turn on, high device stress and EMI related issues, etc. An analytical model to capture the switching dynamics of SiC MOSFET is proposed where detailed non-linear model of the device along with circuit parasitic are considered. It results in accurate estimation of transition time, switching loss, (dv/dt), (di/dt), and transient over-voltage.

High Voltage Engineering: Theoretical studies to design a compensated pulsed alternator (compulsator) to drive an electromagnetic gun has been carried out. Work has been initiated to design and develop pulsed power sources for for coilgun based electromagnetic launchers, electromagnetic manufacturing as well as liquid food microbial inactivation. Experimental and theoretical studies in the area of detection of buried landmines using pulsed electric field have also been carried out. Work is also continuing in the area of nano-dielectrics as insulating material for various high voltage power apparatus. Biodielectrics is yet another active research area of the group.

Research has successfully reduced numerous gaseous pollutants using a cascade of discharge plasma treatment with ozone treatment. Pollution-induced flashover studies on EHV/UHV transmission insulators, condition monitoring of HV apparatus, corona, multi-stress aging studies on composite insulators, and studies on high-temperature high-current low-sag (HTLS) conductors. In the area of high-voltage transformers, closed-form analytical expressions have been derived which correlate harmonic sum of squares of natural frequencies (i.e. both SCNF and OCNF) of a 1-ph, 3-ph, Y- or Delta-transformer winding to its elementary inductances and capacitances for any possible condition of the neutral terminal.

A simplified method has been developed for determining the lightning stroke current distribution on the aircraft. Previously developed self-consistent return stroke model has been extended to include realistic soil models, which required adoption of the finite-difference time-domain method for computation of the dynamic field. Using the same, the role of soils electrical parameters on lightning stroke current has been quantified.

Systems and Signal Processing: New robustness results have been proved for learning multi-class and multi-label classifiers under label noise. Transfer learning method has been suggested for CNNs using the novel concept of bank of filter trees. Fast algorithms for high-dimensional filtering have been designed. Interesting results on convergence analysis of nonconvex ADMM show the efficacy of the algorithm. A distributed algorithm for rigid registration of point sets has been designed and uniqueness results for rigid registration have been observed.

In the area of networked control systems, novel analysis was carried out to explain certain behaviours of inter-event times in event-triggered control that have been observed repeatedly by the community in the past but never explained. In the area of multi-agent systems, new models of population dynamics on networks were proposed and properties on convergence and nash equilibria were studied. In networked transportation, new algorithms were proposed and analysed for coordinating a fleet of vehicles for first and last mode transportation; a novel study on the interplay between ride sharing and a population's mode choice was carried out; and data driven scalable algorithms were proposed for coordinated traffic management of autonomous vehicles/robots.

On the topic of geometric methods for accurate 3D registration of depth representations, a highly efficient and accurate method has been developed for such representations. This method is also extended to the multi-view scenario where the 3D registration problem for multiple scans are solved jointly to improve speed. One of the focus areas of research in computer vision is cross-modal matching, i.e., given data from one modality (eg. image-text), the goal is to retrieve semantically meaningful data from another modality (eg. photo-sketch). Work is in progress on challenging problems including classifying data from unseen classes (zero-shot learning), detecting data from unseen classes (novelty detection), and semantic segmentation of urban scenes to aid autonomous driving.

In the area of digital signal processing, the research work carried out includes Visual speech recognition, Indian sign language recognition, Reconfigurable and scalable FPGA architectures and implementing image denoising in hardware. In the area of image processing and deep learning, the research work includes the development of new wavelet-based reconstruction strategies for unlimited sampling, which is a new sampling strategy that promises to offer an unlimited dynamic range. A patent application has been filed on realising analogue-to-digital converters that work on the principle of unlimited sampling. Novel strategies have been developed for performing shape-specific segmentation and demonstrated applications to fundus images, which greatly aided in the automated assessment of glaucoma. Approaches for acoustic source localisation, new risk minimisation strategies for speech signal denoising, and new and robust techniques for spectro-temporal modelling of the speech signal have been developed. It has been discovered that a new class of signals that can be reconstructed from their magnitude spectrum and established Hilbert integral relations. Advanced techniques for robust extraction of several parameters of voice box from speech acoustics Improved understanding of articulation during different modes of speech has been developed.

In the area of biomedical imaging, the research work includes development of a novel type of regularization for MRI reconstruction that results in lower reconstruction error compared other regularisations used so far. The new regularisation has power to eliminate large amount of noise without suppressing image resolution. Further, a novel type of regularization for reconstructing images from highly under-sampled non-uniform spatial point measurement with application to speeding up confocal microscopy

has been developed. For this problem, the widely celebrated compressive sensing regularisation fails. The regularisation is adaptive to image structure and yield high quality reconstruction.

In the domain of neuroscience, reliable sleep staging has been achieved using a fusion of various features derived from a single channel EEG and an ensemble classifier (RUSBoost), with the best results in the literature on unseen subjects, on three different databases. Work has also been carried out on decoding imagined speech and characterising the changes in brain functional connectivity during altered states of consciousness (anaesthesia, sleep and meditation) using EEG. Further, consistency of covariance matrices over time has been used to characterise meditation EEG. Anomalous heart rate changes have been identified during breath hold at very low breathing rates, which is a phenomenon hitherto not reported in the literature. Also, expanded the research activities in understanding human performance on speech tasks, speech recognition and language recognition.

Speech and audio processing has been one of the active areas of research in the Dept. The directions of research involve understanding speech production and synthesising naturally sounding speech. A Kannada speech synthesiser has been developed using Tacotron2 and WaveGlow, with quality exceeding that of Google's Wavenet TTS and Nuance's TTS. The topics of information extraction from audio including recognition of the spoken content, the speaker and the language/accent are pursued in the EE Dept.

A significant amount of research is representation learning of audio from large dataset from raw audio for various downstream tasks. Further, healthcare based on acoustic data is explored to identify sleep disorders, neurological disorders like ALS, respiratory disorders like asthma as well as for viral infections in respiratory pathway like COVID-19. Also, a new subword-based language model has been proposed, which significantly increases the performance of speech recognition engines in morphologically rich languages such as Tamil and Kannada. A patent application has also been filed based on this work.

Architectures have been proposed that learn end-to-end mapping functions to improve the spatial resolution of the input natural images. These models are unique in forming non-linear combinations of image interpolation techniques using the convolutional neural network. Compared to the state-of-the-art and recent deep learning-based natural image super-resolution techniques, these methods preserve the sharp details in the image, while also obtaining comparable or better peak-signal-to-noise ratio values than them. An edge-preserving robust loss function has also been proposed that further improves the performance of state-of-the-art emotion recognition systems (from face images), image denoising algorithms and image superresolution algorithms. Lipi Gnani – a versatile OCR for documents in any language printed in Kannada script, has been developed, which has been shown to perform faster than Google's Tesseract, while also giving better accuracy.

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SARASIJ DAS | PhD (Western Ontario), Assistant Professor
SRIRAM GANAPATHY | PhD (John Hopkins), Assistant Professor

PRASANTA KUMAR GHOSH | PhD (USC), Associate Professor
VENU MADHAV GOVINDU | PhD (Maryland), Associate Professor
GURUNATH GURRALA | PhD (IISc), Assistant Professor
VISHNU MAHADEVA IYER | PhD (North Carolina), Assistant Professor
VINOD JOHN | PhD (Wisconsin), Professor
UDAYA KUMAR | PhD (IISc), Professor
G NARAYANAN | PhD (IISc), Professor
B S RAJANIKANTH | PhD (IISc), Professor
A G RAMAKRISHNAN | PhD (IIT Madras), FNAE, Professor
GN RATHNA | PhD (IISc), Principal Research Scientist
B SUBBA REDDY | PhD (IISc), Principal Research Scientist
P S SASTRY | PhD (IISc), FNAE, FNASc, Professor
L SATISH | PhD (IISc), Professor
CHANDRASEKHAR SEELAMANTULA | PhD (IISc), Professor
U JAYACHANDRA SHENOY | PhD (IISc), Chief Research Scientist
PAVANKUMAR TALLAPRAGADA | PhD (Maryland), Assistant Professor
M JOY THOMAS | PhD (IISc), Assistant Professor

ASSOCIATE FACULTY

SUPRATIM RAY | PhD (Johns Hopkins), Associate Professor, Center for Neuroscience

The Department nurtures educational research with the theme "Atom to System", which encompasses nanoelectronics, signal and information processing, neuromorphic integrated circuits, diagnostic and healthcare devices, communication networks and Internet of Things (IoT), and power electronic drives. It runs one of the country's most unique and successful MTech programs in Electronic Systems Engineering.

CURRENT RESEARCH

From Atoms to Systems: In nanoelectronics and energy science, software code has been developed to simulate electron-phonon-coupling-based quantum transport in 2D material-based MOS transistors. This is then employed to gain insight into phonon-limited anisotropic quantum transport in phosphorene-based transistors. This work was published in the *Journal of Applied Physics* and selected as the Editor's pick.

In the broad area of signal and information processing, several specific topics are being worked on. In Physical Data Storage, 2D algebraic codes have been developed for correcting random and burst errors. This result can pave the way for codes over multi-dimensional storage channels, QR codes that can be

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IN NUMBERS

16 Faculty & Staff
45 PhD students
79 MTech students
98 Publications
14 PhD conferments

3.3.4 Electronic Systems Engineering

CHAIRPERSON

L UMANAND

customised, and so on. A patent of Reed Solomon decoders was approved. In Quantum Information Processing, techniques for node failure recovery in quantum networks have been developed, as well as modified graph states that are resilient to eavesdropping; further, fundamental work has been carried out on entanglement-assisted Reed Solomon quantum codes. In Neural Networks and Learning Systems, an original theory for spatio-temporal neural memories based on self-organisation has been developed. In Music Signal Processing, a theory towards algorithmic synthesis of South Indian classical music has been developed.

In the neuromorphic engineering and IC design area, the following have been developed: Unlimited Dynamic Range Analog to Digital Converters (Full IP); Handheld, low-cost electronic device for rapid, real-time fluorescence-based detection of Hg2+ using aptamer-templated ZnO quantum dots; Mixed-signal hybrid neuromorphic processor with memristive synaptic crossbar for cognitive computing; Neuromorphic vision; Ultra low power machine learning accelerator.

Work in Reconfigurable Computing has seen the development of Hardware Accelerators for Capsule Network Based Deep Reinforcement Learning, High Throughput Hardware for Hoeffding Tree Algorithm with Adaptive Naive Bayes Predictor, 2-way Superscalar RISC-V CPU with caches, virtual memory with CoreMark and Dhrystone benchmark values of 3.84/MHz and 1.0603 DMIPS/MHz respectively.

In healthcare technologies, the focus is on developing novel biomedical devices and healthcare solutions by combining expertise in microengineering, biomedical engineering, electronic system design, additive manufacturing, sensor interfacing and calibration to solve problems in biology and medicine. Specific topics include technologies for early detection, screening and diagnosis of breast, oral, brain, and other solid tumour cancers, smart catheter technologies for cardiac ablation and neonatal intubation, portable systems for auditory screening of infants and neonates using biopotentials, blue-sky research in bioresorbable devices for recording bio-potentials, and microsystems for rapid antibiotic susceptibility screening. Work in biomedical engineering has led to patent applications for the fabrication of microneedles, a device for the measurement of cervical dilatation and a portable analyzer for in situ testing of the degradation of stored coconut oil.

CORE RESEARCH

Research in the Department encompasses a spectrum of areas, including nanoelectronics, signal and information processing, neuromorphic engineering and IC design, reconfigurable computing, healthcare technologies and biomedical engineering, networked embedded systems & IoT, communication networks, power electronic drives and renewable energy systems. It hosts or co-hosts several very popular MTech programs in Electronic Systems Engineering, Microelectronics and VLSI, and Artificial Intelligence

Work in the Networked Embedded Systems and IoT area has resulted in the following outputs: design and construction of an IoT data management algorithm for efficient data storage and reconstruction, a neural network architecture for Speech to Text decoding, RF localisation algorithms using a hybrid approach consisting of finger printing with cooperative schemes, construction of sensor rich projectiles for remote monitoring and intrusion detection, RFID-based tracking of first responders inside a building, and acoustic signature-based physically unclonable functions for device identification.

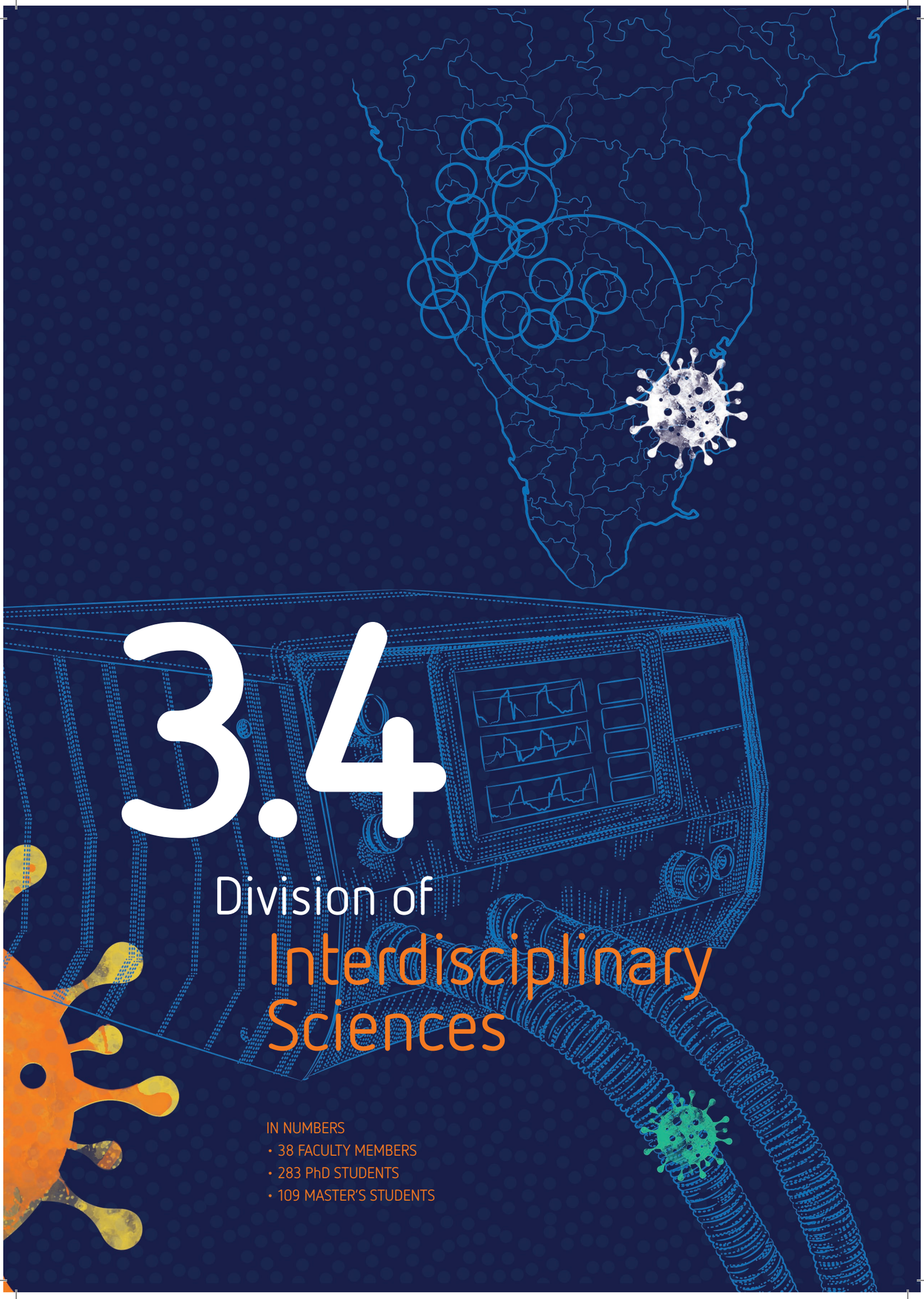
In the context of Industrial Cyber-Physical Systems, a security testbed has been implemented for showing the importance of application context awareness in security mechanisms to detect and mitigate cyber-security threats. The idea is to propose a robust and secure framework, as well as intelligent security mechanisms to manage complex manufacturing plants. In other work, an "Energy Router" has been developed for use in Smart Grid applications. A network of energy routers consists of DC loads as well as DC energy sources. The Energy Router is able to differentiate between loads by assigning priorities to them, and is able to route the power on demand, from sources to loads, through the network by making or breaking the connections in the electrical domain. An ESE faculty member is also part of the team that is developing a metal 3D printer using Electron Beam Generator technology, the first of its kind in the country.

Faculty working in Communication Networks have worked on problems in optimal Virtual Network Function Placement and Traffic Steering, lightweight and energy-optimal scheduling algorithms for wireless networks, energy-optimal VM allocation and VM migration in Data Centre Networks, server pricing and service scheduling in server farms as well as design and control of tactile cyber-physical systems.

The Renewable Energy Systems area has seen work leveraging faculty expertise in power electronics and led to significant contributions in solar photo voltaic based systems, like grid connection and maximum power point tracking, and induction generation systems that can be applied to wind and micro hydel plants. Specific mention can be made of solar cookers, rooftop photovoltaic integration to the departmental grid and ballast-free pico hydel generation.

FACULTY & STAFF

K GOPAKUMAR | PhD (IISc), FIETE, FNAE, FIEEE, Professor
JOY KURI | PhD (IISc), Professor
SANTANU MAHAPATRA | PhD (EPFL), Professor
L UMANAND | PhD (IISc), Professor
NS DINESH | PhD (IISc), Professor
SHAYAN GARANI SRINIVASA | PhD (Georgia Tech), Associate Professor
MAYANK SRIVASTAVA | PhD (IIT Bombay), Associate Professor
ARUP POLLEY | PhD (Georgia Tech), Associate Professor
KURUVILLA VARGHESE | MTech (IISc), Principal Research Scientist
HARESH DAGALE | MSc (Engg) (IISc), Principal Research Scientist
TV PRABHAKAR | PhD (TU Delft), Principal Research Scientist
CHANDRAMANI SINGH | PhD (IISc), Assistant Professor
HARDIK J PANDYA | PhD (IIT Delhi), Assistant Professor
CHETAN SINGH THAKUR | PhD (Western Sydney), Assistant Professor
V NAGA KRISHNA | Scientific Officer Grade II
P RAMACHANDRAN | Scientific Officer Grade II



3.4 Division of Interdisciplinary Sciences

IN NUMBERS

- 38 FACULTY MEMBERS
- 283 PhD STUDENTS
- 109 MASTER'S STUDENTS

Interdisciplinarity is the characteristic feature of the research carried out in this Division. Specific research areas include Bioengineering, Urban infrastructure and transportation, Nanoscale materials, Nano devices and systems, Economics, Finance, Human resource management, Marketing, Optimisation, Public policy, Energy, Water, Internet of things, Distributed sensing, Computer systems, Computational science, Data sciences and bioinformatics.

THEMES

Interdisciplinary research has emerged as a crucial component of the research landscape in recent years. By breaking down departmental barriers, interdisciplinary research facilitates novel breakthroughs that may not be possible within the confines of a particular discipline. The Division of Interdisciplinary Sciences has a wide range of Departments/Centres with the common theme of a strong interdisciplinary focus.

RESEARCH HIGHLIGHTS

The Division of Interdisciplinary Sciences consists of the Centre for BioSystems Science and Engineering, Centre for Society and Policy, Centre for Infrastructure, Sustainable Transportation and Urban Planning, Centre for Nano Science and Engineering, Department of Computational and Data Sciences, Department of Management Studies, Interdisciplinary Centre for Energy Research, Interdisciplinary Centre for Water Research, Robert Bosch Centre for Cyber Physical Systems and Supercomputer Education & Research Centre

DEPARTMENTS | CENTRES | UNITS

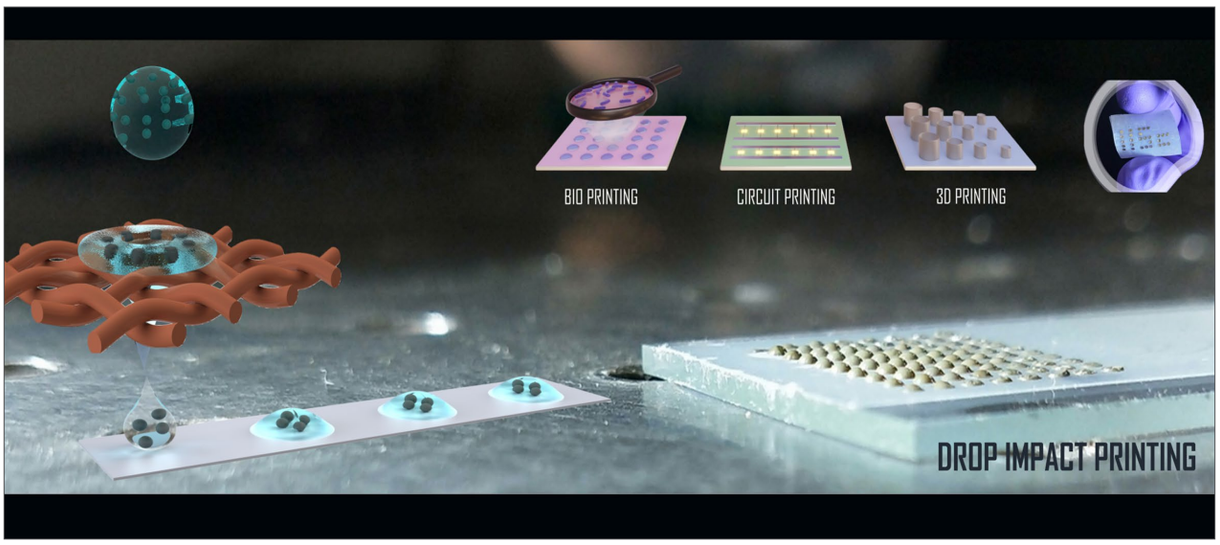
- CENTRE FOR BIOSYSTEMS SCIENCE AND ENGINEERING
- CENTRE FOR SOCIETY AND POLICY
- CENTRE FOR INFRASTRUCTURE, SUSTAINABLE TRANSPORTATION AND URBAN PLANNING
- CENTRE FOR NANO SCIENCE AND ENGINEERING
- COMPUTATIONAL AND DATA SCIENCES
- MANAGEMENT STUDIES
- INTERDISCIPLINARY CENTRE FOR ENERGY RESEARCH
- INTERDISCIPLINARY CENTRE FOR WATER RESEARCH
- ROBERT BOSCH CENTRE FOR CYBER PHYSICAL SYSTEMS
- SUPERCOMPUTER EDUCATION AND RESEARCH CENTRE

2020-21

Research Snapshots

PROSENJIT SEN (CeNSE)

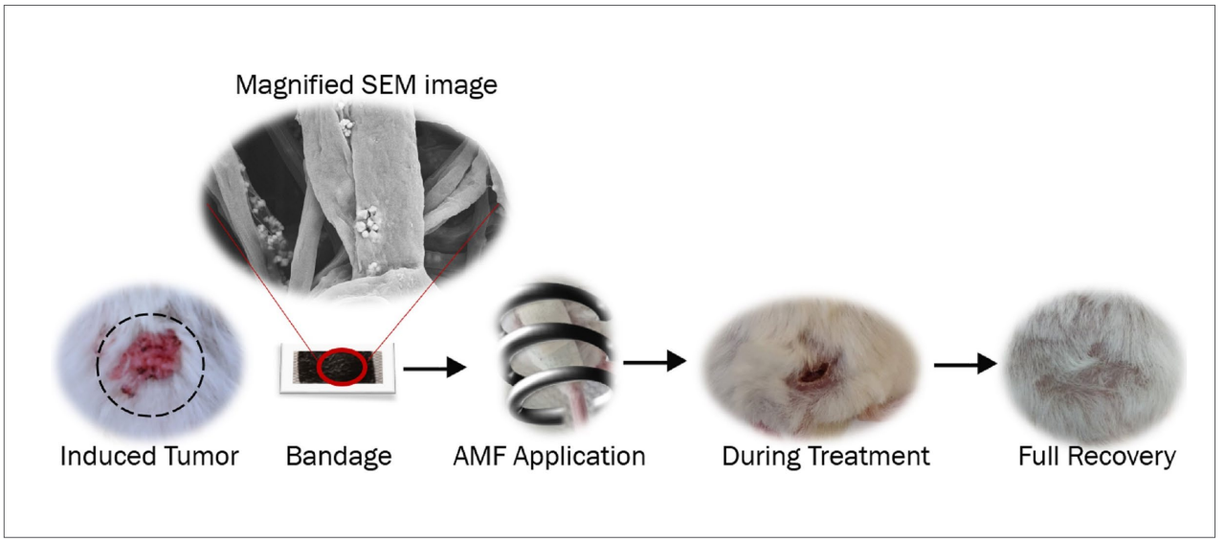
Researchers at the Centre for Nano Science and Engineering have developed a low-cost, drop-on-demand printing technique capable of generating a wide range of droplet sizes using a variety of inks. It could also potentially be useful for 3D printing of living cells, ceramic materials, electronic circuits and machine components. The technique replaces the nozzle found in traditional printers with a mesh covered with chemically treated nanowires that repel water. Large droplets hitting the mesh at high speed break up into micro-scale droplets, which are then printed onto a surface. Because of the short contact time of the droplet with the mesh, particles in the droplet do not clog the pore opening.



Reference: Modak CD, Kumar A, Tripathy A, **Sen P,** Drop impact printing, *Nature Communications (2020).*

SHILPEE JAIN (BSSE) & ANNAPOORNI RANGARAJAN (MRDG)

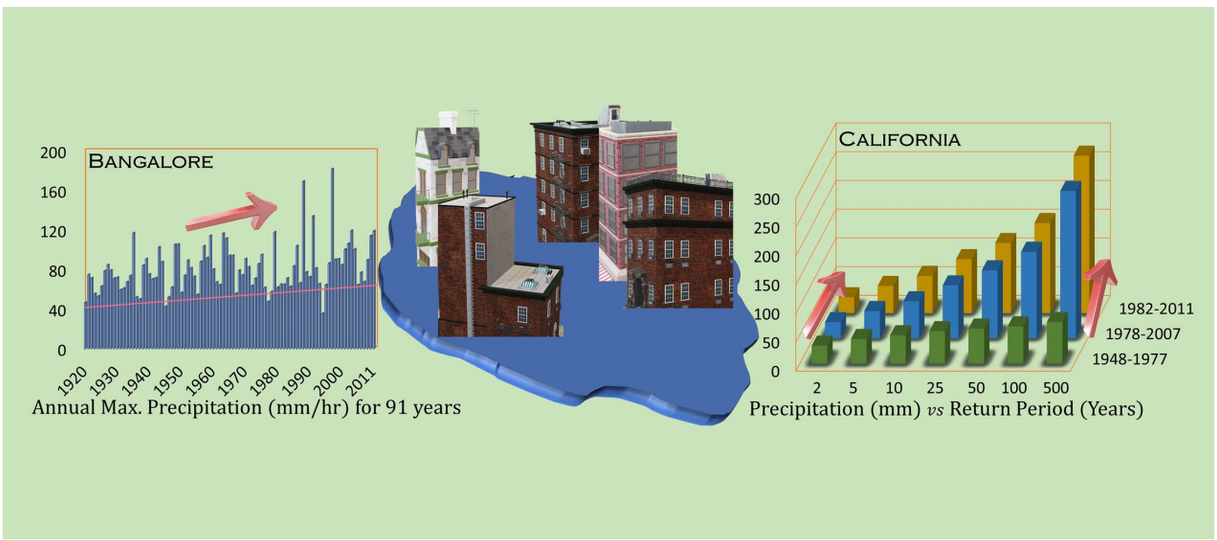
Researchers in the Centre for BioSystems Science and Engineering and Department of Molecular Reproduction, Development and Genetics have developed a non-invasive bandage with magnetic nanofibres that can kill skin cancer cells with heat. It comprises nanoparticles made from an oxide of iron and a biodegradable polymer called polycaprolactone pasted on a surgical tape. The magnetic material generates heat when it is subjected to a high-frequency oscillating magnetic field. When tested on human cancer cells as well as mice with artificially induced skin cancer, the heat generated by the nanofibrous magnetic bandage killed the cancer cells successfully. Moreover, in the mice, the healthy tissue remained intact with no signs of burns, inflammation, or thickening.



Reference: Suneet K, De T, **Rangarajan A, Jain S,** Magnetic nanofibers-based bandage for skin cancer treatment: a non-invasive hyperthermia therapy, *Cancer Reports (2020)*.

PRADEEP P MUJUMDAR (ICWAR)

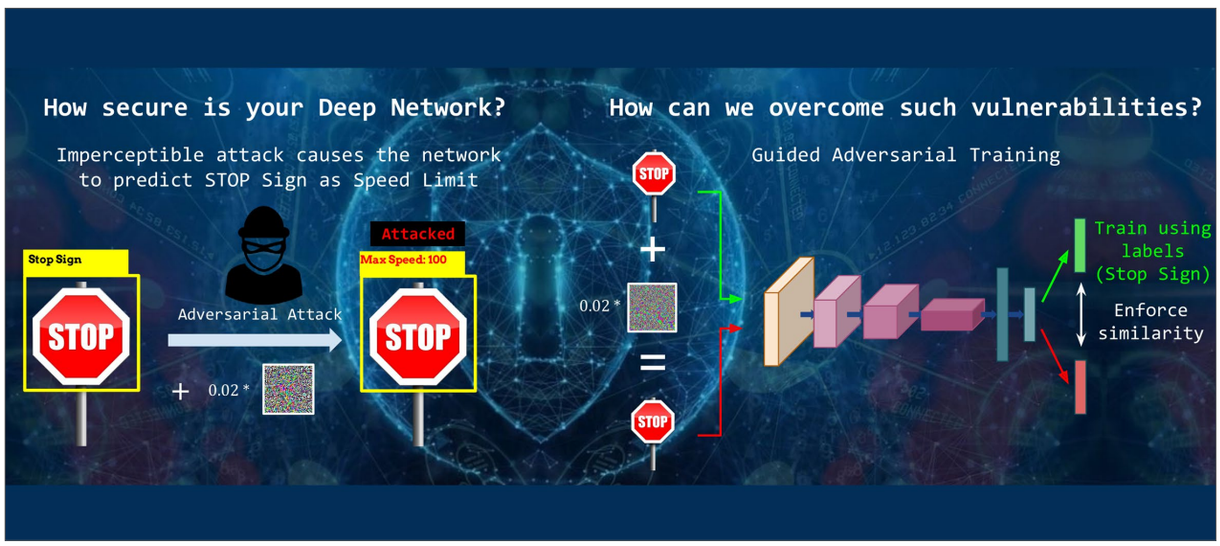
Unprecedented increase in human population in urban areas has led to a rise in the number of unplanned cities, and an increased vulnerability to extreme weather events. Researchers from the Interdisciplinary Centre for Water Research studied changes in several hydrological variables over thirty years in seven cities around the world. The study revealed an increase in yearly average temperature, as well as a decrease in diurnal temperature in all the cities. The amount of rainfall that can accumulate in a given area has increased in the recent past (1982-2011) for most of the cities. In addition, short-duration precipitation events have become more frequent in recent years.



Reference: Rajulapati CR, Gupta H, **Mujumdar PP,** Diurnal variability of hydrological variables in urban areas, *Urban Climate (2020).*

VENKATESH BABU R (CDS)

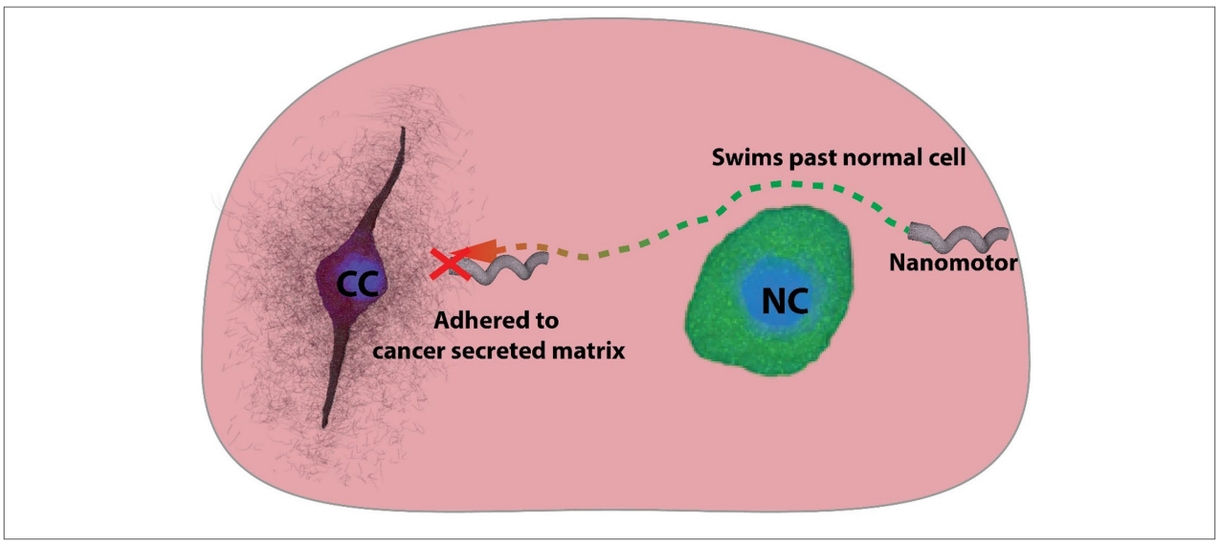
Deep neural networks have diverse applications. Think of Alexa in our homes, self-driving cars, or AlphaGo beating humans. But these machine learning models can easily be fooled using seemingly invisible noise called adversarial attacks. Researchers at the Department of Computational and Data Sciences have been working towards building attacks to identify weaknesses of these models more effectively, and developing defenses to safeguard them from adversaries. In a recent study, they demonstrate a novel attack called GAMA (Guided Adversarial Margin Attack), which reliably estimates the worst-case performance of deep networks, and a novel single-step adversarial defense called GAT (Guided Adversarial Training) to efficiently train the models.



Reference: Sriramanan G, Addepalli S, Baburaj A, **Babu RV,** Guided adversarial attack for evaluating and enhancing adversarial defenses, *Proceedings of the Advances in Neural Information Processing Systems (2020).*

AMBARISH GHOSH (CeNSE) & RAMRAY BHAT (MRDG)

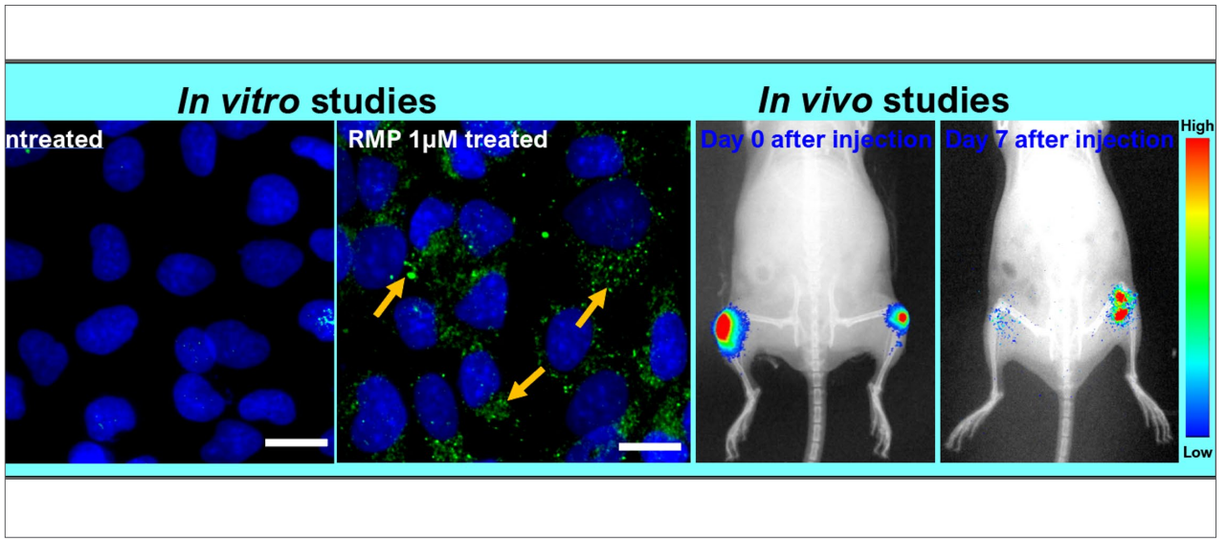
An interdisciplinary team from the Centre for Nano Science and Engineering and Department of Molecular Reproduction, Development and Genetics has used a 3D tumour model and magnetically-driven nanomotors to probe the microenvironment of cancer cells. The team steered helical nanomotors remotely via an external magnetic field through the tumour model to sense, map and quantify changes in the cellular environment. The nanomotors were found to stick to the matrix near cancer cells, but not normal cells, due the negatively charged environment of the cancer cells, conferred by the presence of a sugar-conjugated molecule called 2,3-Sial. The study highlights a new way of targeting cancer cells using nanomotors.



Reference: Dasgupta D, Pally D, Saini DK, **Bhat R, Ghosh A,** Nanomotors sense local physicochemical heterogeneities in tumor microenvironments, ***Angewandte Chemie (2020).***

RACHIT AGARWAL (BSSE)

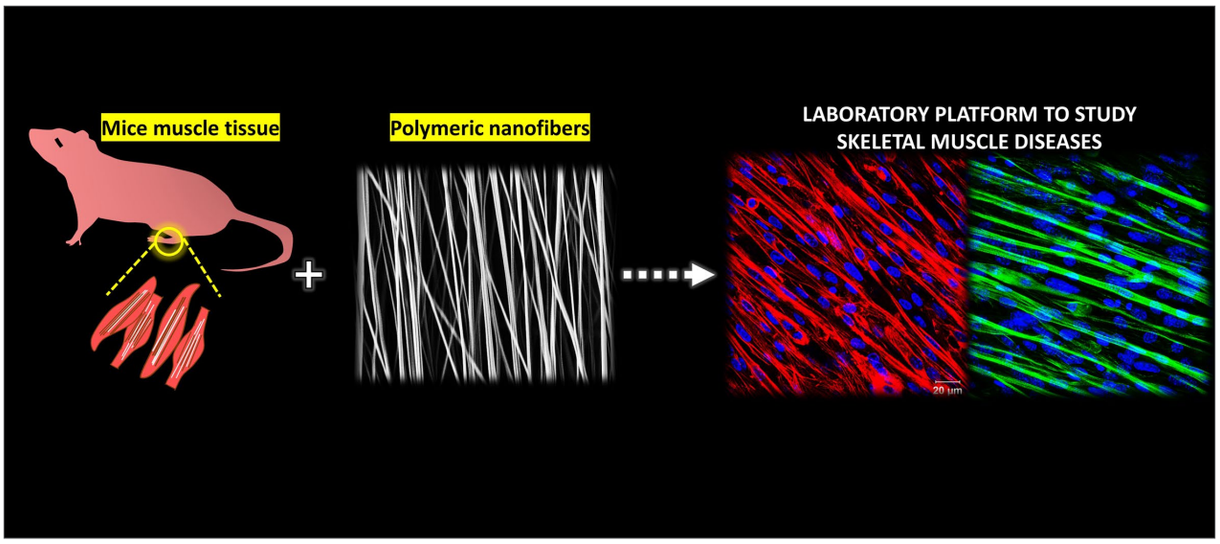
Researchers at Centre for BioSystems Science and Engineering have developed a microparticle formulation that allows sustained release of drugs to treat osteoarthritis, a chronic joint condition. They designed a polymer matrix made of PLGA, an FDA-approved biomaterial, to encapsulate rapamycin, an immunosuppressant drug. Preliminary studies on lab cells as well as in mice models showed promising results indicating reduced inflammation and cartilage repair due to sustained drug release. The formulation has a residence time of up to 30 days at the target site, with no evident signs that it may cause discomfort to patients. Such a sustained release system can improve patient compliance and reduce hospital visits.



Reference:Dhanabalan KM, Gupta VK, **Agarwal R,** Rapamycin-PLGA microparticles prevent senescence, sustain cartilage matrix production under stress and exhibit prolonged retention in mouse joints, *Biomaterials Science (2020).*

KAUSHIK CHATTERJEE (BSSE/MATE) & NR SUNDARESAN (MCB)

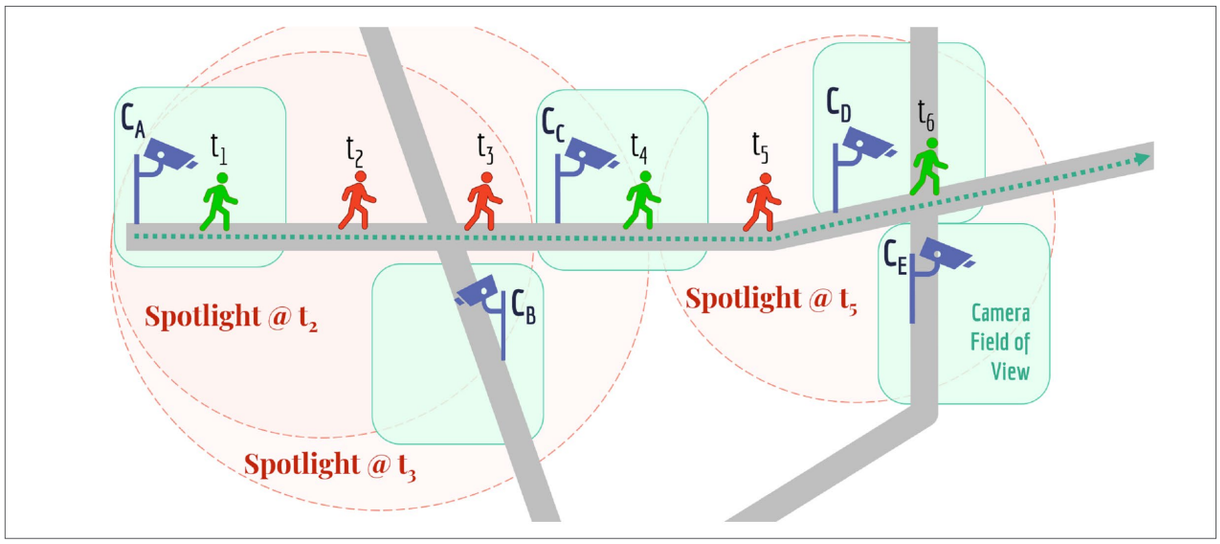
Current treatments for skeletal muscle disorders are often ineffective, mainly due to the lack of suitable lab-made models that closely mimic skeletal muscles inside the body. An interdisciplinary team has now used nanofibers of polycaprolactone, a biodegradable polyester, to create a mesh-like structure on which they could culture myoblasts (parent muscle cells) in the lab and allow them to grow into muscle fibers. The lab-grown muscle fibers retained their alignment when grown on the polymeric substrate and reproduced critical properties of skeletal muscles, such as stress-induced muscle degeneration. The nanofiber mesh offers a robust platform to not only study muscle disorders, but also to test the effectiveness of drugs to treat them.



Reference: Jain A, Behera M, Ravi V, Mishra S, **Sundaresan NR, Chatterjee K,** Recapitulating pathophysiology of skeletal muscle diseases in vitro using primary mouse myoblasts on a nanofibrous platform, *Nanomedicine: Nanotechnology, Biology and Medicine (2021).*

YOGESH SIMMHAN (CDS)

Researchers in the Department of Computational and Data Sciences have developed a novel software platform called Anveshak from which apps and algorithms can intelligently track and analyse video feeds from cameras spread across cities. This can be useful for tracking missing persons or objects, as well as 'smart city' initiatives such as automated traffic control. The platform allows a tracking model or algorithm to focus only on feeds from certain cameras along an expected route, and can automatically increase or decrease the search radius or "spotlight" based on the object's last known position. The platform also enables the tracking to continue uninterrupted even if the resources on the ground are limited.



Reference: Khochare AD, Krishnan A and **Simmhan Y,** A scalable platform for distributed object tracking across a many-camera network, *IEEE Transactions on Parallel and Distributed Systems (2021).*

The Centre for BioSystems Science and Engineering (BSSE) at the Indian Institute of Science was founded on June 4th, 2015. BSSE undertakes research and training in the broad multi-disciplinary area of biological systems with equal emphasis on science and engineering by bringing together biologists, engineers, and those who are trained as bioengineers.

CURRENT RESEARCH

Systems Biology of Cancer

Metastasis and therapy resistance remain two unsolved clinical challenges. A key property enabling cancer cell fitness during metastasis and therapy resistance is phenotypic plasticity and heterogeneity: the ability of cancer cells to reversibly switch to another cell-state during stress and consequent co-existence of many phenotypes in genetically identical population. Our work has decoded the design principles of cellular

CORE RESEARCH

The primary research areas of BSSE include Computational Systems Biology, Mathematical Biology, Drug Delivery, Biomaterials, Quantitative Cell Biology, Biophysics, Molecular Imaging, and Immunoengineering.

3.4.1 Centre for Biosystems Science and Engineering

CHAIRPERSON

NARENDRA DIXIT

networks underlying phenotypic heterogeneity in multiple cancers, including in the highly aggressive small cell lung cancer which has an abysmal five-year survival rate of 7% and no molecular targeted therapy yet. Similarly, our analysis for melanoma has demonstrated how underlying regulatory networks can enable multiple cell-states and how cells can switch among them when exposed to drug, i.e., drug-induced state-switching. Finally, in ER+ breast cancer, we have unravelled how 'reversible' drug resistance can emerge and have developed population dynamics models that show that phenotypic heterogeneity and drug-induced switching can facilitate the long-term survival of cancer cell population, even in the absence of any genetic mutations.

Drug Delivery

Polymeric systems, particularly micro- and nano-carriers, have emerged as a promising solution for the targeted delivery of active drugs. Use of particles for delivery offers several advantages. Biologics are protected from the harsh external environment present (immune clearance and enzymatic degradation) during their voyage and increases their bioavailability at the target site. Particles can be designed to target specific sites including organ, cells and intra-cellular targets. For this part of the research, we are interested in applying biomaterial and nano- and microcarrier-based techniques to bridge the gap between basic biology and clinical therapies by designing polymeric particle-based vehicles to effectively deliver cargo to their target sites. The major focus is to utilize particle technologies to develop engineering platforms for targeted and efficient delivery of therapeutics for treatment of chronic inflammatory diseases such as osteoarthritis and persistent antibiotic resistant bacterial infections such as in case of tuberculosis.

Molecular Imaging

Study of cellular or molecular events outside the body, through in vitro or ex vivo experiments often oversimplifies the complex biological scenario in living subjects. The field of molecular imaging can potentially help to resolve this caveat as it aims to study these molecular or cellular processes within intact living body, in a longitudinal non-invasive manner. Our research focuses on the development of molecular imaging tracers (MRI, photoacoustic and PET) and molecular imaging methods to monitor various molecular targets/biomarkers that could potentially relate to early diagnosis of cancer or early assessment of treatment responses. The ability to image/monitor processes such as gene/protein/enzyme function, protein-protein interactions, changes in tumour microenvironment (TME), metabolic pathways, immune cell function or profiling of signal transduction pathways within an in vivo disease model, in a non-invasive longitudinal manner in real-time can eventually improve medical management of subjects and provide breakthroughs in current diagnostic or theranostic practices in the clinic.

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PhD, UG Minor

IN NUMBERS

5 Academic staff
44 PhD students
27 Publications

Immunoengineering

Research in this area is directed towards the development of drug delivery systems and biomedical implants that have the capacity to modulate inflammatory immune responses with the goal of treating specific diseases. Our current focus is on developing strategies to treat complications that arise from type-2 diabetes and characterizing the immune micro-environment associated with tumours.

FACULTY & STAFF

RACHIT AGARWAL | PhD (Texas), Assistant Professor
VAISHNAVI ANANTHANARAYANAN| PhD (Max Planck Institute, Dresden), Assistant Professor
SIDDHARTH JHUNJHUNWALA| PhD (Pittsburgh), Assistant Professor
MOHIT KUMAR JOLLY| PhD (Rice), Assistant Professor
SANHITA SINHARAY | PhD (Arizona), Assistant Professor

ASSOCIATE FACULTY

GK ANANTHASURESH | PhD (Michigan), Professor
GANAPATHY AYAPPA | PhD (Minnesota), Professor
BIKRAMJIT BASU | PhD (Katholieke), Professor
DIPSHIKHA CHAKRAVORTTY | PhD (NCCS), Professor
NAGASUMA CHANDRA | PhD (Bristol), Professor
KAUSHIK CHATTERJEE | PhD (Penn State), Associate Professor
SAUMITRA DAS | PhD (Kolkata), Professor
NARENDRA DIXIT | PhD (Illinois), Professor
NAMRATA GUNDIAH | PhD (Berkeley), Associate Professor
ASHOK M RAICHUR | PhD (Nevada), Professor
ANNAPOORNI RANGARAJAN | PhD (NCBS), Professor
RAHUL ROY | PhD (Illinois), Associate Professor
DEEPAK KUMAR SAINI | PhD (AIIMS), Associate Professor
SANDHYA S VISWESWARIAH | PhD (IISc), Professor

The Centre for Society and Policy is a policy research centre, established in November 2018. As an interdisciplinary centre for science and technology policy, the centre explores interactions between science, technology, society, and development. The Centre researches and initiates dialogues with the aim to expand the social compact, that is, honour the implicit agreement between science and society to work together for sustainability, and mutual benefit. The Centre organizes seminars, lectures, and outreach through workshops and training programmes. It has a vibrant visiting faculty program to attract leading scientists and researchers in the field of science and technology policy.

FACT FILE

Established: November 2018

Phone: 080-2360-6559

Email: office.csp@iisc.ac.in

URL: https://csp.iisc.ac.in/

IN NUMBERS

4 PhD students

5 Policy reviews

3.4.2 Centre for Society and Policy

CHAIRPERSON

ANJULA GURTOO

CURRENT RESEARCH

The CSP today addresses several policy agendas including sustainable futures, intellectual property rights, genetic engineering and health policy, impact assessments, urban development, genetics and society, smart cities and data economics, food security, Crowd work and informal economic systems. The centre contributes to the knowledge on S&T policy through policy briefs and working papers. The centre has several eminent visiting professors and scholars. The centre is committed to policy engagement and impacting policy at all stages of S&T research.

CORE RESEARCH

The aim of the centre is to forge meaningful interactions between science, technology, society and policy through research and dialogue in diverse areas like information technology, infrastructure, health and genomics, S&T for development, sustainable futures, biotechnology and natural resource and biodiversity

ASSOCIATE FACULTY

ANJULA GURTOO | PhD (IIM Ahmedabad), Professor
ABINANDANAN T A | PhD (Carnegie Mellon), Professor
MOHIT KUMAR JOLLY | PhD (Houston Texas), Assistant Professor
SHASHI JAIN | PhD (CWI, Amsterdam), Assistant Professor

The department focuses on interdisciplinary programs driven by computation and data-intensive methods, systems and applications. The research is aligned along computational science and computer & data systems. The former explores computational methods and applications to scientific domains, while the latter into design, implementation and evaluation of high-performance hardware and software systems.

CURRENT RESEARCH

In the domain of Computer and Data Systems, several advancements were achieved this year. In the area of database systems (Database Systems Lab), a new data security problem of "Hidden Query Extraction" (HQE) was defined as follows: Given a black-box application A containing a hidden SQL query Q_H, and a database instance D on which Q_H produces a populated result R, unmask Q_H to reveal the original query. This problem arises in a variety of real-world situations, spanning across encrypted database applications, imperative forms of database execution, and SQL injection attacks on database security. HQE proves to be a challenging research problem due to factors such as (a) acute dependencies between the various clauses of the hidden query, (b) possibility of schematic renaming, (c) result compression due to aggregation functions, and (d) presence of User-defined Functions (UDFs). Further, a novel algorithm UNMASQUE has been designed that uses a judicious combination of database mutation and synthetic database generation to identify the hidden query Q_H. Currently, UNMASQUE can extract a complex class of data warehousing queries. These results have been presented in the premier VLDB 2020 and SIGMOD 2021 conferences. On the high performance/parallel computing side (MARS Lab), a new algorithm for Pipelined Preconditioned Conjugate Gradient, PIPECG-OATI, that promotes large-scale overlap of communications and computations and reduces the number of global synchronizations was proposed. The method was shown to give better performance than all state-of-art existing methods. Other areas of research focus include analysis of performance of GCNs (Graph Convolutional Networks) and HPC acceleration methods for the classification

3.4.3 Computational and Data Sciences

CHAIRPERSON
SASHIKUMAAR GANESAN

of brain networks, communication optimization techniques for Knowledge Graph Embedding (KGE) problems. Furthermore, algorithms for extending the earlier HPC techniques on community detection to deal with larger graphs on a single node and new GPU methods for InfoMap algorithm for the same are other contributions this year. CAD lab research included addressing important issues in micro-architectural and compiler optimizations for power and performance in Chip Multiprocessors (CMPs) and Runtime Reconfigurable System on Chips (MP-SoCs). Applications of interests relate to reactive computing in avionics and autonomous vehicles, 5G/6G network processing, AI/ML based surveillance and big data analytics.

CORE RESEARCH

- Computational science research deals with mathematical modelling, numerical analysis, computational aspects of numerical methods to solve complex problems and implementation of efficient & robust parallel algorithms in massively parallel computers. The research finds applications in Climate modelling, Electromagnetics, Fluid mechanics, Internet of Things, Materials-physics, Optics, Knowledge Harvesting, Medical imaging, Photonics, Structural biology, Systems Biology, etc.

- Computer & Data Systems research aims to design architectures and platforms for Big Data, Cloud computing, Internet of Things, Databases, Accelerators, Reconfigurable Architectures, hybrid CPU-GPU graph processing, middleware strategies for supercomputer systems, Graph Analytics, Computer Vision, Distributed Data Systems, Machine Learning and Natural Language Processing.

In the areas of big data, IoT, cloud and edge computing (DREAM Lab) -- research focused on the investigation of distributed algorithms and querying over temporal property graphs (ICDE 2020, CCGRID 2020), federated querying over time-series data on edge devices (EuroPar 2020), and technologies for contact tracing for COVID-19 management (JIISc, 2020). In the area of computer vision (VAL Lab), research was focussed on deep models for accurate Dot Prediction for Dense Crowds (WACV'20), a framework for detecting the people in the dense crowds [PAMI'20]. self-supervised and multi-person 3D Human Pose Estimation techniques [AAAI'20, CVPR'20, ECCV'20], a self-supervised deep model for 3D reconstruction form single RGB image [CVPR'20], a novel Frameworks for Domain Adaptation [CVPR'20, ECCV'20, NeurIPS'20], scalable approaches for building Robust deep models [CVPR'20, NeurIPS'20]. A first ever demonstration of achieving robustness to multi-step adversarial attacks without the use of adversarial samples during training was proposed in CVPR'20. A Guided Adversarial Training (GAT) was proposed in NeurIPS'20 for generation of strong single-step adversarial samples to achieve significantly improved robustness when compared to existing single-step adversarial training methods. A Data-enriching GAN (DeGAN) framework was also developed to retrieve representative samples from a trained classifier using data from a related domain (AAAI'20). In Visual computing Lab (VCL), research focused on three main thematic areas - 1. Data-efficient deep learning, 2. Video surveillance and 3. Learning across modalities/domains. Recently in [WACV21], an attempt was made to understand the real utility of semantically similar data points towards composing the transfer set for the task of zero-shot knowledge distillation, and investigated the effectiveness of arbitrary transfer sets such as random noise, publicly available synthetic, and completely unrelated natural datasets for the aforementioned knowledge distillation task. The problem of sketch-guided object localization was attempted in natural images and proposed a cross-modal attention scheme to solve the task [ECCV20]. For the well-known MSDA problem, a novel algorithm was proposed based on the relative importance of the sources to the target [BMVC'20] and achieved state-of-the-art results. During this year, MALL lab has made advances in neural hypergraph link prediction, multi-hop question answering over knowledge graphs, faithful explanation for natural language inference, syntax controlled diverse paraphrasing, GCNs for multi-relation graphs. Some issues in current KG embedding evaluations have been reported and ways to overcome them have been investigated.

In the area of computational sciences too, some very important research successes were observed in 2020. Medical Imaging Group (MIG) research contributions focussed on deep learning (artificial intelligence) based methods to improve medical image analysis in the area of photoacoustic imaging as well as perfusion imaging. These include development of high weight deep learning models for detection of COVID19 using chest X-Ray Computed Tomography and lung ultrasound images. These models are mobile friendly and does not require specialised hardware to utilise the developed models. Contributions related to model based deep learning methods have also been developed that use inherent physics of radiation interaction with matter to improve the medical image reconstruction. In the area of mathematical modelling of physical systems, important results on characterization and structure of Stochastic Differential-Algebraic equations were obtained. Stability of these systems were studied. In the area of data assimilation, a deep diffusion network has been designed. A stochastic model of the differential-algebraic equation approach to dynamical data assimilation has been developed and implemented. Sparsification of the Complex reaction-diffusion network was one other important area of work. In the area of photonics, optics and computational linear algebra (CSPL lab), modified partition of optical states for strong coupling with absorbing matter was proposed. Algorithms more general, parallelizable, and efficient than Markov Chain and Quasi Monte Carlo methods were also proposed. Further work in augmenting these methods is underway in the next year. O(n) and O(n^2) eigenvalue algorithms respectively for sparse and dense matrices with periodicity in entries were also developed. In the area of computational mathematics (CMG group), the main focus of the research in 2020 was to develop an advanced PDE model to predict COVID pandemic. A

novel predictive modelling framework for the spread of infectious diseases using high dimensional partial differential equations is developed and implemented. A scalar function representing the infected population is defined on a high-dimensional space and its evolution over all directions is described by a population balance equation (PBE). New infections are introduced among the susceptible population from non-quarantined infected population based on their interaction, adherence to distancing norms, hygiene levels and any other societal interventions. Moreover, recovery, death, immunity and all aforementioned parameters are modelled on the high-dimensional space. Also, Hybrid CPU-GPU algorithms for Algebraic Multigrid methods (AMG) to efficiently utilize both CPU and GPU have been developed. In QUEST Lab, a physics-based data-driven reinforcement learning scheme for routing autonomous underwater vehicles in strong, dynamic and uncertain ocean currents has been developed. A new particle filter Generative Adversarial Network for dynamic downscaling of sea surface temperature has been developed. A non-intrusive non-Gaussian Polynomial Chaos based filter for a nonlinear dynamical system with limited data has been proposed. Further, a data-driven feature oriented regional modelling and simulation of southwest monsoon current in the Bay of Bengal has been developed. In the area of computational flow modelling (FLAME lab), research areas focused on the development of asynchronous discontinuous-Galerkin method for PDEs arising in flow modelling, investigation of hydrogen-based reheat burner combustion for clean energy, comparative study of unsupervised anomaly detection methods for combustion data - asynchronous computing method for GPU-based architectures. In Materials-Physics & Algorithmic Techniques Research In eXtreme-computing (MATRIX) lab, research focus has been on developing GPU accelerated strategies for quantum modelling of materials using density functional theory. A manuscript is under review in *Computer Physics Communication* in this regard. Furthermore, this computational technique has been employed to provide qualitative insights into charge transport behaviour in double stranded DNA molecules in the presence of gold electrodes corroborating experimental measurements conducted by our collaborators at Israel. This work has been published in *"Nature Nanotechnology".* Another work related to the Tucker-tensor approach for reducing the computational complexity of large-scale quantum mechanical calculations using density functional theory has been published in *Nature NPJ Computational Materials Science.* Further, the lab has also been working on National SuperComputing Mission (NSM) funded research involving the development of scalable finite-element based subspace filtering approaches towards extreme-scale ab-initio calculations with applications to solid electrode-electrolyte interfaces. Hardware-aware algorithms involving matrix-free finite-element based methods have also been the focus of our group with an objective to accelerate linear systems of equations with multi-RHS on hybrid CPU-GPU architectures arising in quantum modelling of materials. Additionally, scalable and efficient computational methods were also being investigated to compute ab-initio polarizability of materials using real-space methods.

In the area of computational biology, Biomolecular Computation Lab (BCL) established a new M3 variant of alpha-antitrypsin in Kashmiri population and explained its potential pathogenic role in causing Chronic Obstructive Pulmonary disease. The aggregation properties of the alpha-antitrypsin was explained through rigorous structure/dynamics analysis. Along similar lines, it was established that the new facets of a motif called NEST are frequently found in proteins. The larger NESTs which have a dominant functional role provided distinct residue and secondary structural signatures that underlined the presence of higher order effects absent in smaller NESTs. At a more fundamental level, studies were also pursued that explained the gas phase thermal entropy of small chemical compounds using graph vertex complexity and class partial information content. Other major research areas which Laboratory for Structural Biology and Bio-computing group is working are (a) structural biology, (b) development of novel algorithms in bioinformatics, (c) internet computing, (d) integrated database development and (e) Data mining or structural analysis of biological macromolecules. In addition, the group has been successfully providing continuous, up-to-date information and access to the internet computing

softwares and databases for the past 20 years. The computing servers developed by the faculty enable sophisticated analysis, manipulation and visualization of biomolecular sequences and structures. One new lab (ATCG: Algorithmic Techniques for Computational Genomics) has been set up in the year 2020 with research focusing on biological data science. ATCG lab develops mathematical and computational techniques for data-intensive computational problems in molecular biology, while working at the intersection of computer science and molecular biology. The algorithms and software designed in this lab find applications in areas such as human genetics, infectious diseases and cancer research.

CDS-industry collaborations have been constantly growing. The WIPRO-GE CDS Collaborative Laboratory on Artificial Intelligence in Healthcare and Medical Imaging was inaugurated in September 2020 with the help of a corporate social responsibility (CSR) grant. An Innovation Lab that was set up in 2019 in collaboration with Huawei continued to make advances on research related to Intelligent Data Analytics and Cloud, supported by a CSR grant. CDS faculty also received faculty grants from Facebook to work on accessible AR/VR and from VMWare for topics related to edge and cloud computing. As a result of the world-class research environment available, the department was recognized as the 'Top Artificial Intelligence Lab in India in 2021' by Analytics India magazine.

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Degree Programs offered MTech and PhD

IN NUMBERS

17 Faculty members

2 Visiting/Adjunct faculty members

03 Administrative staff

10 Postdoctoral students

66 PhD students

23 MTech Research students

50 MTech students

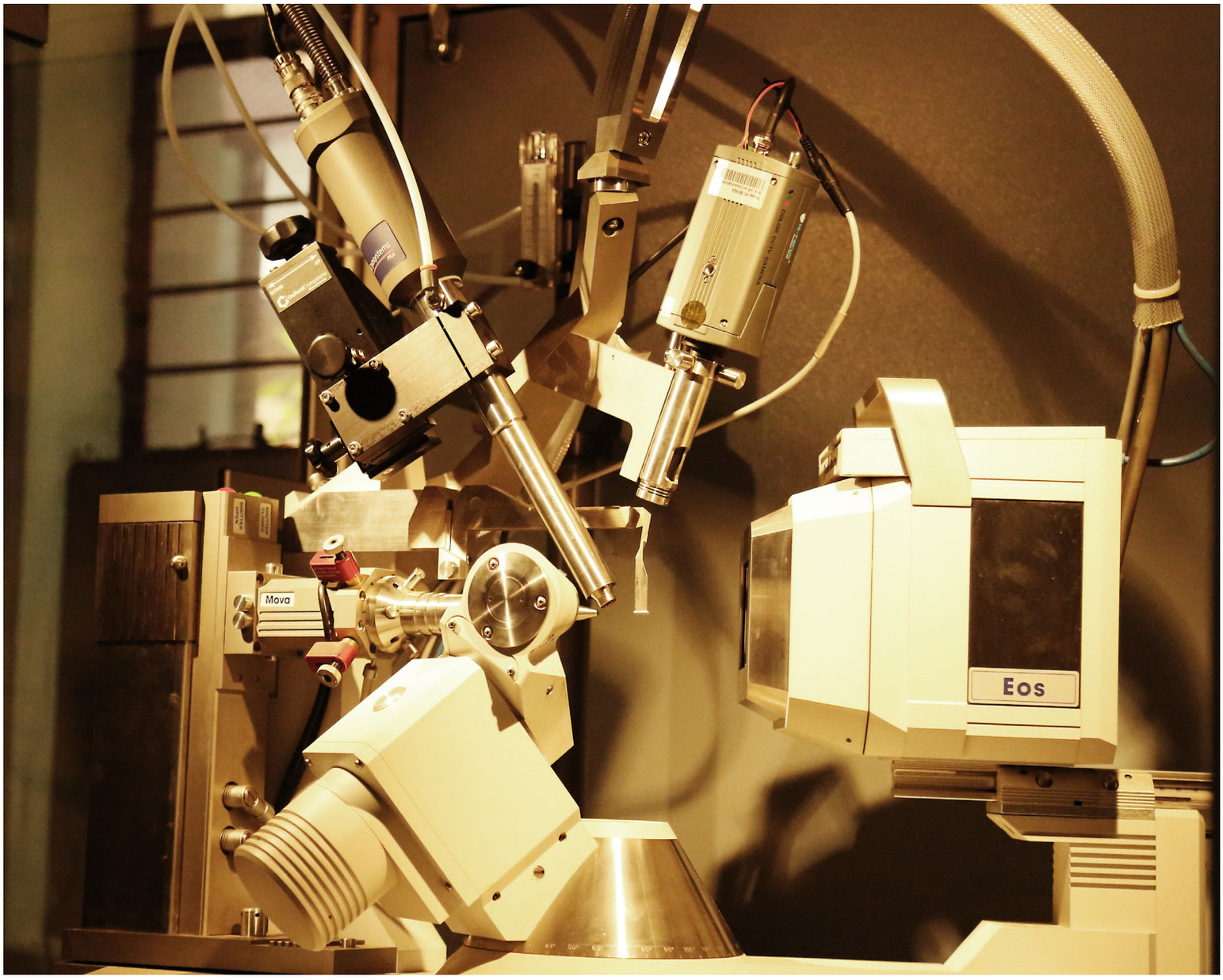
53 Online MTech students (DSBA program)

11 Project Associates

22 MTech conferment

2 PhD conferment

16 MTech Research conferment



CeNSE is an interdisciplinary research centre with a focus on nanoscale systems. The research facilities include a national nanofabrication facility (14,000 square feet clean room) and characterization labs that cater to material, electronic, mechanical, chemical and optical characterization. At present, the centre has 16 faculty members, 142 PhD and 24 MTech students.

CURRENT RESEARCH

OPTOELECTRONICS

Perovskite solar cells: The hybrid organic-inorganic perovskite systems are the most exciting of optoelectronic materials to emerge in recent years for both photovoltaic – and hence energy producing- and light emitting diode applications. At CeNSE faculty members are working on developing new material and device architectures and scaling up. We have managed to develop lift-off compatible large area

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142 PhD students
24 MTech students
117 Publications

3.4.4 Centre for Nano Science and Engineering

CHAIRPERSON

SRINIVASAN RAGHAVAN

nanofabrication process in collaboration with Centre for Manufacturing Technology Institute (CMTI), Bengaluru to enable nanofabricated back contact solar cells. A set of sheet-to-sheet printing equipment that will allow one to translate perovskite PV from TRL 4 to TRL 6 has recently been commissioned. During this development the size of the devices will increase from mm2 to 400 cm2; new fabrication processes will be developed that are scalable; and stability will be improved to more than 10000 hours. One of the biggest challenges of perovskite PV: Lead is being tackled. Lead is a neurotoxin that is unsafe at any concentration. It is debatable if large-scale deployment of water-soluble Pb-based solar cells in Indian countryside is a responsible policy. So, CeNSE is exploring 2-dimentional and Pb-free perovskite.

These novel perovskite compositions usually suffer from defects which limit efficiency. To understand and improve performance we have built a comprehensive defect characterization lab with capability in deep-level transient spectroscopy, microwave-detected photoconductivity, and photoelectromagnetism.

On the photoemitter front, for the first researchers in CeNSE have managed to stabilise the bandgap of mixed-halide perovskites (MHPs) in their nanocrystal form via novel ligand treatment to realise 20% External Quantum Efficiency (EQE) LEDs as compared to the previous best of <5%. This research unearths the absence of photo-instability in tin based MHPs as compared to its presence in lead based MHPs.

CORE RESEARCH

Core research topics include, but are not limited to, nanoelectronics, MEMS/NEMS including resonators, nonlinear dynamics, vibratory mechanobiology, quantum measurements, nanomaterials including pervoskites, oxides on Si and 2D materials, nanophotonics using silicon and other materials, photonic ICs & optical communication, lasers and nonlinear optics, nanobiotechnology, electrochemical and nanopore biosensors, microfluidics, GaN and Gallium Oxide, RF and power transistors, photodetectors, thin film devices, oxide/chalcogenide electronics, 3D systems scaling, heterogenous systems, photovoltaics and energy harvesting devices, autonomous microrobots, bacterial swarms, quantum fluids and materials, soft matter physics.

IR Detectors: Used in thermal imaging and night vision optics, a new program has been initiated in IR photodetectors using I-III-VI2 colloidal quantum dots. Unlike traditional IR detection technologies, quantum dots do not require epitaxy, crystalline substrates, or specialized processing. The detectors can be printed on silicon and still achieve high detectivity. We have already demonstrated SWIR and NIR photodetectors using CuFeSe2 and AgFeS2. We are currently working to demonstrate MWIR and LWIR photodetectors.

NANO-BIO

DNA Nanopore sequencing:

The applications of DNA sequencing, the process of determining the order of the four bases in a DNA or RNA strand, are in numerous fields such as disease diagnosis, biotechnology, forensic biology, virology and biological systematics. Towards creating a nanopore sequencing method, researchers in CeNSE were able to create 20 nanometres diameter pores using the Transmission Electron Microscope (TEM) and thereby reduce the number of processing steps compared to our previous approach based on electron-beam lithography.

Breath Analysis: A prototype system for breath analysis was developed consisting of breath temperature, flow and humidity sensors integrated with a gas sensor array. Exploration of this system in diagnosis of breath disorders is currently being undertaken. A project on modelling the role of sensing in epidemic management was initiated with support from the DST-SERB MATRICS program. Under this project, we have created a network model for epidemic spread incorporating test performance parameters into the disease propagation dynamics. Such a model will provide insights into optimal testing strategies for epidemic spread control.

Realizing Asimov: Researchers in CeNSE have come up wiht a new way of targeting cancer cells by manoeuvring nanomotors inside a tumour and waiting for them to localise in the vicinity of the cancerous site. The extracellular matrix (ECM) is a complex 3D network of proteins and carbohydrates secreted by living cells into their neighbourhood. However, when cancer cells secrete fresh material into the ECM, it disrupts the chemical and physical composition of the native ECM surrounding healthy cells, degrading the local environment. Therefore, understanding how the cellular microenvironment is altered due to cancer cells and measuring these changes quantitatively could be vital in understanding the progression of cancer.

Anti-Bacterial Surfaces: We reported a technique to design light-activated antimicrobial surfaces. As reported in the Journal *Applied Materials and Interfaces,* this study looks into optimizing photoactive coatings on nanostructured surfaces. The generation of free electrons in the photoactive coating depends on the nontrivial interaction of light with nanostructured surfaces. Antibacterial efficacy depends on the generation of ROS and their diffusion to the surface. Surface design optimized using simulation was fabricated and their antimicrobial efficacy was tested. We also reported in the journal Lab Chip a unique double peak signature in the electrical impedance of cells measured in a microfluidic channel. Through extensive simulations, we proved that these signatures are strongly correlated to the membrane capacitance of the cells. Hence, they provide a sensitive technique to differentiate cells based on their membrane properties. We used this technique to differentiate peripheral blood mononuclear cells.

MEMS/NEMS

Micro and nano electromechanical systems are ubiquitous in our everyday lives from triggering airbags in cars to helping navigation in satellites. Using MEMS platforms CeNSE researchers are working on building a cochlear implant using an array of resonators which can have possible applications in Neural Networks, strain sensors for axle load measurement for 50T Volvo trucks, catheter tip low pressure sensors for biomedical application, pressure sensors for ISRO, HAL, the ventilator development in response to COVID and to study skin fibrosis in animals.

Nanoelectromechanical systems (NEMS) offer an exciting platform to study the most fundamental dynamical phenomena in nature. CeNSE researchers use these systems to study the nonlinear dynamics

of the coupled modes of a nanomechanical resonator and synchronization between these modes. They have recently developed a technique that allows one to tune the coupling between various modes of the resonator. If the coupling is very weak, one can study synchronization, and if the coupling is substantial, then one can study internal resonance between different modes.

Integration of mechanical elements on a silicon photonic chip introduces additional functionality, with applications in fundamental research as well as in sensing, signal processing, and communication. We are developing on-chip optomechanical systems in this platform using silicon as well as 2D materials to study interactions between optical and mechanical resonators. We are exploring on-chip optical transduction schemes in these systems as they offer higher sensitivity and signal-to-noise ratio than the conventional electrical transduction schemes used in MEMS/NEMS devices. We are looking at ways to explore quantum phenomena in optomechanical systems. We are also developing new generation of interactive electronic devices using piezoelectric properties of 2D materials. We use dynamic AFM to understand the coupling between the oscillating tip and sample effectively. The goal is to gain insights into the fundamental nature of forces at the graphene-liquid interface.

Energy loss during the motion of very fine elements and its reduction using advanced packaging techniques is another research thread at CeNSE. A novel drop impact printing technique was reported in the Journal *Nature Communications.* The work replaces the expensive nozzles in drop on demand printers with a mesh to make material jetting accessible. Use of mesh makes enables printing a large range of droplet sizes with high mass loading. 3D printing and printing of live cells have also been demonstrated. This work has been highlighted in Rajya Sabha TV

MATERIALS DEVELOPMENT

All technologies require material development and CeNSE has an active program on iterative materials development in which materials engineers work in close collaboration with device engineers to get a feedback that in turn helps them to improve material quality.

The TEM is the ultimate characterization tool that allows on to "see" atoms and atomic scale displacements. Using in-situ microscopy and operando synchrotron experiments, CeNSE research have tried to understand the reasons behind unconventional ferroelectricity in hafnia. They showed that this is a defect-induced ferroelectricity, quite useful in microelectronics.

Using pulsed laser deposition, they have managed to integrate Barium Titanate with Si, the material of choice for modern day electronics such that a switchable dipole can lie both within and out of the plane of the substrate. These films are now being evaluated for memory and integrated photonic applications.

Aluminium gallium nitride/gallium nitride (AlGaN/GaN) transistors are ushering in a new microwave/power electronics revolution today due to their excellent material and device properties at higher power and frequencies. Instead of AlGaN, the use of InAlN/GaN devices offer higher current and output power densities, superior charge control and charge densities. However, the study of Ohmic contacts to such devices is yet to mature. We report on the first study of making Ohmic contacts to InAlN/GaN using scandium and show that such contacts offer state-of-art resistance while providing much smoother metal surface morphology as opposed to using conventional non-scandium-based contacts. The mechanism of contact formation, including the microstructure of the region below the metal contacts, and possible current transport mechanisms are investigated.

PHOTONICS

One the one hand Photonic Integrated Circuits, or "the internet on a chip" allow light confinement and propagation in a sub-micron waveguide cross-section. Such circuits can be realised in various material platforms, including simple polymers. However, the ability to efficiently couple light between an optical fibre and the waveguide is challenging. We have

developed a hybrid coupling mechanism that enables high efficiency coupling between fibre and a polymer waveguide. Furthermore, by using a silicon nitride based photonic circuit, an on-chip spectrometer with an integrated photodetector was realised. The intergrade spectrometer can be used for diagnostics applications.

A far cry from photonic integrated circuits in the power levels involved, CeNSE research also develop lasers that can blast through thick steel. Ultrafast lasers which achieve sub-picosecond and femtosecond scale pulses and continuous wave lasers are on the opposite sides of system complexity with the former being substantially more complex. For the last decade, there has been work across the world to synthesize ultrafast pulses from CW lasers using ideas of electro-optic modulation. Their early work in this area has been one of the seminal papers. This year, the substantially advanced this technology using ideas from machine learning and adaptive signal processing to learn the electro-optic modulation process and optimize it to achieve maximal spectral bandwidth and very short ultrafast pulses. Starting with a CW laser, the achieved a 730fs pulse with over a THz of optical bandwidth using this approach. Such a source is anticipated to be a very useful system in applications in optical communications, metrology and microwave photonics.

They even observed in a full infrared laser operating in passive optical fibers (no quantum electronic effects for light generation), a glow of a visible rainbow. This was a very surprising and difficult to explain effect. On thorough analysis, we identified that this phenomenon occurs due to harmonic generation of light in long optical fibers with Cherenkov type phase matching. Having occurred in continuous wave lasers with low optical intensity, this effect promises to enable simple frequency conversion systems in passive optical fibers.

PRODUCTS AND STARTUPS

•1000W water-cooled and 400W air-cooled fiber laser modules in a rugged package was co-developed with Bharat Electronics. The products are shown below. The end applications are multiple industrial tasks and for ordinance disposal systems.

•A low-cost ICU grade ventilator in response to the COVID pandemic was developed by a team of faculty members at CeNSE and translated to industry.

•2 new startups AGNIT and Theranautilus were incubated by CeNSE faculty

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Centre for Infrastructure, Sustainable Transportation and Urban Planning (CiSTUP) conducts interdisciplinary research on understanding, planning, design, operation, and control of transportation systems. Development of state-of-the-art transportation modelling and analysis tools for safe, efficient, and sustainable mobility and city planning is a focus area. CiSTUP advises transportation agencies, civic authorities, and policy makers on scientific approaches to designing, planning, and operation of transportation systems.

CURRENT RESEARCH

Research under the theme of "Predict and pre-empt traffic congestion", such as multiscale mobility sensing, modelling, inference, and simulation tools for multimodal transport planning and traffic control

Emerging mobility systems – on-demand last mile connectivity for public transit systems, shared mobility as a service (e.g., bike sharing systems; vehicle allocation and routing problems), electric vehicles, etc.

Understanding and modelling traveller choices in complex travel environments. For example, analytical and learning models for driving behaviour in heterogeneous and undisciplined traffic streams

3.4.5 Centre for Infrastructure, Sustainable Transportation and Urban Planning

CHAIRPERSON
ABDUL RAWOOF PINJARI

Decision-support tools for public transit agencies, including ridership forecasting models and bus-bunching avoidance solutions

Development of integrated driving and traffic simulators

CORE RESEARCH

Transportation planning, Transportation Engineering, Travel demand modelling, Traffic operations and control, Transportation networks, Operations research in transportation, Travel behaviour, Integrated and multimodal transportation systems, Public transportation operations and planning, Shared mobility, Smart mobility, Intelligent transportation systems (ITS), Emerging transportation technologies (electric, connected, automated vehicles), Sustainable transportation and urban planning, Transportation infrastructure, Pavement engineering.

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As part of the post-Centenary vision of IISc to take up challenging socially relevant research pursued in various departments brought under one roof. Further, several national-level missions announced by the Government of India directly make a difference to the people of the nation and the world. With this background, the Interdisciplinary Centre for Energy Research (ICER) at IISc launched in 2012 with a major thrust on renewable energy and other research in the broad area of energy.

Although research on energy science and related technologies has a long tradition in the Institute, this was the first time the interdisciplinary approach was undertaken to bring together core expertise from various disciplines under one roof. The group on biomass conversion processes and technologies had paved the way in the industry and societal relevant intervention. Further identifying energy, in general, as an interdisciplinary concern and providing an environment to pool the expertise from various disciplines that cover the basics through to application and development was ICER's focus. Under this new initiative, research on various fields such as biofuels, combustion, concentrated solar power (CSP), next-generation solar photovoltaic (PV), novel energy storage technologies, green buildings, and sustainable technologies are undertaken.

To nurture fundamental research and promote technological development, ICER has a student research Ph.D. degree program in all the broad areas of energy with over 30 faculty members from various departments. The Centre has 13 Associate faculty members and about 30 participating faculty members either through student research or projects. Currently, the Centre offers five courses addressing interdisciplinary energy research.

3.4.6

Interdisciplinary Centre for Energy Research

CHAIRPERSON

S DASAPPA

CORE AND CURRENT RESEARCH

With Sustainable Energy in focus, utilization of all resources for efficient conversion is the focus. ICER provides a platform to integrate expertise from various disciplines such as Mechanical, Electrical, Materials, Physical, and Chemical Sciences to address energy needs, focusing on renewable energy. Advancement of the ongoing R and D areas of solar energy, biomass, hydro, combustion and utilization of a range of fuels, clean coal and also prime movers like new cycle using supercritical CO_2, gas turbines, IC engines for alternative fuels, energy storage, smart grids, the cold and thermal plasma would be of interest.

Apart from these, other areas of national and international importance for collaborative research are in the areas of efficient conversion of municipal solid wastes with a focus on distributed approach meeting the emissions norms, electrical and electronic waste to value-added products, and recovery — efficient conversion of solid, liquid and gaseous meeting the emission norms. A major initiative on the PEM Fuel Cell Research to address improving the performance and useful life of the fuel cell/stack is underway.

Solar research on PV and thermal conversion through material research and process optimization, new cycle development for a range of thermal energy would be of interest.

CONTRIBUTIONS TOWARDS COVID 19

As a part of the expertise developed in the group, the contributions towards supporting various COVID support activities which have led to a product developed is identified here:

- **Oxygen concentrator:** Developed an oxygen concentrator of 10 LPM capacity tested for clinical validation at Bangalore Medical College. The technology is transferred to different agencies, and the products are serving the needs.
- **Oxygen generators:** The system was designed based on a multi-species gas separation process for hydrogen production. Last year, during the COVID-19 pandemic, the team had conceptualized and developed an oxygen generation system based on a swing adsorption process, which uses low power and meets the specifications defined by the Ministry of Health and Family Welfare (MoH&FW) between 50 lpm to 500 lpm. The technology has been transferred to industries and is supporting some of the hospitals.
- **Cannula:** Indigenized non-invasive cannula-based oxygen delivery system with IoT enabled the heater-humidifier unit to provide remote monitoring and alerts to the medical personnel. Developed single-chip integrated sensors and associated control system.
- **Experiments and Modelling of droplets:** Secondary Atomization and Possible Aerosolization of Cough Droplets through Single and Multi-layer Face Masks

NEW INITIATIVES

- Green hydrogen from biomass for PEM fuel cells in transport sector. An industry program initiated is to generate 100 m3/hr of Green hydrogen for PEM fuel cell is in an advanced stage of R and D for deployment.
- Development of Compact Heat Exchangers for Carbon-dioxide Brayton Power Plants for CSP applications. Aims to develop alternate methods to design and manufacture PCHE's using micro-milling and vacuum brazing techniques, in addition to electrochemical etching and diffusion bonding techniques presently used.
- Danfoss Centre of Excellence for Natural Refrigerant based Cooling Technologies with the primary objective to develop a sustainable workforce for installation, commissioning and maintenance of cooling infrastructure through proper training and education.
- For solar applications, nanostructures have a gradual change in refractive index which acts as a multilayer anti-reflective coating (ARCs) that is leading to reduced light reflection losses over broadband ranges of wavelength and angle of incidence
- One of the most promising light-absorbing materials for solar cells is Methylammonium Lead Iodide ($MAPbI_3$). Perovskite solar cells with P-I-N structure fabricated where metal electrodes were deposited by thermal evaporation of bulk and nano-powder form of silver (Ag).
- Waste Heat Recovery technologies utilizing industrial waste heat or automotive exhaust
- Heat transfer and fluid transport in large systems such as data centre facilities, buildings etc.
- Fire safety research towards understanding various phenomena associated with fire dynamics and safety, utilizing high fidelity experiments and numerical simulations.

ON-GOING PROJECTS

The following are the major ongoing R&D projects at the Centre.

- **National Centre for Clean Coal Technologies:** Supported by DST, for Supercritical CO_2 and Steam-based Power Systems, clean coal combustion, coal gasification, high-temperature materials research [Funding of Rs. 30 crores approx. (US $ 4 million) for the period 2018-2023].
- **Two-Stage Adsorption based Solar Cooling cum Desalination:** Supported by DST.
- **Chemisorption based Thermal Storage using Metal Hydrides:** Supported by DST
- **High-Efficiency Solar Receiver for s-CO_2 integrated with Static focus Solar Dish:** Supported by MNRE
- **Use of bio-hydrogen for PEM fuel stacks – Research and Demonstration:** Supported by DST
- **Development of metal hydride based high-temperature thermal energy storage systems for waste heat utilization:** Supported by GAIL

• **Development of Sustainable Thermal Systems, Concentrated Solar Thermal power generation, Heat Driven Hybrid Refrigeration Systems, Waterless Power Generation.**

• **UKICERI:** UK-India Clean Energy Research Institute is an Indo-UK collaborative project jointly funded by the Department of Science and Technology (DST), Govt. of India, and Engineering and Physical Sciences Research Council (EPSRC), UK. IISc is part of a major consortium on intelligent grid and photovoltaics led by IIT Kharagpur from the Indian side and Loughborough University from the UK side.

The project recognizes power from multiple sources, including renewables thus supporting (i) implementing an intelligent and scalable sub-microgrid within buildings, (ii) interfacing distributed generators to the sub-microgrid, both in the presence and absence of conventional grid power, (iii) distributed monitoring and distributed control, and (iv) designing strong coupling between communication and power layers that are inherently integrated into the system.

Detailed study and analysis are required for arriving at optimal hybrid energy storage options for different system configurations, generation mixes (including various renewables PV, BIPV, Wind, Biomass), capacities, load patterns and locations.

• **Research Centre for Solar Power in Challakere Campus:** Under this project, which the Karnataka Government supports, IISc has set up research testbeds in PV and small-scale CSP for cutting edge solar power technologies, including activities such as data generation, controls, and monitoring of performance.

Solar research on PV, as well as thermal conversion through material research and process optimization, new cycle development f or a range of thermal energy would be of interest. Monitoring of these PV performances in real time will be through the establishment of a central control room. The real-time data that we shall be obtaining will be evaluated for development of model for analysis and predictions. Dashboard created for monitoring the PV parameters and meteorological information will be accessible online.

MAJOR COMPLETED PROJECTS

Solar Energy Research Institute for India and the United States (SERIIUS): Co-led by IISc on the India side and National Renewable Energy Laboratory (NREL) on the US side, SERIIUS is a major India-US consortium in engaged in solar energy research, under the US-India Joint Clean Energy Research and Development Center (JCERDC) programme. Altogether, the consortium has 34 partners from both India and US sides, comprising of academic institutions, R&D laboratories, and industries. The consortium received a funding of US$25 million from US and Indian governments, along with matching funding from industry and other partners. The first phase of SERIIUS was for the period 2012-2018, and as a continuation of India-US collaboration in Energy, a new clean energy initiative is under consideration under the JCERDC programme.

National Centre for Combustion Research & Development (NCCRD): Indian Institute of Science and IIT Madras were the two institutions selected to host the National Centre for Combustion Research & Development (NCCRD) funded by DST. Under this programme, IISc received a total funding of Rs.36 crore (US$ 5 million) over five years starting from 2012. Several advanced and state-of-the-art facilities in combustion research have been established, to address grand challenges in the area of combustion.

Corrosion studies of high-performance alloys in high-temperature supercritical-CO_2 Brayton cycle power block for Concentrated Solar Power application funded by DST. Under this programme, IISc received a total funding of Rs.80.28 Lakhs for three years starting from 2017.

Corrosion studies in high-temperature molten salt fluids for advanced CSP plants funded by DST. Under this programme, IISc received a total funding of Rs.70.06 Lakhs for three years starting from 2017.

Detailed Project Report for concentrated solar power plant with supercritical carbon dioxide power cycle (DPR) funded by DST. Under this programme, IISc received a total funding of Rs.151.45 Lakhs for six months starting from 2020.

NOVEL FINDINGS

•Developed India's first closed-loop supercritical carbon dioxide-based Brayton cycle power block, which is more efficient and compact and can replace steam-based power plants in various applications such as nuclear, solar, and waste heat-based plants.

•To meet the hydrogen economy sustainably, IISc has developed thermo-chemical conversion process to generate pure hydrogen from biomass, which can be upgraded for PEM fuel application (99.97 % pure).

•Advanced biofuels like methanol and ethanol from thermo-chemical conversion of biomass

•In photovoltaic research, IISc has developed a large area testbed and dash-board for the reliability and suitability of various PV technologies for unique Indian atmospheric conditions. Also, novel encapsulated organic PV was developed on flexible glass substrates, for extended life and stability of the cells.

•IISc has pioneered the development of Cu-based intermetallic alloy coatings for high-temperature solar reflectors in solar thermal applications.

•IISc has developed a two-Stage Silica gel + Water Adsorption based Solar Cooling cum Desalination System

•Syngas and natural gas-fired ultralow emission combustor technology for hybrid solar thermal energy systems in the 100-kW range.

•Despite significant efforts in developing tandem ceramic coatings for photo-thermal conversion applications, the underlying physics behind spectrally selective high absorptance and thermal stability of the ceramic absorbers.

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PRADIP DUTTA | PhD (Columbia), Professor
SAPTARSHI BASU | PhD (Connecticut), Associate Professor
PRAMOD KUMAR | PhD (IISc), Associate Professor
JOY KURI | PhD (IISc), Professor
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Reaching across traditional disciplinary boundaries ICWAR aims to provide a comprehensive understanding of the impact of complex environmental factors on areas related to water science and technology and subsequently offers efficient and effective engineering solutions to environmental problems. Students in ICWAR receive education in diverse areas and carry out interdisciplinary research addressing some of the grand water-related science and engineering challenges of modern society.

CURRENT RESEARCH

Current research at ICWAR is focused on
(i) assessment of hydrologic impacts of climate change on local and regional hydrological regimes, ecological, social and economic systems

(ii) development of effective methodologies for sustainable water management at local and basin scales

(iii) development of smart water solutions for agriculture sector (irrigation and water management) by integration of in situ and remotely sensed observations and ICT(Information and Communication Technology) tools

(iv) development of methodologies for intelligent water supply network monitoring and control for equitable distribution of water in mega cities

(v) understanding interactions, synergies, and feedbacks that link the land surface, freshwater, ocean, and atmosphere systems

3.4.7 Interdisciplinary Centre for Water Research

CHAIRPERSON
PP MUJUMDAR

(vi) base flow estimation using isotopic mass balance approach in river catchmen

vii) climate-information based season-ahead streamflow forecasting.

ONGOING RESEARCH ACTIVITIES

The focus of research work is on investigating impact of reanalysis data and satellite products in simulating extreme events over Upper Ganga basin, evaluating the impacts of climate change and land use on water quality of Ganga, impact of thresholds in modeling nonstationary extreme rainfall in India and impact of urbanization of hydrometeorological variables across cities around the globe. In addition, a comprehensive review on knowledge of hydrology and water resources engineering in ancient India is conducted.

The performance of different reanalysis data and satellite products to represent extreme rainfall and associated flood is evaluated over Upper Ganga basin. The inferences highlight that fine resolution datasets do not always produce better rainfall simulations. The impacts of climate change and land use change on the water quality across industrialized Kanpur region along Ganga River are assessed. It is found that dissolved oxygen is more sensitive towards climate, while nutrients and faecal coliform concentrations are sensitive to land use change, respectively. The impact of urbanization on hydro-meteorologic variables across seven cities is investigated. The results indicate that changes in the short-duration precipitation and temperature are prominent in the recent past. The influence of threshold selection in modelling extreme rainfall under non-stationary scenario is performed.

CORE RESEARCH

Urban water systems; Urban hydrology / hydrogeology; Watershed and river basin hydrology; Floods and droughts; Water management; Agrohydrology; Satellite hydrology; Wetland science; Land-atmosphere interactions; Lake ecosystems; Aquatic geochemistry; Application of Stable isotope technique in groundwater studies, Geothermal reservoir modelling; Global water cycle and impacts of climate change; Isotope hydrology; Applications of sensor and satellite technologies; Domestic and industrial wastewater treatment; Climate change impact on hydrology of Indian rivers; Urban Floods and lake ecosystem; Hydrologic fluxes; Glacier Hydrology; Nanotechnology based solutions for water purification, Biometeorological impacts.

It is found that threshold uncertainty is more for high return period events.

Use of different adsorbent for removal of pesticides and heavy metal has become obsolete and would address the consequences of different contaminants present in water. A solution to this problem is to adsorb these contaminants using nanocomposites or nanoparticles. The work of Simranjeet Singh involves synthesis of nanoparticles and nanocomposites and their use for the removal of contaminants from water. The use of the nanoparticles or nanocomposites is advantageous over the conventional use of different adsorbents. His present research aims at improvement in the materials properties by coupling them synergistically to have better material characteristics. His research intends to create effective catalyst nanomaterials with enhanced properties and better efficiency, from a class of materials that consists of earth-abundant, low-cost, and mostly non-toxic elements. The research would help us to search answers to the existing challenges of water pollution. He has completed one research work till March 2021 and currently working on second one.

1)Graphene oxide impregnated with Zinc oxide nanoparticles for As (III) removal in an aqueous matrix (Completed)

2)Facile synthesis & characterization of nanomaterials (metal oxide MO decorated on graphene oxide) for efficient removal of Cr (VI) from aqueous solutions (In process).

Pavithra's research work is about the detection and biodegradation of pharmaceutical compounds in wastewater. Tetracycline is currently selected as a drug of interest to enhance the bacterial consortium and avoid antibiotic resistance. The selection of aptamer, which is the first step for designing a sensor, is done. Fabrication, bio functionalization, and specificity of the sensor need to be performed. For tetracycline biodegradation, sludge adaption and enrichment culturing are done by procuring the aerobic sludge from the wastewater treatment plant. A degradation experiment is performed by continuous addition of the drug. Identification of tetracycline degrading bacteria is still in progress.

Kumar's ongoing research is primarily related to the transformation of Multispectral Data to Quasi-Hyperspectral Data using Convolutional Neural Network Regression. Hyperspectral (HS) data are proven to be more resourceful compared to multispectral (MS) data for object detection, classification, and several other applications. However, absence of any space-borne HS sensor since 2017, transformation of readily available MS data into quasi-HS data can be a feasible solution for this issue. We propose the use of convolutional neural network regression (CNNR), a deep learning-based algorithm, for MS (i.e., Landsat 7/8) to quasi-HS (i.e., quasi-Hyperion) data transformation. Contrary to the existing models, the proposed CNNR model has the added advantage of utilizing deep learning-based spectral–spatial features for MS to quasi-HS data transformation through regression-based nonlinear modeling. The developed models and generated quasi-Hyperion data are also evaluated with application to crop classification. The proposed CNNR model-based MS to quasi-HS data transformation approach can be used as a viable alternative for different applications in the absence of original HS images.

Bala and Srinivas are investigating the characteristics of Monsoon Low Pressure Systems. The South Asian summer monsoon brings copious rain to agriculture-dependent country India and bulk of the precipitation in central India is attributed to monsoon low pressure systems (LPS). Large uncertainty exists in the statistics of LPS (frequency, intensity and tracks) during the historical period and in future projections. For an in-depth investigation of the climatology of LPS, we have recently developed an LPS tracking algorithm which is validated by comparing characteristics of LPS from our tracking scheme with previous studies. Our analysis indicates the formation of around 14 LPS per year (over 68 LPS-days). 60-70% of monsoon rainfall in north, east and central India is found to be associated with LPS (location is within 1000 km radii of LPS). Over the central Indian region, around 82% of extreme precipitation events occur during LPS days. Our analysis of extreme precipitation related to LPS has the potential to provide valuable information for flood risk assessment during monsoon season in central India.

Subsequently, we have used the NCAR Community

Earth System Model (CESM1.2.2) to simulate the LPS characteristics over India and the Bay of Bengal. Our preliminary analysis indicates that CESM could reproduce most of the observed LPS characteristics. Using the CESM model simulations, we are investigating the influence of southeast Asian mountains (SAMs), western Ghats and the Himalayan mountains and Tibet on LPS characteristics

Connectivity of groundwater flow within crystalline-rock aquifers controls the sustainability of abstraction and baseflow to rivers yet is often poorly constrained at a catchment scale. The groundwater connectivity in a sheared gneiss aquifer is investigated under the UPSCAPE project of MoES-NERC, by studying the intensively abstracted Berambadi catchment (84 km2) part of the Kabini CZO, using field studies and numerical model simulations. The study indicated a well-connected system, both laterally and vertically, that has evolved with high abstraction from a laterally to a vertically dominated flow system. Also, as a result of shearing, a high degree of lateral connectivity remains at lower groundwater levels. Better representations of groundwater processes are needed in large-scale hydrological models to improve simulations of regional- to global-scale hydrology and climate. As part of the UPSCAPE project, we incorporated a 2D groundwater flow model into the variable infiltration capacity (VIC) hydrological model code to address its lack of a lateral groundwater flow component and allowing bi-directional exchange of water between the aquifer and the soil. Numerical simulations showed that the distribution of water table depths and water budget components varied significantly as grid resolution increased from 1° to 0.05° for the medium and high transmissivity systems.

The forcing given to hydrologic models influences the spatial and temporal variability of simulated streamflow. Observational uncertainty in forcing can be quantified by assessing changes in simulated streamflow on perturbing the forcing. Modelling hydrologic processes in a river basin can be a complex exercise because different hydrologic models incorporate different parameterizations to model the overall land-surface response to precipitation. We quantify the footprint of uncertainty in observational datasets (e.g., IMD, TRMM, APHRODITE) on streamflow using a suite of hydrological models to obtain intra-model and inter-model daily streamflow ensembles for the Brahmaputra River basin. Four models (two semi-distributed – SWAT & HEC-HMS and two fully distributed models – EF5 and WRF Hydro) were chosen to represent the basin physically. The input forcing - precipitation - was perturbed using different schemes to understand the observational uncertainty (variation in streamflow to an uncertain forcing). The representational uncertainty, i.e., uncertainty in how the basin has been physically represented, was studied by estimating the sensitivity of the parameters representing the physical processes of the regional hydrological cycle. We find that most of the streamflow hydrographs simulated by individual models are within the natural variability in the observed hydrograph. Amongst the model ensembles, we find that the semi-distributed model-ensemble yields a better representation of the observed daily discharge and its variability than fully-distributed model-ensemble.

Surface and ground water interaction in driving the perennial stream flow in a tropical river system is investigated in a doctoral study conducted based on time bound sampling of water from river, groundwater and rain revealed participation of different sources in a stream of Kabini water shed of Southern India at seasonal time interval. A study just published (Bhagat et al., 2021 JoH) using a similar strategy to show appreciably high base flow contribution in the upper Cauvery Basin comprising the Western Ghats during the pre-monsoon season. Assessment of isotopic composition at spatial and temporal scale for the surface water and groundwater within the Cauvery River Basin provided a baseline dataset for developing a sustainable plan of river management in the tropical mesoscale riverine system. In a separate study, analysis on carbonate otoliths (fish ear bone) by undergraduate research student revealed migratory behavior of Indian Shad, popularly known as Hilsa found in the Hooghly River Estuary. The variation in otolith $\delta 18O$ in the ear bone showed an independent assessment of a migratory pattern by matching with the water $\delta 18O$ values in the river Hooghly. The study used isotopic tool to demarcate region of spawning in the inland freshwater and a zone of maximum population close to the mouth of Bay of Bengal.

Large seasonal variability in the composition of the Godavari River draining basalts has been documented which has important implications for understanding silicate weathering and climate change. Solute exchange between surface water and groundwater from varying depths in the Sundarbans delta has been investigated.

Recently, Dr. Das Bhowmik published three articles in refereed journals (Water Resources Research, Journal of Water Resources, Planning and Management, and Int. Journal of Climatology). I was first author in all three articles. The first article is regarding the impact of observation data uncertainty in real-time streamflow forecasting (published in WRR). The second article provided a synthesis on large-scale irrigation practices over the United States. The third article is related to multi-model combination approach to reduce model structural uncertainty. Currently, Das Bhowmik is conducting research on multivariate bias-correction for the DST INSPIRE project. D Nagesh Kumar and Das Bhowmik received the SERB Core Research Grant to conduct simulation-type modelling of unprecedented extreme rainfall events. Towards this, a stochastic rainfall generator has been developed, which is currently been validated over extreme rainfall datasets.

FACULTY & STAFF

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PROSENJIT GHOSH | PhD (Physical Research Laboratory), Professor
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IN NUMBERS

18 PhD students

34 Journal publications

2 Conference publications

The oldest management education department in the country, tracing its origin back to 1947, currently has a masters and a doctoral program. The department faculty and students engage in research in a wide array management topics and seek to set standards of excellence in management research and education.

CURRENT RESEARCH

Given that the electricity systems are undergoing transitions from robust, carbon intensive, and firm power conventional systems to uncertain, intermittent, and variable renewable energy integrated low carbon systems, the research, along with 10 PhD scholars (2 awarded, 8 ongoing) and projects, is carried out to develop deeper understanding of such transitions in the context of Indian electricity system, benchmarking and modelling the transitions, model-based planning approaches for sustainability transitions, analysis of policy transitions, possibilities of futuristic transformations and planning for demand-side transitions.

Role of Regional Innovation Systems in the promotion of networks for facilitating the innovation of Indian SMEs for an increasing degree of internationalization to join the ever expanding Global Value Chains of TNCs is being explored. The structure and gap of entrepreneurial ecosystem prevailing in Bangalore and made policy recommendations for facilitating the maturity of the ecosystem in Bangalore is also being

IN NUMBERS

8 Academic staff
48 PhD students
27 M Mgt students
22 Publications
4 PhD conferments
15 M Mgt conferments

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3.4.8 Management Studies

CHAIRPERSON

PARTHASARATHY RAMACHANDRAN

studied. The R&D contributions that emerged from the TBIs of Bangalore, Chennai and Hyderabad is being examined.

Models for Phased Mission System (PMS) reliability is being developed. A few new models have been proposed for incorporating weather variables on the test days into the component reliabilities of the PMS, and their frequentist and Bayesian analyses, with only the available partially complete test-sortie data, have been developed. Research investigations are also being carried out in existence of possible structural breaks in price, production, farmers' income and other agro-economic time series in association with the agricultural reforms. Important variables are being identified and a thorough history of state and commodity-specific agricultural reforms are being studied.

An index for extracting builtup areas in LANDSAT imagery has been developed with application in studying the impact of urbanization on ground water storage in India. A Game theoretic models for river water sharing with negative externalities in the form of dams has been developed. Also, a multidimensional analysis of water sector performance in India has been developed and applied to compare the water sector performance across the states of India.

An important contribution from the group is related to the hedging of any discretely monitored path-dependent (or otherwise) derivative. After Black, Scholes and Merton's seminal work, the hedging strategy followed by the writers of options, and most derivatives traded in the market, has been the dynamic hedging approach. Static hedging is an alternate approach, where once the hedge portfolio is set up, there is no need to change the components of the hedge portfolio dynamically. While it has been shown that a static portfolio of short-maturity options can be used for static hedging of long-term exotic derivatives, the results have been limited to derivatives on a single underlying. In "Neural networks for universal static hedging of contingent claims",

CORE RESEARCH

Industrial Economics, Innovation & Entrepreneurship, SMEs & Start-ups, Energy and Environment, Sustainability Transition, Sustainable Energy Access, Energy System Modelling, Reliability Theory, Financial Econometrics, Optimization, Heuristic Optimization, Business Analytics, Logistics / Supply Chain Management, Operations Research, Demand Management, Revenue Management, Quantitative finance, Real options, Financial risk management, Digital twin, IPR, Sustainability of socio-tech systems, Informal systems, Urban systems

we demonstrate by drawing an analogy with neural networks that any long-term derivative can be semi-statically hedged using a portfolio of basket options. Mathematical and Heuristic Optimization for Industrial Engineering Problems has been developed, particularly for (a) Production Planning and Scheduling of Batch Processors in Semiconductor Manufacturing and other Industries, (b) Routing and Scheduling, Distribution and Facility Location, Supply-chain Management, (c) Logistics of Container Terminal, (d) e-tailing, (e) Urban Road Transport Problems, and Lean Manufacturing.

Translation of Chekhov's short stories.

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SHASHI JAIN | PhD (TU Delft), Assistant Professor
YADNYVALKYA | MS (Engg.) (Moscow), MA (CIEFL), Principal Research Scientist

RBCCPS was established in 2011 as a research and academic centre under the Division of Interdisciplinary Sciences, to promote research in cyber-physical systems (CPS). The Centre brings together expertise from various departments and, together with in-house research staff, focuses on foundational and applied research to solve cutting edge problems in Robotics involving advanced machine learning techniques, Connected Autonomous Systems like drones and 5G-enabled autonomous vehicles, and Socio-Technical Systems like urban transportation systems and Smart Cities.

CURRENT RESEARCH

The Robert Bosch Centre for Cyber-Physical Systems (RBCCPS) @ IISc is a research and academic centre, under the Division of Interdisciplinary Sciences in Indian Institute of Science. The centre focuses on foundational and applied research to solve cutting edge problems in Robotics involving advanced machine learning techniques, Connected Autonomous Systems like drones and 5G-enabled autonomous vehicles, and Socio-Technical Systems like urban transportation systems and Smart Cities.

The centre faculty are drawn from various departments in the divisions of EECS and Mechanical Sciences. In addition, it has a strong research and technical staff, who drive the experimental components of the centre's

3.4.9 Robert Bosch Centre for Cyber-Physical Systems

CHAIRPERSON
BHARADWAJ AMRUTUR

research. The centre also hosts several young INSPIRE faculty fellows, post-doctoral researchers as well as visiting scientists and professors from academia and industry.

The centre hosts a state-of-the-art CPS laboratory called the Makery. It is also involved in creating and running the Drone Research Park and a 5G-V2X Testbed for connected autonomous vehicles research. RBCCPS contributes to development of BIS Smart City Standards for ICT Reference Architecture and Data Exchange Architecture. IUDX has been successfully spun off as an independent project to pursue deployment in Smart Cities. Finally, I-Hub for Robotics and Autonomous systems Innovation Foundation (ARTPARK) has been spun out of RBCCPS as a independent Section 8 company. ATPARK will work closely with RBCCPS for doing technology Innovation, translation and manpower training in the area of Robotics and Autonomous Systems.

RBCCPS has also established strong collaborations with many major technology companies and engages with many start-ups. It also works closely with government bodies and participates in specific standardisation activities.

Developmental work on the walking robot project, Stoch was carried out at RBCCPS. Work related to safety-critical systems was also done. The main focus is to realize real-time optimization-based control laws in a broad class of autonomous systems that guarantee safety. There is an increasing need to ensure safety guarantees in these systems with the increasing use of AI and AI based technologies.

FACULTY & STAFF

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16 MTech & PhD Students

The Supercomputing Education and Research Centre (SERC), at IISc provides the state-of-the-art computing environment catering to the ever-increasing demands of high-performance computing for scientific and engineering research. The Centre hosts 24/7 supercomputing facilities and services including supercomputers of Petaflop capacities for traditional HPC (High-performance computing), deep learning and AI-based applications, HPC software and about 2 Petabytes of storage. The centre also provides periodic HPC training courses to both the Institute community and personnel from outside the Institute and offers HPC consulting services. In addition, the Centre leads several national initiatives.

Our supercomputer systems have served about 44 departments, 134 research groups and 450 users of the Institute in various fields including aerospace, brain research, chemistry, climate modelling, computational and data sciences, computer science, earth sciences, electronics system engineering, inorganic and physical chemistry, materials research, mechanical engineering, microbiology and cell biology, molecular biophysics, physics etc. About 176 million CPU core hours have been provided for research in these areas. The supercomputing usage resulted in a total of about 50 publications across the Institute. SERC resources are also being used by researchers from academic organizations, government-funded R&D laboratories and industry.

3.4.10 Supercomputing Education and Research Centre

CHAIRPERSON
SATHISH VADHIYAR

CURRENT RESEARCH

Faculty conducted research on cloud systems with research students from Computational and Data Sciences in the "Cloud Systems Lab". This year's major contribution is exploring open research problems in the space of cloud resource disaggregation (Mr. Anubhav Guleria's thesis on GPU resource disaggregation), Network Virtualization using Service Function Chain integration into SDN controllers (Ms. Lakshmi B S), Serverless Computing, and scaling microservice-based applications (Ms. Preyashi Agarwal's), Cloud Storage Resilience Frameworks (Ms Archita Ghosh) and Cloud Service Resilience Frameworks (Ms. Dhanya Mathews). GPU disaggregation framework paper won the best paper award in the IEEE-CCEM (2019) Conference. Continued support for HPC systems at SERC: Continued training of support personnel for SahasraT to interface with users, understand their requests and analyse system errors and event logs; Teach at HPC workshops conducted by SERC.

Major focus this year has been on Network Virtualization (http://www.serc.iisc.ac.in/hierarchical-sdn-sfc-controller-design/) and Micro-Services (http://www.serc.iisc.ac.in/faculty/jlakshmi/sizing-and-scaling-of-micro-services/). Both these efforts culminated in completion of two MTech (Res) thesis. Ongoing research is on Cloud storage service and application resilience. Cloud has introduced the utility computing model, where one can use computing resources as a service. This model motivates how reliable or resilient it is to rely on this platform for critical business tasks. Analysing the Cloud Service Architecture, it is evident that it is a multi-tiered one. A cloud service's resilience is dependent and co-related to the underlying services it is realized on. Computing Clouds being large-scale distributed systems and service setups, are subject to failures that can disrupt and cause service loss. In the multi-tiered context, the disruption can cascade into a major outage that can cause business loss. A new initiative on QoS and Function-as-a-Service started this year. Computational Electromagnetics group research involves the development of fast scalable and accurate 3D electromagnetic solvers. These solvers scale to O (N) and O (NlogN) memory and solve time complexity and can be applied to complex inhomogeneous geometries for solving electromagnetic radiation and scattering problems. To reduce the computation time solvers are parallelized for heterogeneous High-Performance Computing (HPC) architecture and ported to SERC supercomputers.

While continued to study the technological development in the areas of Digital Libraries (DL) for better organize and retrieve data from Digital Library. Also, study was carried out that how modern techniques like Deep Learning techniques can be used to retrieve the important hidden information in the books that have been archived in the Digital Library.

CORE RESEARCH

Supercomputing systems, applications and statistics, Cloud Systems, System Virtualization, Cloud Middleware, Operating Systems, Networking, Digital library, Information Retrieval, Machine Learning, Information security

Exploring using deep learning methods to cluster documents of Digital Library of India database, and to extract important information from these documents

FACULTY & STAFF

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J LAKSHMI | PhD (IISc), Principal Research Scientist
SATHISH VADHIYAR | PhD (Univ. of Tennessee), Associate Faculty and Chair
YOGENDRA KUMAR NEGI | MTech (Delhi), Senior Scientific Officer

ASSOCIATE FACULTY

N BALAKRISHNAN | PhD (IISc), Professor
R GOVINDARAJAN | PhD (IISc), Professor

HONORARY PROFESSORS

N BALAKRISHNAN | PhD (IISc), Honorary Professor

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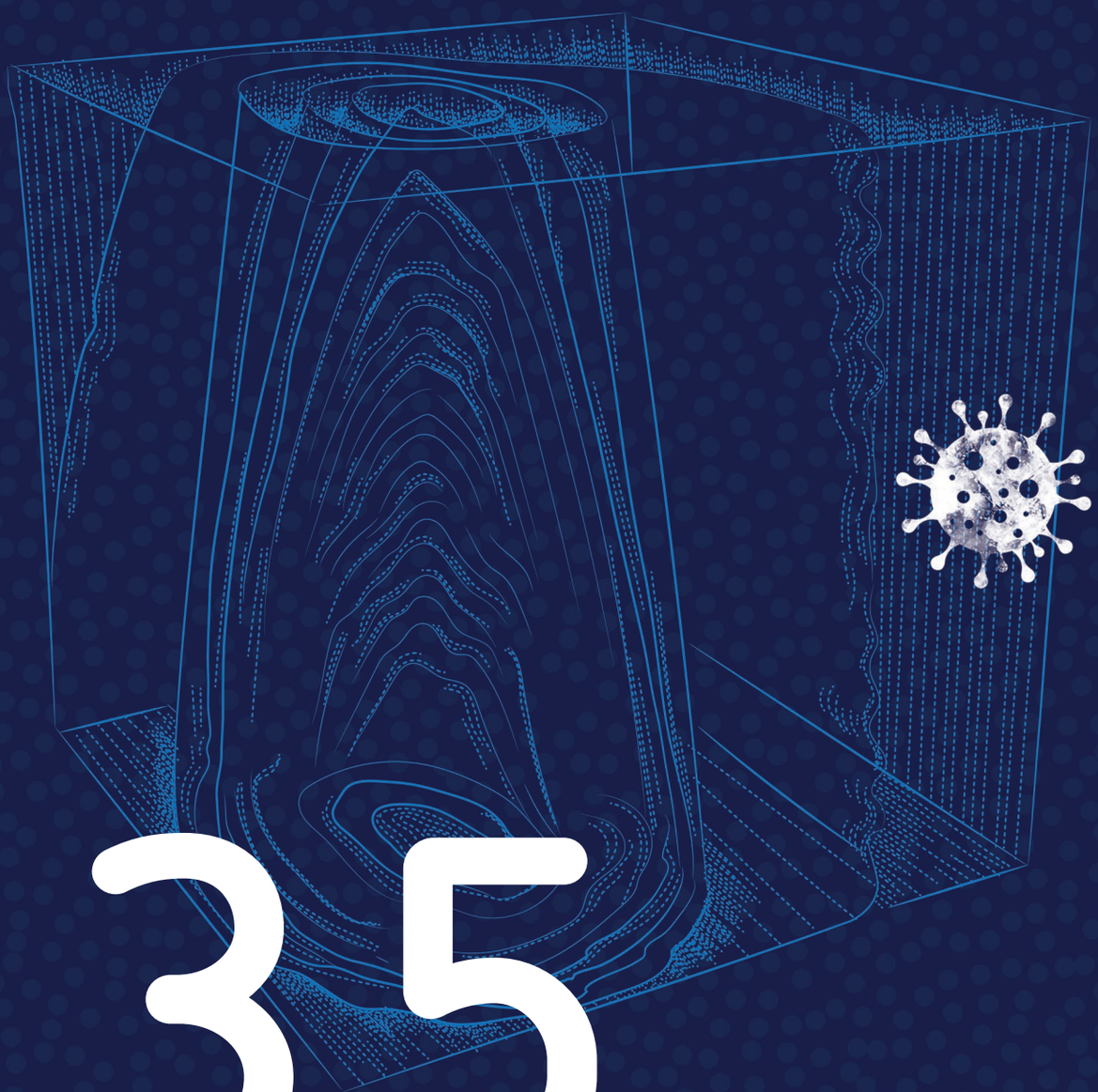
IN NUMBERS

HPC services to 44 departments 134 research groups and 450 students of the Institute
50 publications across the Institute based on supercomputing usage
176 million CPU core hours of usage



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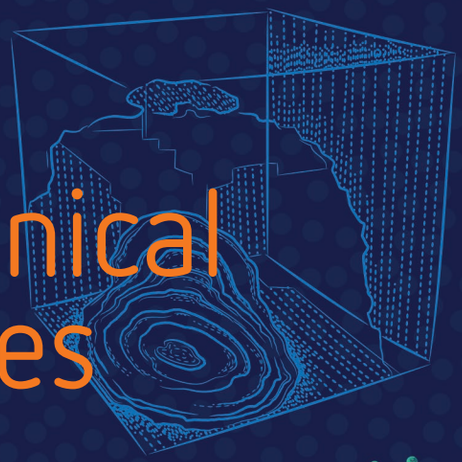
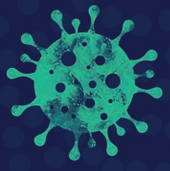
Division of Mechanical Sciences





IN NUMBERS

- 138 FACULTY MEMBERS
- 635 PhD STUDENTS
- 264 MASTER'S STUDENTS

Geotechnical Engineering, Civil & Aerospace Structures, Transportation, Water Resources, Environmental Engineering and Sustainable Habitat, Climate, Structural and Functional Materials, Manufacturing, Design Theory and Methodology, Geochemistry, Tectonics, Planetary Evolution, Remote Sensing and GIS Applications, Aerodynamics, Combustion, Navigation and Guidance, Solid Mechanics, Fluid Mechanics, Thermal Sciences, Acoustics, Robotics, Dynamics, Biomolecular Engineering, Catalysis, Colloids and Interfacial Science, Nanotechnology, Thermodynamics and Simulations across length scales.

THEMES

Research work in the Division encompasses diverse areas. Seismology and climate change - modelling as well as paleo studies - are focus areas, which lead naturally to work on environmentally sustainable materials and design and on waste management. The work on materials includes study and modelling of biomaterials, polymers and photovoltaics. Fluid dynamics, including shock waves and other phenomena at hypersonic speeds, is another key area of study that cuts across the various departments in this Division. Researchers in this Division also work on identifying novel drug and vaccine targets for viral infections such as HIV, hepatitis C and dengue.

RESEARCH HIGHLIGHTS

The Division consists of departments of Aerospace Engineering (which includes DRDL-IISc Joint Advanced Technology Programme and ISRO- IISc Space Technology Cell), Civil Engineering, Chemical Engineering, Materials Engineering, Mechanical Engineering, Centre for Atmospheric & Oceanic Sciences, Centre for Earth Sciences, Centre for Product Design and Manufacturing, Centre for Sustainable Technologies and Divecha Centre for Climate Change

DEPARTMENTS | CENTRES | UNITS

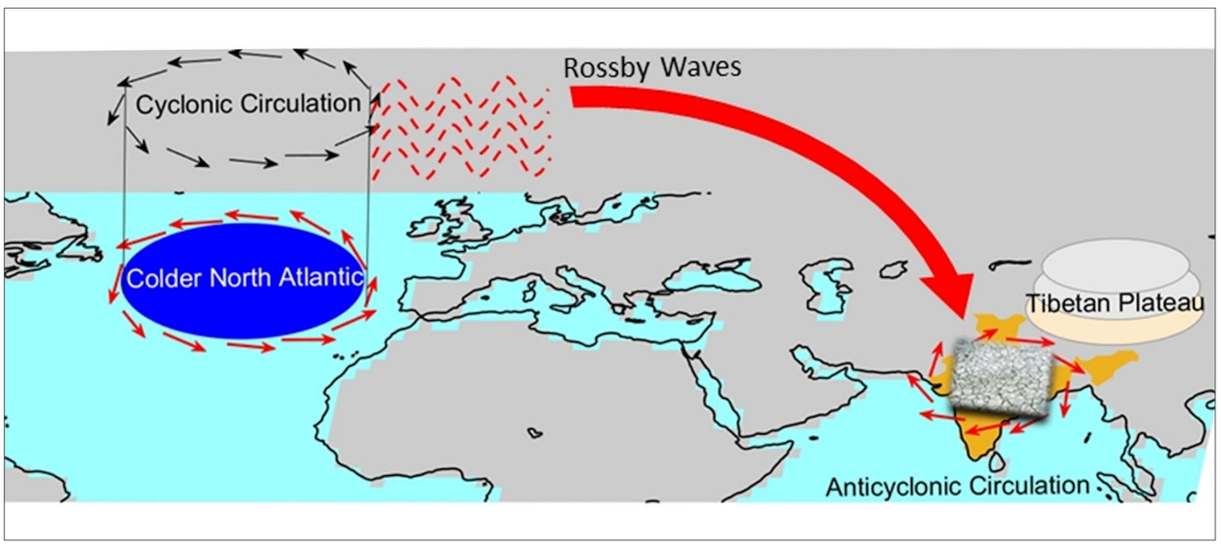
- AEROSPACE ENGINEERING
- CENTRE FOR PRODUCT DESIGN AND MANUFACTURING
- CHEMICAL ENGINEERING
- MATERIALS ENGINEERING
- MECHANICAL ENGINEERING
- CIVIL ENGINEERING
- CENTRE FOR EARTH SCIENCES
- CENTRE FOR ATMOSPHERIC AND OCEANIC SCIENCES
- CENTRE FOR SUSTAINABLE TECHNOLOGIES
- DIVECHA CENTRE FOR CLIMATE CHANGE

2020-21

Research Snapshots

V VENUGOPAL & JAI SUKHATME (CAOS)

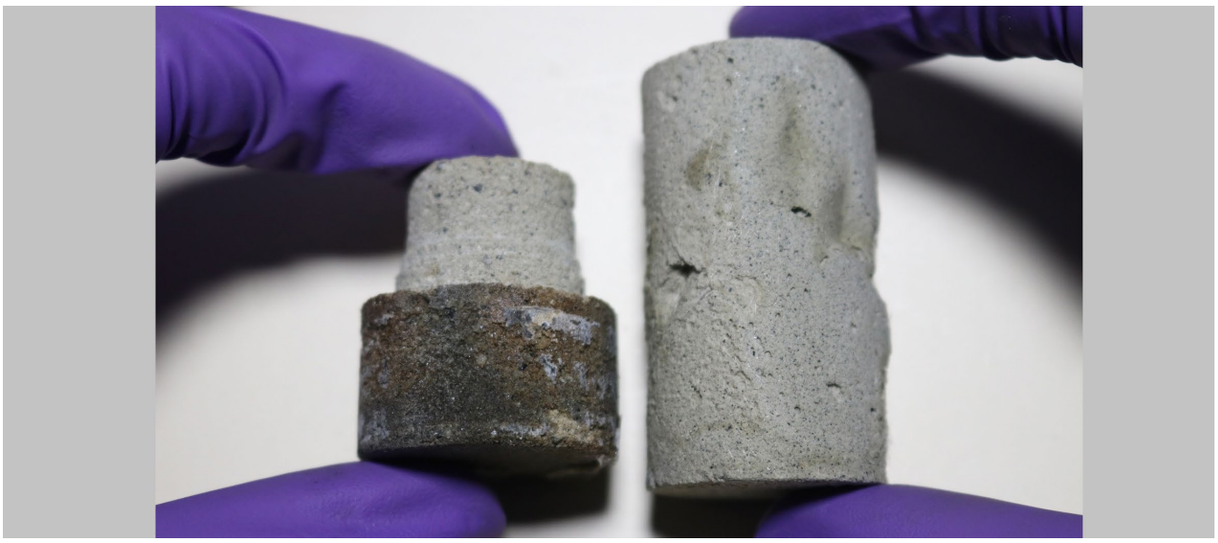
Most droughts during the Indian summer monsoon have been linked to a recurring climate event called El Niño. But ten out of 23 droughts in the past century happened when El Niño was absent. These droughts may have been driven by atmospheric disturbances from the North Atlantic region, finds a new study by researchers in the Centre for Atmospheric and Oceanic Sciences. The droughts were a consequence of a sudden and steep drop in rainfall in late August. This drop was linked to an atmospheric disturbance in the midlatitude region over the North Atlantic Ocean, creating a pattern of atmospheric currents that swoop in over the subcontinent and 'derail' the monsoon.



Reference: Borah PJ, **Venugopal V, Sukhatme J,** Muddebihal P, Goswami BN, Indian monsoon derailed by a North Atlantic wavetrain, *Science (2020).*

ALOKE KUMAR & KOUSHIK VISHWANATHAN (ME)

Researchers from IISc and ISRO have developed a sustainable process for making brick-like structures on the moon. It exploits lunar soil, and uses bacteria and guar gum to consolidate the soil into possible load-bearing structures. These 'space bricks' could eventually be used to assemble structures for habitation on the moon's surface. A bacterium called *Sporosarcina pasteurii* produces calcium carbonate crystals through a metabolic pathway called the ureolytic cycle. When it was mixed with a simulant of lunar soil, urea and calcium sources, it gave rise to brick-like structures via mineral precipitation. These structures were found to be strong and could be fabricated into any freeform shape using a simple lathe.

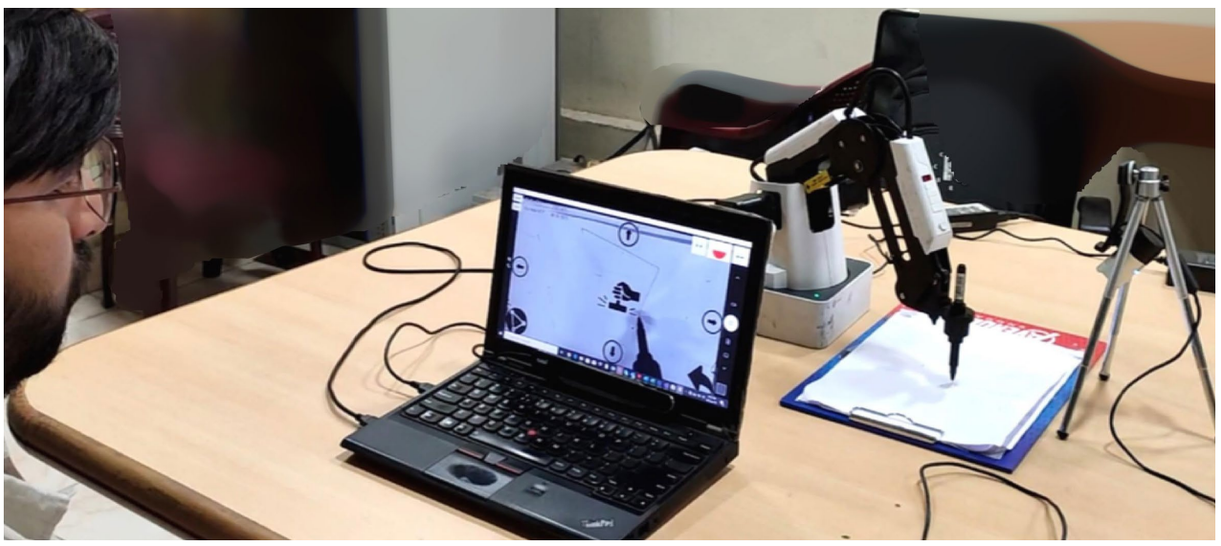


Reference: Dikshit R, Jain A, Dey A, **Kumar A,** Microbially induced calcite precipitation using Bacillus velezensis with guar gum, *PLOS One (2020).*

Dikshit R, Dey A, Gupta N, Varma SC, Venugopal I, **Viswanathan K, Kumar A,** Space bricks: From LSS to machinable structures via MICP, *Ceramics International (2020).*

PRADIPTA BISWAS (CPDM)

People with Severe Speech and Motor Impairment (SSMI) find it difficult to physically operate devices such as a joystick or a mouse, and use speech recognition systems. To help such people, a research team at the Centre for Product Design and Manufacturing designed a robotic arm that can be manipulated by eye movement using a computer interface. The team used computer vision and machine learning algorithms to analyse live feeds of facial video from the users, and estimate where the user was looking. They coupled this with an Augmented Reality application to allow the user to manipulate a robotic arm for tasks like picking up and dropping objects.

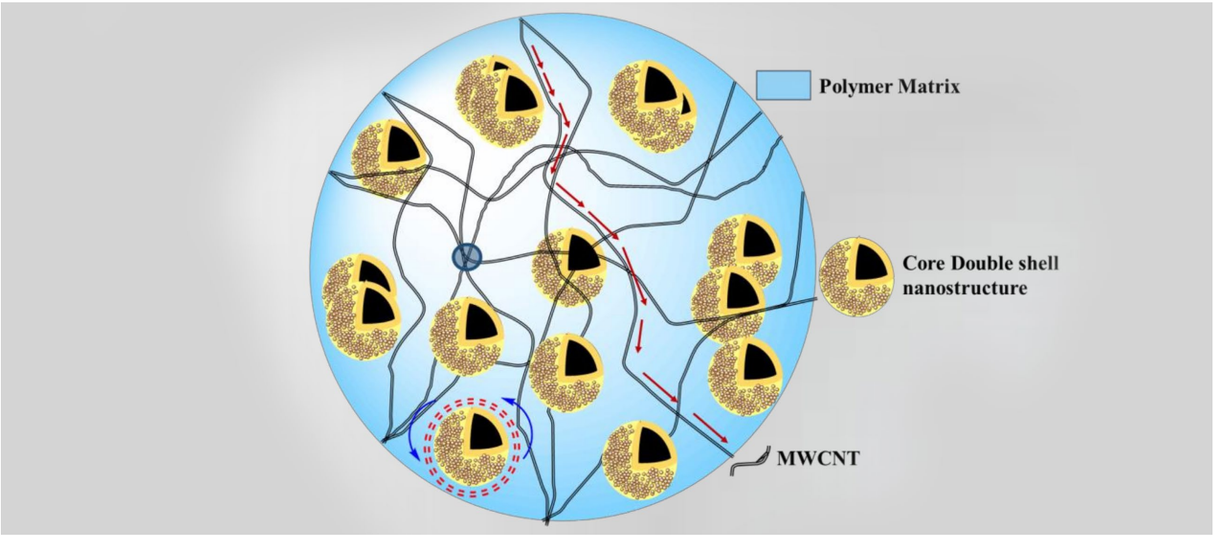


Reference: Sharma VK, Saluja KPS, Mollyn V, **Biswas P,** Eye gaze controlled robotic arm for persons with severe speech and motor impairment, *ACM Symposium on Eye Tracking Research and Applications (2020)*

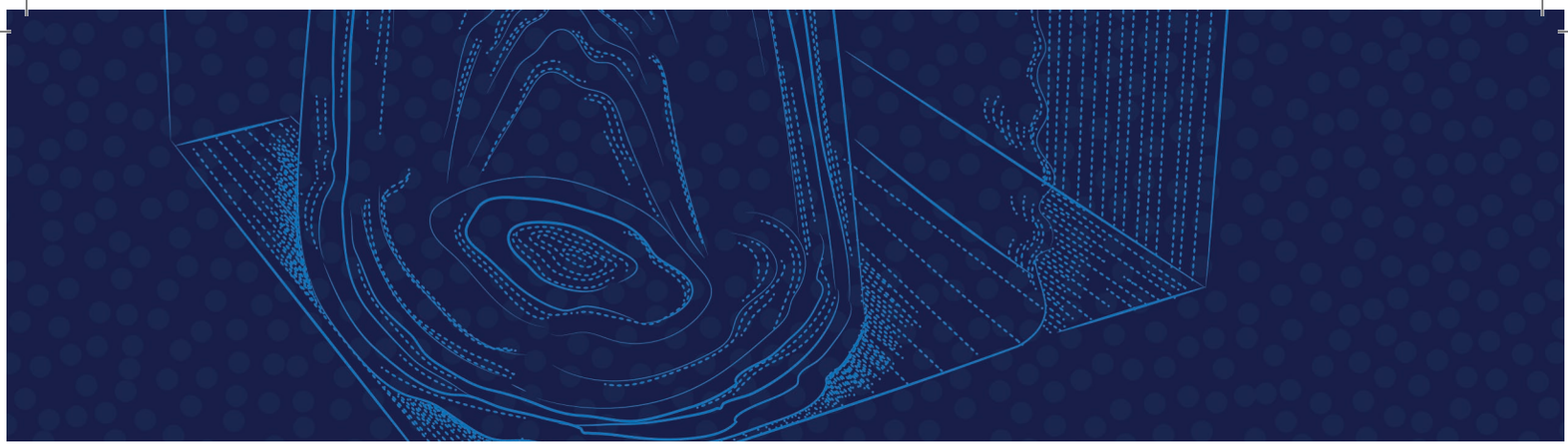
Sharma VK Murthy LRD, Saluja KPS, Mollyn V, Sharma G, **Biswas P,** Webcam controlled robotic arm for persons with SSMI, *Technology and Disability (2020).*

SURYASARATHI BOSE (MATE)

Electro-magnetic interference (EMI) is a persistent issue that plagues modern electronics. Researchers in the Department of Materials Engineering have designed effective nanostructures that can reduce the extent of EMI. They incorporated a conducting carbon nanosphere as the core, and iron oxide and silica as shell materials to develop a core-dual-shell nanostructure. The team found that their structure showed maximum attenuation of incoming electromagnetic radiation - a remarkable 99% - and was also effective in blocking ultraviolet radiation up to 99.9%. The material is also durable at high temperature and under mechanical stress, making it suitable for flexible electronics.

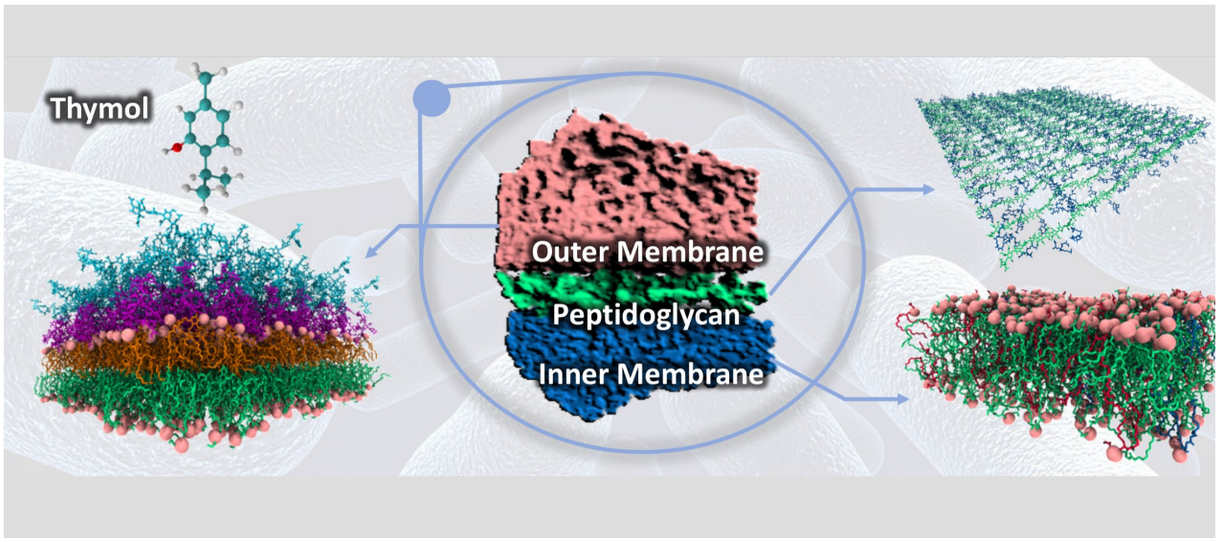


Reference: Bhattacharjee Y, Bapari S, **Bose S,** Mechanically robust, UV screener core–double-shell nanostructures provide enhanced shielding for EM radiations over wide angle of incidence, *Nanoscale (2020).*



K GANAPATHY AYAPPA (CE) & JAYDEEP KUMAR BASU (PHY)

Researchers from the departments of Chemical Engineering and Physics, along with Unilever R&D, have developed improved lab and computer models to understand how antibacterial compounds penetrate bacterial membranes. In one study, using lipid mobility as a marker for the entrance of an antibacterial molecule called thymol, the group revealed the location of membrane barriers. They found that increased phospholipid content in the outer membrane allowed thymol to penetrate it. In another study, they developed a simplified molecular model of the membrane's peptidoglycan layer, which is expected to reduce the computational effort by several hundred-fold. Using this model, small molecules such as thymol were found to rapidly pass the peptidoglycan layer.

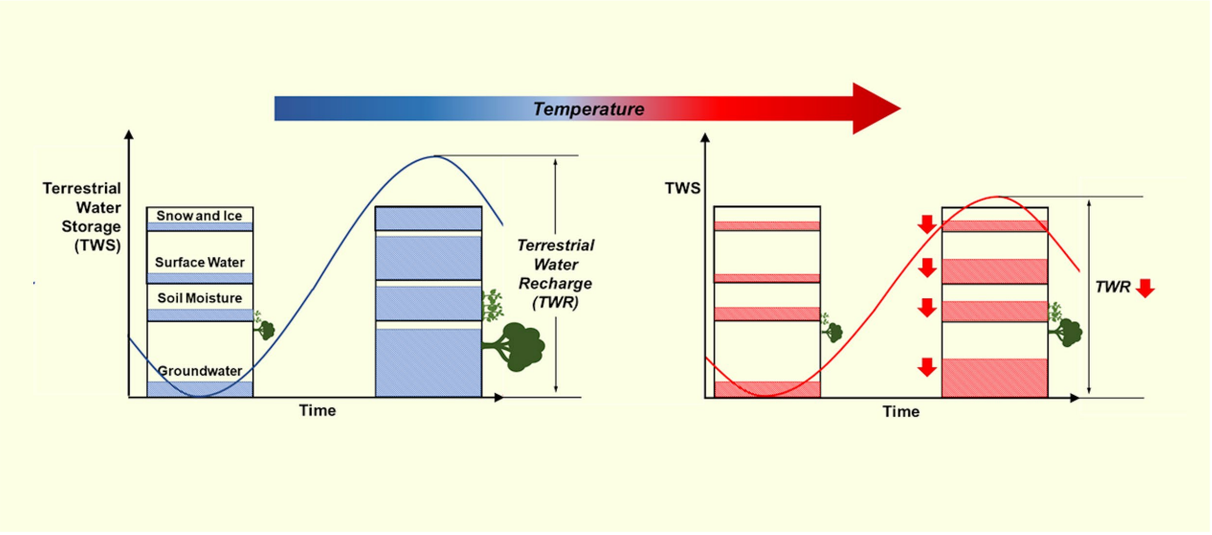


Reference: Sharma P, Parthasarathi S, Patil N, Waskar M, Raut JS, Puranik M, **Ayappa KG, Basu JK,** Assessing barriers for antimicrobial penetration in complex asymmetric bacterial membranes: A case study with thymol, *Langmuir (2020).*

Vaiwala R, Sharma P, Puranik M, **Ayappa KG,** Developing a coarse-grained model for bacterial cell walls: evaluating mechanical properties and free energy barriers, *Journal of Chemical Theory and Computation (2020).*

NAGESH KUMAR D (CiE)

Rising global temperatures are expected to reduce the water availability in many parts of the world. Researchers from the Department of Civil Engineering and Divecha Centre for Climate Change investigated the effect of rise in temperature on water recharge in areas drained by 31 major rivers around the world. Areas drained by 23 out of these 31 showed reduced water recharge with increase in temperature. Vegetation growth was also found to reduce due to decline in the annual water recharge. The findings of this work, based on Gravity Recovery and Climate Experiment (GRACE) satellite observations, are first of their kind and in line with future projections from mathematical models.



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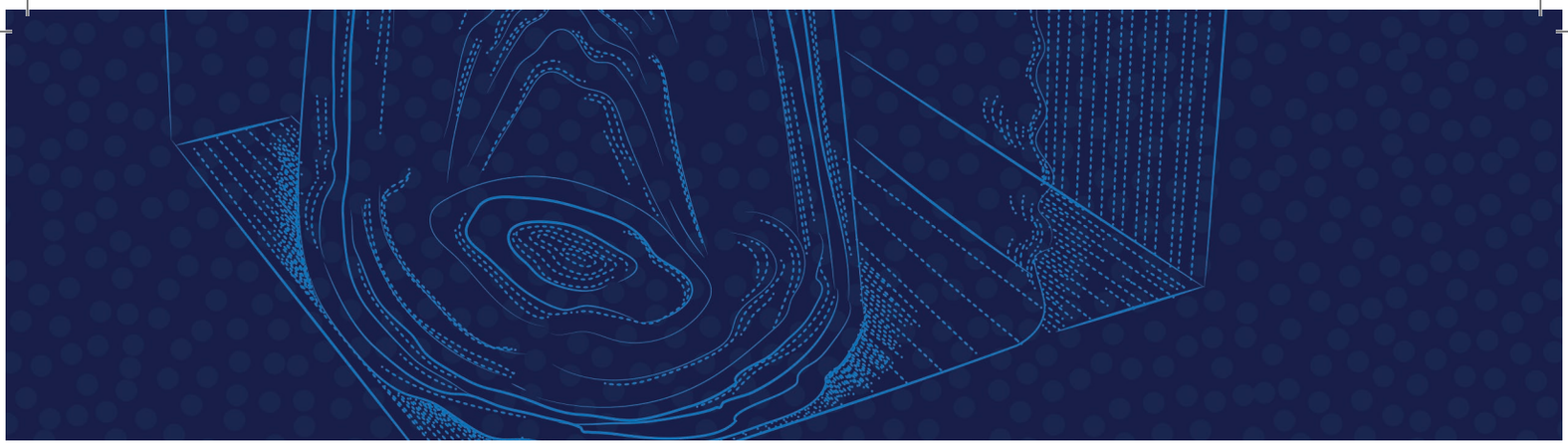
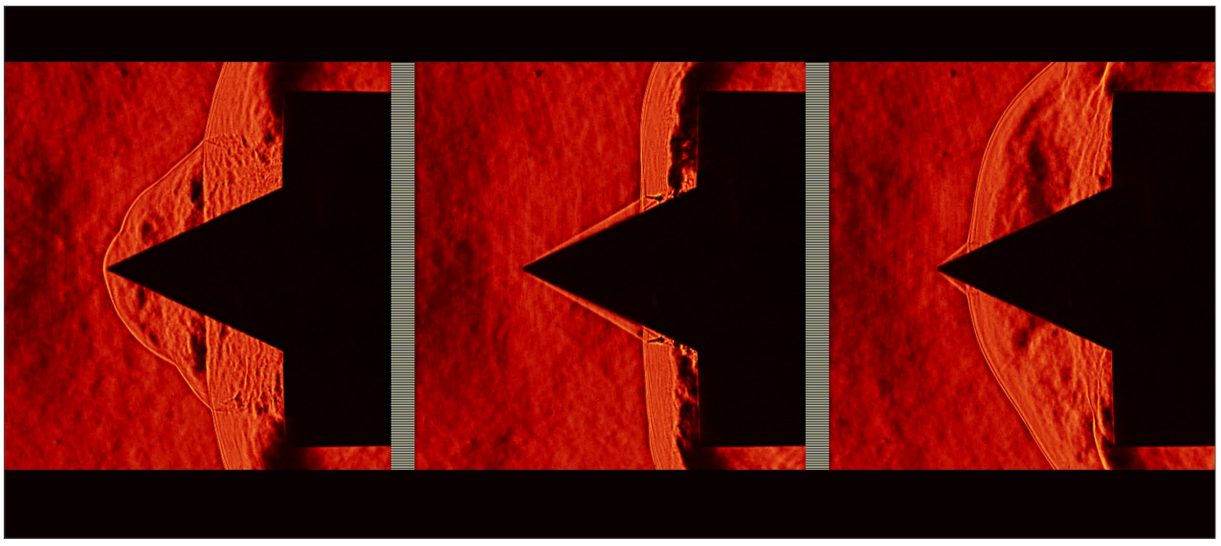


DUVVURI SUBRAHMANYAM (AE)

When rockets and aircraft move faster than the speed of sound, shock waves are created around the flight body. Under certain conditions, shock waves can exhibit periodic oscillatory motion relative to the body. This was earlier studied for simple bodies that can be described by a single geometric parameter. Now, researchers in the Department of Aerospace Engineering have uncovered new and interesting dynamics that govern unsteady shock-wave motion when two geometric parameters are at play. Different air flow patterns created by variation in the governing parameters resulted in two disparate states of shock-wave unsteadiness. In a certain parameter regime, the shock waves were highly disturbed, resulting in 'pulsations' with a much higher amplitude of unsteadiness.



Reference: Sasidharan V, **Duvvuri S,** Large- and small-amplitude shock-wave oscillations over axisymmetric bodies in high-speed flow, *Journal of Fluid Mechanics (2021).*

LAKSHMINARAYANA RAO (CST)

Researchers at the Centre for Sustainable Technologies have developed an efficient decentralised wastewater treatment and recycling system at a primary school situated in the remote village of Berambadi in Karnataka. A key component of this system is a cold plasma ozonator designed to disinfect the water. The research team operated the greywater treatment system for a year and monitored the different physicochemical and biological characteristics of the greywater at the entry and exit points. About 667 litres of greywater from handwash and kitchen wash sinks were treated daily using the system, saving around 180,000 litres of water annually. Such systems can be replicated in both rural and urban settings.

Reference: Subramanian GPS, Raj AV, Jamwal P, Connelly S, Yeluripati J, Richards S, Ellis R, **Rao L,** Decentralised treatment and recycling of greywater from a school in rural India, *Journal of Water Process Engineering (2021).*

Founded in the year 1942 as the Department of Aeronautical Engineering, it was renamed as the Department of Aerospace Engineering in the year 1982 to reflect the growing activities in space research and education. The department offers PhD, MTech and MTech (Res) programs and currently has 33 faculty and 248 research students. The academic and research activities are in four major areas, namely, Aerodynamics, Structures, Propulsion, and Guidance & Control.

CURRENT RESEARCH

Aerodynamics

A strong experimental program spanning low-speed to hypersonic flows has been pursued in the several wind tunnels and shock tunnels, fitted with instrumentation for classical measurements and modern diagnostics and flow visualisation. Computational studies cover external aerodynamics of wings and full aircraft, DNS and LES of turbulent and transitional flows, aeroacoustics and new algorithms. An analysis of viscous and inviscid global stability of the vortex rings was completed. For inviscid rings, growth rates were found to be sensitive to details of vorticity distribution that calls for a global analysis instead of the now classical heuristic model for quantitative accuracy. Studies of a new canonical turbulent flow---twin, round and plane jets---were completed. A notable finding is intrinsic scaling of the initial region before merger with simple linear dependence on imposed parameters---inflow velocity, jet diameter and separation. PhD theses on laminar separation and turbulent boundary layers were completed. Fundamental studies of unsteady shock waves in high Mach number flows incident on bluff bodies were completed. Ongoing numerical studies of jets and plumes were taken into a new direction to understand the spreading of expelled droplet-laden puffs which is relevant to the ongoing COVID pandemic. A study looked at start-unstart characteristics of high compression ratio intakes. The effect of length on the critical operating regime of ejectors was

3.5.1 Aerospace Engineering

CHAIRPERSON
JOSEPH MATHEW

determined and the role of a S-CO2 ejectors in power cycles was determined. A new stability analysis of Lattice Boltzmann Method was introduced. Several improvements to CFD algorithms for meshless solvers, higher-order finite volume methods, adaptive time-stepping and applications to flow control for high lift devices, propellers, design of flush air data sensors, and supersonic base flows were investigated. Transonic buffet of airflow over a wing, and the use of an active aeroelastic wing for roll enhancement and improving lift-to-drag ratio, were explored. The anodised aluminum pressure-sensitive paint (AA-PSP) technique was explored for identifying flow structures in hypersonic flow. A new two-temperature ratio pyrometry technique was developed to measure the temperature distribution around re-entry bodies at hypersonic Mach numbers, and the diagnostics has been integrated with the IISc free-piston driven shock tunnel. Data analytic tools for analysis of time-resolved Schlieren images were developed. The effect of stacking fault energy on the evolution of micro-structure and texture during blast wave assisted deformation of FCC materials was comprehensively investigated. It was shown that shock wave therapy efficiently cures multi-species chronic periodontitis (Dental bio-films) in a humanised rat model.

CORE RESEARCH

Aerodynamics: Low speed flows--transition & turbulence, Supersonic & hypersonic flows – mixing, drag, heat transfer, Computational Fluid Dynamics, LES, Aeroacoustics, Stability, Aeroelasticity.

Aerospace Structures: Composite structures, nanocomposites, functionally-graded materials, vibrations, wave propagation, structural health monitoring, finite element analysis, non-destructive evaluation.

Propulsion: Atomisation & sprays, Combustion instability.

Guidance & Control: Optimal control, path planning, image processing, obstacle avoidance, multi-agent systems.

Structures

Developed theoretical model of nano additive-based fibre reinforced polymer matrix composite materials for thermo-mechanical property enhancement was developed, and results were validated experimentally. New mathematical model and theoretical correlation regarding ultrasonic wave induced heat generation in structural components with cracks for application in new inspection technique was established. Additive manufacturing methods for piezoelectric sensors were developed, and sensor performance was characterised. Optimal design of composite plates was performed while accounting for uncertainty present in composite material properties. Conservative design practices for composite structures were proposed. A stochastic time domain spectral analysis was developed for beam structures. Ionic metal polymer actuators were studied for actuation of underwater autonomous vehicles. Isospectral Timoshenko beams were discovered. These non-uniform beams which have the same frequencies as uniform beams can serve as benchmark solutions. Novel computational methodologies for modeling stress assisted pitting corrosion and inspection of adhesively bonded joints were explored. NDE was applied to friction stir welded joints in Aluminium Alloys, to understand hygro-thermal effects on CFRP Composites, for adhesively bonded joints in CFRP Composites, for impact damage evaluation in metal-fiber hybrid composites, and of corrosion in Aluminium Alloys. Vibration and noise control of composite materials with resistive and resonant shunting. Deicing of aircraft wings. Nonlinear modelling of PZT bonded to beams. Single and dual adhesive bond strength analysis of single lap joint between dissimilar adherends. Micromechanical Analysis for Damage Modelling of Unidirectional Composite Laminae. Qualitative Assessment of 3-D Failure Criteria of Composite Laminae Based on Initiating Failure Mechanisms. Other newer areas include machine learning, artificial intelligence, 3-D weaving, ceramic and metal matrices, ceramic vapour infiltration process modelling, active constrained layer damping, functionally graded magneto-electro-elastic plates, hybrid nano composites, and natural composites.

Propulsion

Studies have been conducted to describe the breakup of liquid jet/sheet discharging from non-circular orifices and gas-centered swirl coaxial atomisers with a focus on the role of atomiser geometry and flow conditions on spray drop size. Impact dynamics of hydrocarbon fuel drops on heated solid surfaces encountered in engine combustors was studied. Linear stability analysis was found to correctly predict characteristics of self-excited instability in swirl-nozzle flows. It can guide nozzle geometry design to induce these instabilities. A thermoacoustic stability modelling tool for evaluating a semi-cryogenic engine was developed. New methods of application of Lattice Boltzmann Equation to low-speed combustion problems were explored. Other work included CFD-based optimisation of Ramjet intakes, simulation of a complete nozzle test facility design, and experimental and computational studies of non-Newtonian.

Guidance & Control

A context-aware deep Q-network for swarm of vehicle performing search mission in an unknown/uncertain environment with heterogeneous targets, an AI driven sense-and-avoid system for rapidly moving drones, and a robust flight controller under resource constraints for were developed. A novel guidance method for mimicking short range ballistic trajectories, a new two-gain guidance structure for trajectory shaping with seeker field-of-view limitations, and a polynomial guidance law that considers line-of-sight profile shaping as a function of range to target were developed. For Patter Generation for Surveillance Trajectories a novel control framework for a unicycle model to generate an extensive set of motion patterns was introduced. The proposed control law leads to Andronov-Hopf bifurcation in speed-scaled angular velocity space of the agent. Patterns are shown to be identical to the parametric form of trochoid curves. In guidance and control of autonomous vehicles, the following areas were covered: Unmanned Aerial Systems for Flood Management; detection of land-water boundary using UAV collected images; detection and tracking of survivors using UAVs in a flood scenario; resource allocation for flood affected areas using game theoretical methods; route planning in flooded urban environments UAV-UGV Systems for Search and Exploration; exploring unknown indoor and outdoor areas using a hybrid system of UAVs and UGVs; strategies for image collection for visual reconstruction of the environment; task allocation

with split and merge of UAV swarms; Voronoi partition based search strategies Modelling onion dynamics in social systems using Viscek's model. MBZIRC 2020 participation addressed research issues in intercepting intruders, building walls and extinguishing fire in high rise buildings, design of manipulators and grippers, and tracking a moving ball in space. Studies also examined Output-constrained Robust Adaptive Control for Uncertain Nonlinear MIMO Systems with Unknown Control Directions, Tracking-oriented MPSP for Optimal Command Tracking, Unscented MPSP for Optimal Control of a Class of Uncertain Nonlinear Dynamic Systems, Waypoint Constrained Multi-Phase Optimal Guidance of Spacecraft for Soft Lunar Landing, Interdependent Estimation and Guidance with Zero-Effort-Miss Enforcement, Generalised Explicit Guidance with Optimal Time-to-go and Realistic Final Velocity, and Three-dimensional Nonlinear Gravity Assisted Aiming Point Guidance.

A new low-cost ventilator technology was developed and transferred to an industrial partner by faculty of the aerodynamics and propulsion streams.

We showed that linear stability analysis can be expected to yield accurate predictions of self-excited, helical, processing vortex core instability modes in swirl nozzles using experimental data from collaborators. We next confirmed this using a LES data from our own computations. This now can allow designer to use linear stability analysis as guide for design. We also delivered a thermoacoustic stability analysis for ISRO's new semi-cryogenic engine. Follow on work is planned.

1. Experimental and numerical investigation of hypersonic boundary layer transition from laminar to turbulent regime using generic models. Present work has clearly shown both cavity driven transition as well as natural transition on 8 deg. half angle circular cone at Mach 6 for the first time in IISc hypersonic shock tunnel.

2. Exploring start-unstart behaviour of a generic scramjet intake in hypersonic flow. The study revealed the source of unstart and its characteristics which includes a very three dimensional unsteady flow development. High amplitude oscillatory phenomenon was observed and a characteristic length was found for frequency of this oscillation.

3. Experimental and numerical studies on shock attenuation in pressure driven miniature shock tubes. A shock tube model was proposed to validate experimental findings. Correlations to predict the variation of shock Mach number worked well for the cases investigated and the experimental data in literature.

We developed hydroxylammonium nitrate based monopropellant for space thruster application.

Through experiments in our in-house large hypersonic wind tunnel facility, my group discovered very interesting unsteady shock wave phenomena with multiple phase-space transitions from stable states to large-scale oscillations. This behaviour is driven by two controlling parameters and has not previously been reported in literature. My group also played a lead role in developing low-cost ventilator technology (motivated by the Covid crisis), and is presently engaged with an industry partner to drive the technology toward a field-ready product.

1. For scale-down model of multi-role micro UAV model, a novel faculty-tolerant controller is designed to stabilise the aircraft under actuator struck (single/Multi), actuator failure, Fin/Wing Shear. The developed controller is implemented I n a edge device and will be tested on micro-UAV class.

2. Developed a SDV in a box simulator for autonomous vehicle. The SDV in a box simulator is a unique simulator to accolade the development AI stack for AV. The simulation integrate realistic environment for operating the AV.

3. Initiated setup of Warehouse automation testbed as a part of Garrett and Nokia initiative. The setup enables researchers to validate multi-robot collaboration and coordination in a typical warehouse environment.

4. Developed a SWARM initiative for active detection of mine-like-object in underwater environment with DRDO. The project focus on development of deep learning approaches for detecting MLO using fusion of Sonar and EO for detection and localisation.

Following are the Major Research Highlights during the calendar year:

1. Wave Propagation in Bio-Inspired Suture Materials for efficient energy absorption, high wave attenuation and reduction in Group speeds of the waves

2. Inspection of Adhesively bonded Joints

3. Propagation of Elastic waves in Peri-dynamics and gradient elasticity theory-based Bars and beams

4. Machine and Deep Learning approaches for Model assisted Structural Health Monitoring

5. Modelling and design of Sand Bunkers for efficient Blast Mitigation

6. New Modelling methods for Blast Mitigation

NDE of Friction Stir Welded(FSW) Joints in Aluminium Alloys. NDE of Hygro-thermal effects on CFRP Composites. NDE of Adhesively Bonded Joints in CFRP Composites. Impact Damage Evaluation in Metal Fiber Hybrid Composites. NDE of Corrosion in Aluminium Alloy used for Aerospace Applications.

Application of Piezoceramic materials for actuation and energy harvesting

Multifidelity analysis of beams for uncertainty quantification was explored using response surface and co-kriging metamodels. Lie algebra was used to find closed form solutions of the axially loaded beam equation. The digital twin of a dynamic system was developed.

Studies of a new canonical turbulent flow were completed. These are twin, round and plane jets. Round jets were observed to develop almost independently of each other and then merge into an elliptical jet, undergo axis switching while becoming a single round jet. In the region before merger, a new intrinsic scaling was found for velocity and length related almost linearly to the impose scales of inflow velocity, jet diameter and separation. Twin plane jets evolve differently because they enclose a region, thus bending towards each other, but intrinsic scaling still exists.

Spray formation inside an engine combustion chamber is a complex fluid dynamic process involving several sub-processes such as liquid jet/sheet instability, ligament breakup, spray-wall interaction, and secondary atomisation. Research studies have been conducted to describe the breakup of liquid jet/sheet discharging from non-circular orifices and gas-centred swirl coaxial atomisers. Currently, the research work focuses on the role of atomiser geometry and flow conditions on spray drop size distribution for sprays discharging from aircraft engine injectors as well as locally developed research gas-centred swirl coaxial atomisers. We also study the impact dynamics of hydrocarbon fuel drops on heated solid surfaces encountered in engine combustors.

G Narayana Naik, has been involved in the research work of composite structures, damage mechanics and failure analysis. Strengthening of the adhesive bond using a mixture of adhesives between dissimilar adherends in a single lap joint. Weak bond effects in adhesively bonded joints between the dissimilar adherends. Single and dual adhesive bonded joint analysis between different similar composite adherends.

SN Omkar is currently working as a Chief Research Scientist at the Department. His research involves both computational and experimental approaches. Omkar has contributed immensely to the field of Helicopter dynamics. His research involves helicopter model development, system identification, and control. A neuro controller, based on flight data, has been developed to meet the ADS-33 handling quality specifications. The research in this field has resulted in 7 journal publications. He has also procured a 7Kg class helicopter UAV and is planning to make it autonomous. Dr Omkar has developed UAVs with rotary configuration. He is presently working on a novel concept of tilt-rotor UAV and has already demonstrated a successful flight. Dr Omkar is pursuing several projects and research work in the area of satellite image processing. He has developed a number of algorithms and used them for a variety of applications li

Studies on the phenomena of start-unstart in hypersonic intakes with particular emphasis on modes of unstart and dynamics of shock oscillations (1 journal article published, 2 submitted and under review)

1. Data-driven analysis of the supersonic ejector (manuscript under preparation)

2. Studies on the effect of length and area ratio on the operation of supersonic ejector in the critical regime of operation.

3. Design and establishment of a new S-CO2 ejector test facility.

4. Optical diagnostic study of the flapping supersonic jet - 1 journal article published.

5. Calibration experiments towards 3D-DIC experimental setup for short duration facilities.

6. Initiated studies on Rotating Detonation Engines and Waverider configurations for hypersonic flight vehicles.

7. Submitted two project proposals

8. Conducted experimental studies temperature distribution over a tractor for VST tractors, Hosur.

Hypersonic aerothermoelasticity using high fidelity CFD, conjugate heat transfer, and elastodynamics of a flexible elastic material placed in hypersonic flow with shock-boundary layer interactions. Fluid-elastic simulations of patient specific aortic aneurysm in human vascular system in order to predict blood vessel rupture. Transonic buffet in supercritical flexible wing using high resolution CFD coupled to elastodynamics of the wing structure to understand shock-boundary layer interactions, flow separation, vorticity transport over the wing, and the influence of elastodynamics on transonic buffet. Transonic flow over a flexible delta wing to understand vortical transonic flow and the influence of elastodynamics of the wing. High fidelity aeroelastic simulations of the full annulus of a transonic fan in a aero-engine with the intent to understand shock-boundary layer interactions and its influence on transonic flutter of a fan.

Research Highlights:

1. Transition mechanism in a separated boundary layer has been investigated numerically for different Reynolds numbers. An extensive analysis has been carried out using wavelet transform and intermittency calculations. A physical cartoon is suggested for the separated flow transition.

2. A detailed linear stability analysis of the Couette-Poiseuille flow has been carried out to provide a mechanistic explanation for the stabilisation of flow with increase in plate speed and to understand the behaviour of neutral curves at high Reynolds numbers.

3. Roughness induced transition is being investigated experimentally in a wind tunnel using hotwire anemometry and PIV.

4. The scaling of the wall pressure spectrum beneath a turbulent boundary layer is being studied. 5. Direct Numerical Simulation of heated and unheated turbulent jets is being carried out to understand the turbulent entrainment and coherent structures.

Handled major development projects for

1. Mazagon Dock (GOI) ship building agency (1. Frigate Scaled model wind tunnel testing (2) Scaled model flow computations (3) prototype flow computations

2. Configuration development studies on SWiFT (blended WB configuration) including ground effect studies for ADE

3. Evaluation of effects of dorsal antenna on stability and control of A330 (scaled model) for CABS

4. VTOL UAV performance studies for NAL. 3.

1. UAV Conflict Resolution: Considering two constant-speed aircraft moving in a horizontal plane, this work proposes deconflicting manoeuvre that resolves the conflict with the desired safety threshold and takes the aircraft back to its original course.

2. Target Tracking Motion Primitives: This work uses pitchfork bifurcation of the UAV look-angle dynamics as a design tool for generating motion primitives for target tracking behaviour. Resulting UAV trajectories are analysed, and the tracking behaviour is classified as spiral search, stand-off tracking, and target prosecution based on the choice of bifurcation parameter.

3. Other problems addressed include obstacle avoidance characteristics of classical guidance laws, UAV formation control, spacecraft attitude determination, and a framework for developing drone-skyway corridors.

Carried out literature survey on the current advances in Missile propulsion. Prepared for a lecture series on missile propulsion, and planning a monograph on the topic.

Five important research problems dominated the attention during 2020:

(i) Modelling of Air-traffic flow over the Indian Airspace (funded by the IMPRINT-II initiative of MHRD

(ii) Development of artificial pancreas (also known as 'Robo pancreas') for Type-1 diabetic patients of India (funded by the IMPRINT-I initiative of MHRD)

(iii) Station keeping of satellites in L1 Halo Orbit (funded by ISRO)

(iv) Autonomous flying of drones (funded by RBCCPS of IISc)

(v) Constrained nonlinear and adaptive control (theoretical developments). A book manuscript was also finalised in 2020 on Satellite Formation Flying, and submitted to the publisher (Springer) for publication.

Guidance and Control of Multi-UAV Systems; Aerial Manipulation; Collision Avoidance; Launch Vehicle Trajectory Optimisation; ML-based Collision Prediction and Avoidance; Guidance Trajectories; Multi-agent model of Biological Entities; Autonomous/Precision Agriculture; Resource Allocation for Disaster Management; Manipulator Design; Mechanism Theory.

Dineshkumar Harursampath and his students at the NMCAD Lab, while leveraging their traditional strength in mathematically rigorous modelling of the nonlinear physics of multifunctional composites applied to flight vehicle structures, including analysis, design and damage mechanics, have forayed into emerging areas such as additive manufacturing, machine learning, artificial intelligence, 3-D weaving, ceramic and metal matrices, ceramic vapour infiltration process modelling, active constrained layer damping, functionally graded magneto-electro-elastic plates, hybrid nano composites, natural composites etc.

Modelling and simulation scheme for evaluation of composite materials with manufacturing process effects were developed and experimentally validated (https://onlinelibrary.wiley.com/doi/full/10.1002/pc.25919); A molecular dynamics based simulation study revealed the dislocation loops and related mechanisms originating from surface deformation on high temperature hard refractory composite materials made of Tungsten based alloy (W-TaC-Ta2O5 nanocomposite) and the study predicted ultra-high rupture strength behaviour that was experimentally verified (https://www.sciencedirect.com/science/article/pii/S0263436820303309); Other Molecular and multi-scale simulations demonstrated new ways to enhance electric field in semiconductor array in fluid (https://aip.scitation.org/doi/abs/10.1063/5.0028899) and scale-up method for graphene exfoliation using electro-spray (https://www.sciencedirect.com/science/article/pii/S0008622320304504).

One major theme is structure of turbulence in a channel flow. Some insights that have emerged including how the fluctuating vorticity migrates from the centre of the channel to the near-wall region with increasing Reynolds number. Secondly by appropriately increasing the contraction ratio of the channel, the onset of laminar-turbulent transition has been delayed considerably. Other study is on the flow over a double delta wing of a reusable launch vehicle. An anomalous post-stall increase in lift has been related to formation of streamwise vortices at the trailing edge that have emanated from the fuselage.

Combustion Research and Advanced Diagnostics Laboratory (CRADL) fully functional and commissioned. Research funding worth of 187 lakhs raised. Industrial funding : Honeywell India Technology Center, L&T Healthcare Govt funding: Core Research Grant SERB, ISRO-IISc STC Co-developed an Electro-mechanical medical ventilator with fine grained pressure, volume, and fractional inspired oxygen control through indirect methods and filed an Indian patent.

CFD Algorithms: 3D Turbulent Flow computations using Meshless LSFD-U solver, Staggered Update Procedure (SUP) towards higher order finite volume method, Implicit Gradient Reconstruction (IGR) method for low memory footprint for highly scalable CFD

solvers, Understanding Residuals in Finite volume methods Applied Aerodynamics: DES simulation of synthetic jets, Supersonic base and plug nozzle flows, Powered propeller aircraft simulations, High lift flow simulations, Design of inter turbine ducts and intakes

Conducted new stability studies on Lattice Boltzmann Method. Developed novel Lattice Boltzmann Relaxation Schemes for Compressible Flows. Developed a novel discrete velocity based kinetic scheme for compressible flows.

The novel combination concept of FFC (forward-facing cavity) with energy deposition inside the cavity region is investigated by chromium exothermic reaction employed by coating the cavity surface with chromium film exposing to the 2.2 MJ/kg (H1, Mâˆž = 7.5), 3.2 MJ/kg (H2, Mâˆž = 10.9) and 5.4 MJ/kg (H3, Mâˆž = 10.2) specific enthalpy of flow conditions. The FFC with opposing air-jet combination experiments conducted for higher pressure ratio (PR â‰ˆ 18) at Mâˆž = 5.9 flow condition. FFC with cylindrical and parabolic cavity geometries experiments are conducted for H1 (1.2 MJ/kg), H2, and H3 flow conditions.

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JOSEPH MATHEW | PhD (MIT), FNAE, Professor
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SN OMKAR | PhD (IISc), Chief Research Scientist
CHARLIE OOMMEN | PhD (IISc), Chief Research Scientist
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IN NUMBERS

26 Academic staff
7 Scientific staff
151 publications
118 PhD students
23 MTech (Res) students
47 MTech students
2 MSc (Engg) conferments
21 MTech conferments
2 Mtech (Res) conferments
26 PhD conferments

The Centre for Atmospheric Sciences was established in 1982 and renamed Centre for Atmospheric and Oceanic Sciences in 1996. Known for pioneering work on monsoon physics and variability, its activities now span a broad range of topics in atmosphere, ocean and climate science

CURRENT RESEARCH

We highlight a few results to convey a flavour of research at CAOS. Lowering of surface temperature by injecting sulphate aerosols in the stratosphere has been suggested as an option to offset the magnitude of human-induced climate warming. We find that stratospheric sulphate aerosols are more effective in cooling climate when they reside higher in the stratosphere, which is explained in terms of effective radiative forcing.

Using Doppler Weather Radar (DWR) data collected at Hyderabad, Nagpur, Kolkata and Patiala, we have shown that monsoonal cloud systems contain a few to more than 20 storms comprised of a few to several cumulonimbus clouds grouped together in a contiguous manner, with these storms occupying 30 - 70%

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IN NUMBERS

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35 PhD students
61 Publications
11 PhD conferments

3.5.2 Centre for Atmospheric and Oceanic Sciences

CHAIRPERSON
DEBASIS SENGUPTA

of the convective area and contributing 90-97% of convective precipitation at any given instant. This has implications for parameterising cumulus clouds in models as well as planning satellite payloads.

Free Space Optical (FSO) communication links are emerging as important communication means, owing to high data rate and bandwidth, but face a challenge of degradation due to optical scintillations caused by lower atmospheric turbulence. We have estimated the performance of different FSO communication links and the effects of atmospheric aerosols through influences on both atmospheric temperature structure as well as turbulence, which affects the Bit Error Rate performance of these FSO communication links.

Very heavy rainfall events, often termed as extreme rainfall, are a major cause of flood and related calamities, and what matters most for flooding is their collocation in space. We showed that during the last couple of decades, the larger extreme rainfall events of Indian monsoon have been increasing steadily, responsible for several devastating floods and a global scale signature in the weather pattern could potentially be useful for their prediction a few days in advance.

We established that Indian monsoon droughts can be categorised into two distinct categories: the conventional one forced by a warm equatorial Pacific (El Nino), and a second category resulting from a cold

CORE RESEARCH

CAOS faculty and students study monsoon and climate variability, cloud physics and tropical convection, space-time variations of rainfall and extreme rain events, the hydrological cycle, physical oceanography and air-sea interaction. In recent years we have studied nonlinear climate dynamics, the planetary boundary layer, aerosol physics and chemistry, radiation and climate, large-scale waves and geophysical turbulence, ocean convection and small-scale turbulence, palaeoclimate, climate change, the global carbon cycle and geoengineering, and planetary atmospheres. In addition to ocean and climate modelling, data analysis and theoretical work, the Centre has a long tradition of field campaigns to better understand physical processes using in situ measurements on land, in the atmosphere and ocean.

North Atlantic Anomaly. The evolution of the second category differs markedly different from the first, providing a substantial advancement in mechanistic understanding of what causes monsoon droughts and offering new avenues for improvements in predictability.

We have studied multi-scale variability of the near-surface ocean and atmosphere in a 14-month long record from an air-sea flux mooring in the north Bay of Bengal, including a monsoon storm which gave 0.5 meters of rain over the ocean in 4 days. Using moored data and simple models, we have explained the observed response of the Bay of Bengal to powerful tropical cyclone Phailin, October 2013, in terms of storm-induced turbulent mixing of the upper ocean. Absence of ocean cooling may have strengthened the maximum windspeed in the cyclone by 5-7 m/s. The southern Bay of Bengal is highly energetic due to intrusion of the Summer Monsoon Current (SMC) carrying high-salinity Arabian Sea water and the presence of the Sri Lanka Dome with its cyclonic circulation. We have used microstructure profiles measured during the BoBBLE field experiment into the southern Bay along with an eddy-kinetic-energy budget analysis to study the mechanisms involved. Observations and model simulation demonstrate that the southern Bay cold pool is maintained by the SMC despite the ocean gaining heat from the atmosphere. The previously overlooked role of the large runoff from the Western Ghats into the Arabian sea has also been demonstrated.

Vertical transport by convection plays a critical role in the global ocean circulation, influencing rates of ocean heat uptake, nutrient transport and CO2 absorption from the atmosphere. These rates are extremely important in climate dynamics and their impacts, but perhaps the most revolutionary result of our work is that convection is also shown to have a substantial influence in driving the broad horizontal circulation of the upper ocean (such as the mid-latitude gyres and the Antarctic Circumpolar Current), which is traditionally seen as being primarily wind-driven. In the area of geophysical fluid dynamics, we have also examined stirring and mixing in the Bay of Bengal, surface turbulence in the Bay, as well as moist-equatorial waves in shallow water.

Biweekly oscillations in the ocean: Data from deep sea moorings and satellites reveal distinct oceanic variability in the north Bay of Bengal in response to the quasi-biweekly (QBW; 10-25 day) mode of the summer monsoon. The Asian summer monsoon alternates between wet and windy spells and clear, calm periods. During the summer of 20125, as surface winds strengthen in active phases of the monsoon, a surface layer of low-salinity water coming from the Ganga-Brahmaputra river is carried to the north and east by swift, wind-forced ocean currents, raising coastal sea level in the north Bay of Bengal by 0.3-0.6 m in days. A week or ten days later, when the winds weaken, southward flow in 300-400 km diameter ocean eddies carries river water back to the ocean interior, and coastal sea level falls. As the river water is carried back and forth past the moorings in late summer, sensors on the moorings measure dramatic quasi-biweekly oscillations in sea surface salinity (SSS) with peak-to peak range of 3-8 psu (or parts per thousand). The salinity oscillations are also seen in remotely sensed SSS from space, and the movement of river water in the ocean inferred from sequential maps of surface salinity.

Basal melting of Antarctic Ice-shelves: In work done with PhD student M. Rosevear and researchers at the University of Tasmania and the Australian Antarctic Division, we carried out a suite of experiments to study the influence of ambient ocean currents and density stratification on the melting of ice-shelves having a near-horizontal base. In order to achieve flow regimes of geophysical relevance, we used large eddy simulations (LES) - our model captures the formation of double diffusive convective layers under ice-shelves, caused by the difference in molecular diffusivity between heat and salt. Furthermore, our simulations explain the water column structure and low melt rates observed beneath the Ross Ice Shelf, the largest in Antarctica. We further demonstrate that diffusive convection is the main process controlling melt (more important than the strength of the mean current) at observed ice shelf conditions *(PNAS,* 118 (6), 2021). Geoengineering: The injection of sulphate aerosols into the stratosphere is one of the solar geoengineering options to reduce anthropogenic warming. There are several uncertainties associated with this option. In a recent study, we investigated a single source

of uncertainty the hygroscopic growth of aerosols which depends on the ambient relative humidity. Hygroscopic growth could lead to an increase in the size of the aerosols and consequently an increase in scattering efficiency. As the relative humidity is larger in the lower stratosphere and decreases with altitude, the cooling efficiency of a fixed mass of sulphates is larger when they reside in the lower stratosphere. This effect of hygroscopic growth can be substantial: for 20 Mt-S04 that offsets the warming from a doubling of C02, we find an additional cooling of about 20%. Our results indicate the need for an accurate parametrisation of aerosol microphysical and radiative processes in climate models. https://doi.org/10.1029/2019EF001326.

Optical communication: One of the major challenges faced by Free Space Optical (FSO) communication links is the degradation due to optical scintillations caused by lower atmospheric turbulence. Our current research interests involve characterising the performance of different FSO communication links (terrestrial, aerial and satellite to the ground) under varying degrees of atmospheric turbulence conditions and its further perturbations caused by aerosols (tiny suspended particles in the atmosphere) which scatter and absorb light and consequently alter the turbulence characteristics. We have quantified the resulting alteration in the local atmospheric temperature structure and the consequent flutter in the refractive index structure parameter. He has shown that aerosol induced atmospheric warming can transform a Weak Turbulence to Moderate or Strong Turbulence, depending on the aerosol composition, size, and atmospheric residence time. This leads to significant increase in the Bit Error Rate performance.

Damaging winds: Many parts of India experience extreme wind gusts and dust storms during the pre-monsoon months of April and May. Despite their annual recurrences, their physical nature (e.g. temporal and spatial scales) and mechanism remained unaddressed in the Indian context. We carried out some case studies of pre-monsoon, damage-causing extreme winds reported from Bengaluru using in situ observations and satellite data. It is shown that all the gust cases share some common features. The first is the arrival of a pool of cold air with minimum temperature at least 10 degrees Celsius lower than prevailing about 15 min earlier. Secondly, instantaneous rainfall rate exceeds 100 mm per hour. Extreme winds are short-lived, instantaneous wind speed may exceed 75 kmph, however, winds exceeding 50 kmph last for less than 5 min. Satellite imageries show that the associated clouds were organised with a spatial scale of at least several tens of km.

Monsoon droughts: We show that over the past century, there are nearly as many number of Indian monsoon droughts that occurred in the absence of warm equatorial Pacific as there are associated with an El Nino. The evolution of rainfall in this category of non El Nino droughts differs from the conventional notion of a season-long deficit besetting monsoon droughts. Specifically, we show that an abrupt decline in rainfall in late August essentially derails the monsoon. We also report a mechanistic pathway from the North Atlantic Ocean whereby an atmospheric wave train causes this dramatic late-season deficit.

Brahmaputra discharge: On the hydrologic modelling front, we use a multi-model multi-ensemble framework to capture realistic variations in the daily discharge of Brahmaputra river. This framework would be particularly useful for the ocean modelling community, because variations of the freshwater discharge from major rivers are important for realistic simulation of upper ocean dynamics and sea surface temperature (SST) in the Bay of Bengal.

Atmosphere of Venus: We have developed a nonlinear oscillator to explain interannual variability on Venus. Water and sulphur dioxide are important trace gases in the atmosphere of Venus, and sulphur dioxide abundances at the cloud top of Venus have been observed to oscillate on interannual to decadal timescales. We have undertaken a research study, introducing a simplified model of atmospheric dynamics and chemistry to bring together the known physics of the Venusian atmosphere, and outline the mechanism that causes such oscillations.

Widespread extreme rain: The Indian monsoon is increasingly experiencing widespread floods induced

by large scale extreme rainfall events (LEREs). LEREs are mainly associated with monsoon low pressure systems (LPS). Our study shows that strong LPS by themselves are not sufficient to produce LEREs - LPS that produce large-scale extremes are accompanied by secondary cyclonic vortices (SCVs). The simultaneous existence of an LPS and an SCV creates a giant mid-tropospheric vortex, increasing static instability and large-scale extremes.

Multidecadal monsoon variability and ocean temperature: We have identified an ultra-low-frequency mode of variability in Indian summer monsoon rainfall (ISMR) with a spectral peak at nearly 67 years using singular spectrum analysis. Not only does this mode modulate the seasonal mean rainfall over India, but also frequent occurrence of excess or below normal rainfall. We show that this mode is associated with hemispheric sea surface temperature (SST) difference. The phase of the SST mode leads that of the multidecadal mode of ISMR by 2-3 years.

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ASSOCIATE FACULTY

PROSENJIT GHOSH | PhD (Indore), Professor

The faculty members are involved in innovative, multidisciplinary research using geological, geophysical and geochemical tools to understand Earth processes. Equipped with state-of-the-art analytical facilities and wide-ranging expertise, they are working on diverse problems in earthquake geology, global tectonics, core dynamics, ocean-atmosphere interaction, climate change and paleoclimate studies, petrology and geochemistry of rocks, and chemical weathering of continents.

CURRENT RESEARCH

Advances were made in understanding the stability and survival of cratons using both instantaneous and time-dependent convection models, understanding destruction of cratons by mantle plumes with a focus on the Indian craton and the evolution of geoid from time dependent mantle convection models using reconstructed plate velocities.

The petrology-based research at the Centre focuses on the evolution and crustal growth processes on the Earth during the late Archaean period (~2.5Ga). The Archean-Proterozoic boundary represents a

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IN NUMBERS

7 Academic staff
27 PhD
4 MTech students
2 MTech students
6 PhD conferments

3.5.3 Centre for Earth Sciences

CHAIRPERSON
BINOD SREENIVASAN

significant transitional period in Earth evolution when there was a sudden rise in the amount of atmospheric oxygen (Great Oxidation Event) and the birth of present-day plate tectonics. Globally, ~2.5 Ga-old terranes are rarely preserved because this period marks a sudden drop in the volume of newly formed crust, which in turn represents the beginning of active plate tectonics. Moreover, Archaean arcs and continents worldwide are unusually rich in mineral resources; accordingly, it is imperative to understand their genesis and evolution. Several fragments of the Gondwana Supercontinent, such as India, Africa, Sri Lanka, and East Antarctica, consist of the Late Archaean crust. Among these, southern India is particularly important as it contains several ~2.5 Ga crustal units metamorphosed to high-grade at ~2.4 Ga.

Our main research objectives were

• Delineation of the chronology and mineral evolution connected with geological events and processes during the late Archaean period.

• Understanding the genesis and evolution of Archaean mineral resources

New experimental and computational studies were performed on the effect of large mantle heterogeneity on core dynamics and the geodynamo. An east-west dichotomy in core convection was proposed. Further, the relative stability of high-latitude magnetic flux in the Eastern hemisphere was explained. The findings were published in the journal Earth and Planetary Science Letters. A study on the role of wave motions in planetary dynamo action was completed as part of a project funded by Ministry of Education under STARS (Scheme for Transformational and Advanced Research in Sciences). A complementary computational study was presented by Aditya Varma (PhD student) at the 2021 EGU (European Geosciences Union) General Assembly. The findings are being submitted to a peer-reviewed journal.

The key publications from the low-temperature geochemistry group includes articles on (1)

CORE RESEARCH

Planetary magnetism, Magnetohydrodynamics, Dynamo theory, Climate Change (Past and Present), Geobiology, Isotope Hydrology, Climate-Tectonics Interaction, Environmental Tracers, Microchronology, Petrology, Metamorphism, Isotope geochemistry, Origin and evolution of the Solar System, Crust-mantle processes, Paleoclimate reconstruction, Early life signatures, Solid Earth Geophysics, Lithosphere dynamics, Mantle convection, Chemical weathering and planetary thermostat, Chemical Oceanography, Seismology, Machine learning applications in geophysics.

vulnerability of corals to ocean acidification; (2) ground truthing of the boron isotope proxy, as recorded in planktonic foraminifera, to reconstruct past changes in ocean pH and atmospheric CO2 concentrations; (3) application of laser based multi collection inductively coupled plasma mass spectrometric technique to accurately determine magnesium isotope composition of marine carbonates.

A new depositional model for the two sub-basins of the Vindhyan Basin has been provided. Large seasonal variability in the composition of the Godavari River draining basalts has been documented which has important implications for understanding silicate weathering and climate change. Geochemistry of heavy mineral bearing beach sands from eastern India has important implications for REE resources. Solute exchange between surface water and groundwater from varying depths in the Sunderbans delta has been investigated.

Neural networks might have an interesting and surprising role to play in the context of geophysical imaging/inversion from sensor data and physical models. The Centre is actively working on networks that can generate helpful virtual deepfake geophysical data that were not originally recorded, but which extend the reach of inversion in a variety of ways. As the process of generating virtual data is generally referred to as redatuming, our centre demonstrated neural-network architectures that performs deep redatuming of geophysical systems. We are currently collaborating with scientists from ISRO to see if the redatuming methodology can be extended to X-ray fluorescence measurements from Chandrayaan-II. In addition to that, our group is designing networks that can be trained to reliably perform various decompositions (for example, into primary and secondary waves) of seismic waveforms.

Research work conducted in the Stable Isotope group equipped with gas source isotope ratio mass spectrometry includes both technical achievements and applications. Sanchita Banerjee (CEaS), Chirantan Pramanik (CAOS) and Subba Reddy (Dept of High Voltage Engineering) published papers demonstrating experimental and theoretical understanding of clumped isotope fractionation during acid digestion procedure during generation of CO2 for clumped isotope thermometry. Ab initio calculations accurately predicted the clumped isotope ratios using different experimental protocols of acid digestion and resolved the inconsistency of thermometry calibration proposed by different workers. A former PhD scholar, Benjamin Fosu along with PhD student Rachana Subba introduced and published a new technique of CO2-O2 equilibration in presence of Platinum sponge for analysis of O17 excess. A former student, Dr Ravi Rangarajan and others published a new method for preparation of carbonate for rapid analysis of stable isotopes using Gas bench II peripheral.

These techniques are applied to assess the behaviour of temperature and oxygen isotopes (mass-dependent fractionation) during the formation of carbonatites from diverse localities worldwide and published in Geochimica et Cosmochimica Acta. This study constrains the temperature and fluid responsible for the crystallisation of carbonate magma and assigning triple oxygen isotopic composition ($\Delta 17O$) of the upper mantle.

Another highlight is the tracking moisture transport and precipitation using stable isotopes in water vapour from Kashmir Himalayas. A paper published in JGR (Atmospheres) by Shakir Dar identified two prominent atmospheric systems: Western Disturbances (WDs) and Indian summer Monsoon (ISM) and their contribution to seasonal precipitation in Himalayan region. In a separate study on the Southern Ocean water vapour isotopes (Journal of Atmospheric Chemistry and Physics), Dr Dar showed that with proper accounting of evaporation and molecular vs. turbulent diffusive transport process in a physical model, one can predict stable isotopic composition in the water vapour with a higher degree of confidence.

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VENUGOPAL VURPUTUR | PhD (Minnesota), Associate Professor

The Department of Chemical Engineering is a center of excellence in chemical engineering research and education. It has 12 full-time faculty, 1 Ramalingaswami fellow, 1 DST-INSPIRE faculty fellow, 1 adjunct faculty fellow that works in industry, and 54 students carrying out research in both fundamental and applied areas with a strong synergy with industry.

CURRENT RESEARCH

Interactions of small molecules and proteins have been investigated using a combination of molecular dynamics simulations and experiments. Influence of pore forming proteins on GUVs reveals a link between bound states of the protein and lipid dynamics. Insert of small molecules into bacterial membranes has been investigated using MD simulations and fluorescence correlation spectroscopy. Using lipid dynamics as a measure of permeation we find that the bacterial lipopolysaccharide (LPS) outer membrane offers a barrier to small molecules. Free energy simulations reveal that the rough LPS has a highest barrier. Bound states which are not membrane inserted lowers the lipid diffusivity, however membrane inserted pore states enhance the lipid diffusivity. In other studies we have investigated the structure and dynamics of

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IN NUMBERS

12 Academic staff
54 PhD students
2 MTech (Res) students
48 Publications
10 MTech conferments
11 PhD conferments

3.5.4 Chemical Engineering

CHAIRPERSON
SANJEEV KUMAR GUPTA

water confined in graphene oxide nanopores. Studies with supercooled water indicate that the dynamical transitions are a strong function of the extent of hydrophobicity.

The flow of granular materials through vertical channels and pipes, and inclined chutes was examined using the discrete element method (DEM). Temporal oscillations were observed in flows of low bulk solids fraction through channels and pipes. For plane shear between parallel plates in the absence of gravity, and flow through a vertical channel, computations were done using continuum equations based on kinetic theory to check the earlier results of Alam and Nott (1997) and Mohan et al. (1997). The trends were similar for some parameter values, but there were some quantitative differences. The continuum model of Barker et al. (2017) was solved for a vertical channel. Velocity profiles were similar to the DEM results, but the solids fraction near the wall was overestimated by the former. For chute flow, the angle at which the flow becomes accelerated increased with the width between the sidewalls.

Integrated transesterification (heterogeneous catalyst + supercritical methanol) of Mahua oil using eleven different solution combustion synthesised metal oxides and supercritical methanol was performed to synthesise fatty acid methyl esters. The solubilities of 10-undecenoic acid, geraniol, 10-undecenol and geranyl butyrate in supercritical carbon dioxide and their variation with operating temperature and pressure was investigated. Five new semi-empirical models based on the association and solution theories with various activity coefficient models to correlate the solubility data with operating temperature, pressure, and densities. Metal free semiconductor C3N4 was coupled with CuWO4 in order to understand the Z-scheme mechanism of photocatalysis for mineralisation of organic matter in waste waters. This Z-scheme composite was exploited for simultaneous inactivation of gram positive and gram-negative bacteria and extensive analysis of kinetics was studied for both the scenarios.

Particulate flows occur widely in nature and industry, but understanding of their mechanics lags far behind that of fluids. The work of my group spans dry granular flows to viscous particle-liquid suspensions and active suspensions. Using tools from graph and network theories, we have developed a statistical understanding of stress transmission in grain assemblies. We have developed a nonlocal constitutive model for dense granular flows that incorporates dilatancy, for use in continuum descriptions. In the area of particle-liquid suspensions, we have demonstrated that the

CORE RESEARCH

Biomolecular and Biomedical Engineering, Catalysis and Reaction Engineering, Colloids and Interface Science, Complex Fluids and Transport Processes, Nanotechnology and Nanomaterials, Energy Science and Engineering, Environmental Engineering, Thermodynamics, Statistical Mechanics and Molecular Simulations

phenomenon of discontinuous shear thickening (DST) is more complex than previously understood.

The research work in our group has been in two broad areas. In the area of particle-gas suspensions, the turbulence attenuation and particle dynamics in the turbulent flow regime was studied using a combination of Direct Numerical Simulation (DNS) for the fluid flow and a discrete element simulation for the particles. It was found that at even at very low volume fraction of particles, as the particle volume fraction is increased, there is a discontinuous decrease in the turbulence intensity by 1-2 orders of magnitude at a critical volume fraction. This decrease is observed for a range of particle and fluid parameters, indicating that this turbulence collapse is a property of particle-gas suspensions. Another area of active research is magnetorheological fluids, where a viscous suspension of magnetic or polarisable fluids are subject to a magnetic field. There is a variation in the viscosity of many orders of magnitude upon application of a magnetic field, and the suspension can virtually jam at a critical value of the magnetic field. Our study has focussed on two aspects, the single-particle dynamics of spheroidal magnetic or magnetisable particles, and the study of conducting particles in a magnetic field. The particle dynamics has been comprehensively studied, and predictions have been made for the effect of particles on the rheology.

The soluble lead redox flow battery for large scale energy storage, from solar, wind, or other sources, offers potential advantages as it does not employ a membrane which typically get fouled and need periodic replacement or a porous electrode that requires high pressure drop as in the currently used vanadium redox flow battery. Our group showed the dominant role played by concentration gradient driven natural convection. In an effort to take it towards a pump-less battery, we have shown a number of configurations that exclusively rely on natural convection driven motion to being about mixing and charge battery at low potentials and discharge it at high potentials. The new configurations include off-wall electrodes, addition of an external circulation loop driven by natural convection, and a set of staggered electrodes of small heights.

A process engineering toolkit is being developed that will enable the use of metallic nanostructures as building blocks for applications in the fields of sensing, energy conversion, and nanoelectronics. We have developed a scalable process for the formation of self-assembled arrays of metal nanoparticles on any desired substrate. This has aided in the fabrication of several devices such as floating gate memory devices, flexible SERS (Surface Enhanced Raman Scattering) substrates and PEMFC (Proton Exchange Membrane Fuel Cell) catalyst layers.

Our work has focused on understanding viral infections and improving their treatments and also the design of microbiomes. We developed a description of the outcomes of viral infections, explaining why some infections are cured while others turn chronic and yet others cause host death *(PNAS).* We constructed a multiscale viral evolutionary framework for viruses such as hepatitis C which are subject to selection pressures within and outside cells *(PLoS Pathogens).* This framework may help identify drug combinations that would not succumb to resistance. We unraveled a synergy-efficacy trade-off that constrains the choice of drug combinations *(Trends in Pharmacological Sciences).* We developed an in silico framework of antibody production and showed how passive immunisation, where external antibodies are injected, can improve the natural production of antibodies *(Cell Reports)*. Finally, with colleagues from Unilever, we showed how high-order interactions stabilize microbiomes (IECR).

Original contributions have been made in the following areas: 1) Solid-fluid interfacial free energy: We have developed a general method for computing solid-fluid interfacial free energy using molecular simulations. The novelty of the method is that this is for the first time, such a calculation has been done for a molecular system. In addition, the simulations can be performed using the open-source molecular dynamics package LAMMPS. 2) Dissociation temperature of semi-clathrates: Semi-clathrates are inclusion compounds formed by water and salts such as tetra butyl ammonium bromide (TBAB). They are similar to gas hydrates, with a major difference being the anions form a part of the hydrogen bonded water lattice. We

have, for the first time, computed the dissociation pressure of TBAB semi-clathrate using molecular simulations. The calculation also helps us to judge the suitability of various forcefields in simulations of these materials.

A simple mathematical framework to describe the temporal evolution of various viral molecules by modeling all the intracellular processes relevant to the viral RNA (for the Flaviviridae family) was developed. We used a stochastic framework to address resource (viral RNA) sharing during the start of infection when viral RNA is present in low copy. This model accurately captures the experimentally measured viral dynamics from many studies across multiple virus families. Based on our findings, we propose a new concept of 'Stochastic Infectivity' that would be useful in analysis of candidate fitness functions like infectivity, viral loads and mutability.

Further, to push the limits of non-optical detection of cells, we have developed a low-cost disposable Lab-On-Chip device for cell-in-droplet counting. We established a novel multi-layer device fabrication methodology that uses fusible alloy to replace metal microelectrodes but demonstrates high sensitivity for cell impedance measurements in a flow cytometry configuration for single cell and microdroplet measurements.

A portable device for detection of tuberculosis DNA called FLIPP-NAAT was developed. A method for uniform mixing of dried reagents with a rehydrating fluid in paper microfluidics was developed. A device called SPECTRA-Tube for dry storage and transport of large volumes (~2 ml) of sputum was developed. A method to expand the dynamic range of commercially available lateral flow assays using real time imaging was developed.

Paper-based on demand separation and SERS detection of mixtures; Inkjet printed strain sensitive nanostructures;

The steady flow of granular materials through a vertical channel of rectangular cross section is examined using the discrete element method (DEM) and the continuum models of Henann and Kamrin (2013), Barker et al. (2017), Schaeffer et al. (2019), and Dsouza and Nott (2020). The channel is bounded by flat walls separated by a distance 2 W in the x-direction. For the DEM, periodic boundary conditions are used in the z- and the y- (vertical) directions. The models are solved for the case of steady fully developed flow, The flow spans the range from slow flow at the centreline x = 0 to rapid flow near the wall x = W. In all the cases, there is a plug layer near the centreline and a shear layer near the wall, in accord with experimental observations. However, there are significant differences between the DEM results and the model predictions, either with respect to velocity profiles, solids fraction profiles, or normal stresses. Measured vertical velocity profiles match the DEM results.

1) We have developed a general method for computing solid-fluid interfacial free energy using molecular simulations. The work was published in the Journal of Chemical Physics (vol. 153, art. 154504) 2) We have, for the first time, computed the dissociation pressure of TBAB semi-clathrate using molecular simulations. The work was published in the Journal of Physical Chemistry B (vol. 124, pp. 9195) 3) We developed a method for modelling many-body interactions between colloidal using a set of symmetry functions. The work was in collaboration with Utrecht University and was published in the Journal of Chemical Physics (vol. 153, art. 064902). The paper was selected as an Editorâ€™s Pick. 4) We simulated the antifreeze activity of a type-III AFP using molecular dynamics. The results revealed valuable insights into the mechanism of antifreeze action by type-III AFPs. The work was partially funded by Unilever R&D and published in Langmuir (vol. 36, pp. 2439)

In the current calendar year, I published the following research articles with an IISc affiliation: (1) Gupta, A.; Govind Rajan, A.; Carter, E. A.; Stone, H. A. Ionic Layering and Overcharging in Electrical Double Layers in a Poisson-Boltzmann Model. Phys. Rev. Lett. 2020, 125, 188004. In this work, we developed a continuum model to describe ionic concentration oscillations in electric double layers that form at electrode-electrolyte interfaces. (2) Gupta, A.; Govind Rajan, A.;

Carter, E. A.; Stone, H. A. Thermodynamics of Electrical Double Layers with Electrostatic Correlations. J. Phys. Chem. C 2020, 124, 49, 2683026842. In this work, we developed a theoretical framework to describe the effect of electrostatic correlations on ionic concentrations at electrode-electrolyte interfaces. Apart from these research articles, I also published 5 other papers, but they are not included here as they were based on work primarily done during my postdoctoral appointment at Princeton University.

A new turbulence collapse transition was observed in numerical simulations of turbulent particle-gas suspension at high particle Stokes number where the particle inertia is significant at very low particle volume fraction of less than 0.1% The dynamics of a conducting particle in a shear flow subjected to a magnetic field was analysed, and it was shown that this could result in an antisymmetric stress which qualitatively modifies the rheology of the flow. The instability of a vibrated fluid-solid system is found to be qualitatively different from that in a two-fluid system, and different modes of instability have been identified.

Molecular dynamics simulations with pore forming proteins illustrate the reorganisation of lipids and cholesterol in phospholipid membranes leading to spatial variation in lipid dynamics. Fluorescence correlation spectroscopy (FCS) reveals the interplay between lipid ejection and crowding due to listerolysin O pore formation on model supported membranes. Insertion free energies in Gram-negative bacterial membranes reveal the presence of barriers in the outer membrane and FCS experiments capture bacterial lipid dynamics in the presence of small molecules. A new coarse-grained model for the bacterial cell wall peptidoglycan was developed. Relaxation dynamics of confined supercooled water in graphene oxide nanopores with varying levels of oxidation states illustrates the connection between surface hydrophilicity and rotational relaxation. In other research, adsorption of carbon-di-oxide in polymeric membranes was investigated using molecular simulations.

We have solved a long-standing puzzle in the mechanics of coarse granular materials, namely the occurrence of "force chains". Using tools from graph analysis and network theory, we showed that their occurrence is purely due to the topology of the contact network, and connected the orientations of force chains to the macroscopic mechanics of the medium. We have developed a nonlocal constitutive model for dense granular flows that for the first time couples the kinematics and density change in a manner that explains Reynolds dilatancy. We have carried out rheometry of dense suspensions experiments to demonstrate that the phenomenon of discontinuous shear thickening (DST) is more complex than previously understood. We have shown by particle simulations and experiments that dilatancy-driven secondary vortices are generic in dense granular materials.

Our work last year has focussed on HIV and SARS-CoV-2 infections as well as on microbial communities. Early treatments using antibodies have been shown recently to induce lasting control of HIV infection in monkeys, obviating the need for lifelong therapy. We developed a new mathematical model that explains the mechanisms involved and may aid the translation of such therapies to humans. Together with colleagues in physics, we performed sophisticated simulations of HIV entry into cells that brought out the important role played by lipids in facilitating HIV entry. With SARS-CoV-2, we elucidated novel synergies that could be realised by drugs targeting its entry into target cells. We have also contributed to the effort on campus to develop models of its spread in cities. Finally, in collaboration with Unilever, we developed new models to quantify the interactions between microbial species in communities that would aid in community engineering.

Porous activated carbon-based super capacitors offer low-cost options for storage and release of electrical energy. They suffer from low efficiency when these processes must occur rapidly over time scale of seconds. Our studies combined measurements with an in-house developed comprehensive transport model to address charge/discharge. If the migration of ions in pores were to slow down as expected for many other systems, the efficient should have remained at 100%. The reason for the observed low efficiency is more than several orders of magnitude smaller conductivity

of ions in pores than the ratio of straight length to the tortuous path length. Orders of magnitude larger than expected impact of pores on electrolyte conductivity was hitherto unknown.

Developed an isothermal (PCR-free) nucleic acid amplification test for COVID19 - Developed a method to expand the dynamic range of lateral flow immunoassays. The method involves time lapse imaging of lateral flow strips using a cell phone app. Development of the method was guided by a transport reaction model of chemical phenomena occurring on the lateral flow strip. - Developed the first stoichiometric and pseudo-kinetic mathematical model of the reaction called LAMP (loop mediated isothermal amplification) - Developed a design toolbox to assist in the design of two-dimensional paper networks for sequential delivery of multiple fluids to a test zone - Developed a barrier-free paper microfluidic device for the multiplex detection of analytes in a body fluid

Our group generated a general model for lifecycle for RNA viruses and demonstrated its wide applicability to replicate several virus-host cell interactions. Moreover, we showed that early bottlenecks in virus lifecycle can result in stochastic extinct of the virus infection and hence single virus infections are difficult for many viruses like HCV. By evaluating the synergy between various anti-viral strategies, we have proposed new ways to inhibit virus growth. Using an experimental model system of Japanese Encephalitis virus infection in cells, we probed how this virus modulates its protein production across its genome with single-nucleotide resolution. While the JEV proteome is translated as a single polyprotein, 40% of the time a frameshifting event stops translation and yields the NS1′ protein instead of the canonical NS1. Similarly, we found previously unidentified putative translated peptides in the 5′ UTR region that might regulated neuro-invasiveness.

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The department spans four major areas: Structural, Geotechnical, Water Resources and Environmental, and Transportation Systems Engineering. A wide spectrum of research activities - analytical, numerical, and experimental - are pursued. In addition to the doctoral and masters research, a unique MTech programme is offered where a student can opt for a major and a minor.

CURRENT RESEARCH

Rupture based seismic hazard analysis methodology was developed by considering seismic energy released in the past and future problem location based on energy difference. The seismic hazard analysis of Krishna Raja Sagar Dam was carried out by a new approach and shown how seismic hazard values are representative compared with an old conventional method. Seismic site characterisation of deep soil sites and shallow bedrock sites are investigated through an integrated subsurface exploration testing and analysis. Further soil moisture prediction model was identified using Indian soil data for soil moisture estimation for the irrigation and water management applications.

The mechanics of granular materials at multiple length scales was investigated. Especially quantification through extensive imaging and image analysis. Quantification of the effects of small amounts of cohesion between particulates, severe plastic deformation in granular materials, and response of granular

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112 PhD Students
5 MTech (Res), 61 MTech
106 Journal Publications
2 MTech (Res), 12 MTech
16 PhD Conferments

3.5.5 Civil Engineering

CHAIRPERSON
ANANTH RAMASWAMY

materials over a range of strain rates. Synchrotron studies on cemented granular materials have been initiated through some preliminary experiments in the Cornell High Energy Synchrotron facility. Experiments conducted on the synchrotron will provide both information on the kinematics as well as force transfer in particulate assemblages. Using orthogonal cutting configuration, the effect of severe plastic deformation in granular ensembles was investigated. The effect of strain rate on the response granular material response is also studied. Indentation, cutting and drilling in model bones was investigated using image based deformation measurements.

Modelling the rocking and sliding of free-standing objects using rigid body dynamics. The features of an open-source finite element software MASTODON, used for seismic analysis and risk assessment of critical infrastructure. Analysing the response of embedded structures such as tunnels and embedded nuclear power plants under near-fault earthquake loading conditions.

Three dimensional (3D) morphological characterisations of sand and correlated the results with macroscopic interface shear characteristics of sand. Investigated the feasibility of using manufactured sand for cover soils in landfill liners. Effects of hydration on soil-geosynthetic interactions, in the contact of landfill lining are explored and important insights on particle trapping in geosynthetics and its effects on interface shear strength for immediate and long-term applications are demonstrated. Use of geo-foam and geotextiles for liquefaction mitigation during earthquakes is explored and pore water pressure development in the presence of polymeric layers is explained in terms of densification effects. Using probability based framework, optimised stabilisation techniques are developed for the ongoing Chenab railway bridge project.

Bio-mineral cementation of soils is demonstrated using microbial activity of cattle manure. One path involved carbonate cementation of mineral grains by the anaerobic reactions, while the other path was extracellular polysaccharide (EPS) bonding by bacteria in cattle manure. Both modes enhanced the compression strength of the stabilised specimen by 720%. Blackwater discharged from onsite sanitation facilities is a major source of groundwater nitrate contamination. However, owing to rapid urea oxidation, the potential nitrate loads in aquifers from

CORE RESEARCH

Some major research thrust areas are predictive science, theoretical and applied mechanics, large scale testing, water resources and environmental engineering, and transportation systems engineering. While the analytical and computational research spans from theoretical development to high performance computing, the experimental research spans from laboratory based to field studies

on-site sanitation facilities is not known, the study on urea transformation reactions in blackwater has shown that the nitrate concentration in 1 km2 of hard rock aquifer would annually increase by 0.004 mg/L due to blackwater infiltration from single household pour flush toilet.

Methane emissions from landfills and dumpsites pose significant environmental hazard in India. New cover systems involving the use of mechanically biologically treated waste are developed. These cover systems convert methane to carbon dioxide reducing the impacts significantly. A methodology for rehabilitation of dumpsites is developed using methane gas extraction and recirculation of dumpsites. This is a novel method which has impact on reducing the contamination of ground, water and air. Methodologies for consideration of variable earthquake motions and rainfall characteristics for incidence of landslides are proposed. These are useful in reducing the hazards due to landslides.

Studies on design methods for pad foundations for large size oil tanks. Methods to improve bearing capacity of pad foundations on soft soils are investigated. Comparison of soil water content estimation equations using ground penetrating radar are studied in detail.

Remeshing framework for simulation of the collapse of voids in micro indentation, Extension of general adaptive remeshing for simulation on polycrystalline aggregate cutting for multi-pass machining and FE of adhesive contacts; first-in-class resolution of snap-through and snap-back instabilities in adhesion.

An error bound for reduced order models is developed in nonlinear dynamical system. This bound is subsequently used to develop a new algorithm of uncertainty quantification, which gives two orders of magnitude of computational speed-up. In this context we also have developed a new training scheme for reduced order model. We have developed a domain-decomposition based method for uncertainty quantification, which is also under review.

Development of an isogeometeric based formulation for bending analysis of laminated composite beams is done. The interface behaviour of cement stabilised rammed earth is characterised through experimental and numerical studies. Furthermore, non-linear finite element analyses for assessing the seismic performance of containment reinforced masonry buildings were conducted. Currently computational investigations are in progress for assessing seismic vulnerability of unreinforced and reinforced masonry buildings using rocking phenomena. In addition, numerical investigations using finite element method are in progress for assessing seismic vulnerability of unreinforced and reinforced masonry buildings accounting for uncertainty in earthquake loading and material response.

Material characterisation - Hygro Thermo-mechanical modelling of structural concrete at macro and mesoscale is in progress. Effects of environmental conditions-relative humidity and temperature effects on concrete, the response of concrete to relative humidity, temperature and mechanical loads is done. Movement of moisture and heat into the concrete system can result in volume change that can contribute to creep and shrinkage loss that would also contribute to loss of prestress in PSC structures and become a factor effecting safety of the structure. Similarly, high temperatures, such as due to fires can lead to moisture agress and breakages in the molecular structure of concrete and degrade the strength and stiffness of concrete.

Research contributions in fracture and fatigue behaviour of cementitious composites are made by making use of the acoustic emission and digital image correlation as a tool in experimental investigations. Through this study, the mechanisms of microcrack formation and the development of the fracture process zone under both monotonically increasing loading and fatigue loading are understood. The effect of various parameters including the size of concrete beams, the amplitude of fatigue loading, the frequency of loading, and notch size on the fatigue behaviour of concrete is understood and important conclusions have been reported. Furthermore, the effect of overloads in the fatigue cycles is included in the development of a crack growth law based on a more rational theory. The drawbacks of existing practices of crack length computation using the compliance method

and fracture energy determination using the RILEM method are highlighted.

Improving the ductility of stabilised rammed earth through natural fibre reinforcement is another area of research being pursued including behaviour of coir fibre reinforced rammed earth under compression, flexure and shear. Fibre reinforcement and the use of novel shear key techniques drastically improves the post peak behaviour of rammed earth, attaining failure strains of the order of 2 - 3%. Studies on alkali activated binders for the manufacture of compressed earth bricks without using energy intensive firing process and Portland cement. A novel manufacturing process for the compressed earth bricks utilising non-organic solid wastes and alkali activation process is under development.

Development of computationally efficient methods based on Markov Chain Monte Carlo and Girsanov transformation based techniques for time variant reliability of vibrating structures is under progress.

Sustainable transportation planning and policy, integrated public transport planning and management, transport and Quality of Life (QoL), transport and climate change, modelling and optimisation of transportation systems, travel behaviour analysis and modelling, pedestrian and crowd flow modelling, driver behaviour and road safety, intelligent transportation system (ITS), traffic control & management, rebalancing in bicycle sharing systems, transit routing algorithms and their applications using Bangalore transit data, development of contact tracing app GoCoronaGo (GCG), bus bunching solutions for public transit, driving simulator using gaming engines and traffic flow models, first- and last-mile supply optimisation, algorithms for cab matching in shared mobility systems

Global satellite-based Soil Moisture (SM) data is being used routinely in recent years in applications pertaining to climate studies, agricultural water resource management, and hydrology. In this context, validation of the remote sensed measurements, which are representative of an area covering 100 sq.m require ground measurements at a suitable scale than conventional in-situ SM measurements at point scale. A study was conducted using the data from the Indian Cosmic Ray Network (ICON) available since 2016, which provides in-situ measurements over an area with a radius of 150–250 m to compare them with remotely sensed SM at different depths. The COSMOS-derived soil moisture is compared to surface soil moisture (SSM), and root zone soil moisture (RZSM) derived from SMOS, SMAP, and GLDAS_Noah. Results of the comparison with surface soil moisture products indicated that the SMAP_L4_SSM showed the best performance overall for the ICON sites, with correlation values ranging from 0.76 to 0.90.

Mapping soil properties is becoming more and more challenging due to the increase in anthropogenic modification of the landscape, calling for new methods to identify these changes. A striking example of anthropogenic modifications of soil properties is the widespread practice in South India of applying large quantities of silt from dry tanks or lakes to agricultural fields. Whereas several studies have demonstrated the interest in tank silt for soil fertility, no assessment of the actual extent of this age-old traditional practice exists. Over South-Indian pedological context, this practice is characterised by an application of black-coloured tank silt to red-coloured soils such as Ferralsols. A study was conducted to evaluate the usefulness of Sentinel-2 images for mapping tank silt applications, hypothesising that observed changes in soil surface colour can be a proxy for tank silt application. We used data collected in the Berambadi cultivated watershed, which is part of the Kabini Critical Zone Observatory for this study. The results showed that 1) the CART (Cost-Sensitive Classification and Regression Trees) method allowed to classify the "Red" and "Black" soil with correct overall accuracy from Sentinel-2 images. With the actual availability of the Sentinel-2 and the past availability of the LANDSAT satellite imageries, this study may open a way toward a simple and accurate method for delivering tank silt application mapping and so to study and possibly quantify retroactively this farmer practice.

Research in broad areas of stochastic hydrology resulted in several contributions: (i) A framework for

streamflow simulation incorporating spatial correlation and time irreversible dynamics is developed. This framework may be used for multisite streamflow generation keeping the physical features of flow hydrograph, (ii) A methodology to investigate the association of extreme rainfall events with physical drivers and to model their dependence structure is developed and applied to the Mahanadi River basin in India. This methodology can capture the non-stationarity in variables: ENSO index, global temperature and local temperature and facilitate modelling their dependence structure with extreme rainfall, (iii) The influence of threshold selection in modelling extreme rainfall under non-stationary scenario is performed. It is found that threshold uncertainty is more for high return period events. Prediction of hydro-meteorological variables and environmental extreme events (e.g., rain storms, floods, droughts) is vital to planning, design, and risk assessment of civil engineering infrastructure, which is meant for water control, conveyance, and management. The task of prediction becomes a challenge for sparsely gauged and ungauged locations and in areas where there is evidence of climate change. For use in these contexts, new approaches are proposed. Recently a new regionalisation approach is developed in a fuzzy framework to delineate homogeneous evapotranspiration (ET) regions. It yielded eighteen regions over India. For those regions, the effect of climate variables on ET and long-term (annual) surface runoff changes is quantified. Furthermore, new relevance vector regression relationships are developed for the regions to arrive at FAO Penman-Monteith estimate of ET from limited climate variables in data-sparse locations. An unresolved problem in the statistical analysis of hydrological extremes (e.g., storms, floods) using the Peaks Over Threshold model is the identification of optimal threshold. There are various issues affecting the performance of different methods available for threshold selection (TS). To overcome those issues, Mahalanobis distance-based automatic TS method is contributed. Furthermore, a fuzzy ensemble clustering approach is contributed to deal with uncertainty in the composition of watershed groups formed using different regionalisation approaches for regional frequency analysis of hydrologic extremes (floods, droughts).

Research is undertaken on remote sensing applications in hydrology/hydrometeorology. (1) Simultaneous retrieval of global scale Vegetation Optical Depth (VOD), surface roughness, and soil moisture (SM) using X-band AMSR-E (Advanced Microwave Scanning Radiometer – Earth Observing System) sensor observations: Simultaneous Parameter Retrieval Algorithm (SPRA) method is proposed to obtain SM, VOD and surface roughness from AMSR-E X-band satellite brightness temperatures (TB). Global surface roughness map developed shows dependencies with vegetation and topography. SPRA soil moisture indicated better consistency with precipitation over India. (2) Partial informational correlation-based band selection for hyperspectral image classification: Hyperspectral (HS) data are enriched with highly resourceful abundant spectral bands. However, analysing and interpreting these ample amounts of data is a challenging task. Optimal spectral bands should be chosen to address the issue of redundancy and to capitalise on the absolute advantages of HS data. Partial informational correlation (PIC)-based band selection approach is proposed for feature selection-based classification of HS images. (3) Surface water storage trends were assessed for increasing groundwater areas in India in peninsular river basins using GRACE (Gravity Recovery and Climate Experiment) satellites data. The GRACE satellite mission launched in March 2002 provides unprecedented data of Terrestrial Water Storage (TWS), comprising of surface and subsurface water storages. GRACE derived gridded TWS time series, and Theil-Sen's slope were used to estimate the trend magnitude. Results showed areas of increasing trend of TWS in the West Central and South-Eastern parts of India having trend magnitude as high as 20 mm/year over a few grids. Instead of a river basin-based approach, a region-based approach was adopted in the present study which considers the heterogeneity of trend in TWS over the Godavari and Krishna river basins, and the relatively small size of the Narmada, Tapi, and Mahi river basins. Granger causality test was performed to identify the causative factors influencing the trends. Recovery from 2002 major drought is observed as one of the major causes of increasing trends in surface water observed in all the river basins studied.

Research is also pursued in the areas broadly encompassing high-resolution remote sensing, ecohydrology, and coupled carbon and water cycles in terrestrial ecosystems incorporating both data-driven and physically process-based modelling approaches. Research contributions include (i) utilisation of newer remote sensing measurements such as solar-induced chlorophyll fluorescence from the ground as well as space-based observations to quantify crop yield, (ii) decomposing reflectance spectra to track gross primary production in a subalpine evergreen forest. Estimation of gross primary production (GPP) from remote sensing indices represents a primary source of uncertainty, in particular for observing seasonal variations in evergreen forests. In this study driving spectral components in the measured canopy reflectance were analysed using both statistical and process-based approaches and (iii) Utilising satellite solar induced chlorophyll fluorescence and process-based modelling to track seasonal and interannual variability in photosynthetic downregulation in response to water stress at a temperate deciduous forest.

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Centre for Product Design and Manufacturing (CPDM) is among the most research and technology intensive design and manufacturing schools in India, steeped in the ambience of Indian Institute of Science (IISc). CPDM is the design and manufacturing face of IISc.

CURRENT RESEARCH

Product Development Process, Informatics, Innovation: A model for synthesis of multiple state mechanical devices is proposed and empirically validated. A gamified tool for training schoolchildren in design thinking has been developed; in studies with schoolchildren it was found to improve their learning at all levels of Bloom's taxonomy, especially at the two highest levels: evaluation and synthesis, that are currently not supported in school education. A Computation of Minkowski sum has diverse applications but its exact computation is complex; using novel slice-representation, a space partitioning scheme for polyhedrons, both exact convex decomposition and computation of non-regularised Boolean of thousands

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IN NUMBERS

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1 Scientific Staff
69 PhD Students
34 MDes; 17 MTech (SM); 1 MSc (Engg); 1 MTech (Res)
20 MDes Conferments
1 PhD Conferments

3.5.6

Centre for Product Design and Manufacturing

CHAIRPERSON
AMARESH CHAKRABARTI

of components robustly and efficiently, has been achieved. A marching sphere algorithm is developed to compare data sets measured off two configurations of a surface where the surface is highly deformable.

Human Factors: Natural behaviour simulation using digital human models through balanced postures, autonomous bracing for performance enhancement without over-stressing itself has been achieved. Development of PURAK, affordable, functional, trans-radial prosthetic device is completed with conduction of pan-India user trials, leading to a start-up. A realistic Virtual Road Environment generation for driving response/behaviour simulation study with India-specific landmarks, unique buildings and trees, unique nature of traffic components etc has been developed for an extended stretch of Indian road to study driver's on-road visibility and response while driving in the simulated environment. Current tools for this provide only partial solutions. To overcome this, a tool has been developed for real time eye-ball detection along with eye landmarks in different eye configurations using data collected using mobile phone cameras. A computational model for sweat evaporation process for Indians is developed. An eye gaze-controlled heads-up display for cars has been invented. A multimodal collaborative robot for assistive tasks for spastic children and young adults as well for smart manufacturing tasks. A digital twin is developed for detecting position and number of people in a meeting room and alert violation of social distance in the context of Covid appropriate behaviour.

Materials and Manufacturing: A solution for improving quality and durability of wood using non-destructive testing, synthesis, and characterisation of nanocellulose reinforced biodegradable composites has been proposed. Significant progress has been made in mechanical characterisation and simulation of jute-polyester/epoxy composites under impact loads, robust constitutive modelling of glass and carbon fibre composites by taking into account off-axis experimental behaviours, and a new cost-effective approach for determining orthotropic lamina properties in a laminate, optimisation of cross-ply composite laminates using machine learning techniques. The national common engineering facility centre (CEFC) for smart factory has started functioning as a testbed for manufacturing research, with development of sparse-data analytics tools that combine physics with data science for prediction of failure in legacy machines. A new laboratory has been setup for research into robotics and autonomous systems, including collaborative motion planning for

CORE RESEARCH

Product Development Process, Informatics, Innovation, Entrepreneurship, Creativity, Biomimetics, KBS, PLM, Human Factors, Digital Anthropometry/Modelling, HMI, OHAS, Clinical Engineering Research, Medical Devices, AR/VR/Haptics, Sustainable Materials, Processes and Built Environment, Design for BoP, CAD/CAE/BIM, Digital and Smart Manufacturing, Additive Manufacturing, Robotics, Controls and Autonomous Systems.

autonomous mobile robots (AMR) for dynamic and complex environments, multi-robot collision avoidance solutions, etc. A four-axis robotic arm and vision system has been integrated for supporting vision-based detection and sorting of objects and planning robot paths. A conceptual model for droplet on demand metal 3D printing system has been proposed, and technology validated for the droplet mechanism. Part tracking and automated inspection are important aspects of implementing industry 4.0. In order to reduce tedium and subjectivity in manual inspection a system has been developed for automating part tracking and visual inspection at the production floor.

Sustainability: Given current environmental disruptions, climate change and inequitable access to wellness, design could play a pivotal role in aiding sustainability by alleviating negative impacts associated with products, mitigating climate change, restore environmental vitality, and as a means to livelihood enhancement, health and overcoming poverty. Design today is imbibing sustainability as a critical product value, and requires careful scrutiny and insight. Current research deals with sustainability as an interdisciplinary science, focusing both on its theoretical basis, and application in architecture (buildings) and design. Designing and manufacturing comprises a globally distributed network requiring assessments characterised to various geographies, associated ecosystem services and cultures. Focus includes assessing active impacts traceable to design and manufacturing for circularity. A framework has been developed for modelling factories for guiding collection of data for assessing sustainability of products made in the factory; collection of data for manufacturing of a product using this framework has led to a substantially improved estimation of sustainability impacts of the product. Various sustainable materials such as Aluminium foam and bio-composites have been developed and characterised, with significant promise for reduction of environmental footprints.

Technology Integration: A formulation for a detailed human-body leg finite element model for biomedical engineering studies and impact/blast injury prediction has been developed. A novel Direct Methanol Fuel Cell-based range-extended aluminium-intensive lightweight electric passenger car has been proposed. Progress has been made in expanding future testing capabilities in the areas of drop-weight impact testing and material characterisation at high strain rates using a Split Hopkinson Pressure Bar device. A suite of the state-of-the-art AI tools for automotive subsystem design and advanced finite element modelling procedures for assessing exhaust valve performance under dynamic pressure loads are being developed. Work has been initiated in developing a next generation tele-ultrasound system for foetal imaging. Development of functional prototype of an indigenous insulin pump has been completed. Connected healthcare solution to support parents of children with hearing impairment is developed in the form of a mobile application with connected training toys. Based on Image processing, process for real time lane detection for driver assistance are being developed for various environmental and road conditions.

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The Centre for Sustainable Technologies established in 1974 as ASTRA (Application of Science and Technology for Rural Areas), pursues cross-cutting collaborative research in areas of sustainable energy, buildings and environment. Current research addresses a host of global concerns while focusing on decentralised S&T based interventions: efficient use of primary resources, development of low energy buildings, building integrated photovoltaics, waste & sanitation, clean & renewable energy, waste management including sanitary land filling, waste to energy, waste recycling & waste disposal, bio-mass for energy, plasma technology, grey water treatment and recycling, plasma hydrocarbon reforming, clean coal technologies, biomass to liquid fuels and fuel cell applications, bio-methanation, turbomachinery research for energy & water pumping.

CURRENT RESEARCH

Climate responsive architecture: Building and architectural sciences dealing with climate-responsiveness and thermal resilience of vernacular and conventional building typologies, particularly in response to climate change. Examining wellness in buildings, particularly the role of moisture and thermal comfort. Integration of

3.5.7 Centre for Sustainable Technologies

CHAIRPERSON
B V VENKATARAMA REDDY

renewables in buildings, with particular emphasis on integrability of building integrated photovoltaics (BIPV) and end-of-life PV as a building material in tropical conditions. Smart building and energy neutrality assessments.

Sustainability science: An interdisciplinary systems approach to sustainability, examining its theoretical basis, and application in architecture (buildings) and design. Sustainability assessment and forecasting in design and technology, identification of effective design-based interventions. Design for the BoP, empowerment, livelihood security and health. Examining geographically characterized active impacts traceable to design and manufacturing.

Plasma Technology, Wastewater Treatment, Recycling and Waste to Energy: Non-Thermal Plasma Cleaning, Enrichment and Reforming of methane and tar compounds. Plasma activated water characterization and its application for wound healing, surface hygiene and green fertilizer production. Plasma grey water treatment for recycling purposes. Decentralized wastewater treatment and recycling, modelling of plasma systems. Refuse derived fuel characterization for waste to energy application. Green methanol and Green hydrogen production. Turbomachinery: Fabrication of axial flow turbine driven multistage pump and its detailed testing are conducted at the department. The constructed pumps work with input head of 2-3 meters and pumps water to 20-25 meters with an overall water to water efficiency of 50%. After testing pumps are shipped to the intended rural location, one of which is Sukma (village Girdalpara). With delivered flow of 5-8 l/s, the pumps can irrigate 25 to 40 Ha of land during Rabi season. Further new designs of low and ultra-low head turbine have been undertaken with international partners. The flagship project of hydroloop at in Bastar in Taipadar village (Kanger basin) is also reaching completion stage.

Wastewater treatment: Salinity effect on nitrifying biofilms, high-rate nitrification of aquaculture effluents. Advanced wastewater treatment, enhanced biological removal of contaminants of emerging concern. Decentralized greywater treatment using biofilm reactors.

Bioenergy and biomass: Green hydrogen towards fuel cell application is the major focus through the thermo-chemical conversion of biomass. Establishing the hydrogen purity to meet the ISO specification is achieved. As a part of biorefinery, the syngas generated paves the way for green chemicals and fuels like methanol, ethanol, DME, and syngas for Green ammonia and fertilizer. Downstream utilization of fuels for application in Solid Oxide fuel cell (SOFC), PEM fuel cells.

Sustainable separation technologies: Recovery of valuable components from waste streams, extraction of a synthesized commodity from the reaction medium, or purification of an effluent stream before discharge into the environment are some examples where separation technologies

FACT FILE

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IN NUMBERS

7 Faculty Members (Core)

7 Faculty members (Associate)

14 Scientific Staff

37 PhD

30 Publications

4 Training and Capacity Building Activities

5 PhD Conferments

are critical. Ongoing projects in this domain are solvent recovery from industrial waste streams using pervaporation, phytochemical extraction using reverse osmosis and nanofiltration, and arsenic uptake from groundwater using a rurally sustainable scheme using bioadsorbents.

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The primary goal of the Divecha Centre for Climate Change is to understand climate variability and climate change and its impact on the environment. The Centre is working with various departments to identify technologies to mitigate/reduce the severity of climate change. The Centre frequently undertakes outreach activities to create awareness among people and policy makers about climate change and its consequences especially on society.

CURRENT RESEARCH

DIVECHA CENTRE GRANT FROM THE GRANTHAM FOUNDATION: Mainly, we are involved in various topics related to atmospheric science, Himalayan glaciers and basic and applied research in renewable energy. Experiments using high-altitude balloons have shown large amounts of black carbon aerosols at higher atmospheric levels. Model simulations have shown that while biomass burning and near-surface anthropogenic activities together with boundary layer dynamics can explain at least part of the lower layer, upper layer can be explained only by including emissions from high-flying aircrafts. Our studies indicate that that once black carbon aerosols are emitted at higher atmospheric levels, they can be lofted further via absorption- warming-convection cycles, which could propel them even to the stratospheric heights. Once they reach stratospheric heights, chemical reactions occurring over their surfaces could have

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3.5.8 Divecha Centre for Climate Change

CHAIRPERSON

S K SATHEESH

strong implications for the ozone layer. The effect of atmospheric conditions like aerosols, temperature and water vapour on the power output has been studied using Concentrated Photo Voltaic (CPV) modules on a dual-axis sun tracker. We are also involved in research to fabricate thin film solar cells, which are semi-transparent following low cost processes. The envisaged application for these cells is for windows and skylights of buildings. We have studied various aspects of GHG inventory, mitigation and adaptation for India to meet the requirements of the Paris Agreement. They have identified requirements for modelling and measurements at the national, state, industry and municipal levels as well as research and capacity building requirements for enabling India to meet these requirements.

DST GRANT: Studies on glaciers have shown that though the rates of retreat of individual glaciers are uncertain, on the whole the Himalayan glaciers are losing mass at an increasing rate over the past few decades. With the changing climate, glaciers would continue to shrink and the rates of retreat may increase even further. This can lead to the formation of glacial lakes, which, with continued accumulation of glacier melt could burst leading to catastrophic impacts on human life, settlement and infrastructure downstream. By using glacier surface velocity, estimated using high spatial resolution satellite data and slope, we have calculated ice thickness, by applying a basic parallel flow model, subsequently outlining the bed topography and located potential lake sites in over-deepening in the bedrocks. We have also developed a model to predict the future expansion of lakes. The slide shows how the measurements go in line with the model projection. The model predictions have been validated using field investigations. A proposal to avoid flash flood has been accepted by the government of Sikkim, a north eastern state in India.

CORE RESEARCH

Glaciers, Renewable Energy, Aerosols and their impacts on climate, Atmospheric boundary layer, Cloud Physics, Geophysical fluid dynamics, Monsoon variability and predictability, Numerical simulation of the Atmosphere-Ocean- Climate system, Paleoclimate studies, Physical-Chemical- Biological oceanography, Satellite meteorology, Space-time structure and scaling in geophysical data, Tropical convection.

FACULTY & STAFF

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INSPIRE FACULTY

PRIYANKA BANERJEE | PhD (CSIR-NIO, Goa)
ROHIT CHAKRABORTY| PhD (Calcutta)

Established in 1945 as Department of Metallurgy and re-named in 2006, the Department of Materials Engineering has a rich history of accomplishments, with active groups pursuing research into materials phenomena spanning multiple length and time scales. With nearly 200 research papers published each year, and with academic programmes leading to bachelors, masters and doctoral degrees, it is recognized as a leading academic centre in materials education and research.

CURRENT RESEARCH

Some of the important research activities are highlighted below

Ceramic actuator materials

The department has an active research group in electroactive ceramics. The group led by Rajeev Ranjan has made notable contributions in the field of piezoelectric materials. In the recent past, there has been a

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IN NUMBERS

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107 PhD students
28 MTech students
212 publications
26 PhD conferments

3.5.9 Materials Engineering

CHAIRPERSON
SATYAM SUWAS

concerted international effort for developing lead-free piezoceramics which can be viable alternative to the Pb-based PZT. The group at IISc has made important fundamental contributions towards understanding the structure-property correlations in Na0.5Bi0.5TiO3 – based lead-free piezoceramics. Very recently the group has shown that the lead-free piezoelectric solid solution series Na0.5Bi0.5TiO3-BaTiO3 stands out in two important respects: (i) low piezoelectric coefficients (~200 pC/N) and (ii) anomalous decrease in the depolarization temperature at the MPB, the reason for which has eluded the community. The group has shown that both the features are interrelated, and is caused by an increasing intervention of a non-ferroelectric structural distortion which compromises the gains the system acquires at the MPB via the inter-ferroelectric instability. The propensity of the intervening non-ferroelectric distortion, identified as in-phase octahedral tilt, grows considerably as the MPB is approached causing considerable structural-polar disorder, weakening the overall strength of ferroelectric interaction.

Printed electronics

Led by Subho Dasgupta, a major initiative has been launched in the area of printed electronics and nanoionics. In a major breakthrough, the group has fabricated a fully printable organic-inorganic semiconductor material. The ultra-flexible TFTs fabricated with such materials show linear mobility in excess of 70 cm2/Vs, at the same time no performance degradation for a bending fatigue test with bending radius of 1.5 mm. The group has also developed a printable silver ink that essentially have infinite shelf life and is curable at as low temperature as 80 °C. The laboratory has developed methods for printing co-continuous, mesoporous structures with pore size tunability, as well as low temperature processed (~100 °C) FETs compatible to inexpensive polymer, paper substrates.

Organic electronics

Praveen C Ramamurthy is leading an ongoing research programme in the field of organic electronics. Over the years, the group has successfully engineered molecules with the view to tune their bandgap and thereby their optical and electronic properties. The group employs this strategy in innovative manner to design new electro active molecules and develop sensors to detect various challenging toxic metal ions like lead, mercury, arsenic in addition to most toxic and hugely challenging nitrate and nitrite ions. The group has also fabricated Biosensors for detection *E. Coli* and Malonaldehyde.

CORE RESEARCH

Metals and alloys, Structural alloys, Superalloys; iron making, high temperature deformation; Materials processing and Advanced characterization; Ceramics, High temperature coatings; Electronic and structural ceramics; Electronic packaging materials; Energy materials; Printed and flexible electronics; Sensors; Computational Modelling. Polymers and nanocomposites; Biomaterials.

Biomaterials

In the field of biomaterials, new alloys of beta-Ti with low modulus and high strength have been developed for orthopaedic applications by joint efforts of Satyam Suwas and Kaushik Chatterjee. Severe plastic deformation of the surface of these alloys was shown to enhance the bioactivity of the alloys. Chatterjee's group has prepared fibrous polymeric scaffolds for bone tissue engineering and enhanced bioactivity using ceramic nanoparticles. In another study, cardiomyocytes on aligned microgrooves have been shown to get organized in a manner similar to the heart tissue; such systems could serve as a promising platform for studying cardiac hypertrophy.

Diffusion processes in alloys

The group led by Aloke Paul has come up with a new experimental method for studying understanding the complex diffusion processes in multicomponent metallic alloy systems. This, in conjunction with the advances made in the mathematical analysis of such systems by the same group, removes the stringent obstacles which have hindered our understanding multicomponent diffusion for over nine decades. The group has successfully demonstrated the efficacy of their new strategy in various multicomponent systems such as Nickel and Cobalt-based superalloys, complex concentrated (high entropy) alloys and high-temperature coatings generally used in jet engines and power sectors.

Fracture phenomenon in thin metallic films/foils

Praveen Kumar is leading a research programme in the department which emphasizes on understanding the highly complex fracture phenomenon in thin metallic films under multiple stimuli like temperature, stress, electric and magnetic fields. The group has demonstrated the occurrence of a synergistic effect during fracture in thin metallic foils due to a combined application of an electric current and mechanical stress. In a related study, they have demonstrated a coupling between electromigration and thermomigration in thin films leads to an enhanced mass transport at the cathode and anomalous backward mass transport at the cathode. Further, whisker growth in Sn coatings has been studied extensively to elucidate the role of factors such as electric current, grain orientation, and thermal stresses.

Metallurgical phenomena/processes

The department has diverse research groups working on different aspects of metallurgical alloy systems-alloy design, microstructural control via processing, modelling, etc. There is an ongoing research activity towards the development of high-temperature cobalt based high strength new class of superalloys. A patent has been filed for a new high-temperature high strength copper alloy. Using the aluminium-magnesium alloy system as a model, the group led by Satyam Suwas has successfully elucidated the role of stacking fault energy in grain refinement and texture evolution during severe plastic deformation. As a more recent development, Satyam Suwas has successfully established the pathways of processing of high temperature titanium aluminides for gas turbine applications, to enable them for service in high pressure turbines.

A joint effort by Praveen Kumar and Vikram Jayaram has led to the development of a small-scale testing method to study creep of high temperature components using cantilevers extracted from boilers or rotors in service. The research team has shown that data from such tests are consistent with the more traditional, larger-sample uniaxial creep measurements and in the process demonstrated that the creep rates of boiler steels that have seen 25 years services is increased by a factor of 6-8. Further, by using additively extended beams, an alternate method for minimising the size of the extracted coupon has been established.

Abhik Narayan Choudhury is leading the simulation and modelling studies of metallurgical systems in the department. Using phase field modelling, his group has predicted equilibrium shapes of precipitates under the combined influence of coherency stresses (including anisotropy both in the elastic and the interfacial energy). Efforts are on to simulate electromigration in mutiphase alloy systems. The group has developed in-house a Bridgman set-up for studying directional solidification of a variety of alloys.

P Padaikathan has made efforts in the direction of designing and developing high temperature Al-alloys. The main aim is to develop next generation aluminium based alloys for high temperature applications. The addition of alloying elements Fe-Ni-Co-Sc-Zr aimed at bare minimum of 0.20-0.50 at% and striving to equate the specific modulus of steel by forming the Nano-sized second phase particles in the matrix. The fundamental strategy behind this processing approach is to combine the reinforcement of Nano-sized dispersed particles during solidification, core shell formation and precipitation of coherent phase during ageing treatment. The primary advantages shall be the possibility of achieving uniform distribution of particles with varied shapes of intermetallic compounds with minimal segregation simultaneously. In order to achieve high temperature stability, the novel microstructural design has been envisioned. The emerging microstructures and misfit-less crystallographic morphologies are correlated and characterized using transmission electron microscopy.

Explored newly proposed method in multicomponent diffusion in different material systems to explain growth and diffusion-controlled microstructure of the phases.

Research Highlights 2021

There are three areas where progress has been achieved in 2021.

1. Cobalt base superalloys We have developed a new series of low-density high strength cobalt-base superalloys to continue our earlier work by adding Cr, V, Ta, and Nb that yield attractive strength. This year, the mechanism and kinetics of oxidation at high temperature for the cobalt-base superalloys developed by the IISc group has also been established.

2. Green synthesis by mechanical milling of Si and Ge nanoparticles saw the development of inkjet printable heterostructure for device applications

3. An extensive research effort was carried out to understand multiphase thermoelectric transport properties of composites of tellurides for better tunability of thermoelectric devices.

4. Oxidation-induced slow fracture of Si wafer comprising Cu-filled through Si via during room temperature storage following annealing treatment.

5. Existence of frustration dislocation density in a material, confirming that dislocation density in a material cannot be reduced below a certain limit via any thermo-mechanical treatment. Frustration dislocation density is responsible for a creep stress exponent of 1-2 at very high temperatures and low stresses.

6. Small scale mechanical testing of coatings and alloys, especially at high temperature, to extract fracture, creep and elastic-plastic properties. Micron-scale cantilevers and beams of brittle thermal protection systems have been evaluated for their fracture and hysteretic behaviour using in-situ and ex-situ methods. Cyclic deformation reveals that system compliance can be used to track crack growth in thin (5-10 micron) pre-cracked beams of Pt-Ni-Al subject to hundreds of cycles of tension-tension loading. Cycling of porous ceramic cantilevers of stand-alone plasma sprayed yttria stabilised zirconia coatings at stresses as low as 20 MPa reveal hysteretic behaviour and creep which are strongly sensitive to heat treatment that induces crack healing even without significant changes in density. An in-house designed miniaturised creep testing set up has been fabricated that allows cantilevers to be tested under creep conditions.

7. A new material design approach for high performance optical thermometry. Instead of focusing only on the PL spectrum of the rare-earth ions, for the first time we emphasize on the use of the Raman signal emitted by the host, in conjunction with the PL signal of the doped rare-earth ions for developing materials exhibiting large tuning of the emission colour with temperature. We demonstrate the success of our approach on Er-Eu co-doped $BaTiO_3$ the emission colour of which changed from orange to green on cooling down to 10 K when excited by a green laser. The large temperature tuning in this case is caused by strong enhancement in the Raman signal due to temperature driven structural ordering, and anomalous low temperature quenching

of the Eu+3 PL emission by defect states. Not only we achieve large tuning of the emission colour, we have also demonstrated that the temperature sensitivity achieved by our approach.

8. Fabrication of first fully printed transition metal dichalcogenide (TMD) transistors with high sub-thermionic and thermionic transport. Demonstration of printed inverters; Demonstration of high performance fully printed gas sensors; Demonstration of fully printed pseudocapacitive ($NiCo_2O_4$) and EDLC (Mn_3O_4) type supercapacitors on rigid substrate and MnO_2 and GQD based hybrid capacitor on flexible substrata, Demonstration of inorganic/organic hybrid semiconductor-based field-effect transistors with excellent transport and mechanical properties. Demonstration of all printed, all oxide pseudo-CMOS logic with record signal gain.

9. Development of a triple layered antiviral mask, radiation resistant textiles which can be a potential candidate for protecting critical biomedical devices.

10. Delivery of mRNA using mesoporous silica to treat Hepatitis C infection. We successfully demonstrated the encapsulation, transport, and delivery of mRNA. Using an infected cell line, we were able to demonstrate the delivery and treatment of such cells. A thesis highlighting this work has been submitted, 1 manuscript published and 2 manuscripts are under review.

11. Development of the fabrication of chitosan nanoparticles with phosphatidylcholine for improved sustain release, basolateral secretion, and transport of lutein in Caco-2 cells. Another important work completed in the year 2020 was developing point-of-care strips for the detection of dopamine.

12. Establishing microstructure-property correlation in metallic coatings and understating the correlation between texture and corrosion in composite metallic coatings contains additives

13. Design and developing high temperature Al-alloys: Developing next generation aluminium based alloys for high temperature applications. In order to achieve high temperature stability, novel microstructural design has been proposed. The micro-structural and crystallographic morphology are characterized using electron microscopy.

14. Thermomechanical processing of titanium aluminides: the indigenously developed processing maps were successfully verified to the actual forging of titanium aluminide. In another activity, a near alpha titanium alloy was investigated to evaluate the phenomenological and microstructural origin of dwell fatigue sensitivity. The phenomenological part was established and microstructural investigation is ongoing. In the area of additive manufacturing, investigations were done to evaluate the conditions of additive manufacturing of materials for high temperature applications.

15. A wrought Mg-8Li-2Zn alloy developed for aerospace applications with tensile properties superior to existing commercial and experimental Mg-Li based alloys. This was achieved by optimizing the alloying additions, processing route and parameters. A novel rolling method introduced by installing an Asymmetric Rolling Mill in our laboratory. This method increased the ductility of the newly developed Mg-7Sn-2.6Zn alloy while retaining its strength. A fundamental study on evolution of plasma electrolytic oxidation coating on AM50 Mg alloy in silicate, phosphate and mixed silicate-phosphate based electrolytes with and without glycerol additive carried out. This coating is imparted on Mg alloys to improve their corrosion resistance.

16. Improvement in industrial SiC production process by 30%; the agreement to transfer this technology.

17. Modelling of process--structure--property correlations in organic photovoltaics during using a novel diffuse-interface approach, Modelling of equilibrium configurations of precipitates in multi-variant precipitation reactions using a novel phase-field model, Experimental determination of process--structure correlations in anisotropic three-phase eutectics such as Ag-Cu-Sb as a function of variation in composition as well as rate of solidification Determination of exotic structures in the Sn-Te eutectic system, Development of a multi-component phase-field model for precipitation reactions incorporating the influence of coherency stresses

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Mechanical Engineering activities at the Indian Institute of Science commenced with the establishment of the Department of Internal Combustion (IC) Engineering in 1945. The Mechanical Engineering section of the Power Engineering Department was established in 1951, and later became a full-fledged Mechanical Engineering department (ME). The IC Engineering Department merged with the ME Department to give it its present form in 1970. Research interests in the department have evolved to span a broad range of areas, from the traditional to emerging fields, to achieve a unique balance that strives to extend the research frontiers with applications in related industries. As a result, students are exposed to international standards and current research methodologies in problems of relevance. The department offers Master of Technology (MTech), Master of Technology (MTech (Res)) and Doctor of Philosophy (PhD) degrees.

CURRENT RESEARCH

Biomechanics: Nonlinear mechanics of soft biological tissues and elastomers; protein rubbers; mechanical characterization of biological cells; mechanobiology and bio-micromanipulation; bio reactors and cell culture in scaffolds and computational design of proteins; biomaterials research and biomimetics; tissue engineering.

3.5.10 Mechanical Engineering

CHAIRPERSON
GK ANANTHASURESH

Combustion & Spray Research: Multi- dimensional modelling of processes involving two- phase flow, turbulence and combustion chemistry; application of laser-based diagnostic techniques in combustion and multiphase flow research; fuel spray characterization using shadowgraphy and interferometric Mie imaging techniques; trapped- vortex based combustor research, Laser-Induced Incandescence (LII) imaging for soot formation studies.

Fluid Mechanics: Stability of unsteady boundary layers; unsteady boundary layer separation; transition and turbulence; turbulence modelling; fish- like propulsion; shear flow control, stall flutter; shock boundary layer interaction; drag reduction using micro-bubbles; two-phase flows; electro-hydrodynamics; atomization of liquid jets.

Fracture Mechanics And Tribology: Fretting friction mechanics; impact fracture; Fracture Mechanics and Tribology fragmentation dynamic, mixed mode, indentation; thin film; tribology; contact mechanics of impact and indentation; nanotribology of boundary lubrication; metal cutting, metal working; scanning probe microscopy; fracture of single crystals, polycrystalline alloys and amorphous metals, computational fracture mechanics; nano composite coatings and mechanics at small scales; effect of roughness and surface asperities on the solid-liquid interface, eco-friendly, cutting oil studies.

Mechanical Systems and Design: Structural and dimensional synthesis of kinematic and compliant mechanisms; theoretical kinematics; multi-disciplinary design optimization; dynamics and control of robot and multi-body mechanical systems; computer-controlled mechanical systems; bio- medical devices; constructing 3D models from sketches, assembly sequence planning and evaluation, tools for early stages in design, nonlinear dynamics, vibrations, structural shape and topology optimization, kinematic assembly modelling, geometric and topological modelling.

Advanced Manufacturing and Metal Casting: Friction stir welding and friction stir processing; semisolid forming; die casting and squeeze casting; mould design and metal flow analysis by CFD; computer aided design of near-net shaped castings; meso-scale manufacturing with metals.

Microsystems: Modelling, design, and micro-fabrication of Micro-Electro-Mechanical Systems (MEMS); energetics of micro and nano devices;

nano-mechanics; acoustic sensors, rate gyroscopes, accelerometers, ultrasound sensors, and polymer pumps; development of analysis tools for coupled multi-physics problems; optimal synthesis methods for MEMS; micromanipulation; in-situ TEM nanoindentation, deformation mechanisms of materials.

Thermal Sciences: Turbulent Rayleigh- Benard convection; double-diffusive convection, mixed convection, heat pipes, heat exchanges, thermal management of electronic systems; heat and mass transfer in buildings natural ventilation, spent nuclear fuel cases, heat and mass transfer in food products; two phase flows and heat transfer, heat transfer in renewable energy systems; solar thermal systems, numerical heat transfer; refrigeration and air-conditioning; automotive climate systems, adsorption coolers and gas storage; mathematical modelling and simulation of thermal systems; thermal modelling and experimentation in solidification; fluid flow and heat transfer at micro/nano scales, encapsulated nanoparticles for thermal storage.

Internal Combustion Engines: Diesel Engines, Spark Ignition Engines with other small engine test beds, eddy-current dynamometers, exhaust gas analysers, crank angle encoder, manifold and in-cylinder pressure transducers, load panels, data acquisition system, Bio-fuels, Fuels transesterification, Engine Performance, Combustion diagnostics, Emission analysis, and other engines related experimental as well as computational research work.

Technical Acoustics: Automotive noise control; vibration diagnosis of rotating machinery; acoustics of ducts and mufflers; industrial noise control; acoustic characterization of absorbing materials. sound from turbulent flows, asymptotics in structural acoustics, nonlinear structural acoustic interactions.

FACULTY & STAFF

ANANTHASURESH G K | PhD (Michigan), Professor
ALOKE KUMAR | PhD (Purdue), Associate Professor
ASHITAVA GHOSAL| PhD (Stanford), Professor
CHANDRASHEKHAR JOG | PhD (Illinois), Professor
GAURAV TOMAR | PhD (IIT Kanpur), Associate Professor
JAYWANT ARAKERI | PhD (Caltech), Professor
JISHNU KESHAVAN | PhD (Maryland), Assistant Professor
M S BOBJI | PhD (IISc), Professor
NAMRATA GUNDIAH | PhD (California), Professor
NARASIMHAM GSVL | PhD (IISc), Chief Research Scientist
NARASIMHAN R | PhD (Caltech), Professor
NAVANEETHA K. RAVICHANDRAN (Caltech), Assistant Professor
PRABHAT KUMAR | PhD (IITK), Ramanujan Fellow Faculty
PRADIP DUTTA | PhD (Columbia), Professor
PRAMOD KUMAR | PhD (IISc), Associate Professor
RAGHURAMAN N GOVARDHAN | PhD (Cornell), Professor
RAMSHARAN RANGARAJAN | PhD (Stanford), Assistant Professor
RATNESH SHUKLA | PhD (California), Associate Professor
RAVIKRISHNA R V | PhD (Purdue), Professor
RINKU KUMAR MITTAL | PhD (IITB), Inspire Faculty
SAPTARSHI BASU | PhD (Connecticut), Professor

SATISH V KAILAS | PhD (IISc), Professor
VENKATA SONTI |PhD (Purdue), Professor
SUSMITA DASH | PhD (Purdue), Assistant Professor
KOUSHIK VISWANTHAN| PhD (Purdue), Assistant Professor
HIMABINDU M | PhD (Anna), Senior Scientific Officer
R T NAIK | PhD (IIT Delhi), Scientific Officer
C DHARUMAN | MSc (Engg) (IISc), Senior Scientific Officer
VENKATARAMAN M K | MSc (Engg) (IISc), Scientific Officer

ASSOCIATE FACULTY

GURUMOORTHY B| PhD (Carnegie Mellon), Professor
DIBAKAR SEN | PhD (IISc), Professor
G. R. JAYANTH | PhD, (The Ohio State University), Associate Professor

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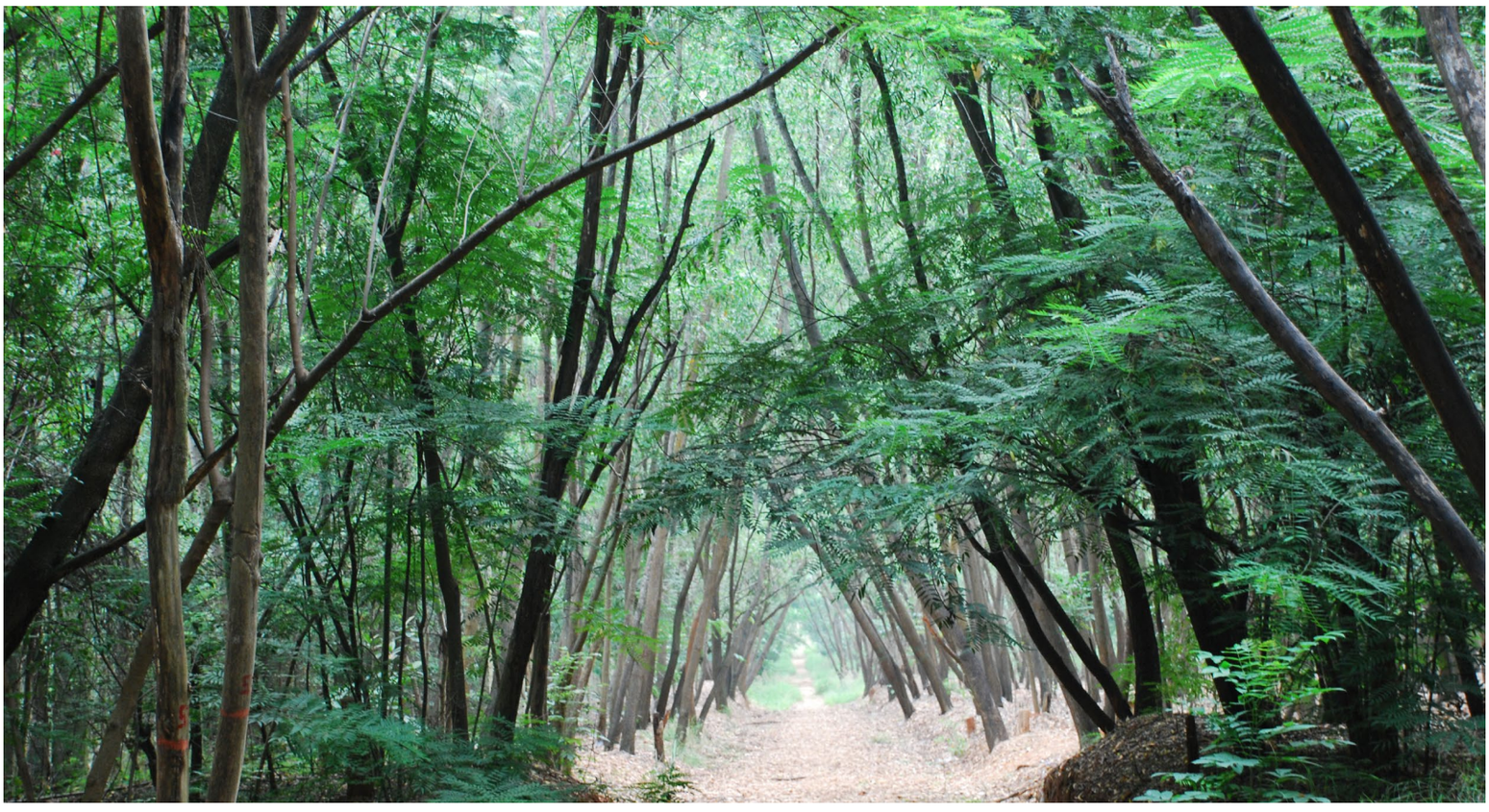
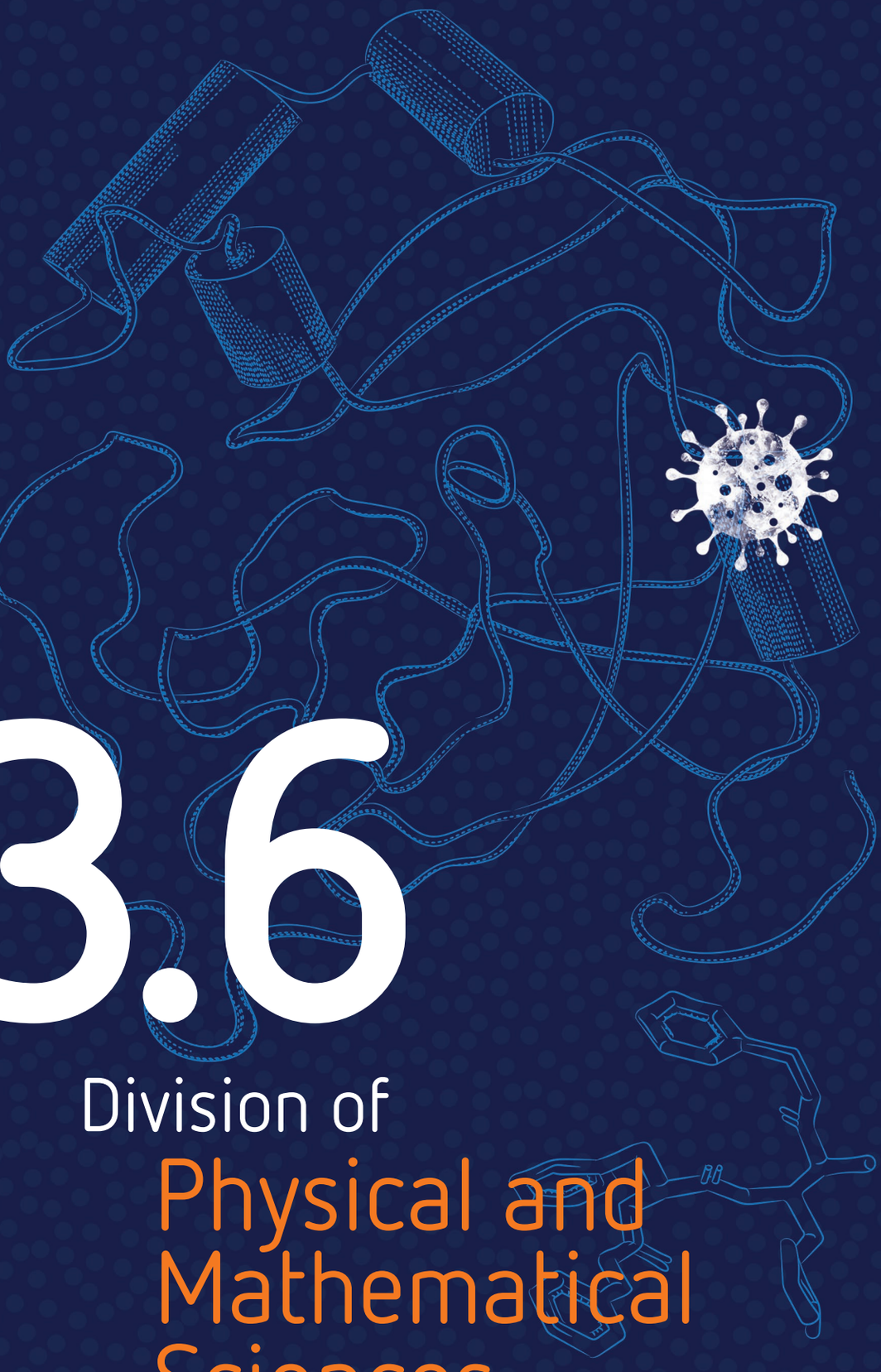
Degree Programs offered PhD,
MTech (Res) and MTech

IN NUMBERS

26 Academic staff
6 Scientific staff
150 PhD students
17 MTech (Res) students
45 MTech students
6 MSc (Engg) conferments
13 M.Tech conferments
11 PhD conferments





3.6

Division of Physical and Mathematical Sciences

IN NUMBERS

- 88 FACULTY MEMBERS
- 231 PhD STUDENTS
- 14 MASTER'S STUDENTS
- 69 INT PhD STUDENTS

Research in the Division covers a wide variety of areas in the Physical Sciences, including fundamental investigations in String Theory, Particle Phenomenology, Field Theory, Condensed Matter Physics (both theoretical and experimental), Soft-Matter and Complex Systems, Biology-Inspired Physics, Biomolecular Structure and Biophysics, Atomic and Optical Physics, Astronomy and Astrophysics, and cutting-edge Applied Physics research including MEMS-based and Fibre-Optic Sensors, Multifunctional Materials such as graphene and carbon nanotubes, Super-Resolution Fluorescence Microscopy, Nano-Scale Imaging, Optics and Microfluidics, Energy and Health Monitoring Instrumentation, and Cryogenic Technologies (including Cryocoolers, Cryogenic Instrumentation, and Cryogenic treatment on materials). Research in Mathematics covers major areas, both pure and applied, including Probability, Partial Differential Equations, Analysis, Geometry, Topology, Algebra, Algebraic Geometry, and Analytic Number Theory.

THEMES

Given the diversity of this Division, there are a wide variety of research themes. These can be gleaned from the core research areas mentioned above. Many of these areas lie in the exact sciences, both theoretical and experimental. Along with these, there are growing interdisciplinary programmes, such as in Mathematical Biology and Nanoscience. Translational research is also being carried out and products based on innovative and cutting-edge technologies, are being brought into the market by faculty entrepreneurs in the division.

RESEARCH HIGHLIGHTS

The Division of Physical and Mathematical Sciences comprise the Departments of Instrumentation and Applied Physics, Mathematics, and Physics, including the Astronomy and Astrophysics Programme, and the Centres of High Energy Physics (CHEP) and Cryogenic Technology (CCT)

Faculty members in this Division have received several awards and honours for their research. Their research has been supported by grants from major agencies and ministries such as the Department of Science and Technology, The Council for Scientific and Industrial Research, the Department of Biotechnology, the Defence Research and Development Organisation, the Indian Space Research Organisation, and the University Grants Commission. A brief report of their research, over the past year, is given here.

DEPARTMENTS | CENTRES | UNITS

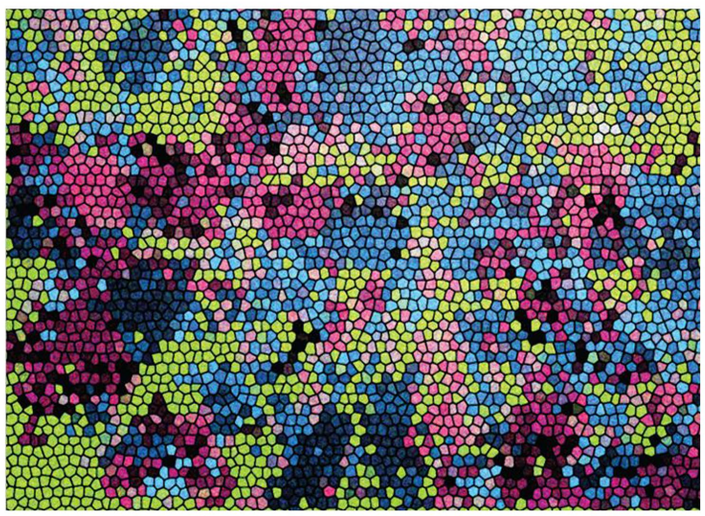
- CENTRE FOR CRYOGENIC TECHNOLOGY
- CENTRE FOR HIGH ENERGY PHYSICS
- INSTRUMENTATION AND APPLIED PHYSICS
- MATHEMATICS
- PHYSICS

2020-21

Research Snapshots

AJAY K SOOD (PHY)

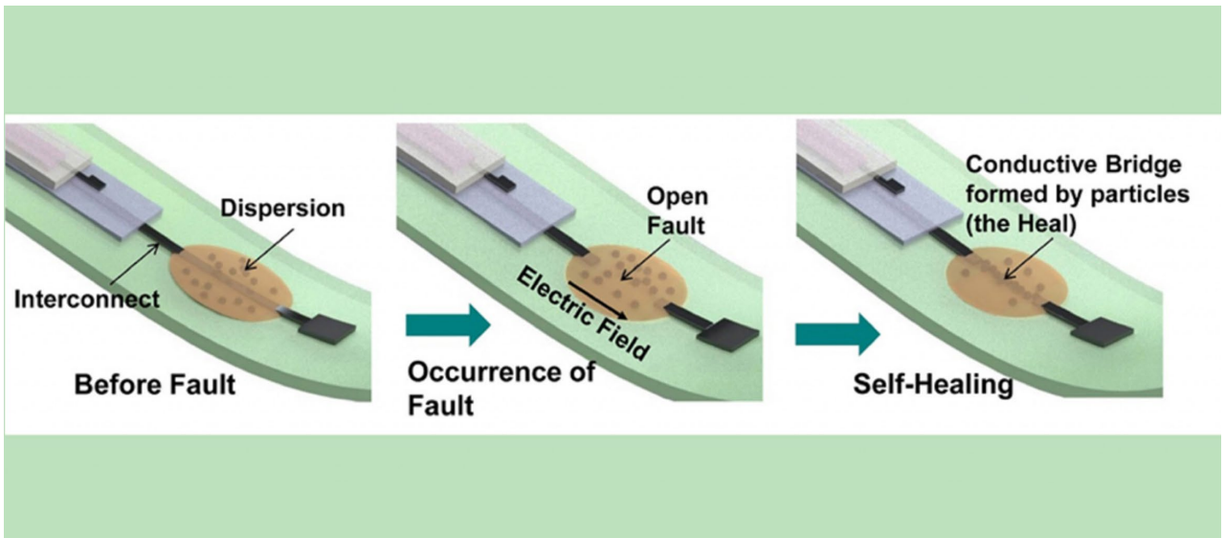
Devitrification, the transformation of a glass into a crystal, is often an unwanted process in industries. It is poorly understood because it can be extremely slow, spanning decades or more. Now, researchers from the Department of Physics at IISc and JNCASR have visualised devitrification for the first time in experiments. The researchers observed different regions of the glass following two routes to crystallisation. Then, they used machine learning methods to determine if there was some subtle structural feature that decides beforehand which regions would later crystallise and through what route. The model also accurately predicted which regions of the glass would crystallise days in advance.



Reference: Ganapathi D, Chakrabarti D, **Sood AK,** Ganapathy R, Structure determines where crystallization occurs in a soft colloidal glass, *Nature Physics (2020).*

SANJIV SAMBANDAN (IAP)

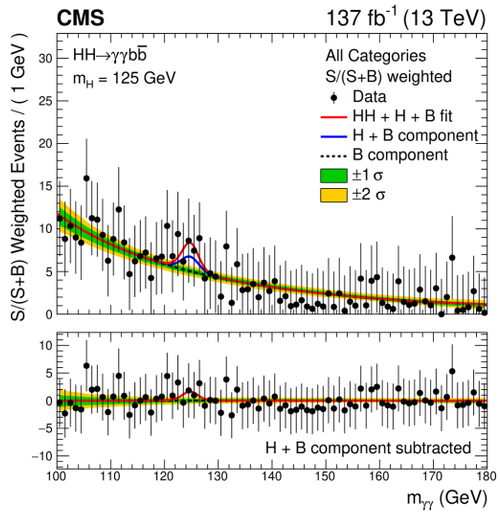
Flexible electronic devices are made up of millions of circuits composed of thin-film transistors (TFTs). These devices are prone to open-circuit failures due to bending or stretching, electrostatic discharge from human contact, or corrosion from moisture or sweat. Researchers from the Department of Instrumentation and Applied Physics and the University of Cambridge have now collaborated to develop self-healing TFT circuits. They packaged silver particles embedded in insulating silicone oil in the TFT circuit such that when gaps are generated, the open current induces the particles to align and form a conductive bridge, thereby completing the circuit and "healing" it. The authors also describe a strategy for efficiently packaging these particles in TFT circuits for large-scale manufacturing.



Reference: Ding L, Joshi P, Macdonald J, Parab V, **Sambandan S,** Self-healing thin-film transistor circuits on flexible substrates, *Advanced Electronic Materials (2021).*

JYOTHSNA KOMARAGIRI (CHEP)

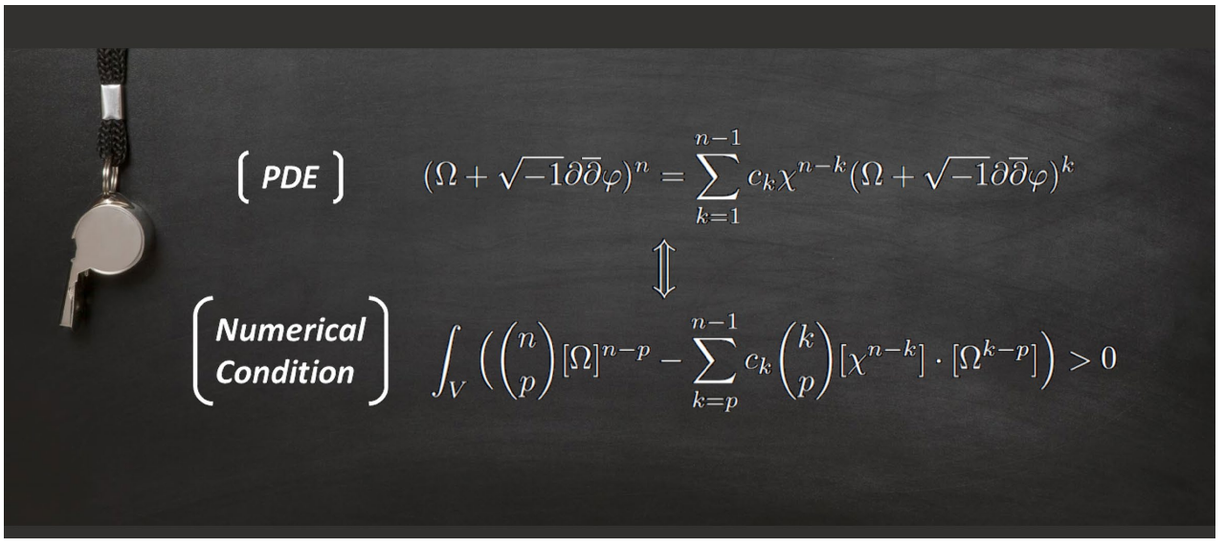
The Higgs boson discovered in 2012 by the ATLAS and CMS experiments is at the pinnacle of scientific results so far at the Large Hadron Collider at CERN, Geneva. Studying the production of two Higgs bosons is the most obvious way to understand the field responsible for the Higgs boson. A new result by the international CMS collaboration, which includes researchers from IISc, gets closer than ever to measuring this field and its physics prediction. Using the large data sample collected during the LHC Run 2, CMS has set the best constraint to date on the ratio of the measured Higgs self-coupling parameter to the Standard Model prediction.



Reference: The CMS collaboration, Search for nonresonant Higgs boson pair production in final states with two bottom quarks and two photons in proton-proton collisions at √(s) = 13 TeV, *Journal of High Energy Physics (2021).*

VED DATAR (MATH)

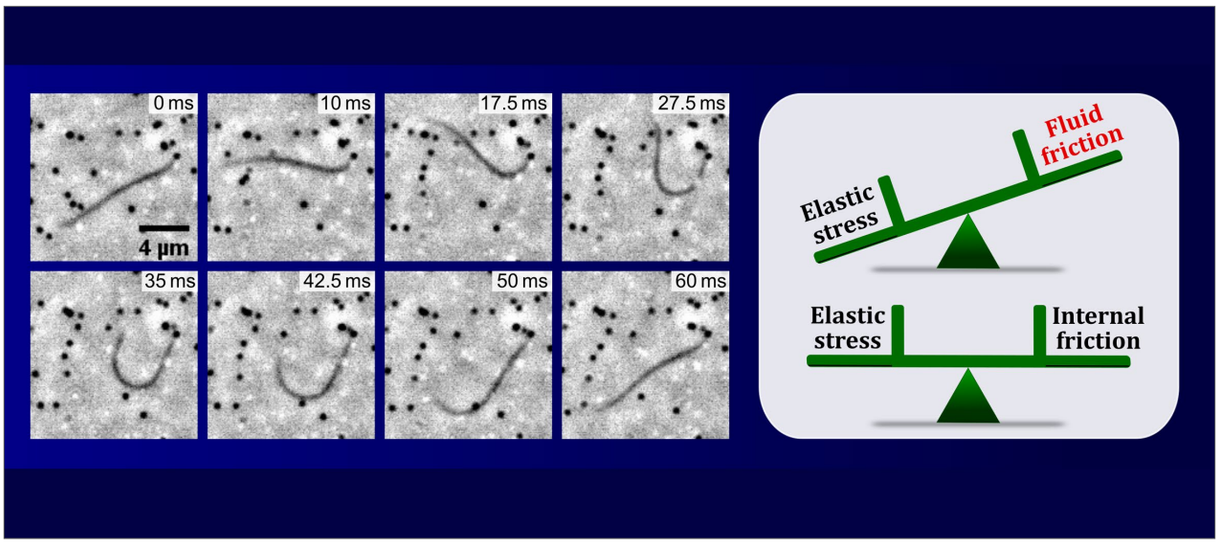
A common theme in modern geometry is that existence of solutions to certain partial differential equations (PDEs) encodes geometric information of the underlying space. For instance, the geometry of space-time is determined by solutions to Einstein's field equations for gravity. In a recent study, researchers from the Department of Mathematics proved that solutions to a certain broad class of non-linear PDEs on projective manifolds (so called inverse Hessian equations) exist if and only if a certain numerical condition is satisfied, thereby providing a practical test of solvability of the PDEs. This work resolves a famous conjecture of Lejmi-Szekelyhidi for the important class of projective manifolds, and the techniques are expected to have broader applications in complex geometry.



Reference: **Datar VV** and Pingali VP, A numerical criterion for generalised Monge-Ampere equations on projective manifolds, to appear in *Geometric and Functional Analysis (2020).*

PRERNA SHARMA (PHY)

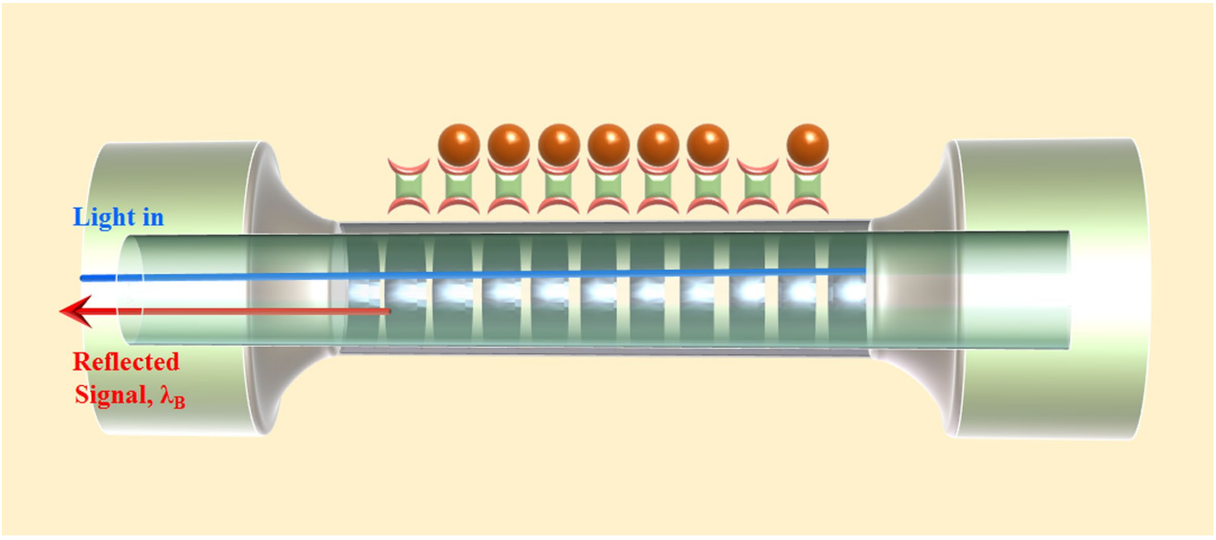
Cilia are whip-like appendages used by cells and tissues to move. They are 'active' filaments that spontaneously oscillate by consuming and dissipating chemical energy. For stable oscillations, the active energy input must be balanced by sufficient dissipation. Scientists have so far believed that ciliary 'beating' or oscillation is governed by external fluid friction. However, in a new study, researchers from the Department of Physics show that it is actually 'internal friction', arising from slow structural rearrangements within the filament, which may be responsible for stable oscillations. The study used a novel method to examine cilia isolated from the green algae *Chlamydomonas.*



Reference: Mondal D, Adhikari R, **Sharma P,** Internal friction controls active ciliary oscillations near the instability threshold, *Science Advances (2020).*

S ASOKAN (IAP) & AJAY SOOD (PHY)

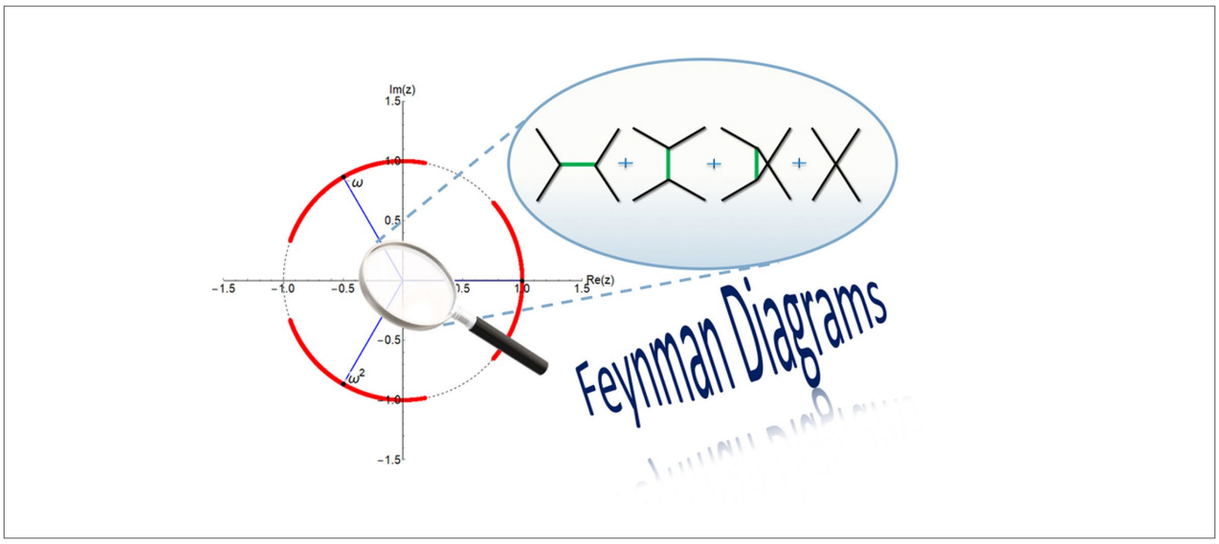
Mercury is a heavy metal pollutant that can damage the kidneys and the brain. Traditional spectroscopy techniques require sophisticated equipment and handling by trained experts. Researchers at IISc and JNCASR have worked to develop a sensitive, portable and cost effective etched Fiber Bragg Grating sensor (eFBG) which can be used in practical settings. The surface of this sensor was coated with cysteine conjugated naphthalene diimide (CNC) bolaamphiphile molecules. The interaction between CNC and mercury gives the specificity to the sensor for it to be capable of detecting minute mercury concentrations (up to 0.0000003 mg/litre or 10 million times less than the hazardous limit) in test samples.



Reference: Kavitha BS, Sridevi S, Makam P, Ghosh D, Govindaraju T, **Asokan S, Sood AK,** Highly sensitive and rapid detection of mercury in water using functionalized etched fiber Bragg grating sensors, *Sensors and Actuators B: Chemical (2021).*

ANINDA SINHA (CHEP)

Feynman diagrams are ubiquitous in particle physics as well as condensed matter physics. Condensed matter physicists use the machinery of quantum field theory to explain universal properties and make quantitative predictions. Calculations that lead to experimental predictions are carried out using the well-known Feynman diagram techniques. In recent work, researchers from the Centre for High Energy Physics provide a novel explanation for the origin of Feynman diagrams, which also clarifies and constrains low energy physics. This makes use of an old and forgotten result found in 1972. The work fills a significant conceptual gap by giving a fresh perspective as to how Feynman diagrams emerge.



Reference: **Sinha A,** Zahed A, Crossing symmetric dispersion relations in quantum field theories, *Physical Review Letters (2021).*

MAHESH KAKDE (MATH)

Iwasawa Theory studies the deep and mysterious relationship between arithmetic objects and values of L-functions at integers. Classical Iwasawa theory studies arithmetic objects that are not "too small" (supported in codimension 1) while it ignores small objects (supported in codimension more than 1). In an earlier work, researchers from the Department of Mathematics started a systematic study of small arithmetic objects in Iwasawa theory by relating their Chern classes to L-functions. In a new study with collaborators, they extend their results to cover more cases as well as remove certain hypothesis from the earlier work.

Theorem A. *For a union $\mathcal{S}$ of two distinct CM types $\mathcal{S}_1$ and $\mathcal{S}_2$ and its complement $\mathcal{S}^c$, we have an equality of second Chern classes*

$$t_2\left(\frac{\Lambda}{(\mathcal{L}_{\mathcal{S}_1,\psi},\mathcal{L}_{\mathcal{S}_2,\psi})}\right)=t_2\left(\frac{(\bigwedge^{\ell} X_{\mathcal{S}}^{\psi})_{\mathrm{tf}}}{\bigwedge^{\ell} I_{\mathcal{T}_1}^{\psi}+\bigwedge^{\ell} I_{\mathcal{T}_2}^{\psi}}\right)+t_2\left(\frac{\theta}{\theta_0}\cdot\frac{\Lambda}{\mathrm{Fitt}(\mathrm{E}^2(X_{\mathcal{S}^c}^{\omega\psi^{-1}})(1))}\right), \quad (1.3)$$

where $\ell=\mathrm{rank}_{\Lambda} X_{\mathcal{S}}^{\psi}$, where θ is a gcd of the characteristic elements $\mathcal{L}_{\mathcal{S}_i,\psi}$ of $X_{\mathcal{S}_i}^{\psi}$ for $i\in\{1,2\}$, and where θ_0 is a generator of $t_1(\bigwedge^{\ell} X_{\mathcal{S}}^{\psi})$.

Reference: Bleher FM, Chinburg T, Greenberg R, **Kakde M,** Sharifi R, Taylor M, Exterior powers in Iwasawa theory, *Journal of European Mathematical Society (2020).*

Over decades, the Centre for Cryogenic Technology (CCT) has always maintained its high reputation of supporting deep low-temperature research activities in the Institute by supplying cryogens (liquid helium and liquid nitrogen) abundantly as per the requirements. Over the years, it has been upgrading its technical infrastructures to meet the ever-increasing demand of cryogens.

CORE RESEARCH

Cryogenics has multiple research applications in space science, atomic and tokomak energy studies, cryocooler technology, biological science, superconductivity studies, medical field, etc. Keeping up with recent advances in cryogenic engineering, faculty, students and project staff have been actively involved in niche research areas like cryocoolers, cryogenic systems and instrumentation, calibration of temperature and level sensors for space applications, thermal conductivity measurement facility down to 4.2K, cryogrinding, cryogenic treatment on metals, etc.

3.6.1 Centre for Cryogenic Technology

CHAIRPERSON

PRABAL KUMAR MAITI

CURRENT RESEARCH

A GM cryocooler-based experimental set up has been developed and is being used for the measurement of thermal conductivity of various materials in the range of 300K to 4.5K. Experimental studies have been conducted on select adhesives and activated carbons for the development of cryosorption pumps.

A project titled "Cryogenic grinding of flashes of different rubber components" funded by M/s C-DAT Pvt ltd, Bangalore has been successfully carried out to grind flashes of different rubber components at cryogenic temperatures. Design and development of a sieving system is under progress to achieve the ground rubber powder less than 80 mesh.

Measurement of cryogenic propellant levels is highly critical for successful launch of rockets. In support of this activity of ISRO, two sets of liquid oxygen and one liquid hydrogen level sensors were calibrated and delivered to LPSC, Bangalore.

For more than couple of decades, CCT has been extending its support in calibrating the temperature sensors for ISRO in the range of 300-4.2K. During this period, 21 temperature sensors were calibrated and delivered to IPRC, Mahindragiri.

A new project has been initiated to cryotreat the diaphragms of propellant pressure transducers for LPSC, Bangalore. The diaphragms are cryotreated at 98K for 36 hours using liquid nitrogen using a specially designed and developed cryotreatment system.

FACT FILE

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IN NUMBERS

2 Scientific staff

4 Publications

FACULTY & STAFF

VICE CHAIRPERSON: JAYDEEP KUMAR BASU

UPENDRA BEHERA | PhD (IISc), Principal Research Scientist

D S NADIG | M Tech (IIT Kharagpur), Principal Research Scientist

The Centre for High Energy Physics was carved out from the erstwhile Centre for Theoretical Theoretical Studies in 2004. Faculty in CHEP carry out research in the general area of particle physics, field theory, string theory, quantum gravity and condensed matter physics.

CURRENT RESEARCH

Several directions of research have been pursued in this centre in areas of theoretical physics and experimental high energy physics.

In the area of quantum information theory, a viewpoint to understand quantum chaos is being explored, where the density matrix is looked upon as the phase space for evolution. The elemental area in this phase space is quantised, and chaos is characterised by its exponential distortion in some direction. The software library that was developed to simulate noisy quantum logic circuit is being converted into an educational software, in a joint project with C-DAC and IIT Roorkee. The broad question about the least resources a future quantum computer would need to describe quantum phenomena was explored. Applications of ideas from quantum information theory to the S-matrix bootstrap program in quantum field theories were also studied.

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IN NUMBERS

13 Academic Staff
17 PhD students
19 Int. PhD students
115 Publications
1 Int PhD conferments
2 PhD conferments

3.6.2 Centre for High Energy Physics

CHAIRPERSON

JUSTIN R DAVID

In the area of condensed matter theory, the effects of periodic driving on a class of non-integrable models where there are special states called "scars" were studied. It was shown that if the initial state has a large overlap with the scar states, there are regions in the space of driving parameters where there is no thermalization and other regions where there is thermalization. It was shown that applying electromagnetic radiation to a finite region of the surface of a three-dimensional topological insulator can lead to interesting features in electronic transport across that region. By varying the frequency and intensity of the radiation, one can go between regimes with high and low conductances.

In the area of string theory, quantum gravity and mathematical physics, as part of the S-matrix bootstrap program crossing symmetric dispersion relations were used to obtain constraints effective quantum field theories. Single interval entanglement and relative entropies of conformal descendants of primary operators in 2d CFT was studied. Entanglement entropy of gravitons across spheres were obtained using their partition function on hyperbolic cylinders. An exhaustive determination of the critical points of N=8, D=5 Gauged supergravity was carried out using machine learning techniques. Arguments were put forwarded to support the existence of `islands' in the evaluation of refined entropies for black holes. These arguments also helped to provide a resolution of the information paradox in cosmological space times. It was shown that the lattice gauge theory based on the non-abelian group S(N) exhibits a large N first order phase transition. The low energy limit of quantum chromodynamics (QCD) via a matrix model approximation was studied. It was shown that the mass spectrum of light hadrons is reproduced excellently. In the supersymmetric version of the model, two new phases in the low energy sector of this theory were identified.

In the area of particle phenomenology a detailed study of the prospects of observing the non-resonant di-Higgs production in the Standard Model at the

CORE RESEARCH

The core research areas of the Centre are quantum field theory and its applications, and experimental high energy physics. The theoretical research areas include lattice gauge field theory, conformal field theory, quantum chromodynamics, beyond standard model physics, phenomenology of standard model and its extensions, string theory, astro particle physics, black hole physics, quantum field theory applications to condensed matter physics, quantum information and quantum computing. The experimental high energy physics is a part of the CMS experiment at CERN, Geneva.

proposed high energy upgrade of the Large Hadron Collider (LHC) was done. Dedicated triggers which can be used to search for Long Lived Particles at the LHC were developed. The implications of lepton flavoured dark matter from Neutron Stars were explored. A study of various features of the landscape like bounds from lepton flavour violation and criticality of the Higgs mass was carried out. A detailed study of proton decay in future water Cherenkov detectors was done. Mellin-Barnes Methods have been applied to problems in elementary particle physics. These methods have been used to obtain the pion form factor at high precision, the anomalous magnetic moment of leptons in QED and evaluate the triple series for sunset integrals.

In the area of Lattice gauge theory, the state-of-the-art lattice QCD results for the skewness, kurtosis, and higher-order cumulants of the net baryon number density at finite temperature and density were presented. These results were compared to the experimental results on net-proton cumulants that were obtained by the STAR collaboration as part of the Beam Energy Scan program at the RHIC collider. At a beam energy of 54.4 GeV it was seen that the experimental results agreed very well with the lattice QCD results close to the finite-density chiral crossover temperature. The 5th and 6th order cumulants for the net baryon density were evaluated for the first time.

In the area of experimental particle physics the search for Dark Matter produced in association with b-jets as well as in association with Higgs boson decaying into a b quark-antiquark pair was carried out. An extensive search for new resonances using the compact muon solenoid run 2 data was done. This was focussed on resonances that occur during the decay into either two Standard Model Higgs bosons or one Standard Model Higgs boson and a Beyond Standard Model Scalar as the final states together with two photons and two bottom quarks.

FACULTY & STAFF

B ANATHANARAYAN | PhD (Delaware), Professor
BIPLOB BHATTACHERJEE | PhD (Calcutta), Assistant Professor
SOMNATH CHOUDHURY | PhD (CEA Saclay), Assistant Professor
JUSTIN R. DAVID | PhD (TIFR, Mumbai) | FASc, FNASc, Professor
PRASAD SATISH HEGDE | PhD (Stony Brook), Assistant Professor
JYOTHSNA RANI KOMARAGIRI | PhD (TIFR, Mumbai), Assistant Professor
CHETHAN KRISHNAN | PhD (Texas), Associate Professor
RANJAN LAHA | PhD (Ohio), Assistant Professor
APOORVA PATEL | PhD (Caltech), Professor
DIPTIMAN SEN | PhD (Princeton), FASc, FNA, FNASc, Professor
ANINDA SINHA | PhD (Cambridge), Associate Professor
SACHINDEO VAIDYA | PhD (Syracuse), Professor
SUDHIR KUMAR VEMPATI | PhD (PRL, Gujarat), Professor

HONORARY FACULTY

ROHINI GODBOLE | PhD (Stony Brook), FASc, FNA, FNASc, FTWAS, Professor

EMERITUS FACULTY

N. MUKUNDA | PhD (Rochester), FASc, FNA, Professor
J PASUPATHY | PhD (Rochester), FASc, Professor

The Department of Instrumentation and Applied Physics was established in the year 1996. The Department pursues a wide area of interdisciplinary research activities in the domain of applied physics and provides post-graduate degrees in this area. With 13 faculty members offering 17 courses, the department is also making a dent in creating social impact.

CURRENT RESEARCH

The research in the Department is highly interdisciplinary and spans the horizons of physics and engineering, applied to the areas of healthcare, food-processing, life-sciences, electronics among others.

The Department also has a lab which works on various aspects of optoacoustic imaging for biological/ medical Imaging, image reconstruction, cancer research and theranostics. Specifically, the lab has started to explore the idea of making low-cost and miniaturized versions of optoacoustic imaging technology. Further multi-modal optoacoustic ultrasound (OPUS) systems are being developed, as this would enable easy clinical translation of the developed technology. In other work, improved glucose sensing using cooled IR optoacoustic spectroscopy (CIROAS) with higher sensitivity (as water does not generate any optoacoustic

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Degree Programs offered: PhD, MTech (Research) and MTech

IN NUMBERS

12 Academic staff
1 Scientific staff
52 PhD students
1 MTech student
50 Publications, 8 Patents
2 MTech conferments, 2 MTech (Research) conferments, 11 PhD conferments

3.6.3 Instrumentation and Applied Physics

CHAIRPERSON

S ASOKAN

signal at 4 degrees) compared to commercially available devices was demonstrated. Lastly optical imaging methods are being explored in the context of theranostics for different diseased conditions.

Metasurfaces are 2D counterparts of metamaterials which are used to manipulate the phase, amplitude, polarization of the light beams. In this context, the Department is working on finding several cost-

CORE RESEARCH

The core research areas pursued in the Department encompass amorphous semiconductors, dynamic metasurface, stretchable electronics, additive manufacturing, phase change memories, fibre optic sensors, nanometrology, precision motion control, microrobotics, chemical sensor, photodetector, supercapacitor, metamaterials, 2D materials, photoacoustic imaging, photoacoustic spectroscopy, chemical sensors, photodetectors, supercapacitors, light-sheet microscopy, super resolution microscopy, nanolithography, biophysics, cell biology, imaging cytometry, optical traps, sensors, semiconductor devices and integrated circuits, flexible electronic systems, mass spectrometry, electromagnetism, scientific computation, tomography, inverse problems, optofluidics, biomedical instrumentation, microfluidics and lab-on-a-chip, optical metrology, nanoscale device physics and electron transport, quantum computation using superconducting circuits, quantum acoustics, quantum dots, self-assembled mono-layers, optoacoustic mesoscopy/ tomography, image reconstruction, cancer research and more.

effective, bio-compatible fabrication methods of such planar devices where the optical properties can be tuned dynamically. Various methods of fabrication techniques like nanoimprinting, additive manufacturing and template-assisted dewetting are utilized to fabricate devices which are of large area. Flexible, stretchable and can be easily integrated into clothing for wearable applications. In the last year, a method of developing a large area mechano-chromic sensor was developed by utilizing the softness of the substrate and wetting properties of liquid metals. In a different work in collaboration with Indian Space Research association a Long Wavelength Infra-red (LWIR) based band pass filter was designed for application in payload sensing. In yet another work, a large area metasurface based sensors was designed for detecting toxic gases in the semiconductor industry.

Experimental realization of light-matter physics using superconducting artificial atoms interacting with microwave radiation is another frontier area of research. Within this broad theme, the Department works on single photon generation, entangled photons for probing matter, multi qubit architecture for quantum computation, new regimes of light-matter interaction using SAW devices, non-Markovian effects in multiqubit architectures, quantum simulation etc. Last year, designing of surface acoustic wave filters was undertaken to make unidirectional transducers for SAW signals for quantum information processing. Further, the first realization of a giant atom with intrinsic non-Markovianity was also demonstrated. This proof of concept experiment showed that an atom coupled at two distant coupling points reabsorbs the quantum emitted by one of the coupling points at the other coupling point with a finite probability. In a different work, a combined Lamb-shift of two superconducting artificial atoms coupled to a long section of transmission line with a grounded mirror at the far end was shown. In yet another work, a strategy based on EIT and AT was demonstrated to control transmission and reflection of acoustic signals using an artificial atom.

In the area of condensed matter physics, electrostatic force microscopy was demonstrated to be a non-invasive sub surface tool to probe encapsulated layers in van der Waals heterostructures Preliminary results were obtained on piezotronics with MoS2 devices. Further, transfer characteristics and hysteresis in substrate engineered MoS2 field effect devices were studied. Experiments also probed correlated phenomena in twisted bilayer graphene systems using thermoelectric measurements.

The Department has also demonstrated carbon dot synthesis by colloidal method and investigated their optical characterization. Quantum yield enhancement by using Hexadecyle amine as functionalising agent was studied and white light emission was achieved. Further, MoS2 Quantum dot synthesis by colloidal method and characterization were performed. PbS, CdS, PbSe and CdSe quantum dot precipitation in silicate glass by melt and quench method was also demonstrated. Optimization of the fabrication methods were performed to achieve high quality quantum dots. Further, design and fabrication of optical fiber winding system for fiber drawing system were also initiated.

In the frontier research area of semiconductor devices and integrated circuits, the Department has pursued new device design and engineering, physics-based modelling, integrated circuits on flexible substrates including thin film transistors (TFTs), impact of mechanical buckling of the substrate on the physics of TFTs, self-stabilizing circuits, circuit design with disordered semiconductor based TFT and self-healing circuits. Further, new activities have been taken up in bio-engineering and bio-medical device design such as edible electronics. Technology Translation forms another important component of this initiative, including wastewater treatment (spinoff openwater.in), brain machine interface for microUAV control via SSVEP and eye gaze (to DRDO) and self-healing circuits (to ISRO). This year a research thread on Edible Electronic Pills for healthcare was established at the Flexible Electronics Lab, IAP. This is in addition to research on self-healing circuits, design and modeling of thin film circuits

In the area of atomic force microscopy (AFM), research on diamagnetic levitation was initiated and precise in-plane control of the levitated stages was demonstrated. Research on replaceable AFM tips was

continued, successfully demonstrating tip replacement within ten seconds duration. Research on magnetic tweezers demonstrated that trapped magnetic micro-particles can be guided to move along a variety of trajectories. Theoretical investigation of the motion of the magnetic particle was also undertaken. A design for a compact Atomic Force Microscope was also developed and initiated eigen-frequency analyses of compliant mechanisms and of piezo-actuators using the Rayleigh Quotient technique. Research on optical beam deflection-based motion measurement demonstrated automated calibration and multi-point measurement using the system.

Further research has been carried out on a novel spray coating and a transfer method was developed for fabricating a suspended bolometer of vanadium oxide-coated multiwalled carbon nanotubes (VCNTs). A parametric study was performed to evaluate the effect of the substrate, modulation frequency, and temperature on the bolometric performance and revealed that the performance of the bolometer solely does not depend on the substrate parameter but modulation frequency and bias current as a function of temperature also play a key attribute. The TCR (temperature coefficient of resistance) of the suspended VCNT bolometer is ~−0.41%/K which is ~486% higher than the reported suspended multiwalled CNTs at 300 K. Moreover, the suspended bolometer has a voltage responsivity of ~67.42 ± 5.46 V/W (~7.68 times that of unsuspended) at 200 K. Thus, the study presents an efficient method to develop the suspended bolometer that has not been realized so far to obtain much higher TCR and responsivity.

In the field of Optical Metrology, a new structured-light projection technique (Circular Fringe Projection) was introduced and demonstrated to overcome a long-standing problem in the field of dynamic deformation measurements that the four-decades old conventional counterpart (Linear Fring Projection Technique) couldn't solve. Innovative Lab-on-a-Chip device is developed to perform In-flow Decantation and is validated to offer over 99% purity in Plasma-Separation from Blood. This microfluidic device offers solutions to multiple problems of importance in the field Sheath-free Flow Focusing, and Cell Enrichment without Centrifugation. Novel Technique for In-situ Detection of analyte via interferene synthesis of Copper-Nanoparticles is developed and a way of enhancing the fluoresce properties of these particles was reported.

Further, investigations have been undertaken on the electrical switching behaviour and topological thresholds in Fast Ionic Conducting and chalcogenide glasses. Fiber Bragg Grating based sensors have been developed for displacement sensing, thermography of embedded tumours, eye ball tracking, structural shape sensing and sensing acceleration. Highly sensitive Fiber Bragg Grating sensors have been developed with side hole packing and coated-etched Fiber Bragg Gratings for special applications such as underwater acoustic sensing.

In the area of ion mass spectrometry, work on power series expansion of axially symmetric toroidal harmonics for toroidal ion trap was undertaken. A different study used an optical grating with irregular spacing and the nature of light coming out was analysed. This has application in precision spectroscopy mainly in astrophysics. Differentiation in a non-invasive way between different types of brain lesions is important in both diagnostics and treatment. This work concentrated on differentiating Ischemia and brain tumor using statistical analysis. Lastly, a cryosorption pump and flexible cryo transfer lines were also developed.

In the past year, two key findings: (1) tailoring hysteresis effects in MoS2 transistors and (2) thermoelectric measurements on twisted bilayer graphene heterostructures were demonstrated. The former work showed that hysteresis in MoS2 FETs can be tuned via surface plasma treatment, and we analysed the behaviour of the hysteresis systematically and found them to originate from trap states created at the interface of gate dielectric and MoS2 channel. In the latter work, we used thermopower to investigate the correlated states in twisted bilayer graphene observing excess thermopower at half filling of the Moire band. Further, close to the magic twist angle, we observed signatures of Lifshitz transitions in thermopower, signifying correlation effects. In a collaborative work, we also

performed electrostatic force microscopy analysis of PbTe—Bi2Te3 1D-superlattice nanostructures. Furthermore, significant progress in few other projects was made: (1) tunneling in twisted bilayer graphene heterostructures, (2) nonlinear effects and magnetophonon transport in large area graphene samples.

Two novel ideas were opened up during the last year from the Laboratory of Advanced Nanostructures for Photonics and Electronics (LANSPE) lab. One of them was in the design of LWIR filters based on planar metasurface for satellite payload sensing. The fabrication of such filters is yet to be done based on our design which was done last year. Further, we have found a novel way to fabricate soft bio-compatible structured colour mechano-chromic sensors based on liquid-liquid interaction. Such techniques open up applications in niche area of soft robotics, and in mechano-chromic sensors. In another work, we have developed a design method to detect toxic gases based on optical processes. In addition, a bilateral NDA with Applied Materials was signed last year.

Over the past year, the FIST lab has developed an inversion method which integrates denoising procedure within the iterative model-based reconstruction to improve quantitative performance of optoacoustic imaging. Compared to the standard total-variation image reconstruction, the non-local means-based image denoising integrated with total-variation scheme was found to generate images with a improved SNR of about 2.5 dB, this work was published in Journal of Biophotonics. Further, a binary tomography approach was developed to accurately image vasculatures in photoacoustic imaging, wherein the dice similarlity coefficient was found to improve by about 10% and the same was accepted for publication in Journal of Biomedical Optics. The collaborative efforts with Shell Technology Centre on accelerating three-dimensional iterative image reconstructions using multi-GPU platforms has been submitted for publication.

FIST lab has also worked in collaboration with MIG lab at CDS to develop a light-weight neural network-based architecture which could run on mobile platforms to accurately segmentation of COVID-19 abnormalities, this work was published in IEEE Trans. on Neural Networks and Learning Systems, and had widespread media attention by different news outlets like TechnXplore, The Hindu, Times of India, Times Now, Deccan Herald, The New Indian Express etc. Specifically this work was deployed on different platforms like Nvidia-Jetson, Raspberry-PI etc, making it a clinically useful tool.

Contributions for scaling-up the diagnostic testing of COVID-19 by Optics and Microfluidics Instrumentation (OMI) Lab have led to a multi-pronged solution: (i) The Mobile Infection Testing and Reporting (MITR) Labs: ICMR Certified BSL2+ Mobile labs Facility for enabling RT-PCR testing at the hotspots/continent zones with a significantly reduced turnaround time (few hours) while retaining the throughput as that of the centralized labs. A single van configuration of MITR Labs is being deployed at large scale by TataMD (Medical Diagnostics spin-off) for conducting CRISPER based test. (ii) Indigenous Portable PCR System developed by our group at 1/10th of the RT-PCR Instrument cost eliminates the dependency on the skilled technician to operate the instrument and analyse the test results (tested with 200+ COVID-19 samples in CIDR and in the process of obtaining certification). (iii) Further, the Opto-thermal Ultrafast PCR System developed holds great promise in making the dream of Point-of-Care PCR Tests a reality.

Research in the Depatment also included a diamagnetically levitated platform with millimeter-scale positioning range and nanometer scale positioning resolution in 3-Dimensions. A compact AFM and developed an open-loop control system form contact mode AFM was designed and analysed. Experiments on trapping and manipulation of permanent magnet micro-spheres in 3-Dimensions and demonstrated moving particles into occluded areas were continued. And a high-speed positioning stage for atomic force microscopy was designed and fabicated. A side-hole packaged, nanolayer molybdenum (Mo) coated etched Fiber Bragg Grating (eFBG) sensor, with a pressure sensitivity enhancement of nearly 2000 times, has been developed for sonar applications. Further, etched fibre Bragg Grating (eFBG) based sensors have been developed for the detection/characterization of copper nanoparticles

templated by double stranded DNA, with a sensitivity of 1.5395 nm/RIU. Also, a highly sensitive and label-free technique based on a reduced graphene oxide (rGO) coated etched Fiber Bragg Grating (eFBG) sensor has been developed for the detection and quantification of dsDNA. In addition, Alternating Differential Scanning Calorimetric studies have been carried out on bulk Ge-Te-Tl glasses, over a wide range of compositions, to understand the effect of thallium addition on the non-isothermal crystallization process; The optical and mechanical properties of Ge-Te-In-Ag chalcogenide glasses, have been studied. To be able to resolve molecular-clusters it is crucial to access vital information (such as, molecule density, cluster-size, and others) that are key in understanding disease progression and the underlying mechanism. Traditional single-molecule localization microscopy (SMLM) techniques use molecules of variable sizes (as determined by its localization precision (LP)) to reconstruct a super-resolution map. This results in an image with overlapping and superimposing PSFs (due to a wide size-spectrum of single-molecules) that undermine image resolution. Ideally, it should be possible to identify the brightest molecules (also termed as the fortunate molecules) to reconstruct ultra-superresolution map, provided sufficient statistics is available from the recorded data. Probabilistic Optically-Selective Single-molecule Imaging Based Localization Encoded (POSSIBLE) microscopy explores this possibility by introducing a narrow probability size-distribution of single-molecules.

Development of silicon compatible thin film transistor process: A new class of amorphous oxide semiconductors based on InO x doped with Ti, W or Si seems to show great promise for large area, flexible, electronics. Of particular interest is the In2O3 :SiO2 system as it has a relatively large bond dissociation energy, hence highly suited for long-term environmental stability. present a sub-200Â°C fully photolithographically-processed indium oxide thin film transistor that is fully compatible to circuit integration on plastic substrates.

This year a research thread on Edible Electronic Pills for healthcare was established at the Flexible Electronics Lab, IAP. This is in addition to research on self-healing circuits, design and modeling of thin film circuits

Technology Transfer:

1.) NDA with Tata Steel for Manufacturing of Wastewater Treatment System

2.) Agreement with Neyvelli Coal Plant for Product Deployment - Effluent treatment System

3.) Agreement with Mavallipura Panchayat - Groundwater treatment system

4.) Agreement with BIRAC - Deployment of Greywater treatment system, Barapullah, Delhi

Research on scattering of light from a grating with unequal spacing is continued. This study will now be extended to a grating of unequal spacing and uneven surface. 2. The effect of photoelectric effect and compton effect on the scattering of x-rays during ct detection is studied. 3. Mathematical modelling of the covid-19 pandemic is taken up. We have concentrated on a few BBMP wards of Bengaluru city.

Other areas of research included embedding Carbon dots in polymer matrix for stabilization and higher quantum yields, conversion of plastic waste to carbon nanomaterials, development of Blue light emitting MoS2 quantum dots, and the development of CsPbBr3 perovskite quantum dots for LED applications.

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The Department of Mathematics comprises 32 faculty and over 60 affiliated researchers. Its research profile represents diverse interests, ranging from pure to applied mathematics, and collaborations with related fields. It has a vibrant atmosphere in which members with different interests collaborate with each other, and with mathematicians internationally.

CURRENT RESEARCH

A domination result for the simple length spectrum of surface-group representations into PSL(2,C) was obtained in joint work with Weixu Su. A conjecture concerning representations into PSL(n,C) was also formulated. Second, in joint work with M. Trnkova and K. Dias, a long-running project concerning proving a correspondence between pairs of measured foliations on punctured surfaces and meromorphic quadratic differentials was completed.

A study of the limits of the largest connected components (viewed as metric spaces) obtained by critical percolation on uniformly chosen graphs and configuration models with heavy-tailed degrees was completed. Of independent interest, refined asymptotics for various susceptibility functions and the maximal diameter in the barely subcritical regime were obtained. Second, an explicit algorithm for sampling a uniform simple connected random graph with a given degree sequence was obtained. By products of this central result include: (1) continuum scaling limits of uniform simple connected graphs with given degree sequence and

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IN NUMBERS

32 Academic staff
22 PhD students
32 Int PhD students
76 publications
2 Int PhD conferments
2 PhD conferments

3.6.4 Mathematics

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asymptotics for the number of simple connected graphs with given degree sequence under some regularity conditions, and (2) scaling limits for the metric space structure of the maximal components in the critical regime of both the configuration model and the uniform simple random graph model with prescribed degree sequence under finite third moment assumption on the degree sequence. As a substantive application, this answers a question raised by Cerny and Teixeira.

A numerical intersection-theoretic criterion was proved for the solvability of generalised Monge-Ampere equations. An approach by Demailly towards the Griffiths conjecture was found to be problematic via a uniqueness result for the cushioned Hermitian-Einstein equation. An asymptotic Ohsawa-Takegoshi type characterisation of Griffiths semipositivity was found.

The density of modular points in pseudo-deformation rings (that is, `big' R=T theorems in the residually reducible case) was explored. Such big R=T theorems were previously known due to Bockle for residually irreducible representations. The main aim of this project was to extend Bockle's result to the case of residually reducible representations and study its arithmetic applications such as level raising of modular forms.

With Alexander Belton (Lancaster), Dominique Guillot (Delaware), and Mihai Putinar (UCSB), a comprehensive paper on the preservers of total positivity / total non-negativity on kernels on arbitrary domains was completed. This includes (rectangular) matrices, Hankel matrices and kernels, as well as Toeplitz (one-sided or two-sided) kernels on subsets of the real line (including Polya frequency functions/

CORE RESEARCH

Algebraic and combinatorial topology, arithmetic geometry, number theory, algebraic number theory, modular forms, p-adic families of automorphic forms, automated theorem proving, combinatorics, commutative algebra and algebraic geometry, K-theory and algebraic cycles, complex geometry, differential geometry, functional analysis, harmonic analysis, mathematical finance, mathematical physics, nonlinear dynamics, numerical analysis, operator theory, partial differential equations, calculus of variations, Geometric analysis, probability and stochastic processes, representation theory, several complex variables, statistical mechanics, time-series analysis, Teichmüller theory.

sequences). Second, with Belton/Guillot/Putinar, another longstanding work on matrix stratifications and their ramifications in matrix multiplication, computing eigenvalues, etc. was also completed.

Risk sensitive stochastic differential games in the positive orthant have been investigated. These classes of problems typically arise in communication networks with heavy traffic. Both discounted and ergodic cost criteria on the infinite horizon have been studied. Nash and saddle point equilibria have been established and characterized for relevant cases.

It was shown that generalised Monge-Ampere equations have solutions if and only if a Nakai-Moizeshon style numerical criteria are met. This solved a conjecture of Lejmi-Szekelyhidi in the projective case and improved the result of G Chen. With A Khare, a conjecture of Deng-Ning-Wang-Zhou on the characterisation of Griffiths semipositivity of Hermitian metrics being equivalent to the multiple coarse L^2 extension property was resolved affirmatively.

It was shown that for any n-vertex stacked (d-1)-sphere, there exists a sequence of -vertex stacked spheres of dimensions respectively. If it was a flag sphere, then it was shown that is a subcomplex of a combinatorial d-sphere on the same vertex set. Finally, it has been shown that semi-equivelar toroidal maps are quotients of vertex-transitive toroidal maps.

The study of hypergeometric functions associated with standard multiplicities was continued. Sharp estimates were obtained for these functions which include spherical functions on a hermitian symmetric space which transform according to a given one dimensional character of the maximal compact subgroup. Projective representations of finitely generated groups were studied. Existence of a covering/representation group for finitely generated groups for which the second integral homology group was finitely generated was established. These groups include the class of finitely generated nilpotent groups. As applications a characterization of monomial projective representations of finitely generated nilpotent groups was established. A characterization of polycyclic groups which projective representations are all finite dimensional was also obtained.

In joint work with I Fischer, bijective proofs of skew Schur polynomial factorizations were obtained. In joint work with P Singla, a novel on finite commutative rings was analyzed using group representation theory. The spectrum, stationary distribution and mixing time was calculated exactly. The monopole-dimer model was studied for a special class of finite graphs where the partition function is an exact square and a combinatorial interpretation was given. In joint work with M. Josuat-Verges and S. Ramassamy, a theory for the enumeration of polytopes which are defined by inequalities in [0,1]^n of consecutive coordinates was built.

Andrianov's conjecture on the functional equation of the spinor zeta function for holomorphic Siegel modular forms on the symplectic group of degree 3 was proved.

A model of Dirichlet boundary control problems governed by the diffusion operator is considered with pointwise constraints on the control variable. Finite element discretization is introduced, analyzed for theoretical convergence and tested with computational experiments. Subsequently, Stokes operator is considered and analyzed for the Dirichlet boundary control problem with constraints. A class of first and second order finite element methods based on hybrid high ordered methods are introduced and analyzed in both two and three space dimensions with computational evidence. A class of nonconforming methods are analyzed for parabolic obstacle problem which is observed to be natural for treating the low regularity of the time derivative of the solution.

Work on establishing the scaling limit of the minimal spanning tree on a heavy-tailed inhomogeneous random graph was completed. In addition, the topological properties of the limit were studied, and this work supports a prediction made by statistical physicists in the early 2000s. Second, work on establishing the global lower mass bound for heavy-tailed critical configuration models was done. This implies convergence in distribution of the maximal components at criticality for such a configuration model with respect to the Gromov-Hausdorff-Prokhorov topology.

Proofs of analogues of Ingham's theorem in several contexts such as: compact and non-compact Riemannian symmetric spaces, Hermite and special Hermite expansions and Fourier transform on Heisenberg groups were completed. For the Laplacian on Heisenberg group, an analogue of Chernoff's theorem was proved. Characterisation of certain eigenfunctions of the Laplace-Beltrami operators on harmonic NA groups as Poisson integrals in terms of their holomorphic extendibility to certain domains in the complexification on the nilpotent group N was provided.

An investigation, begun in 2019, of the Bergman geometry of domains whose boundaries have isolated infinite-type points was completed. Optimal estimates from above and below for the growth of the Bergman kernel (on the diagonal) and the Bergman metric, as one approaches an infinite-type boundary point, were obtained. The class of domains studied subsumes all classes of infinite-type domains in 2-dimensional complex Euclidean space for which estimates have previously been obtained in the literature. An exact formula for the topological entropy of finitely-generated rational semigroups was obtained. For rational semigroups comprising maps in more than one variable, the literature presents several dynamical invariants with entropy-like properties, for none of which an exact formula was known. The work concluded presents an exact formula for one of these invariants (while the problem is addressed fully in one variable). It thus suggests lines of inquiry for future research.

Conducted work on the following three themes: a) The stability of the solution of the so-called global Bishop Problem (a Plateau-type problem) for a model real n-dimensional sphere b) A construction of holomorphic Hardy spaces (reproducing kernel Hilbert spaces of boundary values) for a new class of domains. c) New bounds for the embedding dimension problem associated to polynomially convex embeddings in the special case of odd-dimensional manifolds.

In joint work with S. Viswanath (IMSc, Chennai), the decomposition theorem for g-stable affine Demazure modules for the cases g = E_6,7,8 and F_4 was proved. The connection between the graph polynomials and Lie algebras was studied in joint work with Kartik Singh.

In joint work with Ved Datar and Jian Song, the following result was proved: If a compact Kahler manifold, with Ricci curvature bounded below by a positive constant has volume close to that of a projective space, then it is Gromov-Hausdorff close to the projective space.

A very long-standing conjecture of Brumer and Stark was proved. In addition, Higher Chern classes, constant terms of Eisenstein series and Iwasawa theory over finite fields were studied.

Ongoing work on potential estimate for quasilinear systems of differential forms, topology of weak G-bundles in supercritical dimensions and regularity of polyharmonic map type systems.

Given a split connected reductive group G over Z and a non-archimedean local field F, Kazhdan considered the Hecke algebra H(G(F), K_m), an important object in representation theory, and proved that for any field F' sufficiently close to F the Hecke algebras H(G(F), K_m) and H(G(F'), K_m') are isomorphic. This result was generalized to general connected reductive groups. As part of an ongoing joint work with Xuhua He, a nice set of representatives of the elements of the Iwahori Weyl group were chosen in G(F). This set of representatives enjoys some interesting properties; in particular, this has allowed us to define the Tits group of the Iwahori Weyl group and gain deeper understanding of the structure of certain Hecke algebras that show up naturally in representation theory.

Homogenization of an elliptic PDE with periodic oscillating coefficients and associated optimal control problems with energy type cost functional is considered. The domain is a 3-dimensional region (method applies to any n dimensional region) with oscillating boundary, where the base of the oscillation is curved, and it is given by a Lipschitz function. Further, we consider a general elliptic PDE with oscillating coefficients. We also include very general type cost functional of Dirichlet type given with oscillating coefficients which can be different from

the coefficient matrix of the equation. We introduce appropriate unfolding operators and approximate unfolded domain to study the limiting analysis. The present article is new in this generality. We establish the equivalence between laser speckle contrast based and diffuse correlation spectroscopy methods in in-vivo imaging of blood flow using the Volterra integral equation theory.

Studied connectivity properties of an inhomogeneous random geometric graph and derived the scaling regime under which a Poisson approximation for the number of isolated components holds. A sufficient condition for the graph to be connected asymptotically with probability approaching one was also obtained. Conditions under which a non-trivial phase transition occurs was derived for three enhanced random graph models on the plane, the enhanced versions of the homogeneous and inhomogeneous random connection models and the Poisson stick model with unbounded stick lengths. A RSW Lemma was derived using which it was shown that in all the three models, percolation does not occur at criticality.

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The Department of Physics was established in 1933 by the Nobel Laureate CV Raman, and several other illustrious names of Indian Science such as Homi Bhabha, Vikram Sarabhai, RS Krishnan, GN Ramachandran, S Ramaseshan and TV Ramakrishnan have been associated with this Department. It is now a well-established research centre for condensed matter physics and astrophysics.

CURRENT RESEARCH

THEORETICAL CONDENSED MATTER PHYSICS

Theoretical condensed matter physics branches into soft and hard condensed matter systems, studying classical, and quantum phenomena. Some of the main topics include superconductivity, fractonic phases, twistronics, many-body localization, entanglement, diverse aspects of turbulence, soft active matter, membranes for CO_2 absorption, and others.

In quantum condensed matter physics, a novel superconducting state in recently discovered nickel-oxide superconductors was predicted. A new direction of research on fracton phases was initiated leading to new dualities in tensor gauge theory. A hitherto unexplored instability of the d-wave superconductivity to a d+is state was found for underdoped cuprates. Prediction of a new low-energy phonon mode in twisted bilayer two-dimensional (2D) materials was made. Possibility of novel topological hall effect in a non-magnetic

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IN NUMBERS

28 Academic staff
5 Scientific and 1 Technical staff
160 PhD students
134 Int PhD students
242 Publications
9 Int PhD conferments
17 PhD conferments
6 JAAP conferments
2 MS conferments

3.6.5 Physics

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PRABAL KUMAR MAITI

band insulator $KTaO_3$ was proposed. Lifshitz transitions in interacting 2D systems was studied using the renormalization group approach. Various aspects of non-ergodicity, dynamics and entanglement were explored in disordered interacting systems with single-particle mobility edge and with non-Hermitian drive. A new path integral formalism to compute quantum entanglement of interacting fermions was developed.

In soft condensed matter physics, a potential finite-time singular solution of the three-dimensional Euler equation was examined. Spiral- and scroll-wave dynamics in an anatomically realistic mathematical model for canine and human ventricular tissue was studied. Emergent inertia, conservation laws, and transient growth in the viscous sedimentation of disc arrays were explored. A new hydrodynamic analogue of the Higgs mechanism for long-range order of flocks in a thin fluid film was found. Inter-dendrimer interactions on graphene, using atomistic molecular dynamics simulations was studied. A polymer melt that provide high permeance and selectivity for the important problem of the separation of CO_2 gas was found.

EXPERIMENTAL CONDENSED MATTER PHYSICS

Experimental condensed matter physics groups focused on two-dimensional materials and their heterostructures, zero-field nuclear magnetic resonance (NMR), high-pressure Raman spectroscopy, thermoelectrics, superconducting quantum devices, magnetic materials, superconductivity, and light-matter interactions.

CORE RESEARCH

Astronomy and Astrophysics: Cosmology, black holes, nuclear astrophysics, galactic dynamics, interstellar medium, radio astronomy, solar physics, and plasma physics

Atomic and Optical Physics: Laser cooling and atom trapping, laser tweezers

Experimental Condensed Matter Physics: Spectroscopy, electrical transport, bulk and thin films, low-temperature physics

Theoretical Condensed Matter Physics: Strongly correlated electrons, topological insulators, twistronics, many-body quantum dynamics, soft matter, biophysics, and nonlinear physics

Pressure-dependent phase and structural transitions were measured using in-situ Raman spectroscopy and synchrotron x-ray diffraction. Novel magnetic phenomena and excitonic insulator to semiconductor transitions were observed. Zero field NMR of iron and cobalt using a home-built spectrometer was carried out. High-temperature dielectric properties of lanthanum nickelates and cobalt ferrites were measured, with composition-dependent relaxation mechanisms ascribed to electrode polarization. Magnetoresistance studies in platinum nanowire experimental verified Kohlar's rule in nanowires. Synthesis and characterization of skutterudites, PbTe based chalcogenides, alloy chalcogenide materials were carried out for thermoelectric applications, including miniaturized coolers and laser cooling. Multicomponent semiconducting chalcogenide glasses and topological insulators were synthesized with applications in photovoltaics, memory and novel electronic devices. Magnetic proximity effect in Ta/Pt/Co/Pt multilayers was studied by interface-sensitive, element-specific X-ray resonant magnetic reflectivity. Proximity-induced magnetic moment was found to be sensitive to the thickness of tantalum buffer layers. Topologically non-trivial spin textures (for example, skyrmions) were studied in KTaO3 with oxygen vacancies. The local moments around a vacancy can form bound magnetic polarons resulting in topological hall effect, opening a route to modify topological phenomena through defect engineering.

Experiments with twisted bilayer graphene showed exceptional sensitivity of cross-plane thermoelectricity to twist-angle-dependent band-structure. The lowest noise (to date) graphene field-effect transistors were created. Inter-layer charge-transfer rate was found to be sensitive to Fermi energy of graphene layer in graphene-transition metal dichalcogenides (TMD) hetero-interfaces. Unique Coulomb drag experiments in dimensionally-mismatched 2D graphene and 1D InAs nanowire were performed to measure electron-electron interactions, and showed energy drag as the dominant drag mechanism. Discovered the quantum spin Hall effect in graphene. Observed proximity-induced superconductivity in 2D TMDs. Long-range optical energy propagation resulting from exciton coupling to surface lattice resonances was measured in hybrid semiconductor quantum dots (SQDs) – silver nanoparticle array devices. Photonic spin-momentum locking was observed in SQDs coupled to achiral hyperbolic metamaterials. Localized irradiation to create single-photon emitters in 2D materials was explored.

Hybrid devices consisting of superconducting transmon qubit and a mechanical resonator were fabricated. This device can be used to implement time-domain protocols to create non-classical motional states. High-quality NbN superconducting coplanar waveguide resonators were employed to measure magnon-photon coupling. Novel atom optical measurements including laser interferometry with atomic coherence and microwave electrometry with Rydberg atoms were carried out.

In soft-matter physics experiments, ciliary oscillations were measured through a simultaneous measurement of motion and flow field of an isolated and active Chlamydomonas cilium. Internal friction emerged as the sole source of dissipation for ciliary oscillations. Through a combination of experimental and theoretical insights, an instability of oscillations was observed when active stresses were strain-softening and shear-thinning.

ASTRONOMY, ASTROPHYSICS AND COSMOLOGY

The research interests of the Astronomy, Astrophysics and Cosmology group cover a vast range of topics such as solar physics, Magnetohydrodynamic (MHD) turbulence, theoretical astrophysics of galaxies, galactic dynamics, accretion disks, physics of compact objects, nuclear and plasma astrophysics, numerical simulations, properties of the intergalactic medium, radio astronomy, neutral hydrogen 21-cm, turbulence in the interstellar medium, observational cosmology, inflationary cosmology and physics of the early universe.

In solar physics, the group developed a new theory of the near-surface shear layer inside the Sun based on the thermal wind balance equation. In understanding the astrophysics of galaxies, the group studied the vertical density distribution of a multi-component galactic disk in the gravitational

field of the dark matter halo and applied this to a low-surface brightness galaxy UGC 7321. The stellar disk is shown to flare with radius in the outer disk despite the dominance of the dark matter halo. In accretion physics, the group focused on studying the stability of accretion disks and origin of viscosity therein, luminosity of magnetized white dwarfs and their detection, the ultraluminous X-ray sources and blazars, modified virial theorem in the presence of a strong magnetic field and in general, various aspects of physics in and around white dwarfs. In plasma astrophysics, the group worked on diverse topics such as simulations of radio halos of Milky Way-like galaxies, significant star formation rate and cooling in the Phoenix cluster, observations of short cooling cycles in intracluster medium (ICM) cooling and feedback jet simulations, a mean-field dynamo in the global MHD simulations of hot accretion flows and high-resolution 3-D simulations of stratified turbulence relevant for the ICM medium. In radio astronomy, the group focused on the observational studies of the interstellar medium (ISM) of the Milky Way and nearby galaxies, dust-gas correlation in the nearby galaxies using archival radio and infrared observations, analysis of molecular, atomic and ionized phases of the ISM with the THOR survey team and detailed study of low-frequency deep fields and the TGSS survey data to characterize the low frequency galactic and extragalactic foregrounds. In theoretical cosmology, the group studied the induced stochastic gravitational waves (GW) from large scalar perturbations forming primordial black holes on small scales and their detectability with future GW observatories such as LISA, DECIGO and BBO. The group also studied the impact of primordial helical magnetic fields on the axion dark matter along with stringent constraints on the QCD axion decay window due to overproduction of axion dark matter, and new consistency relations for primordial correlation of gravitons with gauge fields and their resulting imprints on the Cosmic Microwave Background observations.

PLASMA PHYSICS

The research interests of the plasma physics group were focused on wave and particle dynamics in plasmas, nonlinear theories and large-scale numerical simulations. Advanced simulations for studying turbulent transport were developed, based on the flagship fusion code GTC-X. These first principles massively parallel simulations, and associated theory led to physics discovery in turbulence self-regulation by zonal flows in fusion plasmas.

FACULTY & STAFF

SUMILAN BANERJEE | PHD (IISC), Assistant Professor
JAYDEEP KUMAR BASU | PHD (Calcutta), FASC, Professor
AVEEK BID | PHD (IISC), Associate Professor
PRASAD VISHNU BHOTLA | PHD (IISc), Chief Research Scientist
ARNAB RAI CHOUDHURI | PHD (Chicago), FASC, FNASC, FNA, Professor
ANINDYA DAS | PHD (IISc), Associate Professor
TANMOY DAS | PHD (Northeastern), Assistant Professor
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PS ANIL KUMAR | PHD (Pune), Professor
ANIMESH KULEY | PHD (IIT Delhi), Assistant Professor
PRABAL K MAITI | PHD (IIT Kanpur), FASC, Professor

RAMESH CHANDRA MALLIK | PHD (IIT Madras), Associate Professor
REGHU MENON | PHD (IISC), Professor
SRIMANTA MIDDEY | PHD (Calcutta), Assistant Professor
SUBROTO MUKERJEE | PHD (Princeton), Associate Professor
BANIBRATA MUKHOPADHYAY | PHD (Calcutta), Professor
DV SUVISESHA MUTHU | PHD (IIT Kanpur), Principal Research Scientist
VASANT NATARAJAN | PHD (MIT), Professor
RAHUL PANDIT | PHD (Illinois), FASC, FNA, FTWAS, Professor
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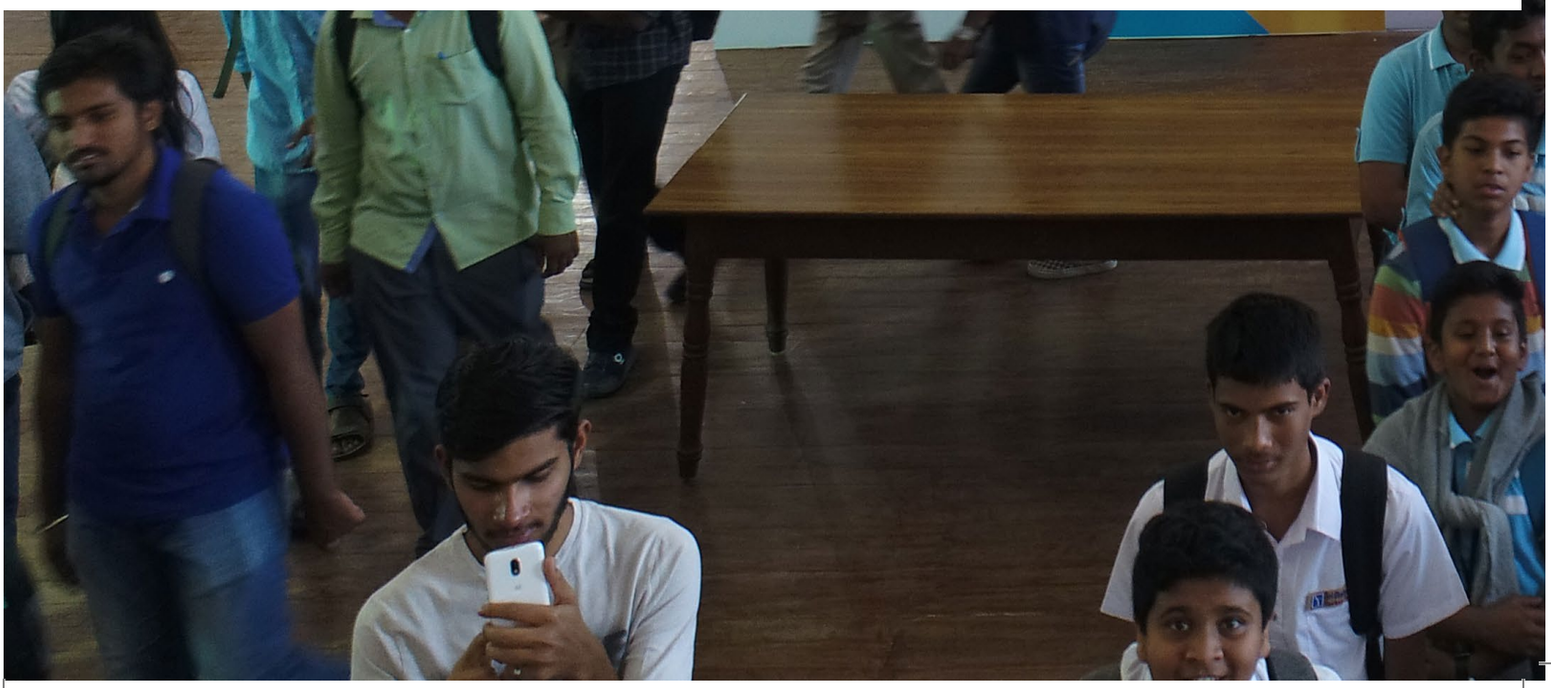
AKSHAY SINGH | PHD (UT-Austin), Assistant Professor
VIBHOR SINGH | PHD (TIFR), Assistant Professor

ASSOCIATE FACULTY

ARVIND AYYER | PHD (Rutgers), Associate Professor
AMBARISH GHOSH | PHD (Brown), Professor
DIPTIMAN SEN | PHD (Princeton), FASC, FNASC, FNA, Professor

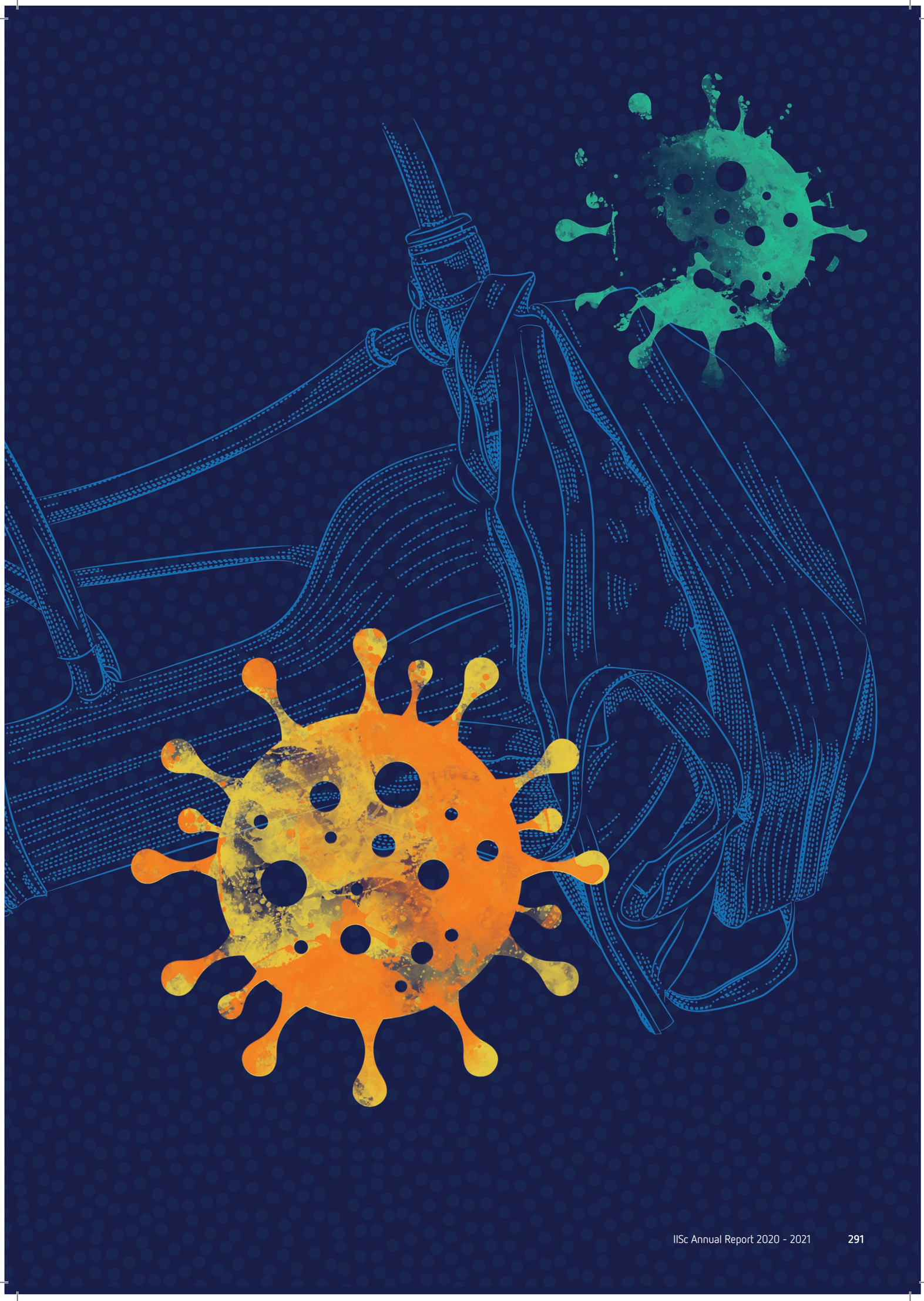
HONORARY & DISTINGUISHED FACULTY

TV RAMAKRISHNAN | PHD (Columbia), FNASC, FASC, FNA, FTWAS, FRS, Foreign Associate, Academie Desscience (Paris), Distinguished Associate
AK SOOD | PHD (IISC), FASC, FNASC, FNA, FTWAS, FRS, Professor
H R KRISHNAMURTHY | PHD (Cornell), FASC, FNASC, FNA, FAPS, FTWAS, Professor
CHANDAN DASGUPTA | PHD (Pennsylvania), FASC, FNASC, FNA, FTWAS, Professor
CHANDA J JOG | PHD (New York), FASC, FNASC, FNA, FTWAS, Professor



3.7

Centres under the Director



The J R D Tata Memorial Library at the Indian Institute of Science is one of India's oldest yet modern Science and Technology libraries. Started in 1911, as one of the first set of departments in the institute, it has become a precious national resource centre in the field of Science and Technology. The library's collection, which includes books, journals, reports, theses, Indian patents and standards, is regarded as one of the richest collections in the country. This rich and valuable collection built over ten decades has some of the rare reference materials and back volumes of several important journals. Apart from its print resources, the library subscribes to an extensive collection of e-journals, eBooks and online databases. Functioning as an effective support system for information services across the campus is the library's primary goal.

During the Financial year 2020-21, the library added 1946 documents, including 1195 books, 27 donated books, 237 eJournals, 183 eBooks, and 304 PhD theses and M.Tech dissertations. The library's total holdings have now increased to about five lakh plus physical documents, including physical books, bound volumes of journals, technical reports, standards, and theses & dissertations. The library continues to subscribe primarily to electronic-only journals, and currently, about 13000 e-journals are being subscribed, spending nearly INR 18.50 crores.

The Circulation section has registered 41 new members. The Circulation section carried out a total number of 845 transactions during the period. Work such as reshelving, shelf rectification, shifting etc., are being carried out in the library daily.

The library continued to maintain pre-eminence in providing access to a large number of e-resources. Some of the significant e-resources include the complete journal publications of the following publishers and Societies:

1. American Chemical Society
2. American Institute of Physics
3. American Physical Society Journals, including Physical review Online (PROLA) Collection
4. American Society for Microbiology - All Journals
5. American Society of Civil Engineers
6. American Society of Mechanical Engineers
7. Association of Computing Machinery
8. ASTM Journals and Standards
9. Elsevier collections
10. Emerald
11. IEEE / IEE
12. Institute of Physics Publishing
13. JSTOR
14. Oxford University Press
15. Royal Society of Chemistry - All Journals and its Archive

3.7.1

J R D Tata Memorial Library

LIBRARIAN

ANANDA T BYRAPPA

e-Shod Sindhu (eSS) Consortium

The eSS consortium for higher education electronic resources provides access to e-resources to universities, colleges, centrally funded technical institutes in India, including the IISc. IISc has online access to the following list of e-resources subscribed by the eSS.

	List of e-resources procured under e-Shodh Sindhu in 2020-21
1	ACM Digital Library
2	American Institute of Physics
3	American Physical Society
4	Annual Reviews
5	ASCE Journals Online
6	ASME Journals Online
7	JSTOR
8	Oxford University Press -262 titles
9	Project Muse
10	Springer Link 1700 Collection + Nature Journal

	Databases
1	Economic & Political Weekly
2	Institute for Studies in Industrial Development (ISID) Database
3	JGate Plus (JCCC)
4	MathSciNet
5	Web of Science

LibSys Software

The library uses LibSys, an Integrated Library Management Software, for its day-to-day functions such as acquisition, cataloguing, serials control, circulation and online catalogue of the library holdings. Using the online catalogue, users can browse and search the library resources. They can also view the status of a document and make online reservations.

Library Services

The library provides both conventional and contemporary services. Some of the conventional services include document delivery service, photocopy service, reference service, referral service. The UGC has identified the library as a document delivery centre for the county's southern region.

The library procured about 265 eBooks to support the online-only courses offered during the January – April semester of 2021

Some of the contemporary services provided by the library include:

1. IISc Publications Repository (ePrints@IISc)

ePrints@IISc (http://eprints.iisc.ac.in) is one of the country's earliest and largest institutional repositories for the research publication of the institute. The erstwhile National Centre for Science Information (NCSI) started the ePrints@IISc service. Since May 2012, the library is administering and managing the service. The repository collects, preserves, and disseminates the research output created by the IISc research community. The repository content can be accessed through the search and browse functionalities. As of date, the total number of publications in the repository is more than 53,000.

2. IISc Theses and Dissertations Repository (ETD@ IISc)

ETD@IISc (https://etd.iisc.ac.in) is one of the country's earliest institutional repositories for theses and dissertations. NCSI started the service in 2005. Since May 2012, the library is administering and managing the service. ETD@IISc is a digital repository for the theses and dissertations submitted by the IISc students. The repository captures, disseminates, and preserves the theses and dissertations of IISc. The repository content can be accessed through the search and browse functionalities. As of date, the total number of records in the repository is more than 5500

3. IISc Faculty Profiles

Faculty profiles (https://iiscprofiles.irins.org/) is a research information management service that helps the institute and individual faculty members collect, curate, and showcase scholarly communication activities. As of date, there are 534 faculty profiles.

4. Remote Access to Subscribed Online Resources through Shibboleth-based Single Sign-on Service

During the lockdown, the library received several enquiries about accessing the online resources from off-campus as students and faculty were unable to connect to the campus network through VPN. Realising the importance of the situation, the library quickly assessed the various possibilities for facilitating seamless off-campus access to the subscribed online resources apart from the VPN based access. Shibboleth, a single sign-on log-in system, was identified as a solution for off-campus access to the subscribed online resources.

The Shibboleth software implements widely used federated identity standards, principally the OASIS Security Assertion Mark-up Language (SAML), to provide a federated single sign-on and attribute exchange framework. A user authenticates with organisational credentials, and the organisation (or identity provider) passes the minimal identity information necessary to the service provider to enable an authorisation decision. Shibboleth IDP server is accessible via the link: https://libraryidp.iisc.ac.in

5. A cloud-based kiosk software solution for digital display of all the services provided by the library.

The presentation from a big smart television placed at a prominent location will attract the users' attention entering the library.

6. Low-cost computing using Raspberry-Pi Board:

Raspberry-Pi is a trendy, low cost, single-board computer (SBC) developed by the Raspberry-Pi Foundation in the UK. The board costs around INR 3,500.00, and including other peripherals like Monitor, Keyboard and Mouse, it works out to less than INR 10,000/- to build a PC. It runs on Raspbian, an open-source Debian-based operating system for Raspberry Pi. We have been using two Raspberry-Pi based PCs in the Library as Web OPAC (Online Public Access Catalogue) terminal and for online exit survey (Graduating students and retiring Staff/Faculty). It is working satisfactorily for the last two years and has proved to be a cheaper alternative to costly Desktop computers.

The library subscribes to several specialised databases like Scopus, SciVal, Web of Science, SciFinder Scholar, Reaxys, ChemOffice, Cambridge Structural Database, Turnitin, etc. The library periodically organises user awareness programs to benefit students and faculty members to create awareness and familiarity with such specialised resources. Some of the virtual user awareness programs organised by the library include:

1. Reaxys: An Innovative Data Analytics Tool Webinar (December 2020)

2. SciFinder-n: Less search, more research (November 2020)

3. Academic Integrity with Turnitin (September 2020)

4. Web of Science, Journal Citation Report, and Incites-Information tools that take your research to the next level (AUgut 2020)

5. Research Management Using Scopus and Scival (July 2020)

6. Learn to Publish: Wiley Webinar Series (June 2020)

7. Make the Most of Wiley Online Library (June 2020)

8. Learn more about SciFinder-n (June 2020)

9. Springer Nature Materials Webinar - A data-driven approach to Identify trends between materials' properties

10. The Value of the Review. Presented by Annual Reviews (May 2020)

New initiative

The library has implemented a web-scale discovery service for the library hosted services, viz. IIScprofiles, ePrints@IISc, ETD@IISc, library catalogue, and the Journal of the Indian Institute of Science using open-source software, VuFInd. The service (https://library.iisc.ac.in/vufind) provides a single interface for searching across the four services mentioned above.

Invited talks and Publications

The top-level library staff have delivered several invited talks in various institutes and organisations across India. Some have also been invited to serve as a member, board of studies, member, advisory board, member, book selection committee, etc. They have also published several papers in national and international journals and conferences on the themes relevant to modern-day librarianship.

PROFESSIONAL CONTRIBUTIONS

Dr Ananda T. Byrappa

1. Member, National Negotiation Committee for subscriptions, INFLIBNET, MHRD, India

2. Member, Technical Advisory Committee, (TAC) ISI, Kolkata, India

3. Member, Board of Studies (BoS), Bangalore North University, Bangalore

4. Member, Board of Education (BoE), Bangalore North University, Bangalore

5. Chairman, Content Selection Committee, Karnataka State Digital Library, Department of Public Libraries, GoK, Karnataka

6. Member, State Library Authority, Govt. of Karnataka

7. Convener, Ranking and Performance Committee, IISc, Bangalore

8. Chair, Committee for selecting 'Best Innovation Award' in Library and Information Science, Library Technology Conclave, (LTC) Bangalore, 2021.

The Archives Cell was established in 2007 with a mandate to collect, catalogue and preserve all documents, images, and other articles of relevance to the Institute. It became Archives and Publications Cell (APC) in 2008 with the additional responsibility to coordinate and facilitate the publication activities of the Institute through the IISc Press. Archives and Publications Cell has been renamed the Office of Communications (OoC) with effect from 24th April 2019.

Some notable initiatives are the following:

•OoC has extended the copy-editing services to the Institute community, students and faculty members for their papers, thesis, books, etc.,

•Gifts and memento display and sale are one of the major tasks at OoC from 2018.
The list of items that are being sold:
o Centenary Copper Medallion with a wooden gift box
o Key chain and pen drive in customized wooden box
o Book-Marks (set of twelve) neatly packed
o Parker pen, Roller pen, Gel pen with IISc logo engraved and gift box with a logo
o IISc Mugs (Big and Small) of various designs (Madhubani paintings – original campus images converted into paintings)
o Leather folders
o Bamboo Frame
o Tea Coaster
o Main building gemstone painting
o IISc Press Books
o IISc Press Jute Bags
o Handmade paper bags of various sizes
o Snippets from Archives
o Set of Picture Postcards of various themes: Dignitaries at the Institute, Aerospace 75, Early dept. buildings, Jubilee years, Main building, Tata Statue Complex.
o Sweatshirt, Track suit, Caps, T-Shirt and Backpack
o IISc Steel Water Bottle
o IISc Pen Stand and Envelope Cutter

IISc Press sets up stalls in the major Conferences at the Institute and displays and sells the above mentioned mementos.

IN-HOUSE PUBLISHING

OoC is coordinating the overall publication process like Copy Editing, Design and Layout and printing of the in-house publications of the Institute to:

- Annual Reports (Hindi and English)
- Annual Accounts (Hindi and English)
- Court Report
- CONNECT (Quarterly magazine of IISc)
- Journal of the Indian Institute of Science -Quarterly (co-published by Springer)
- IISc Directory and Planner
- Student Information Handbook and Scheme of Instructions (Four Year Bachelor of Science (Research) programme
- Quarks (A magazine of the undergraduate students)
- IISc Note pads
- Faculty Information Handbook
- Students Certificates and Transcripts along with folders

3.7.2 Office of Communications

CHAIRPERSON
KAUSHAL VERMA

- Medal Certificates Folders
- Faculty Award Certificates and special folders
- KERNEL (Monthly Newsletter of IISc)
- Translation of IISc Kernel Newsletter to Kannada and Hindi

PARASPAR SERIES

Office of Communications, IISc started a Paraspar Webinar series. This is a platform for conversations about knowledge systems, particularly science.

- Paraspar Series 1 – Journey of Discovery of Science – 7 Lectures
- Paraspar Series 2 – Science & Society – 6 Lectures
- Paraspar Series 3 – Understanding India – 6 Lectures
- Paraspar Series 4 – Reading the Past – 1 Lecture

IIScPress

The following committee for IISc Press is continuing with effect from January 2017:
Chair:Amaresh Chakrabarti
Members:
Diptiman Sen: Series Editor, Lecture Notes Series:
Prabal Kumar Maiti: Series Editor, Research Monographs
S P Arun: Series Editor, Popular Science Series
Kaushal Verma: Ex-officio Chair, OoC

IISc Press was established in 2008, with a mission to bring quality books at affordable prices for helping Indian post-graduated education in science and engineering. Prof. Anurag Kumar was appointed as the first Chairperson of the IISc Press.

Besides self-publishing, IISc Press publishes a variety of books with its co-publishing partners, and brings out research monographs, collected works of distinguished scientists, lecture notes, textbooks, biographies, popular science books, general books and other books.

The IISc Press has been publishing books in collaboration with World Scientific Publishing Company (WSPC) since 2008. In 2013, IISc Press signed a co-publishing agreement with Cambridge University Press (CUP).

The series that are published with co-publishers are:

IISC PRESS – CAMBRIDGE SERIES

Cambridge-IISc Research Monographs
Cambridge-IISc Centenary Lectures
Cambridge-IISc Lecture Notes

The following books have been published under these series:

Other than co-publishing agreement, IISc Press has also published the following books:

- **'Fundamentals of Physics'** by Vasant Natarajan Professor, Dept. of Physics, IISc
- **'Partial Differential Equations - Classical Theory with a Modern Touch'** by A K Nandakumaran and P S Datti

JOURNAL OF THE INDIAN INSTITUTE OF SCIENCE

Director appointed a new committee for Journal with the external members w.e.f., 9th October 2018:

Editor-in-Chief: G K Ananthasuresh, P/Mech., Engg., IISc
Executive Editor: Kaushal Verma, P/Mathematics | Chair, Office of Communications

Editorial Board

E Arunan, P/ Inorganic and Physical Chemistry (IPC), IISc
Rashna Bhandari, Centre for DNA Fingerprinting and Diagnostics (CDFD)
Madhavi Latha Gali, P/Civil Engg., IISc
Anil Kumar, Dept. of Chemistry, IIT Bombay
Prabal K Maiti, P/Physics, IISc
Biman B Mandal, Biosciences and Bioengineering, IIT Guwahati (IITG)
Sanjay P Sane, NCBS, Bangalore
Aravind Srinivasan, Department of Computer Science and UMIACS at UMD,
Rajesh Sundaresan, P/RBCCPS, IISc
Gaurav Tomar, AcP, Mech. Engg., IISc
Editorial Assistant: Kavitha Harish

IISc has always recognized the role of international relations in improving the global outreach of its faculty and students. Hence, the Office of International Relations (OIR) was constituted in 1998. Since its inception, OIR has been overseeing all the international programs of the Institute, including:

• To coordinate all the exchange/visiting programs for students, faculty and researchers for the cooperation in education and research.

• To facilitate the admission of international students to various programmes of the Institute [B.Sc. (Research), M.Sc., M.Tech. (Course and Research) and Ph.D.] and disseminate the information with foreign institutions and embassies for its wider advertisement.

• To coordinate the visit of IISc delegation to foreign universities to strengthen our existing collaborations and finding new partners.

• Formulation and execution of the Memoranda of Understanding (MoU) and agreements between IISc and institutions abroad.

• To liaise between international students/researchers and their sponsoring agencies for any support required.

• To provide any kind of assistance to all the international students and researchers, including their campus accommodation and local transport.

• To provide all the required documents and support letters for the registration with FRRO/e-FRRO.

• To facilitate the networking by connecting the newly admitted students to the Institute' international students and student council.

• To organize orientation program for all the international students at the time of their Institute admission, during which new students can interact with the OIR committee, staff and other international students on campus.

The Institute of Eminence (IoE) status bestowed by the Government of India to the Institute has provided strong impetus for further internationalization. Recently, the Institute has formulated several mechanisms for engaging with foreign universities and research institutions, including joint supervision of research students, joint degree programs (including Ph.D.), international summer internships, visiting positions for international faculty members, researchers and students, nurturing joint research ventures, etc., and is committed to significantly increase the number of international students enrolled in its various academic programs. OIR is playing a pivotal role in realizing these goals of the Institute.

Academic meetings and Delegations to the Institute: OIR facilitates the IISc visit of academic delegations, dignitaries and diplomatic staff from various parts of the world, who are interested in knowing more about the Institute, our research focus, identify the potential areas of mutual cooperation, and

3.7.3 Office of International Relations

CHAIRPERSON
PRAVEEN KUMAR

possible ways to establish the new collaborations and strengthen the existing ones. On account of Covid-19, most of the physical visits, meetings and visiting programs were not held, however OIR has coordinated the online meetings with Institute' various academic partners and diplomats to keep the momentum alive. A total of 43 such online and physical meetings were executed, which included the high-level online meetings of our senior administrators with the Vice-Chancellor of the University of Colombo (Sri Lanka), Chancellor of the Washington University in St. Louis (USA) and the Ambassador of the Republic of Poland to India. In addition, Institute was honoured to host the prominent VVIP delegations of the Rt. Hon. Dominic Raab MP, First Secretary of the State for Foreign, Commonwealth and Development Affairs of the United Kingdom and the H.E. Marcos Pontes, Brazilian Minister of Science and Technology.

During the IISc visit of UK VVIP delegation, "Sustainability Showcase Event" and "Roundtable on Emerging Tech, Ethics and Governance" was coordinated in association with the British Deputy High Commissioner's office in Bangalore. The Sustainability Showcase displayed 6 different businesses with innovations ranging from drones to mobility solutions. It included Blue Planet, Chakr Innovation, Aerologiks, Euprime, Openwater. in (founded by Dr. Sanjiv Sambandan & Dr. Karthik Raghunandan at IISc), Nutan Labs (a spinoff company from the Centre for Nano Science and Engineering at IISc), Transvahan e-rickshaw (developed by Professor Ashish Verma from IISc's Department of Civil Engineering). The idea of the round table was to convene the UK and Indian business leaders and academia, to discuss the twin challenges of ensuring that policy frameworks covering new and emerging tech are appropriate to enable growth, and address issues of ethics and inclusion. The discussion covered topics on cyber space, quantum, AI and 5G technologies, where the objective was to identify the opportunities for stronger UK-India collaboration in new and emerging technologies, particularly around sound governance structures to address equity and inclusion.

MoU/Agreements with Academic partners: Currently, IISc has about 120 active MoUs and agreements with international universities/ institutions across the globe. Although the Joint doctoral program (JDP) with foreign universities has recently been approved by IISc' senate committee and we have signed our first JDP agreement with the University of Melbourne, Australia, IISc prefers to initiate new cooperation through a general MoU, followed by the Joint PhD supervision program (JSP). JSP involves the identification of a collaborative project between IISc and Foreign University faculty as investigators, where the counterpart is listed as the joint supervisor of the student. The PhD student under this program can spend up to 18 months at its co-supervisor's lab, while the degree will be awarded by the home institute. Home institution provides the travel support for visiting student, while the host institute can provide local support, that includes the stipend for visiting period on reciprocal basis.

During the reporting period, OIR has facilitated the formulation and execution of 17 MoUs/agreements with various universities/institutions across the globe to enhance the academic & research cooperation in Science and Technology. Most prominent agreements that were signed by the Institute, included Joint Doctoral Program agreement with the University of Melbourne (Australia), Joint PhD Supervision program agreement with the Georgia Institute of Technology (USA) and Tri-partite agreement with the University of Stuttgart (Germany) and Universidade Federal De Santa Catarina (Brazil).

Bilateral exploratory workshops and informative sessions: For the past couple of years, OIR has been facilitating the theme-based workshops between two institutions involving the interested academics. Aim is to provide a common platform for detailed discussion and identify the potential partners with the possibility of submitting joint research proposals in future. This year, we have been involved in coordinating 3 online workshops to strengthen our bilateral research collaboration with the University of Manchester in Environmental Sciences and Industry 4.0; whereas University of Wollongong, Australia in Infrastructure, Transport and Energy.

In addition to the workshops, OIR has coordinated the online informative session for IISc students &

researchers on various opportunities in Germany, Switzerland and France; Summer internship opportunities across different faculties at Vanderbilt University, Nashville (USA) and Research and Funding Opportunities in Germany, in association with the concerned embassies, office and DAAD, respectively. As a result of the previous year' informative session by DAAD, IISc has been awarded two Indo-German partnership (IGP) proposals in Higher Education (Prof. Sashikumaar Ganesan at Computational & Data Sciences and Prof. Sekhar Muddu at Civil Engineering). More details could be found here.

Institute's nomination/application process for various international opportunities: In addition to announcing the calls/opportunities by various funding agencies, OIR coordinates the Institute' nomination/application process for highly competitive scholarship programs and opportunities. During this period, OIR has processed the nomination for following programs:

- 2020 Virtual Summer School on 'Entrepreneurship for Global Challenge: Empowering Tomorrow's Innovators', hosted by SATU Presidents' Forum and National Cheng Kung University, Taiwan, where 5 IISc nominations were submitted at UG, PG and PhD levels. All the IISc nominees have attended the school from 25th to 29th August 2020 and received the completion certificate from NCKU;
- Schmidt Science postdoctoral fellowship programme 2021-22, where 8 nominations were submitted from IISc across various departments & Centres;
- Joint proposal with Imperial College, London in Water Research to the NERC Global partnerships Seedcorn fund 2021.

INTERNATIONAL STUDENTS/VISITORS AT IISc:

Full-time International students: As on March 31, 2021, IISc has 47 full-time foreign students from different parts of the world. The Institute offers its highly competitive Full-Time International Programmes in Course and research that leads to B Sc (Research), M Tech (Course & Research) in Engineering and Doctoral (PhD) degrees in Science and Engineering.

Admission process for the academic year 2020: OIR has solicited the applications for its international programmes through online admission portal in January 2020. After reviewing the completeness and eligibility of received applications, OIR has coordinated the relevant departments/centres and applicants to schedule the online interviews in June-July. A total of 180 online applications were received: 40 for M Tech (Course) and 140 for the M Tech (Research) and PhD programs. All the departments at IISc have participated in the screening process, where 25 departments/centres (9 in Course and 16 in Research) have shortlisted 61 candidates for the web-based interviews (Microsoft Teams/Skype/Zoom) and recommended 14 for the admission. Out of 14 offers made, 12 candidates have accepted the admission offer for the academic year 2020 that includes 5 students in M Tech/M Des (Course) program, 3 in M Tech (Research) and 4 in PhD program.

Mid-term PhD admission 2020: This year, Institute has announced the Mid-term PhD admissions for international students for the first time and hosted an online informative session for the prospective students. Application process involved the receipt of 128 applications, selection process by the concerned departments and admission of 8 mid-term international students. Here, 6 students have joined physically, 1 has joined online and 1 would be joining in August 2021. During this period, recruitment process for the Advisor to the International Students/Scholars was also done, who would be responsible for guiding the full-time international students and coordinate the admission process. Lastly, the full-time programs for international students for the year 2021 was announced in March.

Short-term Students/Visitors: IISc has always embraced the importance of short-term international visitors. It provides a stimulating international environment and exchange of best ideas and practices. Majority of our short-term students come with secured funding, which are often sponsored, co-developed by their IISc faculty host or Institute. During the reporting period, a total of 8 students/researchers/faculty members have visited or are presently at the Institute for short-term collaborative research from various universities/institutes around the world. This mainly includes the visiting scientists or researchers from France, Ethiopia and Taiwan under our bilateral or short-term visiting programs. During

the lockdown situation, OIR has been responsible for taking care of their Visa renewal and other legal stay renewals.

NEW ASSOCIATIONS:

Indian Council for Cultural Relations (ICCR):

With the approval of Institute' senate committee, we agreed to coordinate with ICCR to consider their 20 nominations to our Masters (M.Tech./M.Des./M. Mgmt.) course programmes from 2021 onwards. Based on the progress and student performance, the number of these nominations could be increased from next year.

Study in India program 2021: After internal discussion, Institute confirmed its participation for the 'Study in India' program 2021. OIR would be coordinating with the program coordinators for creating the available program links and additional information on SII program website for international applicants.

The Centre for Continuing Education (CCE) has been rendering and organising several refresher/specialized courses for teachers/working professionals from different target groups ranging from high school science teachers to research Scientists/Engineers of the Industries/Institutions. In view of rapid advancements in Science and Technology, continuous education for teachers and working professionals is required to update their knowledge with regard to latest trends. CCE caters various programmes for the benefit of teachers.

Programmes conducted during April 2020 – March 2021 are given below:

Sl.No.	Programme Type	Details	Students/Participants benefited
1	National Programmes	a) QIP: Degree program (Ph.D./ME/M.Tech)	8 PhD 2 M Tech
		b) QIP Short Term Courses: (Engineering College Teachers)	NIL
2	Industry Oriented programmes	a) CCE - Proficience: 28 Semester long courses	407 successfully completed
		b) Industry sponsored short term/full term courses (Self Support)	386 participated

PROGRAMMES IN DETAIL

1. NATIONAL PROGRAMMES:

a) QIP (Quality Improvement Programme)

Programmes Leading to Award of Degrees:

During the current year, under this programme, 8 teachers were admitted for Ph.D. and 1 intake for M.E/M.Tech. Apart from this, 4 persons were given advance admission for Ph.D. during 2020.

3.7.4

Centre for Continuing Education

CHAIRPERSON

GL SIVAKUMAR BABU

During the year2020 - 2021	At IISc	
	Ph.D.	ME/MTech
Students admitted	8	1
On Roll	23	-

b)QIP – Short Term Courses

These courses are sponsored by Government agencies such as AICTE- QIP and are primarily for teachers from Engineering/Science Colleges. During this year, no Short Term Courses were conducted and that was due to the changes in the guidelines in conducting the Course and lack of response from the faculty.

2.INDUSTRY PROGRAMS:

a) CCE – Proficience Program

The programme is the first of its kind and unique in India. Under the CCE - PROFICIENCE programme in 2 semesters during the year 2020-21, 28 evening courses were conducted, 628 students/professionals attended out of which 407 successfully completed the program. Under this programme, a sum of Rs. 91,62,300- has been received, towards application and course fee.

b) Self-supporting Intensive Courses:

The CCE organises various refresher/extension programmes to enable the participation of Scientists and Engineers working in different organizations. During the year, 10 such courses were organized for different organizations with a total participation of 386. Under this programme a total sum of Rs.1,97,45,090/- has been received as overheads to the Institute:

c) Curriculum Development Cell:

The Curriculum Development Cell provides financial assistance for book writing, Preparation of Laboratory Manuals, Holding of Conference, Workshops, Seminars, Special Lectures and Panel Discussions, for the preparation of monographs and audio-visual aids for teaching etc. Since 1979, the Centre has provided financial assistance for 101 faculty members for book writing, out of which, 56 books have been published/completed. The CCE is using CCE-FACE funds for this purpose.

3.EXTENSION LECTURE PROGRAMME:

This programme is also unique in the country. Under the Continuing Education Program Extension Lectures have been organized by the Institute faculty since 1990 in institutions of higher learning at the technical level, in Engineering and science colleges and in schools, public/cultural organizations, Doordarshan and All India Radio at the popular level. These extension lectures are expected to be of great help in the transfer of information on the latest scientific developments in this Institute and other organization in India and abroad.

These lectures are arranged not only in Bangalore, but also in centres in the entire state of Karnataka and sometimes even outside the state. Even though the majority of these are in English, lectures are also arranged in regional languages like Kannada, if specific requests are received. Many of these lectures are supported by demonstration, slides, and models.

During this year, due to COVID 19, Extension Lecture Programmes were not organized/conducted.

4. HOYSALA GUEST HOUSE:

Centre for Continuing Education runs a Hoysala Guest House named after the famous Hoysala Dynasty, which ruled ancient Karnataka. It has 60 self-contained and fully furnished single rooms. These are mainly intended for accommodating the participants of the programmes conducted under CCE, like short term courses and invitees to the Institute. During this year, revenue of Rs.7,16,550/- is received through Hoysala Guest House.

1. Department Profile

IPTeL (Intellectual Property and Technology Licensing) is the Institute's gateway to filing for intellectual property protection and technology licensing. The mandate of this office is to ensure that the knowledge being generated at the Institute is protected and then leveraged, by responsible licensing, for the benefit of the Institute and thereby to the society at large. IPTeL strives to enable rapid filing for IP protection, so that it does not unduly delay the submission of results to academic journals.

The activities at IPTeL thus fall in two large buckets. One is IP management that includes all the processes from IP disclosure by IISc staff and students to maintaining the patent till its point of expiry. Two, licensing of the IP so generated in the form of know-how and patents. During the calendar year 2017 IPTeL embarked on the process of automating the IP management system, so that more emphasis could be placed on licensing. Towards this end, IPTeL has planned in 2018 to increase its interface with industry by various licensing modes. From the year 2017 onwards, IPTeL had worked extensively towards IP licensing and towards testing and getting the IP Management software (ProrIISe) at IPTeL up and running, which was successfully launched in April this year.

2. Patent Licensing

IPTeL is getting increasingly involved in licensing and pursuing transfer of technologies to various companies. We have, from the year 2017 till now, entered into exploratory agreements with many companies. A sample list of such engagements is as follows:

Industry/Company	Technology
Log 9 Materials	Confidential know-how
Technomed Electronics	Fiber lasers for high power within a medical device – associated optics / alignments / software / integration
M-Core Technologies Pvt Ltd	Power System Emulator
Jiva Sciences Pvt Ltd	Multidimensional Fluid Focusing Device
1. Syscon Instruments 2. India Finishing Technologies	SPT Hammer

3.7.5 Intellectual Property and Technology Licensing

CHAIRPERSON

SURYASARATHI BOSE

NeoDx	ELISA test to detect COVID19 antibodies in people with prior exposure to the virus
Vasmed Health Sciences Pvt Ltd	1. Measurement of fluid viscosity using MEMS-based cantilever system 2. Catheter tip MEMS pressor sensor
AdobeSP Grid	Generalized substation Panel
Mitsubishi Heavy Industries, Ltd.	An algorithm to bridge the gap between CAD modeling and kinematic analysis packages by extracting kinematic information directly from part geometries
CUMI	Method and Process for Production of Silicon Carbide
Pennsylvania State University	FEhydro – software library for hydrodynamic stability analysis
Huwel Lifesciences Pvt. Ltd and ATNT Labs	LAMP Kits
Nanatom	Design and development of lateral force driven parallel pendulum tribometer
NSOFT (India) Services Pvt Ltd	Mobile Desilting Machine
Cognito Networks	Soil moisture sensors
Reva technologies, Pune	H2S Scrubbing Technology
Astha Energy Services PVT LTD	H2S Scrubbing Technology
SLPP Renew LLp	H2S Scrubbing Technology
M/s Praj Industries Ltd	H2S Scrubbing Technology

IISc Patents licensed from IISc Start-ups:

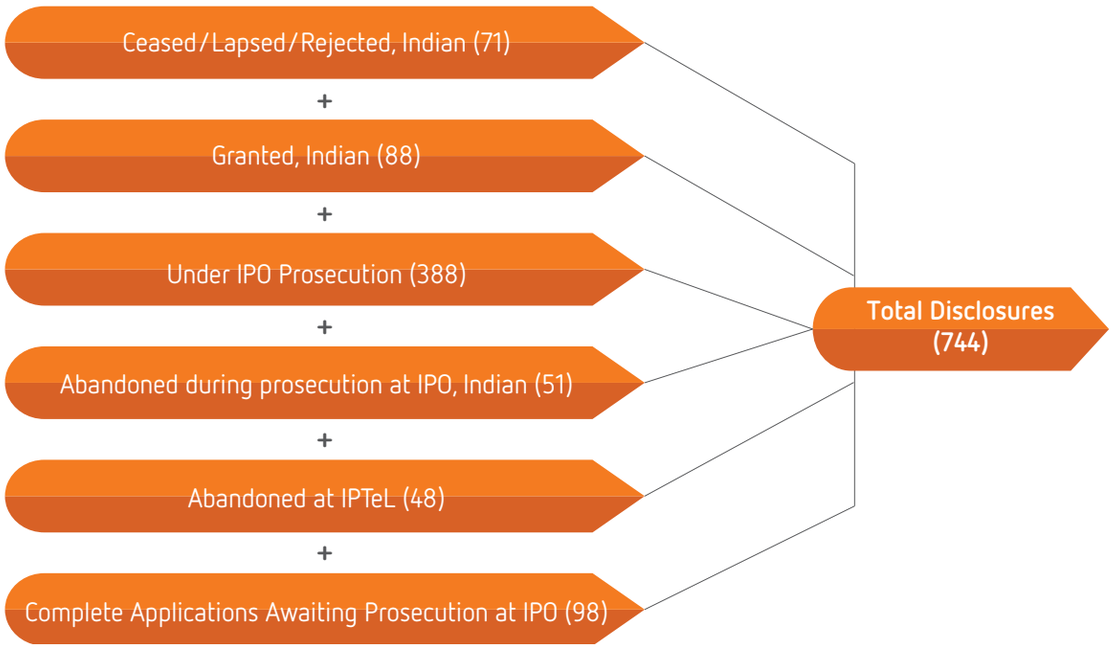
- Superwave Technologies
- Pathsodh Healthcare Pvt Ltd
- Mynvax
- In Scientific
- Sickle Innovations
- Open Water
- Mimyk
- Pratimesh Labs Pvt Ltd
- Ragavera Indic Technologies
- i2n Technologies Pvt. Ltd
- Mithra Increst
- Protein Design Pvt. Ltd
- NeuIntegrals MedTech
- Urjalinks Pvt. Ltd
- Grasp Bionics
- Simyog

3. Basic portfolio index (1995 – March 2021):

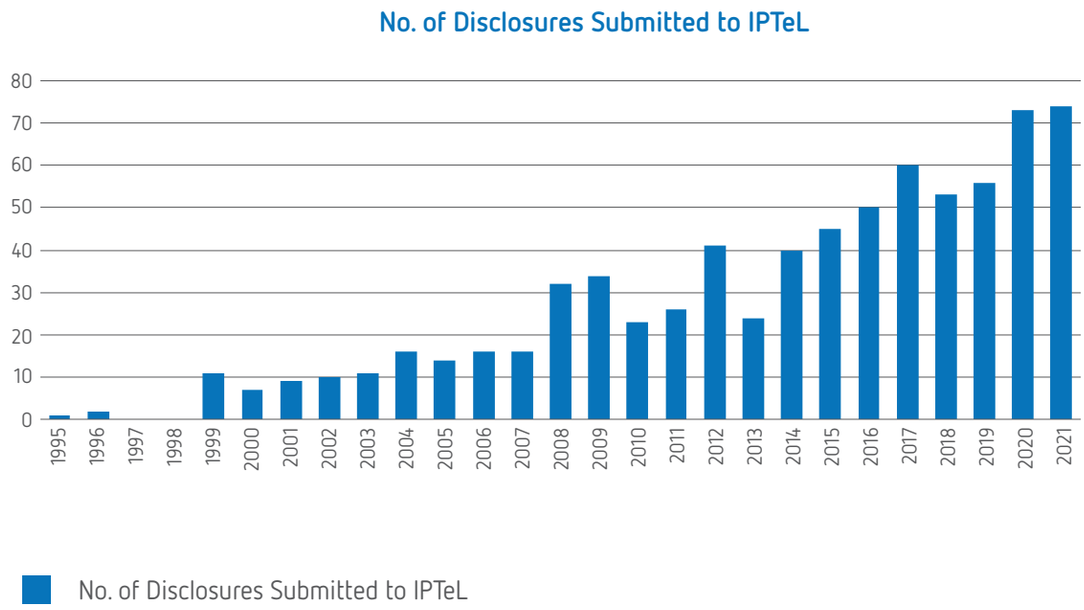
IPTeL embarked on the process of taking the IPTeL-Inventor-Attorney interface online through the IPMS software. IPTeL has also worked towards compiling the data porting of the existing portfolio that was available in soft format into the IPMS software, to aid subsequent automation of most processes requiring manual monitoring, making the IISc IP portfolio management and licensing procedure easier. The IISc portfolio is now available on the software and

has also been made available for download in a standard format on the IPTeL website. The current portfolio is as follows

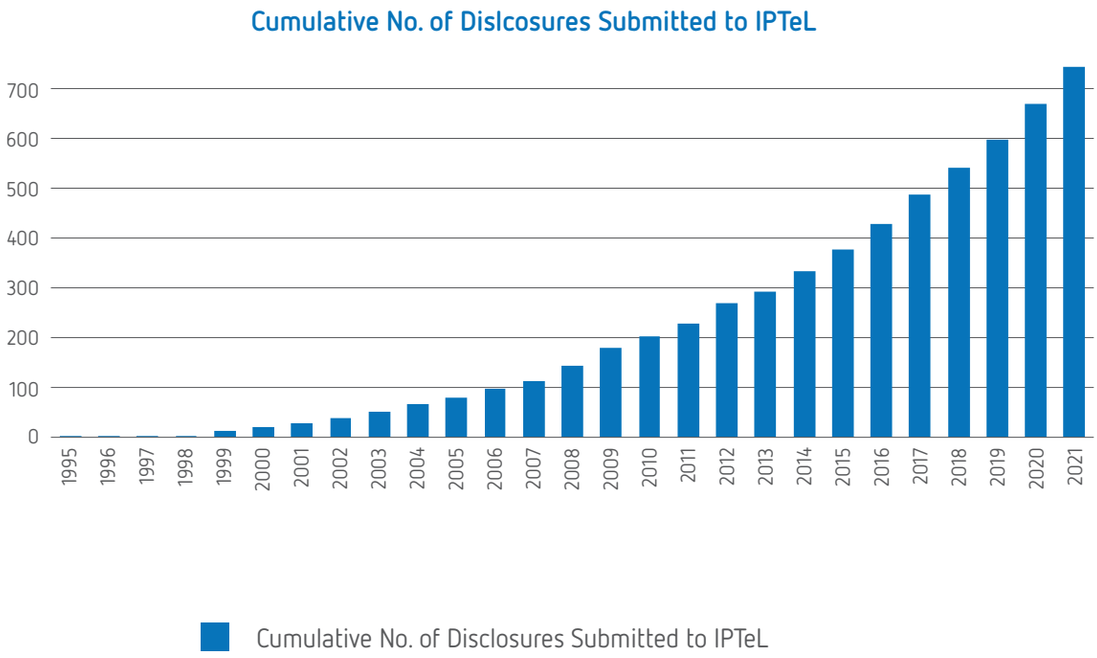
Total disclosures submitted by IISc faculty to IPTeL (1995 – March 2021): 744



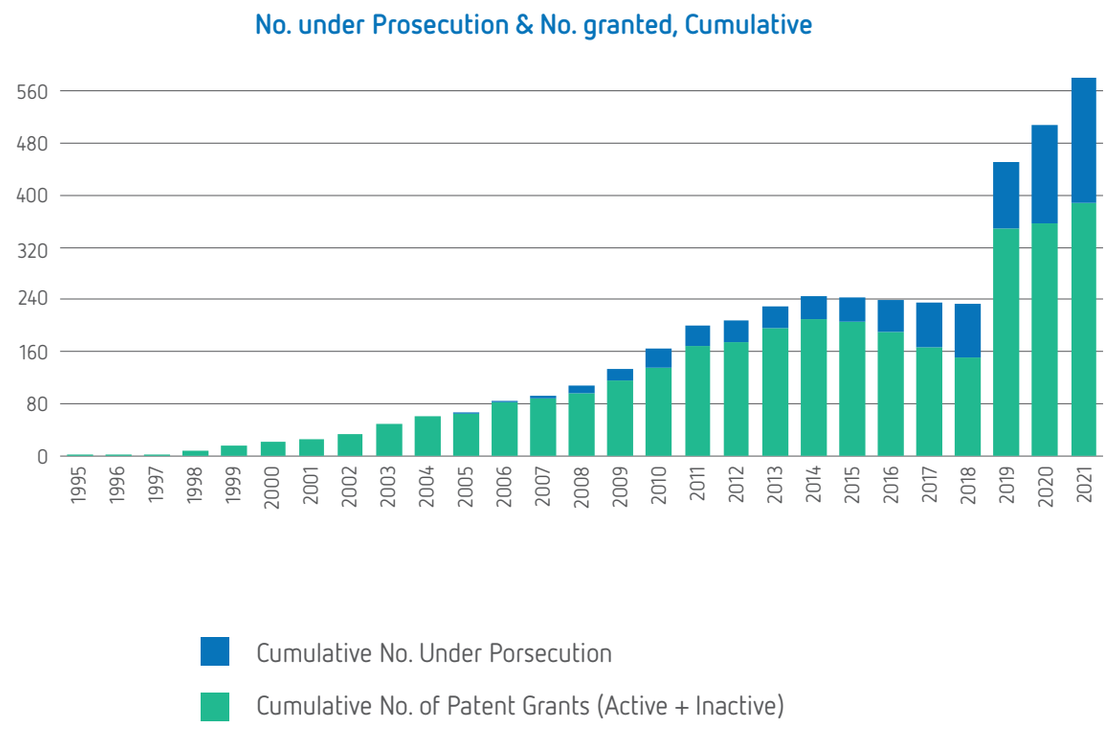
I. Year Wise Break-up of Disclosures Submitted to IPTeL:



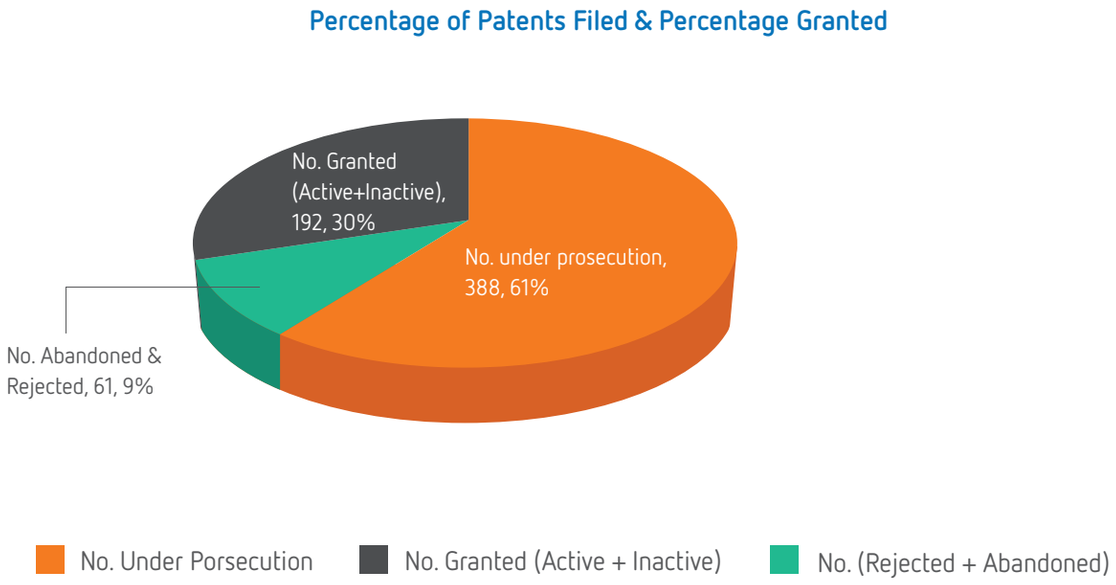
II. Year Wise Break-up of Disclosures Submitted to IPTeL; Cumulative:



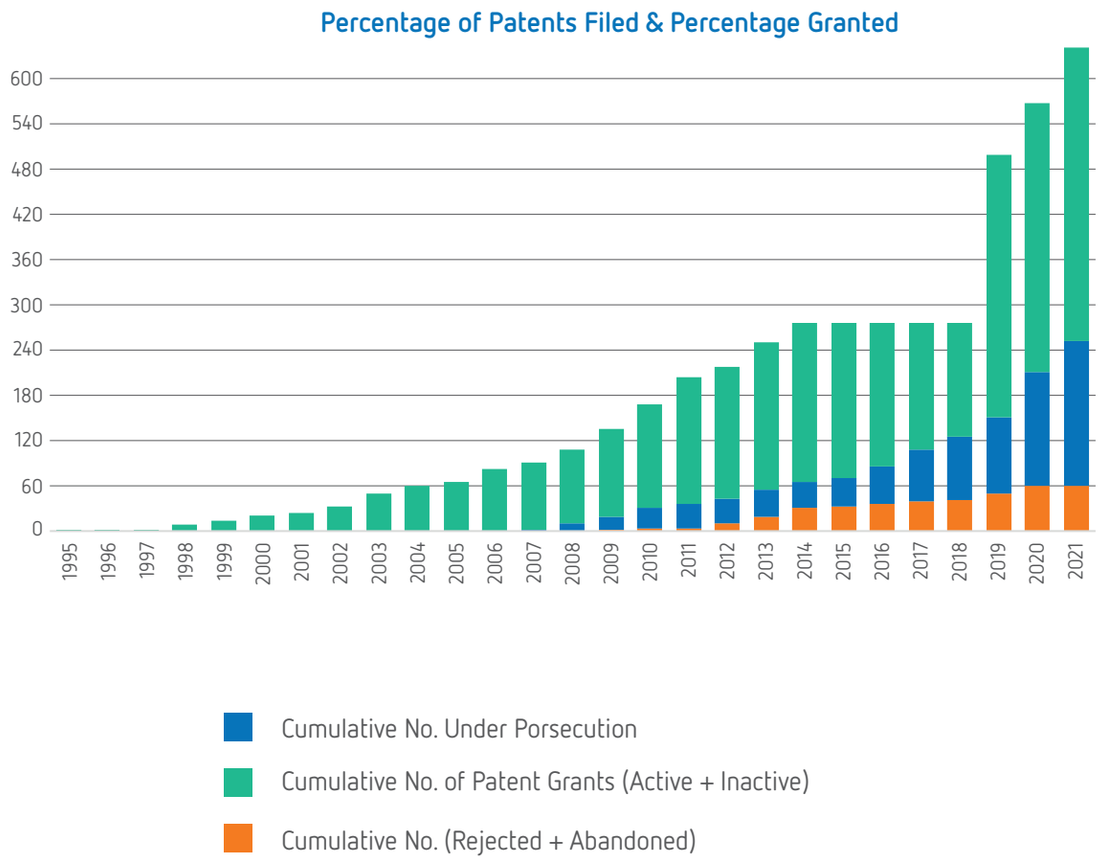
III. Year-wise Break-up of Patent Applications Under Prosecution and Patent Applications Granted (Indian):



IV. Cumulative No.s of Applications Under Prosecution, Patents Granted & Applications Abandoned/ Rejected at IPO (Indian):



V. Year-wise Break up of Cumulative No.s of Applications Under Prosecution, Patents Granted & Applications Abandoned/ Rejected at IPO (Indian):



The Office of Development and Alumni Affairs (ODAA) was established at the Indian Institute of Science in 2015 to build a vibrant Industry-Institute-Alumni ecosystem, and raise funds for various special projects from corporates, philanthropists and alumni. In addition, the ODAA provides support for alumni-related activities and engagement programmes at the Institute.

Chief Development Officer
Ram Turaga

Development Officer
Sooraj Ravindran

Alumni Relations Officer
Vanishree Hebbar

Project Manager
Priyanka Vazirani

3.7.6 Office of Development and Alumni Affairs

CHAIRPERSON

PHANEENDRA K. YALAVARTHY

Projects Completed

- HAL-IISc Skill Development Centre

Shri Rajnath Singh, Defence Minister, inaugurated the HAL-IISc Skill Development Centre (SDC) established at IISc's Challakere campus through a video conference on August 13, 2020.

- Teachers Training Programme and Supply of Laboratory Experimental Kits to High Schools
- Dissemination of Sustainable Technologies in Rural and Peri-Urban Habitats

Corporate Partnerships

In addition to several ongoing projects, many organizations and individuals have funded several new projects this year through Corporate Social Responsibility (CSR), philanthropy and research grants.

New projects funded under CSR

Area	Project	Donors
Infrastructure	Women's Hostel Block C	L&T Technology Services
Labs	M Tech AI Lab	GroupM Media Timken Engineering and Research
	Instructional Lab for CSA	Wells Fargo International Solutions
	Center for Excellence in Networked Robotics	Nokia Solutions and Networks
	Lab at ICER	Triveni Turbine
	Quantum Lab	Rohde & Schwarz
Covid19 Projects	Mobile Diagnostic Lab	SBI Foundation Colin Aerospace
	Covid19 testing at IISc	Ocwen Financial Services Citrix R & D
	Accelerated Development of Covid19 Antibody Test	Cap Gemini Technology Services
Fellowships	Fellowship program for Women M Tech Students	Sony India Software Centre
		Wells Fargo International Solutions

New philanthropic contributions and grants

- VM Ware : Support for Research at CDS & CSA
- Google Asia Pacific : Support for Research and Education in Artificial Intelligence
- Facebook Realty Labs: Support for Research in AR
- United way of Bengaluru: Mobile Diagnostic Lab Facility of Covid-19 for Government of Karnataka
- IBM India : IBM STEM for Girls
- Nokia Solutions and Networks OY (NF 185): Unrestricted Research Grant Award
- Infineon Technologies: Electro-Mechanical Ventilator (PRAANA) & Portable Fluorescence Reader

Alumni Relations

Since 2015, the ODAA has maintained an exclusive alumni portal to help alumni connect with each other and with the Institute (www.alumni.iisc.ac.in). More than 9000 alumni have currently registered for this free website and receive periodic announcements through this portal. In an effort to build this database, since 2018 all graduating students have been mandated to register on this alumni portal as part of their no dues process.

The ODAA has also built a large network of alumni through Linkedin (~13500).

Alumni contributions

The Institute has been receiving generous funding from alumni towards several projects. Apart from ongoing projects, contributions were made by alumni towards the following new initiatives in 2020-21:

- Research and travel support for ECE students-Contributions from BE, ECE, 1970 batch (Mr. Ramachandra Kini, Prof. Sargur Srihari, Mr. G. Venugopal, Mr. B.G. Satyanarayana, Ms. Malathi Limaye, Ms. Lalitha Umanath)
- Donation to Support Students with Laptops, Internet facilities for Online Classes at IISc (Various alumni-53)
- Donation to support UG Smart Classroom (Mr. D.N. Prahlad, Prof. Jemmis Devassy)
- Laptop initiative for the Department of Computer Science and Automation (Mr. D.N. Prahlad)
- Contributions to establish Institute Gold Medals:

Programme	Department	Name of the Medal	Alumni Name
UG with a major in Physics	Physics	Prof. R. Srinivasan Gold Medal	Mr. Vikram Srinivasan and family
M.Tech. (Nano Science and Engineering)	Centre for Nano Science and Engineering (CeNSE)	Prof. R. Vasudevan Gold Medal	Mr. Vikram Srinivasan and family
M.Tech. (Smart Manufacturing)	Centre for Product Design and Manufacturing (CPDM)	Mr. Dheeshjith V. G. Gold Medal	Mr. Dheeshjith V.G.
Ph.D.	Brain and Artificial Intelligence (BAI)	The Thippur Family Gold Medal	Prof. Thippur Sreenivas Prof. Hareesh V. Tippur Dr. Shekhar Kirani
Ph.D.	Climate Change (Offered by Divecha Centre for Climate Change)	Shri. Kudli Srinivasa Murthy Gold Medal	Mr. Ajay Kumar K. S and family
Ph.D.	Mathematical Sciences (IMI) – Interdisciplinary Program	Prof. Pandurangan Gold Medal	Prof. C. Pandurangan and his students

• Support for the project "Theory and Practice of Secure Computation" at the Department of Computer Science and Automation (Mr. B. M. Ponnappa)

Virtual Awards Ceremony: IISc Distinguished Alumnus/Alumna Awards 2020

Due to the global concern regarding coronavirus outbreak, subsequent travel restrictions, and other circumstances, the Institute was unable to hold the Annual Alumni Reunion 2020. Hence this year, the IISc Distinguished Alumnus/Alumna Awards Ceremony was held in a virtual mode on 1st March 2021. The online event began with Prof. Phaneendra Yalavarthy, Chair ODAA, inviting the Director and DA awardees. Prof. Govindan Rangarajan, Director inaugurated this online event.

This year, the following alumni/ae received the Distinguished Alumnus/Alumna Awards of the Indian Institute of Science (IISc):

Dr. Rajalakshmi Menon, Program Director – D (ISTAR), DRDO, Bengaluru.

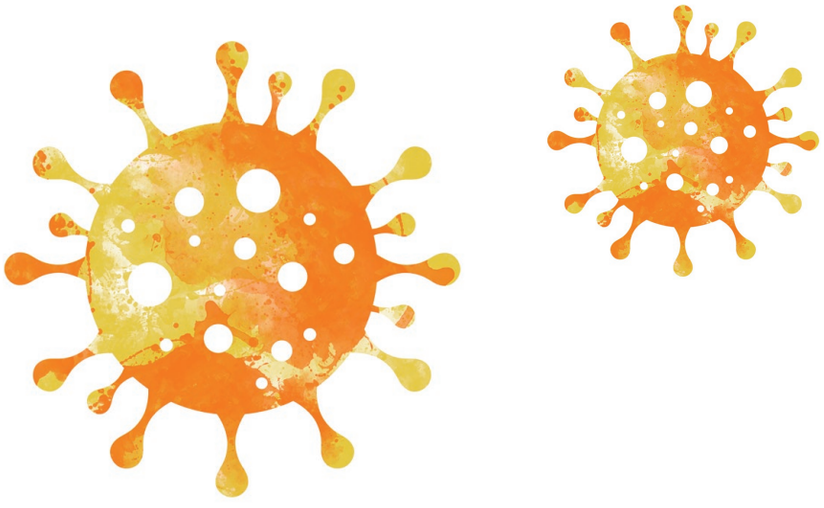
Prof. B. S. Murty, Director, IIT Hyderabad

Prof. Sethuraman Panchanathan, Director, NSF, USA

Dr. Keshab Panda, CEO & MD, L&T Tech Services Ltd., USA

The citation of each awardee was read by Prof. Yalavarthy, followed by the acceptance speech from DA awardees. Prof. Rangarajan addressed the event and congratulated all the awardees.

The event ended with a vote of thanks by the Chair ODAA.



TALENT DEVELOPMENT CENTER

Video tutorial:

TDC has developed a video tutorial in Kannada language for Karnataka Secondary Education Examination board's science and mathematics text books for the 8th, 9th and 10th classes. This video materials consisting of 172 modules and approximately 60 hours. The motive behind this video tutorial is that students who wish to review and clarify concepts after attending class and this tutorial will guide and assist them.

Teachers Training program:

TDC conducted a total of 12 courses of teacher training during a slowdown period of covid-19 cases (December 2020 – February 2021), six each of mathematics and science

Teachers for the Karnataka government schools. In total, 464 teachers from Chitradurga, Bellary, Tumkur and Madhugiri districts have been trained during this period. Pre training test and post training test performances indicates that teachers have greatly benefitted from this training process.

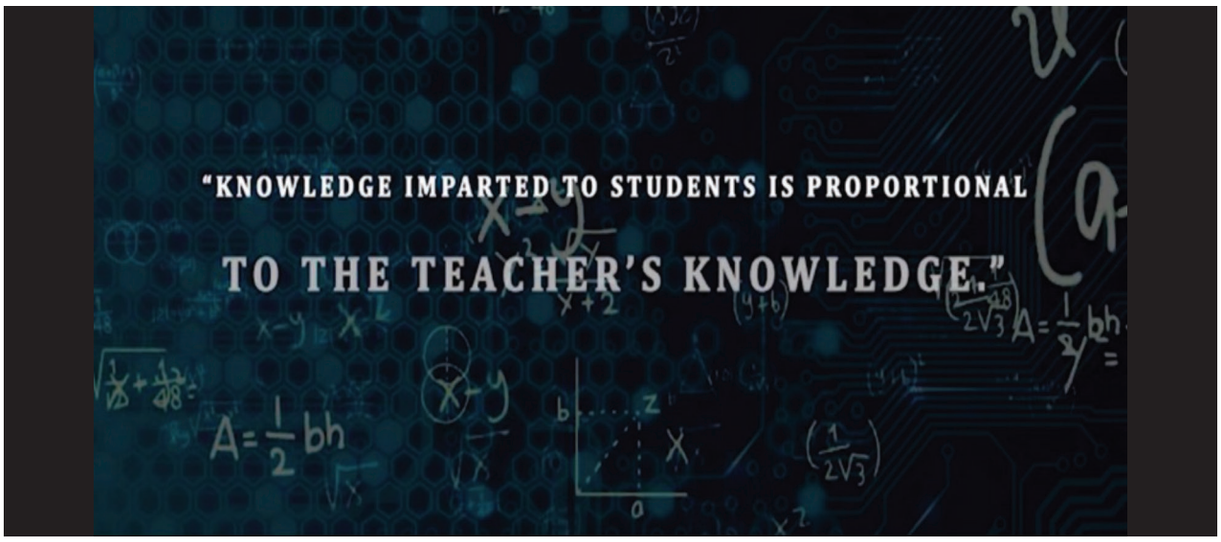
TDC adhered to all covid rules defined by Govt of India. Class rooms and laboratories were sanitized at the end of the day.

3.7.7

Challakere campus, Khudapura, ChitraDurga

Tenth anniversary of TDC

TDC moved from a historic sheep breeding enterprise to its own building SDC as a benchmark. A series of well-equipped laboratories was established.



Prof. M.S. Hegde, previous convenor, TDC brought out a book titled "Training Science and Mathematics Teachers from High School to University," which outlines the experience in establishing Talent Development centre.

Internet Facility

TDC was using the 8Mbps iInternet facility, which was an extension of the IISc-Bangalore network via a point-to-point link provided by BSNL. This 8Mbps network link has been upgraded to 100Mbps by KNK/ RailTel, and the service is now available throughout the IISc-Challakere campus.

High School laboratory Kits given to schools

A total of 150 high school science experimental kits were given to 40 schools in the Chitradurga and Uttara Kannada districts. We visited to each of the 40 schools to assist in the setup of the equipment and to learn how the experimental kits are being used.

TDC Farm

During the covid-19 pandemic, inhouse personnel started a vegetable & fruit garden as a hobby. During lockdown periods, vegetables and fruits from the garden were used in our in-house kitchen and dining facility.

Asphalting the road on Check Dam

There are two tank bunds on campus. The road on check bund of length approximately 1 km was asphalted. The entrance to the main gate from the road is also asphalted.

CLIMATE OBSERVATORY

Continuous ground-based measurement of physical and optical properties of aerosols and its associate changes due to prevailing meteorological conditions are being made from Challakere Climate Observatory (CCO) building located inside the second campus of Indian Institute of science (IISc), the region comprises a flat semi-arid terrain as shown in Figure-1. The actual sampling site is far from industries and township, also ~30 km away from nearest national highway which makes the site well suited for measurement of continental background aerosols. Aerosol measurements comprised of (i) mass concentration of black carbon aerosols (ii) Total Particulate Matter (iii) composite aerosols (iv) columnar spectral aerosol optical depth using dedicated instruments starting from year 2012 onwards as seen in Figure-2 are operated continuously. To understand the local meteorological conditions at

Challakere, meteorological parameters like wind speed, wind direction, ambient temperature and relative humidity are measured using sensors mounted on 32 m tower Figure-3.

During past few years several research activities are conducted especially during nationwide lockdown and results are published, following are the few research papers related to impact of air pollution during lockdown and study of turbulence characteristics from Challakere.

• "Impact assessment of change in anthropogenic emissions due to lockdown on aerosols characteristics in a rural location".

• "Entanglement of near-surface optical turbulence to atmospheric boundary layer dynamics and particulate concentration: implication of optical wireless communication systems"

• As a part of renewable energy, we have designed and implemented a portable hybrid power system that combines wind (1kW capacity at height of 30 feet, wind turbine) and solar energy (2 kW with polycrystalline solar PV system) to generate reliable and sustainable electricity as the site is having very good wind potential which makes the hybrid system to function well. Collectively it makes a 3-kW solar-wind hybrid system with storage as seen in Figure-4.

Figure-1: Local geographical feature of Challakere and Challakere Climate Observatory (CCO – white circle) building inside IISc campus (white dotted lines).

Figure-2: Aerosol measurement instruments (Nephelometer, Multi Wavelength Radiometer, Aethalometer).

Figure-3: 32-meter meteorological tower measuring wind speed, wind direction, ambient temperature and relative humidity at 5 different levels.

Figure-4 Solar and Wind Hybrid system.

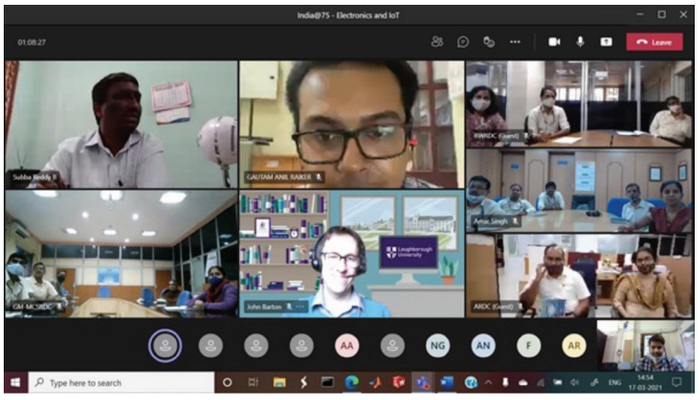
HAL-IISc SKILL DEVELOPMENT CENTER

The HAL-IISc Skill Development Centre (SDC) Committees (Empowerment & Curriculum committees) were constituted by the Director IISc, on September 3, 2020 to strengthen the mandated activities as well as to improve the ongoing interactions with the HAL.
In the first cohort of the training programs (held during Sept 2020 till March 2021), the HAL-IISc SDC successfully conducted SIX online training programs related to aerospace, Electronics, Renewables etc and ONE offline course focussing on Atmanirbhar Bharat under India@75 for Avionics sector, a total of 200 participants across the country including few from abroad have benefited from the training.

The first program, workshop on IoT and embedded applications, was Inaugurated on 7th Dec 2020 by Shri Alok Verma, Director (HR), HAL Bangalore, in the presence of Shri Venkateshwara Rao, GM (HR-CSR &FM), HAL and Prof. S K Satheesh, Dean (Planning & Infrastructure), IISc.

Establishment of various training laboratories related to Aerospace, Composites, Electronics and Renewables at SDC Challakere including the audio/Video telepresence network between IISc Bangalore and IISc Challakere is in final stages of completion. Further, in the second cohort during August – December 2021, the HAL-IISc Skill development Center has planned to conduct about 10 training programs for the benefit of various groups of the society.

Participants from HAL Training Academy at HAL-IISc SDC, IISc, 5th March 2021



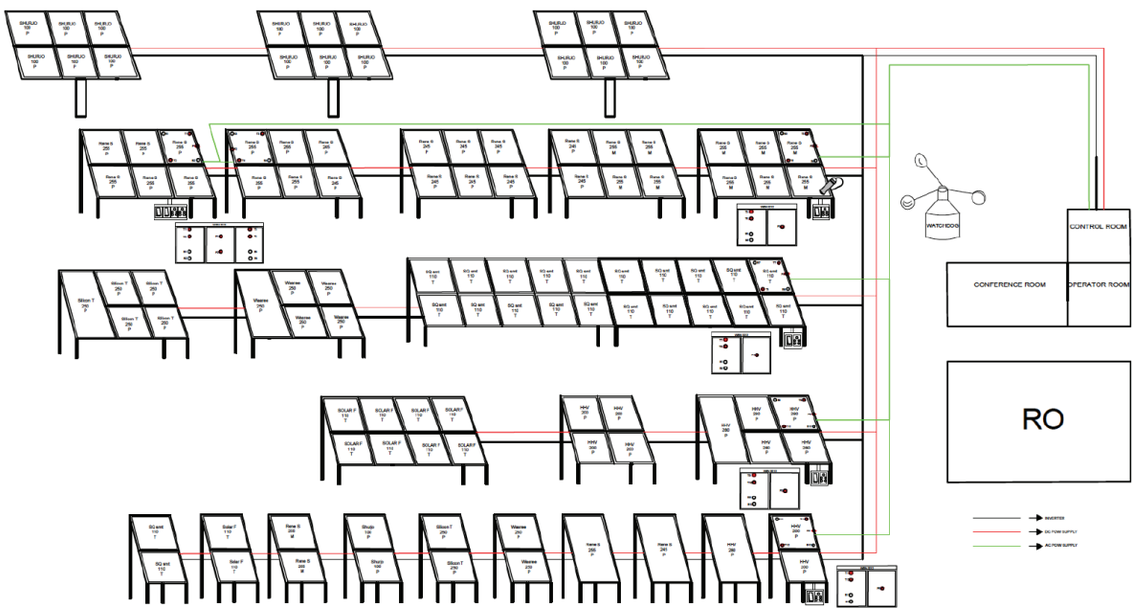
Participants attending training program on IoT & Electronics on 17th March 2021

CHALLAKERE SOLAR PV TEST BED

Solar PV laboratory of Indian Institute of Science is set up for the assessment of the characteristics and performance of photovoltaic modules based on various technologies like monocrystalline silicon (m-Si), polycrystalline silicon (p-Si), amorphous silicon (a-Si), thin film silicon, multi- junction technologies, CIGS, CIS, CdTe, concentrated PV and other technologies. Detailed monitoring system of sensors and data acquisition instruments that measure significant physical parameters with the aim of determining the characteristics of the various PV modules is set up. Monitoring of these PV performances in real time will be through the establishment of a central control room. The real time data that we shall be obtaining will be evaluated for development of model for analysis and predictions. Dashboard created for monitoring the PV parameters and meteorological information will be accessible online.

This multi-technology photovoltaic test bed is for the detailed performance evaluation of various module technologies and mounting systems. The installation is further equipped with various sensors, including a pyrheliometer, pyrgeometer, pyranometers, radiometer, and temperature sensor in addition to PV reference cells (normal and KG5-filtered). The site includes eight separate technologies and two mounting systems. The test site has an overall nominal power of 22 kWp. The following is the PV test bed layout and wiring diagram.

Till last year the performance of each MPPT was recorded manually periodically by technical assistant and the security personnel. Recording of these data from 2017 till date is carried out on both ledger and electronically on a computer. This year to organize and optimize the data collection an app is developed which is deployed on cellphones of the personnel in the field. Following are the data entry that was happening before the developed app.



During the year under review, the Centre for Scientific and Industrial Consultancy (CSIC) has strengthened the faculty-industry interactions in the form of informal discussions and advice to formal projects, involving design, development and transfer of technology. The Centre has strived to enhance, qualitatively and quantitatively, the nature of Institute - Industry linkages. The Centre has undertaken major consultancy projects of national significance involving scientific and technological challenges, with the ultimate goal of technology transfer for industrial development.

The ranges of professional consultancy services offered by the Institute faculty through CSIC include:

- Systems design/analysis
- Software development
- Product design/development
- Process design/development
- Model investigations
- Advice on R & D
- Transfer of technology
- Evaluation/overview
- Diagnostics

The above services have been utilised by a wide range of clientele, comprising of educational/ research institutions, health/pharmaceuticals industries, department of space, defence laboratories/ organisations, irrigation departments, electricity boards, electronics/telecom industries, engineering industries and chemical industries from both the public and the private sector.

3.7.8 Centre for Scientific and Industrial Consultancy

CHAIRPERSON

K J VINOY

DIGITS (Digital Campus and IT Services) Office is a unit set up by the Institute to conceive, plan, and create a best-in-class information technology (IT) and networking system, and implement agile IT and networking services for operational excellence in the Institute. The DIGITS office has the mandate of consolidating and coordinating all digitalisation activities and services in the Institute.

During April 2020-March 2021, the activities of DIGITS have resulted in the following outcomes.

DIGITS RESPONSE TO COVID 19

In March 2020, the Covid 19 pandemic hit the nation in full force and the country went into a lockdown from March 22, 2020. The Institute suspended all classes in March second week and the students were asked to leave the campus to their homes by March third week. It was decided to hold online classes by April 2020. All meetings in the Institute went online. There was a need for a robust platform for video meetings. A variety of platforms were explored by the Institute community: Skype on Business, Microsoft Teams, Google Meet, Zoom, Zoho, Webex, etc.

Microsoft Teams: Skype on Business and Microsoft Teams are an integral part of the Microsoft Office 365 suite which the Institute procured in 2016. In addition, every faculty member, every permanent staff, and every student of the Institute has access to 1 TB of storage on OneDrive. These platforms came in very handy and became quite popular. Microsoft Teams soon emerged as and continues to be a platform of choice for most online meetings including online classes. This in conjunction with a host of Microsoft Applications is proving to be quite useful to the community.

Google G Suite: Google India has provided a complimentary subscription to G Suite, their bouquet of powerful products with enterprise features. This includes enterprise versions of all their applications such as Google Meet, Google Classroom, Gmail, Google Drive, Google Forms, Google Sheets, Google Slides, Google Maps, etc. Up to 10000 G Suite accounts can be created.

Online Research Interviews: Conducting research interviews in the Institute during the week of July 6-10th was a major exercise for all the Departments. DIGITS organized a live lecture on June 22, 2020 on how Teams and Google Meet could be used for conducting research interviews. DIGITS updated the SOPs for conducting research interviews

3.7.9

Digital Campus and IT Services Office

CHAIRPERSON

ANIL KUMAR P S

based on various technical inputs received. The following updated documents were made available on the DIGITS website:

- Research Interviews using Teams
- Research Interviews using Google Meet
- Teams Guide sheet for Candidates appearing for Interview
- Google Meet Guide sheet for Candidates appearing for Interview

SOPs for various Online Sessions: DIGITS, with the help of several faculty volunteers, has created standard operating procedures for online sessions of various kinds. These include: Conducting research interviews, Ph.D. comprehensive examination, Ph.D. Colloquium, Ph.D. Defense, Institute-wide Meetings, and Live Events.

PORTALS FOR THE PANDEMIC

Covidprep (Covid Peer Review Portal): This was a portal that was created in two weeks time in April 2020 on the request of the Office of the Principal Scientific Advisor (PSA) to the Government of India to enable a platform for fast-track peer scientific review of Covid19 innovation proposals submitted to the PSA Office. The platform hosts a team of senior editors and associate editors. Each proposal is assigned by a senior editor to a group of associate editors and on receiving their reviews, the senior editor sends a final recommendation to the PSA Office.

PMRF Portal: The Covid19 Committee decided to seek voluntary contributions from all IISc employees to be donated to the Prime Minister's Relief Fund. A portal was quickly implemented to collect the information on the exact amount volunteered by the employees and the information was communicated to the payroll section for automatic deduction from the month's salary.

Employee Welcome Portal: Once the lockdown was lifted, information had to be collected from the faculty members and employees re-entering the Institute campus. A portal was set up for this purpose.
Student Re-entry Portal: The COVID Committee in the Institute has drawn up a detailed protocol for stage-wise re-entry of students into the IISc campus. In order to facilitate the re-entry information logistics for the re-entering students, DIGITS has implemented a student re-entry portal.

Hello Dept Portal: The COVID Committee in the Institute conceived an idea of contactless daily logging of movement of people at the departments. DIGITS has worked on a QR-code based solution which can be used at all departments and hostel bocks. The solution works on both Android and iOS platforms. This portal called Hello Dept portal will be launched soon. The backend will provide information regarding department-wise attendance and other related information helpful for contact tracing. A person moving from one department to another will also get logged. At any time, the user may look at the user's own log.

Project ISTAR: Wave 2 went Live on January 08,2021: Project ISTAR (Implementing SAP S/4 HANA for Transforming Administration and Research) for ERP implementation is being executed in two waves:

- WAVE 1 modules: Finance & Accounts; CSSP; HR & Payroll; Stores & Procurement
- WAVE 2 modules: Student Lifecycle Management (SLcM); CCMD; Hostel &Mess

After completion of the final preparation stage of the Realisation phase of Wave-2 of ISTAR went live on January 8, 2021. Several types of Post-GoLive issues like No Dues, Mess Sign in/Sign Off and some implementation bugs (like Auto Approval of registered courses, Course/Instructor Feedback) have been fixed and a few new requirements like DAP, Basket Rule reports, parallel workflow for SCRC, staggered approval of scholarship etc. have been addressed.

Total 2007 (1573 Int, 434 Ext) scholarship payment for Feb21 and 1633 (976 Int, 657 Ext) arrear payment are being processed in Mar21.

Till Mar 22, out of 3716 issues raised, 3272 have been resolved, work in progress for 140 and business inputs from Academic section were awaited for 304 issues.

SAP Solution Manager (SolMan) and its usage

In order to address the issues raised by IISc users, SolMan (SAP Solution Manager) application has been installed for raising an incident or a service request in the form of a ticket.

All IISc SAP users have been provided with SolMan User Ids and passwords by the SAPSupport team to raise tickets. They can raise tickets in the form of i) incidents for implementation issues, production bugs/ hot fixes, data errors, ii) service requests for user credentials (SAP User Ids/Passwords, accesses to processes and reports), maintenance of master data and configuration tables etc.) and iii) change requests for minor or major enhancements and customized developments and track the progress of the resolution and deployment of the solution until the closure of the ticket(s). Our ISTAR Core Support team and Wipro's O&M Support team track the incidents and service requests regularly address them based on priority (Critical, high, Medium Low) as per their service level agreement (SLA) with IISc.
New version of SolMan went Live and the revised User Manual for SolMan was hosted in DIGITS Website in Mar,2021. One more online training session on SolMan for the end users was conducted on last week of Mar,21.

Simple User Interface for SAP PS Project Builder module: Based on feedback from 40 faculty members on the complexity of current SAP PS Project Builder module and its excessive requirements of data inputs, a simple User Interface for SAP Project Builder module has been designed, developed and tested by DIGITS team last week. Wipro team is resolving the issues raised by DIGITS and SAP User Committee (SUC) and expected to release it for User Acceptance Tests (UAT) by last week of March. The interface is expected to go live by the end of March, 2021.

SAP License Audit: Measurement report for our Devlopment and Production system, sought by SAP India, will be generated and hosted in SAP Website for the purpose of audit.

Additional SAP Student Lifecycle Management (SLcM) Licenses

Additional SLcM licenses will be procured shortly after assessment of all active students in the current roll of IISc.

Adobe Sign: Adobe Sign is a Cloud based solution that offers an end-to-end digital document scheme with trusted, legal electronic signatures. Adobe Sign enables to easily initiate, sign, track, manage, and archive digital documents from web or mobile app or from within an organisation. Adobe Sign complies with many regional regulations and industry standards and is accessible anywhere on any device. Adobe sign is hosted on robust cloud-based service and securely handles large volumes of e-signature) processes, including:

- Managing user identities with capability-based authentication
- Certifying document integrity
- Verifying e-signatures
- Logging recipient acceptance or acknowledged receipt of documents
- Maintaining audit trails
- Integrating with other business applications and enterprise systems

The use of Adobe Sign requires a license. At IISc, licenses have been provided to all faculty members, all admin officers, and all admin and office staff members who will be needing to use Adobe Sign. An adobe Sign license is required to "initiate" an Adobe Sign "transaction." An Adobe Sign transaction involves one or more digital documents (it could be for example, a combination of a PDF document, a WORD document, and a JPG file) and enables this set of digital documents to go through a workflow of sequential and parallel steps where in each step, multiple signatures and approvals may be involved. The signatories need not have an Adobe Sign license.

More than 580 user accounts have been created and the program rolled out with an introductory Live program to the user group from Adobe. Several account related issues have been sorted out. Currently more than 1200 document transactions

have been initiated by the various users for Adobe Sign.

During this period, various user reported technical issues have been addressed and resolved internally as part of the administrator role. Weekly usage reports along with a trend graph is prepared and circulated among the DIGITS management. We are also planning to organize another technical presentation from Adobe staff to further improve the usage of digital signatures.

Students No Dues Portal

An essential requirement for any graduating student is to produce a No-Dues certificate which is a record of owing no dues to different sections in the Institute such as the Department, the Finance section, the Library, Computer Centre, etc. This requires signoff by as many as 10 sections/units. Due to the current pandemic situation, this has to be manged innovatively. DIGITS has designed and implemented an innovative portal that obtains online signoff from the 10 units/sections and automatically generates a No-Dues certificate for the students after all the steps are completed.
SAP has started the No Dues activity, but NDC portal is still maintained, running in parallel with SAP. Around 400 + No Dues Certificates are already issued from the NDC portal.

IISc Strategy for fully automated payment

IISc is pursuing its strategy for fully automated payment system to all its vendors through the SAP module. As a first step, it is critical to ensure that we have accurate vendor information especially their validated authentic Bank details. In SAP, there is a provision to register the vendor details. However, it is carried out now by primarily by IISc Purchase section users as external vendors are not integral part of our SAP Sourcing & Procurement module. DIGITS, with the help of the Integra Micro team, has implemented VIP (Vendor Information Portal) in August,2020, which is now accessed by all the external vendors to update their Bank details with documental evidence. The captured vendor information details are uploaded into SAP Vendor database through an interface regularly.

As part of the Basic Cash Management in S/4 Finance, we have recently implemented the Automated Payment Program (APP), which serves the purpose of posting accounts payable like payment to a vendor based on vendor invoices through automated payment run.

APP is used to find out due/overdue invoices and to process a list of customer and vendor invoices to make payments in one go. It also import/upload electronic bank statements (for Bank statement reconciliation with General Ledger).

However, as Bank Communication Management is not part of the Basic Cash Management in S/4 Finance, end-to-end payment automation is not possible through APP. Therefore, we got the Cash & Liquidity management licenses as part of Advanced Cash Management module of SAP, where Bank Communication Management (BCM) is included. BCM is a workflow based process for Outgoing Payment Management with the possibility of grouping payments, approving payments, monitoring of payments, sending payment instruction to bank through SWIFT network. Liquidity Plan/Cash Flow Plan from BPC on S/4HANA can be brought into Cash management, to generate plan vs actual variance analysis for cash flow & liquidity. SAP experts have demonstrated all aspects of Bank Communication (BCM) and Cash & Liquidity planning (CLP) modules to IISc F&A and DIGITS teams. IISc advised Wipro to proceed implementing all aspects of BCM on priority. CLP implementation will be next priority.

APP is used completely now for making vendor payments. Only registered vendors in VIP are being used currently for PO processing. Those vendors who have not registered through VIP are being now forced to follow the process strictly. This will ensure that the data available in SAP is correct and accurate. We are continuously working with WIPRO to make sure the whole integration between VIP and SAP is becoming more and more seamless.

TINA (Telecom and Internet Access)

During Jan-Mar 2021 quarter, the TINA team has completed many important tasks despite the

pandemic and are being continuously monitored and preventive/corrective actions taken.

OFC Backbone: The campus network can be modelled as a multi-level tree, with main departmental switches as vertices and fibre-optic links as edges of the graph. This causes two problems: (a) a single fibre cut results in multiple departments losing connectivity, (b) even if there is no fibre cut, power failure in an upstream departmental switch results in loss of the network in other departments. The TINA team has completed a major upgrade of the OFC backbone to bring in connection redundancy and resilience to power failures.

Hostel Wi-Fi Coverage: Wi-Fi connectivity in hostels has been a long-standing demand of students. TINA took up in May 2020 the massive task of procurement of access points and switches, extension of the campus OFC backbone to the hostels, as well as Ethernet cabling in all blocks.

This task has been completed successfully record time and "iiscwlan" is now available in all the hostel blocks. It will soon be available on the Gymkhana side of the campus as well. Students in the hostels have started using the Wi-Fi network already and are satisfied with the experience.

We are looking at finding an alternate to our existing NKN connectivity for critical operations like Teams video calls. Additional service providers like ACT and Tata are being evaluated. Currently we have an issue with many dropping during Teams video calls.

Video Security Equipment (VISE)

The VISE committee is headed by Prof. Venkatesh Babu and the committee has recently been reconstituted. The campus currently has video cameras installed in key locations for obtaining live feed from these locations (as a part of Phase 1). Phase 2 of VISE has now been initiated and partly completed. In the first stage of Phase 2, 70 cameras have been installed in 38 locations using the existing OFC backbone. This Phase became fully operational by December 2019. In the second stage of Phase 2, more than 30 additional locations are being covered using the upgraded OFC backbone. The tendering process is commencing soon, and this phase will be fully operational by March 2021.

For phase 2B, the tenders were put up and we have received 3 responses. We are currently doing the technical evaluation of the bids submitted. Post this activity, we will call for the demonstration of the equipment by the suppliers at the campus. There is a delay due to the current pandemic situation.

Google G-Suite, Grammarly, Power BI, Overleaf

Google G-Suite: Google India has provided a complimentary subscription to G Suite, their bouquet of powerful products with enterprise features. This includes enterprise versions of all their applications such as Google Meet, Google Classroom, Gmail, Google Drive, Google Forms, Google Sheets, Google Slides, Google Maps, etc. All faculty members, admin officers, and students have been provided with G-Suite accounts. Routine issues related to Password reset, new accounts creation and removal of accounts for termination cases, ongoing.

Grammarly: Grammarly is a popular, third-party, automated grammar, proof-reading, and writing revision tool for academic writing. Grammarly does not fix the writing for you but provides useful feedback. It is for the writer to decide what suggestions are most appropriate. Grammarly premier accounts have been assigned to the faculty, admin officers and the students community within the institute. More than 3600 people are currently using this. For the institute community, also provided instructions regarding downloading and installing plug ins for MS Word and Outlook, both for Windows and Mac sytems.

Power BI: This is a data analytics and visualisation tool from Microsoft. It is a collection of software services, apps, and connectors which enable graphic and visual insights to be obtained from multiple sources of data. The source data may be an Excel spreadsheet, or a collection of cloud-based and on-premise databases. Power BI lets you easily connect to your data sources, visualize and discover key sections of the data. Multiple licenses of Power BI have been obtained. Communication channels have been established between the Data operations team and Microsoft to

address technical queries. Required email addresses have been created to meet the operations of the data team.

Overleaf: The Overleaf platform for Latex publishing is designed to enable cloud-based collaborative authoring in academic institutions. This platform is intended to make the entire process of writing, teaching and publishing scientific documents in LaTeX faster, easier, and completely trackable. Overleaf operates by keeping the document in a single central place on the cloud through its entire lifecycle, stored securely, so that students, faculty members, and collaborators can each write, review, or comment on a document using only a web browser. DIGITS is all set to acquire the Overleaf Commons subscription to make Overleaf available to all the faculty and students of IISc. Only GTE (Global Tender Enquiry) clearance is awaited.

Azure Cloud: Azure cloud resources are being continuously reviewed for effective usage and from a cost optimization perspective. We have more than 100 portals/websites in Azure cloud. We have implemented two rounds of reservations to optimize cost. Some on-prem portals are moved to Azure cloud to provide better uptime and accessibility; for ex: Health Management & Information Systems (HMIS) Process is now in place to continuously review and remove any unused infra items, effectively optimizing the cost. Security settings on the whole Azure cloud set-up are also being reviewed with Microsoft specialists and appropriate changes implemented.

The Centre for Brain Research (CBR) spearheads interdisciplinary research and foster large scale research programs to understand the mechanisms underlying healthy and pathological aging of the brain. CBR adopts an integrative approach encompassing genetic, imaging, molecular, functional and computational methods to study the risk and protective factors that contribute to healthy ageing. To achieve this common goal, faculty, students, and staff of CBR carry out research in human subjects and model systems to study the mechanisms underlying aging. These studies will eventually contribute significantly to the understanding of the ageing brain, and lead to innovative interventions, that can reduce the burden of dementia and other age-related disorders of the brain.

RESEARCH PROJECTS AT CBR

1. TATA Longitudinal Study of Aging (TLSA)

TLSA is a prospective, community-based cohort study of individuals more than 45 years of age (projected n=1000), recruited from urban Bengaluru, in the state of Karnataka, India. Awareness programs are conducted in the city to inform participants about the disease and the study, from where the participants are recruited. Participants who give consent undergo detailed clinical, neurocognitive, biochemical, genetic and neuroimaging (MRI) assessments, which is done in 1-2 visits. The first visit occurs at Indian Institute of Science where participants undergo detailed clinical and cognitive assessments. In the second visit they undergo neuroimaging which also occurs in the Indian Institute of Science. Blood is drawn at their residence for biochemical and genetic assessments.
COVID-19 crisis, suspension the study and our crisis response: Recruitment was halted from March 2020 as COVID restrictions. However, regular telephonic contact were made with participants. Around 400 participants were contacted in total and health-related advice were provided for their medical problems. To continue engagement, virtual tours of museums were provided.

Psychological impact of COVID-19 pandemic was studied in the population through brief telephonic assessments. Out of 297 consented participants, 18 (6%) had depression and 5 (2%) had anxiety. Furthermore, detailed SOP, describing all the safety precautions to be undertaken for the safety of the staff and participants were prepared to restart study recruitment and assessments.

Restarting the study with COVID-19 safety precautions: The study restarted with online clinical and cognitive assessments in September 2021 and following CBR Ethics Committee's approval of SOPs for COVID-19-related safety precautions, in-person recruitment and assessments resumed on 16th November 2020. Blood investigations and subsequent MRI sessions were also restarted. Currently, total of 479 baseline assessments and 564 follow-up assessments have been completed since the start of the study. In future recruitment will be ramped up and follow up sessions will be continued.

3.7.10 Centre for Brain Research

DIRECTOR
VIJAYALAKSHMI RAVINDRANATH

Table: TLSA study progress (1st April 2020 – 31st March 2021)

Title	Overall					April 2020 to March 2021				
Participants consented	479					15				
Baseline assessments	479					15				
Follow up assessments	F1 F2 F3 F4					F1 F2 F3 F4				
	324 168 64 8					45 84 44 7				
Brain MRI	BL	F1	F2	F3	F4	BL	F1	F2	F3	F4
	281	168	63	24	5	0	21	18	10	4
Sample collection completed	BL	F1	F2	F3	F4	BL	F1	F2	F3	F4
	375	262	131	51	5	18	43	74	32	5
Feedback/consultation sessions completed	All participants are given feedback immediately after the assessments					All participants are given feedback immediately after the assessments				
Awareness programs	50					0				
Community engagement (brain health talk + sports events)	2					0				

2. Srinivaspura Aging, Neuro Senescence and Cognition (SANSCOG)

SANSCOG is a first of its kind, large, cohort study in the rural Indian population (projected n=10,000) that follows an interdisciplinary, multimodal approach including detailed clinical, neurocognitive, biochemical, genetic and neuroimaging assessments, to understand the risk and protective risk factors for dementia and related disorders. End-to-end digitization has been done for all the assessments. Recruitment for the study started in January 2018. The pilot phase of the study (n=1,000) was completed in March 2019. The main phase of the study is currently ongoing, and the follow-up assessments also commenced from February 2020.

COVID-19 crisis and suspension the study: The study was severely impacted by the COVID-19 pandemic and the associated lockdowns; recruitment and assessments had to be suspended between March 2020 and October 2020.

Our response to engage participants during the COVID-19 lockdown period: Throughout the lockdown period, regular telephonic contact with the participants were made to enquire about their well-being and to reassure them. When necessary, the doctors in the clinical team also offered telephonic health-related advice for the participants who sought help for their medical problems. In view of poor awareness in rural areas, CBR collaborated with the Digital Nerve Centre (DiNC) – a digital health service initiative by the Tata Group, operating in Kolar district, to offer telephonic counselling to consenting participants on COVID-related awareness and safety precautions. In addition, telephonic assessments for depression and anxiety were carried out in the participants. The prevalence rates of depression and anxiety disorder were found to be 28.4% and 5.5%, respectively.

Restarting the study with COVID-19 safety precautions: Based on the official advisories and guidelines, a detailed SOP for COVID-19-related safety precautions were prepared to be followed when restarting the study. Following the Institutional Ethics Committee's approval of the SOPs, recruitment and assessments resumed on 5th October 2020, with strict safety measures. The study started with a minimum number of 2 participant assessments per day. To avoid participant travel and make it more convenient, the mobile unit was deployed at Srinivaspura, and the assessments were carried out in the participants

villages itself. After a period of stabilizing the logistics and ensuring that assessments proceeded smoothly with the COVID-19 safety precautions in place, the number of assessments were gradually increased. Assessments restarted at the SANSCOG project office from 24th November 2020. The number of assessments were gradually increased to 8 per day, with mobile unit and office assessments running parallelly. The backlog of blood camps and feedback camps that had been stalled due to the lockdown were cleared. All camps (awareness camps, blood camps, feedback camps) were conducted with restricted numbers, social distancing, temperature screening for participants as well as providing masks for all participants and staff.

Table: SANSCOG study progress (1st April 2020 – 31st March 2021)

Title	1st April 2020 – 31st March 2021	Overall
Participants consented	495	2621
Villages recruited from	9	34
Baseline assessments	384	2214
Follow up assessments	114	126
Brain MRI	16	116
Interim telephonic + home visit contact	0	1208
Based on interim contact, participants interested in follow up	0	1117
Blood sample collection camps	33	78
Sample collection completed	469	2252
Feedback/consultation sessions completed	24	64
Village surveys	15	35
Awareness programs	16	47
Community engagement activities	0	4

3. GenomeIndia

GenomeIndia project aims to identify the genetic variations (common, low frequency, rare, single nucleotide polymorphisms or SNPs, and structural variations) present in Indian population through whole genome sequencing of representative population groups across the country. This will lead to the development of a genome wide association chip specific for Indian population and facilitate large scale genetic studies in the future. This will help to identify the genetic variations in our population that makes us susceptible to complex diseases such as diabetes, cardiovascular diseases, obesity and mental illness, among others. The comprehensive list of genetic variation obtained from healthy individuals will serve as filter for non-causal mutations and help perform genetic studies on monogenic disorders. The results from this project would thus be a valuable national resource for the country and will be made publicly available through an interactive web portal. This project is led by Centre for Brain Research (CBR), with collaboration from nineteen other national institutes across India, including IISc, IITs, AIIMS, NIMHANS and other leading research institutes of the country.

The project has been sanctioned by Department of Biotechnology, Government of India in January 2020. The total funding is for INR 237.74 crores. As part of this project, CBR has helped conduct several workshops in the partner institutions between January- March 2020 for population identification, community outreach and adhering to standard

operating procedures for sample collection. Most importantly, one workshop was taught by instructors from BROAD institute of MIT and Harvard who are part of the GATK and Terra developing team, the program suite used worldwide by various researchers for this purpose.

At CBR, 905 individuals have been contacted for probable participation in the study. 765 individuals from varied population groups have consented and been recruited into the study. Sample collection and phenotyping has been done for these 905 individuals. In total, 6177 individuals have been recruited into the project by all the sample collecting institutes. CBR has installed the data collection app for the participating sample collecting institutes that would aid in having background information of study subjects as well as store and transfer anthropometric, biochemical data for all subjects enrolled in the project from across 13 sample collecting institutes in the country. Additionally, CBR proudly hosts a scalable storage system of 2 PetaBytes for data storage, and high-performance computing infrastructure of 170 Teraflops capacity, that supports data analysis and storage of the massive amounts of multimodal data generated by human studies spearheaded by CBR.

Four standard Corriell cell lines were obtained from the NIST Genome in a Bottle consortium. The cells were passaged, and the extracted DNA was shared with the 3 other sequencing centres. We, at CBR, also sequenced the 4 samples of standard DNA, and the variant calling concordance for SNPs and InDels was > 94% between our results and benchmarked NA12878 cell line dataset. The coverage for all these four cell line samples were >37X. Concordance check of these results with those from other sequencing centres is currently underway.

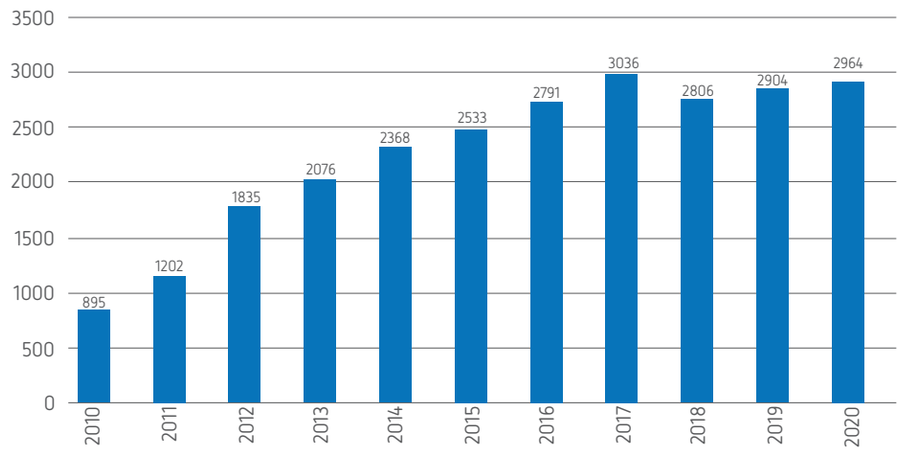
CBR has analysed data from 819 WGS. Call rate is in the range of 96 to 99%, and mean genotype quality for most samples is >70. The average transition-transversion ratio is 1.8 across autosomes and sex chromosomes. About 40 million genetic variations were identified from 650 individuals, and 34.5 million of them are single nucleotide polymorphisms (SNPs), and 5.4 million are short insertions and deletions (InDels). Among the SNPs and InDels that are present in both Indians as well as other populations, about 1.76 million variations differ in prevalence among Indians and others by at least 15% frequency of the alternate allele. 8.4 million SNPs are unique to the Indian population, 565,000 are novel InDels. Majority of the novel variations uncovered in Indian population are of low frequency (1-5% frequency) or rare (<1%).

About 56% and 34% of all the variations are respectively intergenic and intronic. Out of the exonic variants, ~53% are nonsynonymous, and ~38% are synonymous changes. About 5% of the insertions and deletions are present in exonic region, which points to enormous consequences in terms of protein coding variations affecting phenotypic changes on our population.

The Kishore Vaigyanik Protsahan Yojana (KVPY) is a programme established in 1999 by the Department of Science and Technology, Government of India to encourage students to take up research career in Basic/Natural Sciences. The Department of Science and Technology, the nodal agency of the Government has entrusted the overall responsibility for organizing and running the KVPY Program to the Indian Institute of Science, Bangalore and set up a KVPY Management Committee which oversees all the aspects of implementing KVPY program including declaration of results. The National Advisory Committee (NAC) oversees proper implementation of the program and a Core Committee looks after both the day-to-day and academic aspects of the KVPY Program. The aim of the programme is to identify and encourage talented students with an aptitude for research. This programme strives to assist the students to realise their potential and ensure that the best scientific talent is tapped for research and development in the country.

KVPY programme is open to Indian Nationals studying in India. Students enrolled in an undergraduate course in Basic Science subjects such as Chemistry, Physics, Mathematics, Statistics, Biochemistry, Microbiology, Cell Biology, Ecology, Molecular Biology, Botany, Zoology, Physiology, Biotechnology, Neurosciences, Bioinformatics, Marine Biology, Geology, Human Biology, Genetics, Biomedical Sciences, Applied Physics, Geophysics, Materials Science or Environmental Science, in their degree courses leading to B.Sc./B.S./B.Stat./B.Math./Int. M.Sc./Int. M.S., during the academic year in which the fellows awarded are made, are eligible to apply for the KVPY fellowship under various streams – SA, SX and SB. Since 2010 there is more than 350% increase in the number of KVPY Fellowships offered under various categories as depicted in the bar chart.

Number of KVPY Fellowships Awarded during 2010 – 2020



3.7.11

Kishore Vaigyanik Protsahan Yojana

CONVENER

AK NANDAKUMARAN

During 2020, 1,56,430 students have applied for KVPY Aptitude Test, out of this 1,31,326 applicants appeared for the online examination held on January 31, 2021. The Aptitude Test was held at 296 examination centres in 145 cities across the country. Based on the approval of KVPY Management Committee, the students were selected for the KVPY fellowship award solely on the basis of their performance in the Aptitude Test. In view of prevailing COVID-19 pandemic, the KVPY Management Committee, has decided to dispense with interview for the years 2020-2021. After evaluating the marks obtained by the students in the Aptitude Test, 2964 candidates have been recommended for the provisional award of KVPY Fellowship-2020 tenable from August 01, 2021

Empowerment initiative in the KVPY Program:

i. A certain number of fellowships under the various streams as stated above are available for the students belonging to SC/ST community.

ii. A certain number of fellowships under various streams as stated above are available for the students under the category of Person with Disability (Physically and Visually Challenged).

Application fee: General Category: Rs. 1250/-
SC/ST & PWD: Rs. 625/-

Fellowships (Rs.5000 - Rs.7000 p.m and a contingency grant equal to 4 months of fellowship per year) are given up to the Pre-Ph.D level or for a period of five years whichever is earlier to the selected students.

Fellowship Details

Fellowship Value	Qualifications
Rs. 5000/- p.m.	I to III year B.Sc/B.S/B. Stat/
	B. Math/Int. M.Sc/Int. M.S
Rs. 7000/- p.m.	I/II year M.Sc
	IV/V year B.S/Int. M.Sc/Int. M.S
Contingency Grant	Equivalent to four months of Fellowship per year

KVPY Fellows SA/SB/SX are eligible to attend the Interview/Counselling for admission to the five-year Integrated B.S./M.S. Programme conducted by the Indian Institute of Science Education and Research (IISER) Kolkata/Pune/Mohali/Bhopal/Thiruvananthapuram/Tirupathi/Berhampur.

KVPY fellows SA/SX/SB are also eligible to apply for Undergraduate degree programme conducted by IISc Bangalore.

ASIAN SCIENCE CAMP & NATIONAL SCIENCE (VIJYOSHI) CAMP:

The Department of Science and Technology sponsors 20 students to the Asian Science Camp which will normally be held during the month of August every year. The responsibility of selecting the students for the Asian Science Camp was vested with HBCSE till 2011. From 2012 onwards the selection of students for the Asian Science Camp was entrusted to KVPY. The KVPY had readily accepted this challenge and taken appropriate actions for selecting the students to represent India at the Asian Science Camp.

The Department of Science and Technology, in addition to the KVPY Fellowship award, will also encourage in

conducting National Science (Vijyoshi) Camp every year during the month of December. During the National Science (Vijyoshi) Camp eminent speakers from India and Abroad will be invited to address the students followed by tutorials. This is with a view to keep the students abreast of the scientific development around the world.

The National Science (Vijyoshi) Camps is to provide a forum for interaction between bright young students and leading researchers in various branches of science and Mathematics. With boundaries between disciplines fast disappearing, these camps serve as an ideal platform for the young participants to get an exciting global viewpoint of questions relating to basic Sciences as well as application oriented themes.

A comprehensive programme has been designed for the participants. This includes thought provoking lectures followed by a round of discussion at the end of each day's programme. In addition, the previous meetings have ultimately served to motivate and inspire the participants by bringing them together, in what is hoped will be their first step towards a career in research in the Basic Sciences and Mathematics.

In view of the prevailing global COVID-19 pandemic, the Asian Science Camp and National Science (Vijyoshi) Camp were suspended for the year 2020. The DST has suspended the Asian Science Camp for the year 2021. The DST/ KVPY is proposing to conduct an online Vijyoshi Camp during December 10-12, 2021, for the benefit of the students.

COMMITTEE MEMBERS

Convener
AK Nandakumaran
Co-Convener
Abha Misra

Members of the KVPY Core Committee
Santanu Mukherjee
Thirupathi Gudi
Patrick D Silva
Abhishek Kumar Singh
Manish Jain
Vishwesha Guttal
Adviser
S Raju
Administrative Officer
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PROFILE

Karnataka State Council for Science and Technology (KSCST) an autonomous S&T organization under Department of Science & Technology, Government of Karnataka established in the year 1975 is one of the first State S&T Councils to be set up in the country. During the last 45 years of its existence, KSCST has been pro-actively engaging itself to identify, propose and implement S&T based solutions to locale specific needs / problems in the broad areas of Water, Education, Geospatial Technologies, Housing, Energy, Digital Heritage, Health and E- governance. In association with the Indian Institute of Science and several other premier R&D institutions, KSCST has been executing many projects and programmes aimed at improving socio-economic conditions of the people of the state.

Over the years, a number of technologies have been translated, from research and demonstration phase to the implementation and operational phase. KSCST provides support to the State Government in formulation of S&T based policies and to both Central and State Governments in scientific surveys, project implementation, evaluation, co-ordination & monitoring, organization of scientific meets and awareness campaigns.

VISION: Application of Science & Technology for the management of resources, improvement of environment, quality of life and socio-economic conditions of the people of Karnataka.

MISSION: Co-ordinate R & D activities for generation of knowledge for scientifically based interventions, development and popularization of appropriate technologies for adaptation by the civil society to overcome local-specific problems and, inspire and improve human resources of the S&T sector in the state.

MAJOR PROGRAMMES

- **Natural Resources Data Management System (NRDMS)** - A Repository of Natural Resources and Socio-economic database to support local level developmental planning. Developed guidelines for generating village cadastre using high resolution satellite imageries. First state to generate Geospatial Action Plan for line departments.

- **Karnataka State Spatial Data Infrastructure (KSSDI):** KSSDI is a web portal to find and access spatial information/services via the Internet. Assisted in establishing National Data Registry.

3.7.12 Karnataka State Council for Science and Technology

SECRETARY
ASHOK M RAICHUR

EXEC. SECRETARY
H HEMANTH KUMAR

• **Academic and Industry Interaction Cell (AIIC)** – Under Student Project Programme (SPP), supporting and mentoring innovative under-graduate and post-graduate engineering student projects. Supported more than 13,500 projects so far. More than 100 projects commercialized. Established E-learning centres in government high schools to improve access to advanced educational resources, digital contents, Lab experiments in the form of 3D animations using latest IT gadgets and internet.

• **Rainwater Harvesting (RWH)** - End-to-end solution on RWH including awareness and technical support, implementation, preparation of DPR and support to enforcement. Has a patent on RWH and assisted state government in drafting RWH policy and guidelines.

•**Digital Heritage** - Laser scanning of state archaeological sites and Hampi World Heritage site for creating virtual walk through and reconstruction/ restoration.

•**Geospatial mapping of Traditional Surface Water Bodies for restoration and rejuvenation**. Based on these reports state government is taking up restoration works of water bodies under Jal Shakti Abhiyan and MGNREGA programs.

• **Energy Cell** – Demonstration and dissemination of new technologies, workshops, techno- economic feasibility reports and energy conservation & management including bio-energy. Providing detailed project reports to government institutions.

• **Housing** - Research, development & dissemination of energy efficient building technologies. Over 1 lakh houses built in India and over 20,000 houses built in Bengaluru using cost-effective and energy efficient building technologies. Organizing training programs to engineers and architects.

• **Patent Information Centre** - Promotion, protection and commercialization of Intellectual Property Rights of inventors and creators. Established over 40 IP cells in engineering and degree colleges/institutions to encourage faculty, students, startups and entrepreneurs. Supported filing more than 80 patents.

• **Centre of Excellence in Cyber Security** - Promoting the cyber safe and conducive environment for industry collaboration, address the skill gaps, build awareness & facilitate innovation in this emerging technology field of Cyber Security Startups mentoring,

• **Established SC/ST cell** to promote adaptation of appropriate and relevant technologies for socioeconomic development of target population by assessing natural & human resource endowment, upgrading skills and creation of micro enterprises for sustainable livelihoods.

• **Establishing SHG/FPO enterprises** to address malnutrition and provide rural livelihoods in Yadgir District, Karnataka.

• **The Centre of Excellence in Aerospace & Defence** - In association with Visvesvaraya Technological University trains graduates and post-graduate engineering students on Aircraft and Aerospace Technologies.

• **Science popularization / Communication / Teachers Enrichment programs**; Radio Serial on Artificial Intelligence; National Science Day / National Mathematics Day

• **State Awards for Scientists and Engineers** - Recognize and reward Scientific and Technological eminence in the state. Instituted by Government of Karnataka.

The Office of Career Counselling and Placement (OCCaP) Centralized the management of campus Placement & Internships. Several placement activities and events were organized to facilitate interaction between students and industries through special meetings (pre-placement talks, alumni connect meetings, etc) in IISc and helped students hone up their skills to meet industry requirements. This office is managed by a Placement Officer, who is supported by temporary staff for routine activities and by a committee of four professors for policy matters.

A. Completion of Final Placements for Batch 2019-20
B. Connect with Batch 2020-21 & Batch 2021-22
C. Pre-Placement Offers Post Internship – Batch 2020-21
D. Final Placement Campus Season 2020-21
E. Special counselling for specific students
F. Internship Placements 2021-22
G. Special Attempts for PhD & Post Doc students
H. Technical and Soft Skills for students

A. Completion of Final Placement 2019-20

Final placement for batch 2019-20 continued and closed in June 2020 for UG, M.Tech, M.Tech(Res), M.Des, M.Mgmt and PhD students registered with OCCaP to seek placement support

B. Connect with batch 2020-21 & batch 2021-22

Students from batch 2020-21 were addressed in July/ August 2020 and students of batch 2021-22 were addressed in January/ February 2021. These interactive sessions with the students were to understand their inclination for campus placements, share information about placement process/ policies and to identify their needs for personal skills and those necessarily requiring additional attention.

C. Pre-Placement Offers Post Internship – Batch 2020-21

About 50% students from batch 2020-21 received direct pre-placement full time offers (PPO) in September 2021 who participated in internship season 2020.

D. Final Placement Campus Season 2020-21

Pre-Placement Talks (PPT's) for UG/Master/ PhD/ Post Doc students scheduled from August and continued till September.

- Pre-placement talks by companies were scheduled virtually in August and September
- Placement process, PPT, Test, Interviews conducted via virtual mode.
- Campus Placement interviews commenced from 10th September 2020.
- 180+ companies participated in campus hiring for full time placements.
- 294 students secured full time jobs with highest of 95.3 Lakh JPY as highest international offer and 61.2 LPA highest domestic offer

3.7.13 Office of Career Counselling and Placement

Final Placement	2020-21**	2019-20*	2018-19	2017-18	2016-17
Total Students Placed	294	238	269	235	207
Highest CTC (LPA)	95.3 L JPY (international) & 61.2 L (domestic offer)	43.3	62.4 L (International) 43.3 (domestic)	45	30
Average Annual CTC (LPA)	21.8	21.9	20	16.7	15
No. of students placed with >40 LPA	10	13	7	1	NA
No. of students placed with 30- 40 LPA	50	43	45	10	2
No. of students placed with 20-30 LPA	97	76	56	53	33
No. of Master students placed	261	192	231	194	198
No. of PhD/ Post Doc Students Placed	28	34	35	31	3
No. of UG Students Placed	5	12	3	10	6

* ** L – Lakh, JPY – Japanese Yen

**2020-21 – placements commenced in mid-September 2020 and to continue till July 2021

*Note: 2018-2020 MTech admission (batch 2019-20) was only 268 compared to 346/457 in the previous year

E. Special counselling for specific students

Students who were finding their way difficult to get through the interviews and secure a job were addressed to understand their problem areas beyond technical domain and help them overcome the same to prepare for further interviews.

F. Internship Placement (Batch 2020-21)

• Internship placement for batch 2020-22 commenced in March 2022.

• Virtual internships for selected students for 8 weeks duration staring from June.

• Highest Stipend –1.25 L per month (PhD and Master's programme)

G. Special Attempts for PhD & Post Doc students

Continuous meets with PhD and Post Doc students to familiarize them with the prospective work opportunities available in industries. PhD/ Post Doc placement for final placement and internship open round the year.

H. Technical and Soft Skills

• Technical/ soft skills/ mentorship sessions(virtual) with industry leaders free of cost to students

• Student Mentorship sessions in association with Talent Acquisition leaders of industry to take them through various aspects like Expectations of Industry on a Fresher, Future Skills, Creative Problem Solving, preparing a Great CV, Virtual Interview, How to Crack Virtual Interview etc.,

• Technical & soft skill sessions by BT Leaders on - Big Data Technical, Cloud Computing, Women in Technology, Importance of Communication, Agile, DevOps etc.,

A. PROJECTS SANCTIONED

During the period under review SID got 53 projects sanctioned covering different departments of the Institute involving the participation of more number of faculty.

B. INDUSTRY R&D CENTRES IN SID/IISC CAMPUS:

1. I-HUB Centres

1. United Technologies Corporation India Private Limited (Pratt & Whitney R&D Centre)
2. Tata consultancy Services
3. NLC India Limited
4. TIH for Robotics and Autonomous Systems Innovation Foundation
5. IUDX Programme Unit

2. OTHER CENTRES

1. Robert Bosch Centre for Cyber Physical Systems
2. Centre for Infrastructure, Sustainable Transportation and Urban Planning
3. Energy Storage Systems Initiative
4. Centre for Brain Research

I. AGREEMENTS/MoU:

Agreements with the following organizations have been entered into during the period under review.

1. Hitachi India Pvt. Ltd.
2. Toyota Motor Engineering & Manufacturing North America, Inc
3. Autoliv India Private Limited
4. AIOT Foundry Pvt. Ltd
5. Analog Devices Inc,
6. Ministry of Housing and Urban Affairs, Government of India
7. Extensions for Faurecia Projects
8. Unilever Industries Private Limited
9. Honeywell Technology Solutions Labs Limited
10. Bill & Melinda Gates Foundation
11. Boeing (Extension)
12. Vinati Organics Private Limited
13. Novartis Health Care Private Limited
14. Texas Instruments incorporated
15. Alpha and Omega Semiconductor incorporated
16. Larsen and Toubro Limited
17. Coramandel International Limited
18. Department of Heavy Industries, GoI

PROJECT & PROGRAM MOU PIPELINE

1. Mercedes-Benz Research and Development India Private Limited

3.7.14

Society for Innovation and Development

2. Oracle

3. GIZ

4. Human Spaceflight Centre, ISRO

5. NLC INDIA LIMITED(NLCIL)

6. Sony India Limited

7. NDMA, Govt of India

II. STEM CELL

B1. Companies currently being incubated:

Sl No	Incubation MM/YY	Company	Incubatee	Technology Area	Status	Impact Area
2	Dec 2019	AI Health Highway Pvt Ltd	Dr (Maj) Satish J	AI based Stethoscope	Early Stage	Healthcare
11	Jan/2016	Astrome Technologies	Ms. Neha Satak	Satelite Based Internet Services	Developmental phase + Outdoor testing in campus to start	Digital India
12	Apr/2014	Azooka Life Sciences	Ms.Fatima Benazir	DNA Stains	Early Prototype in market	Societal
8	Jan/2017	Bellatrix Aerospace	Mr. Rohan M. Ganapathy	Orbital launch vehicles	Signed Contract with ISRO; Raised $3MN in Pre-Series A round	Aerospace Industry
2	Oct/2020	Delta X Auomotive Pvt Ltd.	Kithir	portable electric scooter	Early Stage	Automotive
1	July-2020	Digantara Research & Tech Pvt Ltd	Rahul Rawat, Tanveer Ahmed + team	Space Tech	Early Stage	Space
3	Nov 2019	Direct Electric Pvt Ltd	Dr. Anil Adapa + Team	EV Battery Charging Station	Early Stage	EV Tech
6	May/2017	General Aeronautics	Dr Kota Harinarayana	Aerospace	Growth Phase	Aerospace industry
4	Oct 2019	Grasp Bionics Pvt Ltd	Nilesh and Vinay	Prosthetic limbs	Early Stage	Social
9	Jan/2017	Lab to market innovations	Prof. S. K. Sinha	Iol based applications	Development phase; Have raised <1cr from external investor	Transportation Industry (Railways)

7	May 2017	Mimyk Heathcare	Shantanu Chakraborty	Laproscopy Simulator	Early Stage investment being worked out	Healthcare
13	Jan/2014	Pratimesh Labs	Mr. Prakhar Jain	Low-Cost Medical Devices	Developmental phase	Rural Health
5	Jan/2018	Protein Design Pvt Ltd	Dr Rajan Dighe	BioSciences	Early Stage	Healthcare
10	Aug/2016	SIAMAF Healthcare Pvt Ltd	Dr. Subhasis Sarangi	Nano technology based diagnostics	Clinical Trials in Progress	Health care
1	Dec/2020	Tiea Connectors Pvt Ltd.	Ajith P S	Electrical Connectors	Early Sage	Automotive
1	Feb/2021	Tsalla Aerospace Technologies Pvt Ltd	Dr T S S Narayana	Drones	Early Stage	Unmanned aerial systems, Defense, Medical, Agritech

B2. Companies incubated under the Faculty entrepreneurship programme:

Sl No	Incubation MM/YY	Company	Incubatee	Technology Area	Status	Impact Area
10	Aug 2016	Bio-Synth	Prof. B. Gopal	Enzyme engineering	Revenues	Biotechnology, Chemicals, Pharma
12	Apr 2015	Equine Biotech Pvt. Ltd.	Prof. Utpal Tatu	Veterinary Diagnostics	Revenue Positive	Animal Health
1	May 2020	HealthSeq Precision Medicine Pvt Ltd	Prof Nagasuma Chandra	Precision Medicine	Early Stage Development	Healthcare
1	Dec/2020	Indriya Sensotech Pvt Ltd.	Prof Praveen Ramamurthy	Sensing Materials	Just Incubated	Sensors
5	Aug/2018	Invitrosense Pvt Ltd	Prof Venkatraman	BioSciences	Early Stage	Bioscience, Chemicals
2	May 2020	Kenome Technologies Pvt Ltd	Prof Partha Talukdar	Enterprise Knowledge Graph	Product in Market – Making Revenues	Enterprise Graph
	Dec 2020	Mithra	Prof N K S Rajan	Silica extraction	Just Incubated	Renewable Energy
6	Aug 2017	Mynvax Pvt Ltd	Prof Raghavan Vardharajan	Protein based Vaccines	Early Stage	Healthcare
8	Jan 2017	OpenWater	Prof Sanjiv Sambandan	Water Purification	Beta Testing with Customers in progress	Water / Societal / Industries

11	Sep 2015	Pathshodh Healthcare Pvt Ltd	Prof. Navakanta Bhat	Diabetes Diagnostics	Revenue Positive	Societal
4	Dec 2018	RaGaVeRa Indic Technologies	Prof AG Ramakrishna	TTS to Indic Languages	Early Stage	Software
9	Aug 2016	Shanmukha innovations Private limited	Dr. Sai Siva Gorthi	Optics and Microfluidics Instrumentation	Developmental Phase	Medical Diagnostics
7	May 2017	Simyog	Prof. Dipanjan Gope	Computational tool for modelling and simulation in electromagnetics	Product Development; Strategic investor on board	Electric vehicle
13	Sep 2014	Superwave Technology Pvt. Ltd	Prof. K.P.J Reddy/Prof. Jagadeesh	Shock Wave Dynamics	Revenue Positive	Petroleum, Tea Industry and Healthcare
13	Feb 2021	Theranautilus Pvt Ltd	Dr Ambarish Gosh	MedTech	Just Incubated	Drug delivery
3	March 2019	Urjalinks	Prof Gurunath Gurralla	Energy Efficient home automation	Early Stage	Home & Industries

B3. Incubation under InCENSE:

Startups incubated	Nuthan Labs Pvt Ltd., & Agnit Semiconductors Pvt Ld.
Incubation Pipeline	JK Nano Solutions

B4. Incubation under CPMED:

Startups incubated	Yosi Innovations Pvt Ltd. Switchkase Technologies Pvt Ltd., Maithra MedTech Pvt Ltd., Neu Integrals Pvt Ltd.,
Incubation Pipeline	

INCUBATION PIPELINE:

STEM Cell has a healthy pipeline of proposals from prospective inucbatees. The following are in advances stages of evaluation and discussion: received new proposals from start-ups and these are in various stages of evaluation and processing.

Domain	Product / Initial Offering
Healthcare	1. Prof Bhushan Toley - low cost point of care diagnostic devices 2. Prof Hardik Pandya – Healthcare wearable devices
Nano / Semiconductor	1. Prof Vasu – Gallium Nitride 2. Prof Arindam Ghosh - Manufacture ultra thin nanoflakes 3. Tiea Connectors Pvt Ltd.
LPG Sensor	Prof Praveen - Incubation in progress
Clean Water	Prof Chanakya' students
Defence	1. Prof Gaurab Bannerjee – Radar on Chip Technology 2. Dvizira Pvt Ltd - Exoskeleton for Healthcare / Defence
AI / Software	1. Radometech Technologies and Services - Aircraft monitoring system using AI / ML
MedTech	1. Sepsis Treatment – External
Aerospace	1. Drones for Military – In Progress

OTHERS:

- Received a grant of Rs. 5crores from CITI Bank to support Startups working in the area of COVID-19
    - ¤ Money disbursed to six startups
- CSR Support also received from SBI, Infineon for Shanmukha Innovations
- Received a grant of Rs. 3.10 crores from MEITY towards TIDE 2.0 implementation.
    - ¤ Completely utilized the first installment. Submitted the Utilization Certificate (UC) in Sep'20 and waiting for the subsequent tranche.
- Honeywell has given a CSR grant of Rs 2 crores to support startups
- MoU signed with Shell India towards collaboration in incubation around clean tech
- Facilitated the I-NCUBATE initiative of GDC.
- Conducted Student Innovation Program (SIP) - 3.0 in collaboration with AIM, NITI Aayog for the school students
- MoU signed with MathWorks towards Accelerator & Incubator Program
- STEM team is undergoing a three-month Incubator training program 'iCREST Cohort 3' jointly conducted by AIM and Wadhwani Venture Fastrack, for Incubator Capabilities enhancement.
- SID Incubation team attended Master Class, which is a part of 'AIM iCREST' training program held between Dec'20 to Mar'21. SID had pitched the presentation on the final day of the training program i.e., Mar-26, 2021.
- STEM Cell had completed the Yearly review meeting with AIM on Mar-2021 and MeitY' TIDE 2.0 on Apr-2021.
- STEM cell has on-boarded two full-time mentors Mr Sanjiv Sarin & Mr Shekar Viswanathan to guide the startups in Product development and Business strategy.
- Disbursed the seed funding of more than 50L to various startups through seed fund support from AIM, TIDE and CSR support funds.

III. TIME^2

NEW PRODUCT DEVELOPMENT ACTIVITY WITH SMES

Below is the list of companies which have collaborated with SID-TIME2 in developing products jointly.

Sl. No.	Year	Company	Product area	Status
	2020	Contracense	Power Electronics	MoU Signed Prototype Ready
	2018	Electronics Relay India, Bengaluru	Smart Motor controller	Under pre-production phase
	2019	Electronics Relay India, Bengaluru	Food processing M/c	POC ready, IP Filed
	2019	EP Lab	Personal cooling	Ongoing
12	2020	KAS Technologies	Medical	Prototype Ready
	2020	MicroSolutions	Medical	Project Started
	2019	Microtech CNC solutions Pvt Ltd, Hosur	Smart storage system	POC ready
	2020	Microtech CNC solutions Pvt Ltd, Hosur	Smart Vending M/c	Discussions resumed post lockdown
	2020	Mr. Hariprasad	Medical	Prototyping under progress
	2020	Mr. Jay Krishnan	Medical	Project Started
	2020	Mr. Vibhor Agnihotri	Medical	Prototype testing under progress
	2019	Oorja Energy Solutions, Hyderabad	Dew Point Chiller Tech development	POC ready
	2020	PCT India	STEM Edutech	MoU under Progress
	2020	REVARON PRIVATE LIMITED	Medical	Prototype Ready
	2020	Uttejna Technologies	Medical	Project Started

1. Working with licensees(6) of Oxygen Concentrator developed by IISc in collaboration with SID.

2. The following technologies developed with MSMEs are ready.

- Antiviral coatings
- Isolation stretchers
- Isolation beds
- Quick-deploy Isolation wards
- Antiviral room air purifiers
- Behaviour forming antiviral hand gloves

Proposals received and under final stage of review

Sl. No	Company name	Technology area
1	We3 Solutions	Medical
2	Meccano Instruments	Medical
3	Resil Chemicals Pvt Limited	Medical
4	Savtoa software technologies pvt ltd	Medical
5	Sobujokhkhi Pvt. Ltd	Medical
6	Scholar Lab Foundation	Medical
7	VerifygnTech Pvt. Ltd	Medical
8	Sar Daya Enterprises	Medical
9	Universal Technologies	Medical
10	Pasumai Biotech Pvt Ltd	Medical
11	Mr Vijay Yashvanth B C	Electronics Display
12	Mr Balmukund Madhukar Hirwe	Medical
13	IDIYA design	Medical
14	NSoft India Pvt Ltd	Clean tech
16	PC Tech	Lab kit for school
17	Turbo Tech India, Bengaluru	Steam turbines
18	Kaanha Aerospace	Coimbatore

PIPELINE

Interaction with industries to collaborate and develop technologies for fighting COVID19 pandemic. Discussion are in different phases

Sl. No.	Company	Product area
1	Bhat Bio-Tech, Bengaluru	Medical
2	Inhouse Interior	UV Box for disinfecting
3	Microtech CNC	UV based disinfectant
4	Technomech	Medical equipment

WORKSHOPS/ CONFERENCES/EXHIBITIONS

Sl. No.	Event name	Organized by	Place
1	National workshop on Design expertise to manufacturing MSME sector	Ministry of MSME	Delhi
2	Muncipalika - Future cities	GoK	Bengaluru
3	MSME Crisis & Opportunities under COVID situation	Gujarat Chamber of Commerce	Webinar
4	EXIM bank Schemes for MSMEs	EXIM Bank	Webconference
5	Technology Development Fund – New Projects	Invest India	Webconference
6	SeTU for Atmanirbhar Bharat	DST	Webconference
7	Funding opportunities available for MSMEs – A Venture Capitalist Perspective	MSME-DI, Bengaluru	Webconference

ORGANIZED WEBINAR ON TATPAR PROGRAMME

Techproducts Accelerated by TIME2 for Pandemic Relief

TIME² focuses on transforming SME industries by developing in-house technology innovation capability. Often, SMEs pair up with Startups with innovative technology & product ideas, bridging the gap between a proof of concept prototype 'in hand' and a commercial product 'on the shelves'. We prefer lab proven prototypes with ready production partners so that solutions can rapidly reach the market, and help combat COVID immediately. We only incubate ideas that need significant intellectual contribution from SID, IISc.

Sl. No	Event Name	Industries contacted	No. of Industries selected for webinar	Date
1	Webinar on TATPAR	>50	22	27/06/2020

Matter Facility

A facility for mechanical fabrication and integration with electronics has been established with help of a grant from DST under their Prayas scheme.

IV Targeted Research

1. A proposal to DST on 'Establishment of a Science and Technology Hub' at Challakere campus of IISc for upliftment of skills of SC/ST population of Karnataka has been sanctioned by DST. We are awaiting release of the money. The location for the proposed Hub in Challakere campus has been identified. An introductory workshop for all the stakeholders was held in the Challakere campus in March 2021.

2. A safe and efficient machine for extraction of banana fibres from its pseudostems has been developed in collaboration with CPDM. Feasibility studies for prevention of wastages of horticultural products by installation of customised cooling or drying facilities at the farm level completed.

3. A virtual meeting was convened with representatives of the agri-business of ITC and Green Foundation, a grass-root organization to discuss potential areas of mutual research interests where scientists from IISc can contribue. The following areas were identified:

   a. Prevention of wastage of core product

   b. Increasing productivity

   c. Conversion of by-products to value-added goods

   d. Precision irrigation for sustainable farming

   e. Sustainable agriculture by organic farming in a protected environment

4. Participated in several virtual webinars on AgriTech including GoI's Vaibhav Summit between Indian experts on AgriTech in India and Indian diaspora working on AgriTech in other countries.

5. A series of meetings were convened with a start-up company, EarthBasics. The company wants improvements on its disposable tableware products made from areca nut wastes and wishes to explore sal and banana leaves for such applications. Faculty has been identified and a proposal is being drafted.

6. Collaboration initiated with ICAR and GKVK Bangalore with the finalization of an MoU for joint research and development.

The Office of Research Grants (ORG) provides services and support for the effective administration of sponsored projects at the Indian Institute of Science. The office maintains and shares information on funding opportunities from national and international grants calls with Institute researchers and supports faculty, post-doctoral and graduate students with tools and processes to solicit, secure and manage extramural project funding. The office serves as an intermediary between national and international grant agencies and the various administrative offices at the Institute to provide oversight for grant availability, policy and research administration compliance, grant management and financial reporting, and communication of research highlights.

3.7.15 Office of Research Grants

4

Combating Covid-19

Early in March 2020, IISc began shutting most of its operations in response to the growing COVID-19 crisis. But its researchers did not stop working. Many of them immediately turned their attention to developing devices, technologies and solutions that will help healthcare workers, government agencies and institutions respond better to the crisis. These efforts have also brought together faculty members from diverse disciplines to work together, reflecting the interdisciplinarity that is enshrined in the Institute's ethos. This section provides a snapshot of the dozens of projects that our researchers have worked on since the pandemic began.

VACCINE & BIOLOGICAL STUDIES

'Warm' vaccine candidate: A 'heat-tolerant' vaccine candidate which can remain stable for a month at 37°C. The vaccine triggered a strong immune response in animal models and was found to be effective against all current variants of concern. Clinical trials are expected shortly.

Proteomics and genomics: A series of comprehensive proteo-genomic analyses shedding light on new mutations in the novel coronavirus. Using high resolution mass spectrometry, the study also identified unique host proteins produced as the body's immune system fights the infection.

Structure of spike protein: Visualising the different conformations of the virus's S protein at physiological pH (7.4) and near this value (6.5 and 8.0) using single-particle cryo-electron microscopy. About 68% of S proteins were found to exist in open conformation at pH 7.4.

Repurposing drugs against main protease: Screening existing drugs to test if they can target the SARS-CoV-2 main protease, a key enzyme in the virus life cycle. More than 20 known drugs or drug candidates that could bind to and block the enzyme have been identified.

SARS-CoV-2 and immune system interplay: A minimalistic yet rigorous model to study host-virus dynamics, immune response and disease progression. The model helps identify key parameters that affect clinical outcomes, and explain the role of risk factors and effects of antiviral drugs.

Role of flu and BCG vaccination: Analysing the link between incidence of TB and flu with COVID-19 deaths in different countries. Preliminary data shows that countries with higher flu cases and BCG vaccination coverage may have a relatively lower number of COVID-19 deaths.

Targeting host proteases: Modelling how existing drugs can block host enzymes that play a key role in virus entry. Drugs targeting two key pathways, although independent, displayed strong synergy in blocking virus entry. Exploiting this synergy may improve deployment of drug combinations.

Analysing Indian SARS-CoV-2 strains: Determining genetic diversity among Indian SARS-CoV-2 strains compared to worldwide strains. More than 600 viral genomes have been analysed to trace the origins of these strains and monitor their dynamics over time.

Drug-repurposing using graph neural networks: A model to capture local and structural information in a complex interaction network comprising drugs, diseases, genes, and anatomies. It can learn from known treatments and predict unknown links between approved drugs and novel diseases like COVID-19.

HOSPITAL ASSISTIVE DEVICES

PRAANA electro-mechanical ventilator: An ICU-grade ventilator, built entirely from components made in India or easily available in domestic supply chains. It uses customised algorithms and techniques to blend air and oxygen in the desired ratio, and has fine-grained control of patients' respiratory parameters.

Low-cost ventilator using inexpensive electronics: A ventilator system that uses basic electronics and can easily interface with existing hospital infrastructure in the absence of a full-fledged ventilator. Advanced versions offer fine-tuned control of pressure and volume.

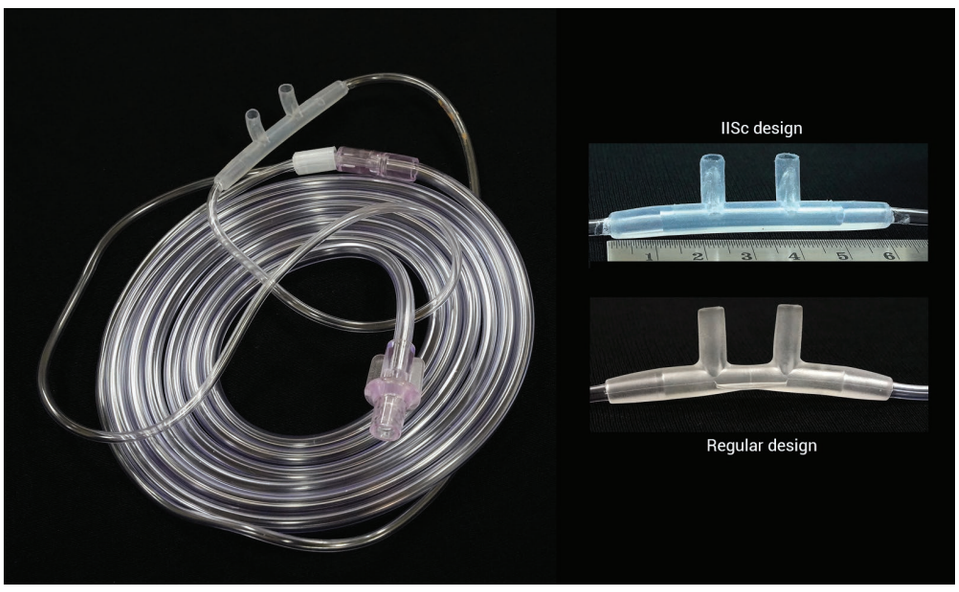
3D printed valves for split ventilator use: Valves that enable the use of a single ventilator for multiple patients, made using 3D printing. Preliminary designs were fabricated and tested in a hospital setting using simulated lungs.

Aerosol shield for intubation and anaesthesia: A transparent box that can be placed around a patient while putting them on a ventilator or under anaesthesia to reduce the risk of infection for doctors and healthcare workers. Initial designs have been developed and tested at NIMHANS, Bengaluru.

Medical oxygen generator: An oxygen generation system for small-scale medical requirements using low power. Oxygen is separated from ambient air using a twin-bed vacuum swing adsorption system integrated with a discharge vessel and various safety systems.

Oxygen concentrator: Low-cost oxygen concentrators that can be coupled with ventilators to ensure reliable oxygen supply for patients. Atmospheric air is pumped through mineral sieve beds that preferentially absorb nitrogen, in order to increase oxygen concentration.

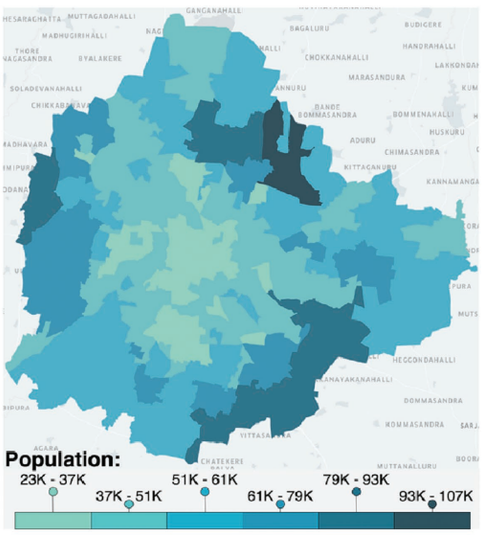
Nasal cannula: Efficient nasal cannula with nozzle to reduce oxygen wastage by regulating the flow during breathing in and out. The design facilitates reuse of tubing and only the nasal cannula part to be disposed of, reducing overall cost by ~50%.

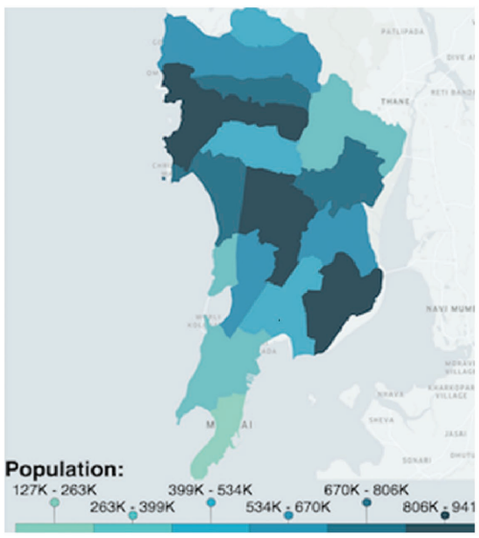


Co-bot for OPD: A low-cost Collaborative Robot to help doctors and nurses record vital parameters while maintaining social distance with a patient. A scaled-down prototype has been developed.

MODELLING, SIMULATION AND ANALYSIS

Modelling epidemic spread in cities: City-scale simulations to evaluate the impact of post-lockdown scenarios. The agent-based model mimics various interaction spaces such as households, schools and workplaces, where infections are tracked under different intervention scenarios.





Workplace readiness calculator: An advisory tool to enable organisations to understand their current level of preparedness and key risk areas, plan and establish pandemic-specific policies, procedures, and necessary management practices, and also provides targeted suggestions.

Simulating cough/sneeze flows: A direct numerical simulation code for studying "cough/sneeze flows" by applying principles from computational analysis of atmospheric clouds. Highly-resolved simulations are being run on IISc's CRAY XC40 (SahasraT) supercomputer.

Visualising phases of spread: A new interactive visualisation system to represent and compare phases of spread of COVID-19 across different countries. It uses a knee detection algorithm that divides the exponential spread into multiple linear components.

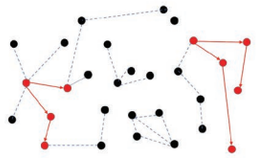
Estimating infection spread: A reliable estimator to gauge infection rate within a target population. The estimator takes as input the time series formed by the number of hospitalised cases that test positive each day.

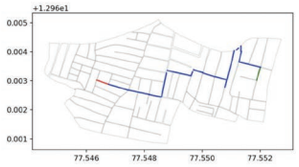
Studying testing strategies: An agent-based simulation framework to evaluate and compare various testing strategies and policies. These include random symptomatic testing, contact tracing and spatially aware sampling of hotspots, as well as interventions such as lockdowns.

Projecting medical inventory: A dashboard that forecasts medical inventory such as PPEs, ventilators, oxygen and masks, across districts and states. A robust algorithm for estimating asymptomatic patients and predicting the medical inventory required is also being developed.

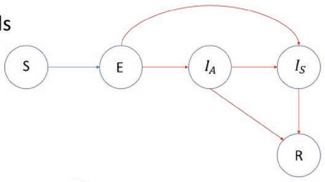
Modelling infection distribution: A six-dimensional population balance predictive computational model for an epidemic. Unlike existing models, it predicts the distribution of infected population across region, age, days since infection and severity of infection over a period of time.

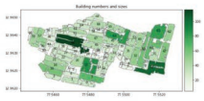
Capture the geography of the area in a GIS file





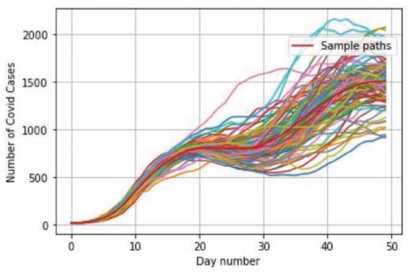
Model how disease spreads in the local community





Study and compare testing strategies

BuildingNo	IsSeniorCitizen	IsMale	BuildingSize	RiskScore
14.0	1.0	1.0	27.0	0.898734
2.0	1.0	0.0	26.0	0.856525
19.0	0.0	0.0	17.0	0.851974
2.0	0.0	0.0	26.0	0.851601
14.0	1.0	0.0	27.0	0.851140
14.0	0.0	0.0	27.0	0.850384
27.0	1.0	1.0	31.0	0.850000
43.0	1.0	0.0	21.0	0.847262
27.0	0.0	0.0	31.0	0.844243
19.0	1.0	0.0	17.0	0.842262



Software clone is ready

Modelling cities as small world communities: Modelling cities as multi-lattice small world networks where each ward is modelled as a 2D lattice and nearby wards are connected together. The model simulates several post-lockdown interventions on such networks to study their effectiveness.

CoviHawkes: An AI tool for district-wise forecasting and monitoring of infections. Based on powerful ML techniques, it combines observed patterns in case counts from the past with additional factors like demographics and mobility of the region.

Managing vaccination strategies: A model that evaluates the vaccination requirement and proposes three different roll-out plans, based on population size, seroprevalence, and number of cases – including active or recently recovered infections in a state or district.

Tracking aerosols during eye surgeries: Doctors at Narayana Nethralaya collaborated with IISc researchers to visualise the generation of aerosols during routine eye procedures such as cataract and LASIK surgeries, using high-speed imaging and aerodynamic models.

Quantifying aerosol spread: Using computer simulations and theory, researchers quantified the time taken for fine droplets (aerosols), which pose greater transmission risk, to reach a certain distance from their source for the first time via turbulent advection.

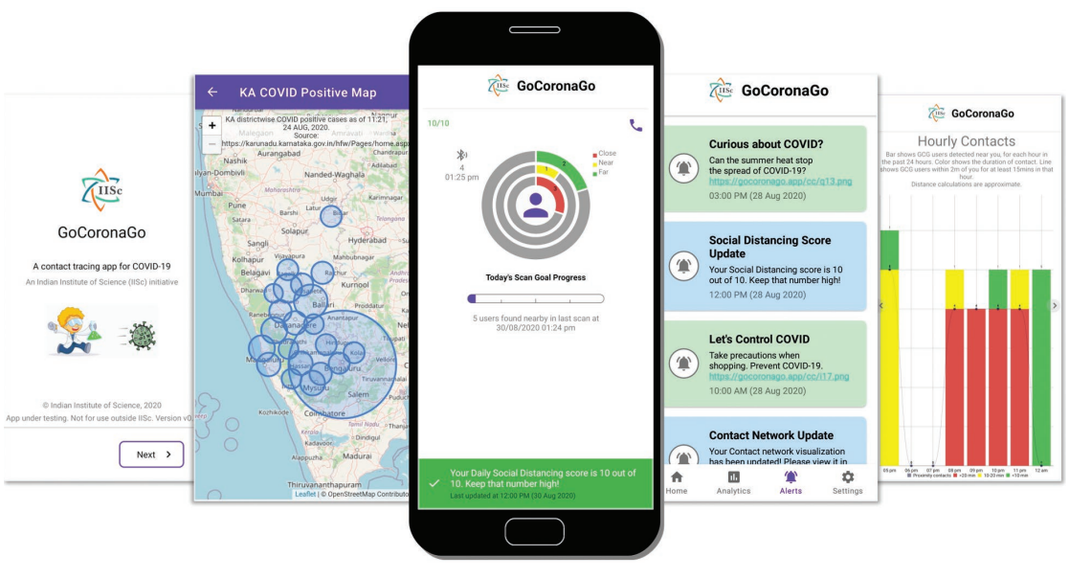
DIAGNOSTICS AND SURVEILLANCE

Electrochemical antibody test: Semi-quantitative electrochemical ELISA test for COVID-19 IgM and IgG antibodies (CDSCO-approved), developed by IISc start-up PathShodh. Low-cost, shows results in five minutes, easy-to-use, portable, has cloud connectivity and links to Aadhar / Aarogya Setu.

Mobile diagnostic testing labs: A fleet of BSL2+ compliant, ICMR-approved mobile diagnostic labs that can travel to and operate in remote areas. The mobile labs allow healthcare workers to collect, process and test samples using RT-PCR onsite, and upload results directly to the ICMR portal.

RNAWrapr for secure transportation: A viral transport medium that does not need refrigeration, thereby greatly reducing the cost of transporting samples for RT-PCR testing. RNAWrapr also inactivates the virus to some extent, reducing the risk of infection and protecting the RNA from degradation.

GoCoronaGo contact tracing app: An app to help identify people who may have crossed paths with COVID-19 positive subjects by tracking their interactions in the past using Bluetooth and GPS. It also provides alerts on isolation and proximity scores, and helps enhance social distancing.

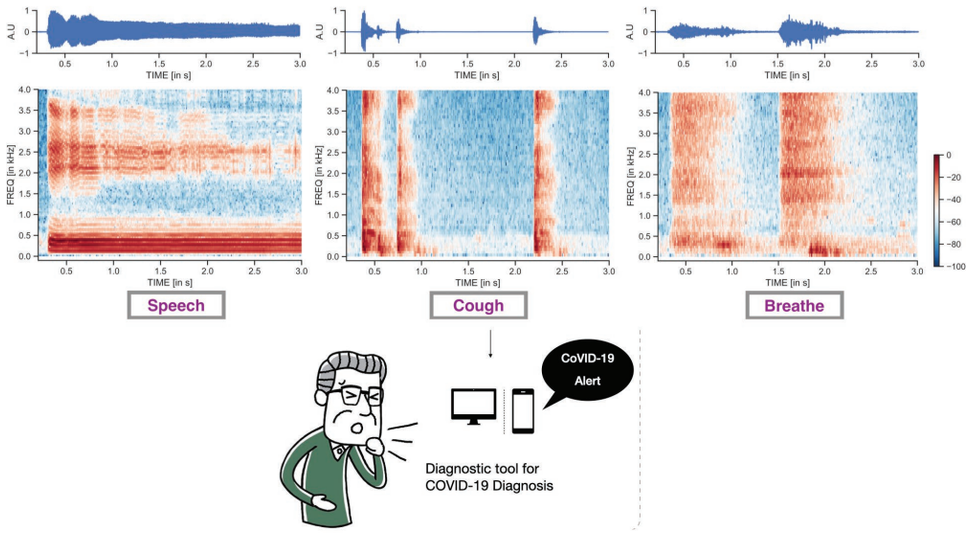


AnamNet (AI for diagnosing lung infection): AI-based software tool that can segment CT scans and reveal the severity of lung infection in COVID-19 patients. It is highly accurate, has a small memory footprint and is being developed into a mobile app for point-of-care diagnostics.

RT-PCR test: IISc start-up Equine Biotech has developed an extremely sensitive, rapid, and affordable COVID-19 diagnostic kit approved by ICMR. It is highly specific for the E and RdRp genes of the virus with human RNase-P as internal control.

Portable PCR system: A portable thermal cycler and fluorescence reader instruments to enable molecular diagnostic tests for COVID-19 and other infections. Pre-compliance testing and regulatory approvals were initiated and the technology has been licensed to IISc-incubated start-up ShanMukha Innovations for commercialisation.

Coswara (Sound-based diagnostics): A tool for diagnosing COVID-19 based on respiratory, cough and speech sounds. As the major symptoms include respiratory problems, it aims to detect and quantify biomarkers of the disease in the acoustics of these sounds.



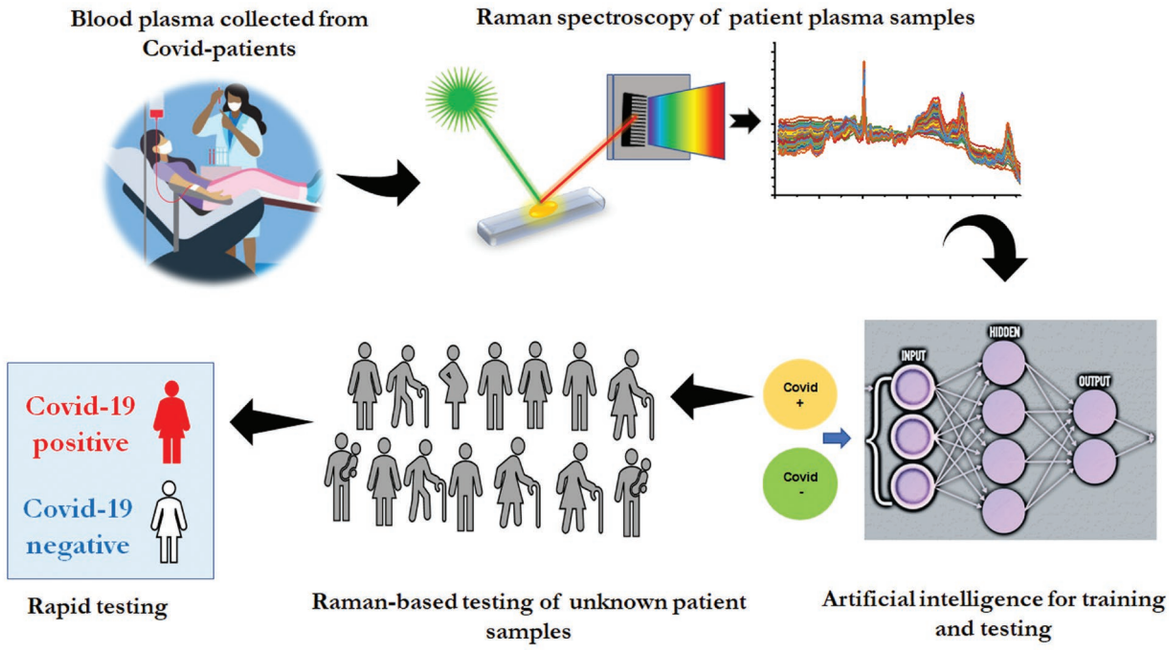
Antibody testing kit: An RNA-based test that relies on isothermal amplification of nucleic acids instead of PCR, obviating the need for expensive thermal cyclers. It leverages previous research on developing paper-based tests for diseases such as TB.

X-ray Setu: ARTPARK, IISc and Niramai Health Analytix have developed an AI-based tool to interpret chest X-ray images sent over WhatsApp by doctors and generate automated reports. The tool works even with low-resolution images and is suitable for different lung abnormalities.

PCR-free RNA detection test: A test kit for SARS-CoV-2 with all components fitted within a specially engineered strip of paper. Several different readout methods to detect and view the results are being tested. Efforts are also on to develop dry reagents that can be rehydrated just before use.

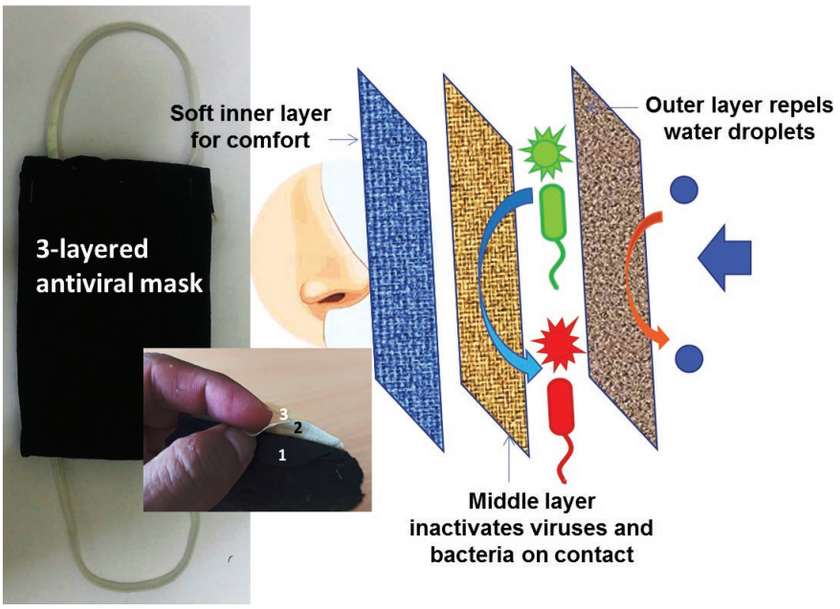
CovidWATCH (WhatsApp-based monitoring): A rapid monitoring tool for areas with low smartphone penetration. It offers a basic screening test based on ICMR strategy and a daily symptom tracker, via a multi-language WhatsApp chatbot, specifically built for people with little to no tech expertise.

Raman spectroscopy to detect biomarkers: Exploiting Raman spectroscopy, a technique that probes chemical bonds and structures, to identify biomarkers in infected patients' blood plasma. No extraction procedure or reagents are required. The process can be automated using artificial intelligence and deep learning.



MASKS AND SANITISATION

Virucidal composite fabric for PPE: A cost-effective, antiviral and antibacterial three-layered mask based on a nanofibrous polymer membrane. The membrane can also be deposited on the surface of other PPEs such as gloves and lab coats for healthcare personnel.



N95 mask renewal and testing: A system to test whether it is safe for healthcare workers to reuse their N95 masks after decontamination, based on breathing resistance and particle filtration efficiency tests. This setup is now being used to test the efficiency of all kinds of masks.

Multilayer masks and aerosols: New study shows how cough or sneeze droplets can strike the inner surface of masks and break up into smaller droplets with greater infection potential. N95 or multilayer masks prevent this protect better than single or double-layered masks.

Drones for disinfection: Using drones to spray disinfectants over large areas, especially in places that are hard to reach, in order to reduce risk for sanitation workers. Several key areas in Bengaluru, including outdoor spaces and markets, have been disinfected using these drones.

Plasma sterilisation and disinfection: Rapid plasma-based system for sterilising PPEs such as masks. It uses atmospheric air to generate ozone, a powerful disinfectant that can kill bacteria and viruses, and does not require any special gas preparation system.

UV-based disinfecting device: A UV-based disinfection system for public spaces and hospital environments where shorter cleaning cycles are needed. This can also be used to decontaminate reusable PPEs in times of extreme scarcity.

Anti-microbial surface coatings: A surface coating was developed using electro-spun nanofibers (biodegradable), which exhibit excellent antimicrobial activity. A portable electrospinning unit has been developed that can be used to coat smaller surfaces including filters for masks. This material also exhibits good breathability.

Quick-deploy isolation wards: A modular array of one or more isolation pods with negative or positive pressure containment areas for individuals, processes and protocols for maintaining hygiene and avoiding cross infections, while permitting testing and safe interaction with local teams.

Isolation stretchers and beds: A quickly deployable patient isolation canopy that creates a physical barrier between the patient and their surrounding and prevents the spreading of contaminants. This canopy can be mounted onto a stretcher to create an isolated space.

Behavior forming antiviral hand gloves: A wearable that regularly reminds the user to sanitise their hands and also enables this.

COVID-19 TESTING CENTRE

IISc set up its own COVID-19 test centre towards the end of March 2020 in the Infosys Wing of the Centre for Infectious Diseases Research (CIDR). It was established within a short span of two to three weeks with support from the Institute and the Government of Karnataka. As of March 2021, the centre has tested about 80,000 samples for the novel coronavirus, SARS-CoV-2. The facility is being supported by generous grants received from various corporates and donors.

IISc already has a Bio Safety Level-3 (BSL-3) facility with labs that study infectious diseases such as TB and HIV. The stringent protocols and sophisticated biocontainment equipment in a BSL-3 facility are required for handling highly infectious pathogens.

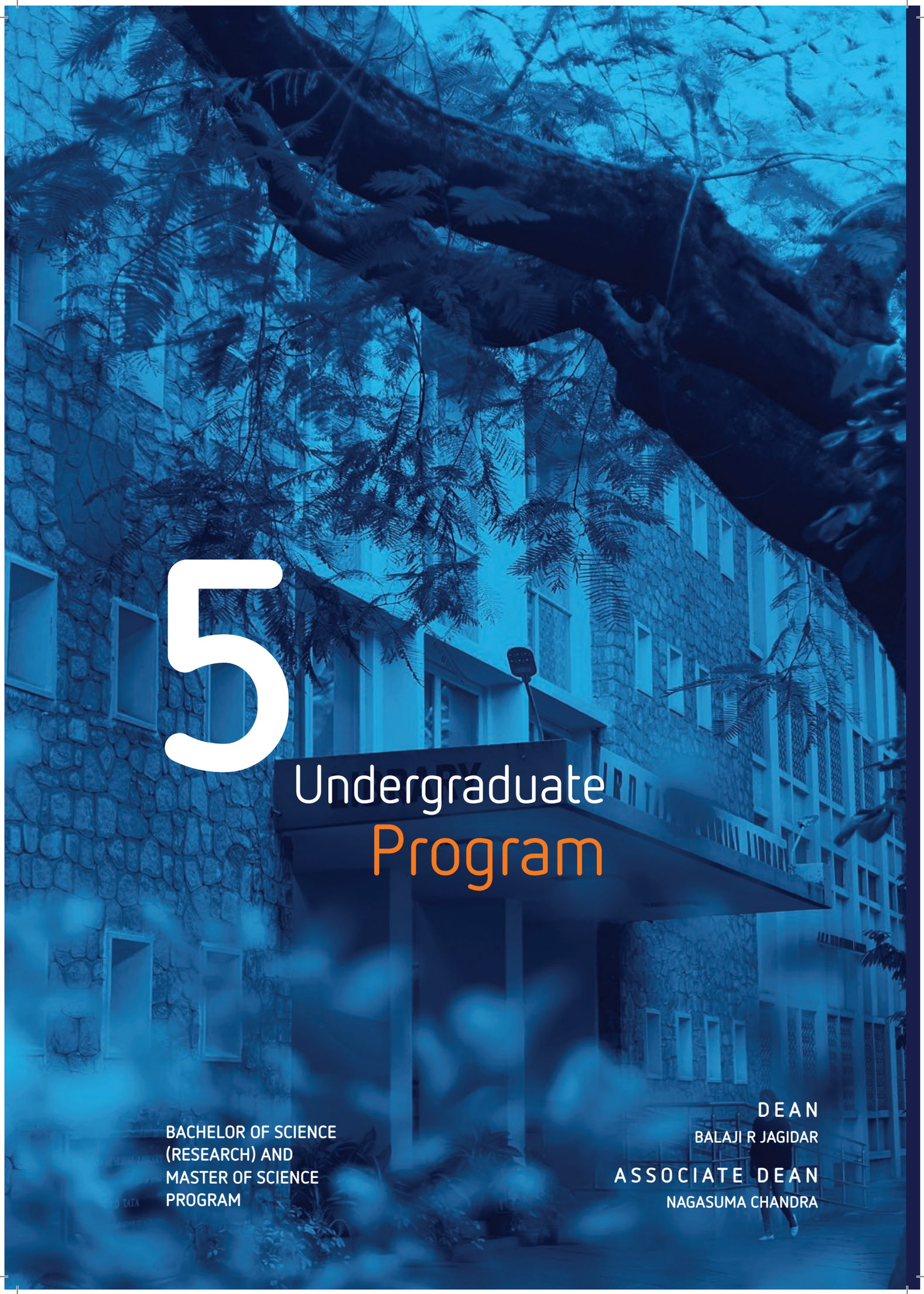
Personnel who work at the COVID-19 test centre undergo training for two weeks in Standard Operating Procedures (SOPs) specific to working with samples that may contain SARS-CoV-2. The test centre uses RT-PCR, considered the gold standard for SARS-CoV-2, to detect the genetic material of the virus. It employs RT-PCR kits that have been approved by the Indian Council of Medical Research (ICMR). Several faculty members are involved in managing the test centre along with dedicated research staff members.

VACCINE TESTING CENTRE

With support from the Biotechnology Industry Research Assistance Council under the Department of Biotechnology (DBT-BIRAC), a COVID-19 Vaccine Testing Center has been established at the viral BSL-3 facility in IISc. At this Centre, solutions to tackle COVID-19 – vaccines, antivirals, materials and equipment – from academic and industry partners will be tested via a fee-for-service model.

Before the pandemic hit, the Division of Biological Sciences had commissioned the establishment of a dedicated viral BSL-3 facility at CIDR, with funding from the DBT-IISc partnership, to support research on highly pathogenic human viruses. It became operational in January 2021 with all the necessary Standard Operating Procedures (SOPs), and was made available to academic labs (within and outside IISc) and industry, for training personnel and carrying out antiviral research.

By February 2021, work began on establishing SARS-CoV-2 cell cultures and animal models, including a Syrian hamster model for evaluating COVID-19 vaccines and antivirals. To expand these operations, DBT-BIRAC provided funding under its Mission COVID Suraksha. In addition to SARS-CoV-2, this facility will also support the development of antivirals and vaccines against other viral pathogens responsible for diseases like influenza, dengue, chikungunya and HIV, through similar fee-for-service collaborations with academic and industry partners.



5 Undergraduate Program

BACHELOR OF SCIENCE (RESEARCH) AND MASTER OF SCIENCE PROGRAM

DEAN
BALAJI R JAGIDAR

ASSOCIATE DEAN
NAGASUMA CHANDRA

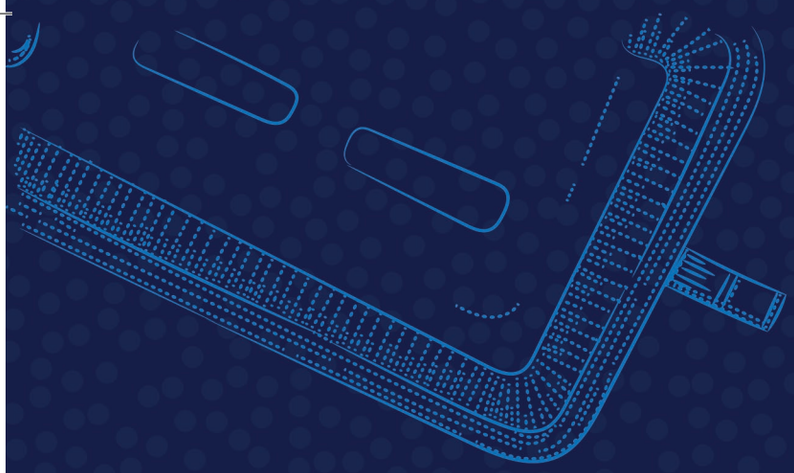
The undergraduate program in science which began in 2011 has seen six batches of students who graduated with a Four-year Bachelor of Science (Research) degree and five batches of students who graduated with a Master of Science degree. The year 2021-2022 is the tenth anniversary year of the UG program. In September 2020, a sixth batch and a fifth batch of students will be up for graduation with a Four-year Bachelor's degree and a Master's degree, respectively. Roughly 50% of the students in each batch opted to continue for a fifth year to pursue a Master of Science program. The UG students have been continuing to secure fellowships such as S. N. Bose, Khorana, DAAD fellowships, which allows them to carry out summer projects in universities in the U.S.A. or Germany. During the Covid-19 pandemic and the ensuing lockdown, some of these activities have been conducted through online mode. Some students have taken up summer projects in the industries and several others, in academic institutions within India and abroad. These activities as well, had to be conducted through online mode due to the pandemic. Since the program started in 2011, the UG program's popularity has been growing continuously; it is now the most sought-after undergraduate programs for several scientifically oriented, bright, young and energetic minds of the country. This had a strong bearing on admissions for the academic year 2020-'21; the cut offs in various qualifying examinations for admission to the UG program for the academic year 2020-'21 had to be raised compared to the year 2019-20.

CAREER PATHS OF OUTGOING STUDENTS

In each batch, roughly 50% of the students have been opting to continue for the Master's program. Of the remaining 50%, a large fraction of students takes the Bachelor's degree and go elsewhere in pursuit of PhD and other programs. Students who will be graduating in the forthcoming convocation have got admission offers for PhD. or Master's programs in top universities/institutes around the world including within India. This is a testimony of the great reputation that the UG program of the institute has carved out itself in the world scenario in a short span of 10 years. A very small number of students opted to take up jobs and have secured jobs in multinational companies. One of the graduates is in the process of setting up a start-up company while a few others have decided to pursue careers in alternative fields such as management sciences.

CO-CURRICULAR ACTIVITIES

The UG students are involved in several co-curricular activities apart from academics. Due to the Covid-19 pandemic, several co-curricular activities had to be either curbed or were conducted through online mode. The annual national science, technology, and cultural fest called PRAVEGA, an event organized by the UG students brings out the best in these students; additionally, the UG magazine QUARKS which exemplifies their literary talents, and certain other activities such as SAMANWAY, the industry outreach initiative of the institute in which UG students have an active role in organization, RANGMANCH and RHYTHMICA which bring out the dramatic and the dance talents respectively, are a demonstration of their exemplary talents.



6

Awards / Distinctions

Aerospace Engineering

Division of Interdisciplinary Sciences

Name	Awards
Gopalakrishnan Srinivasan	Fellow, Institute of Mechanical Engineers, UK (FIMechE)
Gopalakrishnan Srinivasan	Charted Engineer, Institute of Mechanical Engineers, UK (CEng)
Gopalakrishnan Srinivasan	Nominated Member of Research Council, CSIR-Structural Engineering Research Center, Chennai
Gopalakrishnan Srinivasan	Editor-in-Chief, ISSS Journal of Micro and Smart Systems
Radhakant Padhi	Fellow, AeSI
Dinesh K. Harursampath	Represented India at The Global Engineering Deans Council (GEDC) Industry Forum, Canada. Transformational Engineering: Developing the next generation of engineering innovators, experts and leaders, 28th September â€" 1st October 2020
Dinesh K. Harursampath	Member, Organising Committee, VaiBhaV Summit, Govt. of India
Dinesh K. Harursampath	Member, DRDO Committee for Design of CMC & MMC for Aero-Engine Components
Dinesh K. Harursampath	Vice-President, Nanotechnology for Better Living, a registered society

Biochemistry

Division of Biological Sciences

Name	Awards
Ganesh Nagaraju	Fellow of Indian National Science Acdemy
Ganesh Nagaraju	Sreenivasaya Memorial award from SBC, India
Purusharth I Rajyaguru	Priti Shankar Teaching award
Sandeep M Eswarappa	SwarnaJayanti Fellowship (DST)

Atmospheric and Oceanic Sciences

Division of Mechanical Sciences

Name	Awards
Govindasamy Bala	Co-Chair of the Modeling working group of Earth Commission, Future Earth
Satheesh SK	Alumni Award for Excellence in Engineering
Satheesh SK	Homi Bhabha Chair Professor

Chemical Engineering

Division of Chemical Sciences

Name	Awards
Kumaran Viswanathan	IIT Madras Distinguished Alumnus
Ganapathy Ayappa	Fellow of Indian National Science Academy

Biosystems Science and Engineering

Division of Interdisciplinary Sciences

Name	Awards
Rachit Agarwal	Intermediate Fellowship award from the Wellcome Trust/DBT India Alliance
Mohit K Jolly	InfoSys Young Investigator Award
Mohit K Jolly	Young Investigator Award, Cells Tissues Organs journal (Karger Publishers)
Mohit K Jolly	Outstanding Reviewer, Experimental Biology and Medicine journal
Mohit K Jolly	Adjunct Faculty, Queensland University of Technology (QUT), Australia

Computational and Data Sciences

Division of Interdisciplinary Sciences

Name	Awards
Jayant R Haritsa	Fellowship, Indian National Science Academy (INSA)
Jayant R Haritsa	President, Association of Computing Machinery (ACM) India
Venkatesh Babu Radhakrishnan	SERB Science and Technology Award for Research (SERB-STAR), 2020
Venkatesh Babu Radhakrishnan	Verisk AI Faculty Research Award 2020
Anirban Chakraborty	Young Scientist Research Award (YSRA), Dept. of Atomic Energy
Anirban Chakraborty	Outstanding Reviewer Award, Computer Vision and Pattern Recognition (CVPR) Conference 2020
Konduri Aditya	Best Paper Award - Honorable Mention, IEEE Pacific Visualization 2020
Yogesh Simmhan	IEEE TCSC Award for Excellence in Scalable Computing (Middle Career Researcher)
Yogesh Simmhan	VMWare Faculty Grant
Yogesh Simmhan	Facebook Faculty Grant
Chirag Jain	Pratiksha Trust Young Investigator Award

Earth Sciences

Division of Mechanical Sciences

Name	Awards
Dr. Sambuddha Misra	Swarnajayanti Fellowship
Sajeev Krishnan	Visiting Professor, IPGP France
Sajeev Krishnan	Liaison Professor, Niigata University, Japan

High Energy Physics

Division of Physical and Mathematical Sciences

Name	Awards
Anant	Member of Scientific Advisory Board, Avesthagen Companies

Ecological Sciences

Division of Biological Sciences

Name	Awards
Kartik Sunagar	INSA Young Scientist Medal
Kartik Sunagar	Deputy Editor of PLOS Neglected Tropical Diseases
Maria Thaker	DBT- Wellcome Trust India Alliance Fellowship
Renee M. Borges	1. IISc Alumni Award for Excellence in Research for Science for the year 2020; 2. Nominated to represent INSA at National Academy of Sciences (USA) G-Science 2020 meeting to prepare draft statement on Collapse of Insect Population.
Renee M. Borges	3. Chairperson, National Committee, International Union of Biological Sciences (IUBS) 2020; 4. Member of the FIST Subject Expert Committee - Life Sciences, 2020.
Renee M. Borges	5. Member, Thematic working group to review and evaluate the programmes being implemented in Energy and Environment Biotechnology area DBT, 2020-2025; 6. Member of the Research Council for CSIR - North East Institute of Science & Technology 2020-2023
Renee M. Borges	7. Secretary, Indian Academy of Sciences, 2019-2021; 8. Member, Faculty Evaluation Committee, IISER Trivandrum, 2020
Sukumar Raman	J.C. Bose National Fellow, Department of Science & Technology, India (2010-2023)
Sukumar Raman	Lead Author for Working Group 2, Assessment Report 6, Intergovernmental Panel on Climate Change (IPCC) (2018-2020)

Electrical Engineering

Division of EECS

Name	Awards
Ramakrishnan Ganesan Angarai	Best paper award of the IEEE Bangalore Humanitarian Technology Conference - Oct. 2020
Soma Biswas	Google India AI/ML Research Award
Gurunath Gurrala	SERB-STAR AWARD
Sriram Ganapathy	Verisk AI Faculty Research Award
Sriram Ganapathy	Subject Editor - Speech Communications

Nanoscience and Engineering

Division of Interdisciplinary Sciences

Name	Awards
Aditya Sadhanala	Pratiksha trust young investigator chair award
Aditya Sadhanala	MRS Nelson â€œBuckâ€ Robinson Science Technology Award for Renewable Energy
Aditya Sadhanala	2020 Clarivate Analytics (Web of Science) Highly Cited Researcher in the Field of Cross-Field (Interdisciplinary)
Ambarish Ghosh	Elected fellow of Indian National Academy of Engineering (INAE)
Ambarish Ghosh	Senior Fellowship from Wellcome Trust/DBT India Alliance, 2020-2025
Ambarish Ghosh	Early promotion to full Professorship
Digbijoy Nath	INAE Young Engineer Award
Srinivasan Raghavan	Abdul Kalam Technology Innovation National Fellowship
Shankar Kumar Selvaraja	Prof. Ramakrishna Rao Chair

Civil Engineering

Division of Mechanical Sciences

Name	Awards
Nagesh Kumar Dasika	Editor-in-Chief, Journal of Water and Climate Change, IWA Publishing, UK
Pradeep Prahald Mujumdar	Rustom Choksi Award for Excellence in Engineering Research, 2019 (Awarded in 2020)
Ashish Verma	Best Research Presentation Silver Award in ILUTM-6 13th December 2020
Ashish Verma	Guest Editor Special Issue (SI): WCTR-2016, Transport Policy, Elsevier, July 2020
Anbazhagan P	Life Fellow, Indian Geotechnical Society (LF-0591)
Anbazhagan P	Associate Editor Earthquake Seismology and Geodesy, Arabian Journal of Geosciences - from April 2020m A
Nanjunda Rao K S	Chairman, Tender committee, JNCASR, Bangalore
Nanjunda Rao K S	Member, Building works committee, JNCASR, Bangalore
Nanjunda Rao K S	Member, Board of studies, Department of Civil Engineering, Presidency University.
Nanjunda Rao K S	Member, Board of studies, Department of Civil Engineering, B M S College of Engineering, Bangalore.
Venkat	Chair, CED-30 committee of Bureau of Indian Standards
Madhavi Latha G	Best Woman Geotechnical Researcher Award

Computer Science and Automation

Division of EECS

Name	Awards
Arindam Khan	Best Paper Award at 45th International Symposium on Mathematical Foundations of Computer Science (MFCS) 2020.
Gugan Thoppe	Distinguished Alumni 2020, Shah & Anchor Kutchhi Engineering College
Gugan Thoppe	Outstanding Service as Reviewer of the IEEE Control Systems Letters - 2020
Shalabh Bhatnagar	Fellow, National Academy of Sciences, India
Shalabh Bhatnagar	J.C.Bose National Fellow
Shalabh Bhatnagar ()	Associate Editor, Systems and Control Letters
Raghavan Komondoor V	Distinguished Reviewer Award, by IEEE/ACM Conference on Automated Software Engineering (ASE 2019)
Shirish Shevade	2020 IBM Global University Program Academic Award
Arpita Patra	Google India AI/ML Research Award 2020
Arpita Patra	funding from Mathematical Research Impact Centric Support (MATRICS), Science and Engineering Research Board for the project titled "Cryptography with Minimal Communication"
Uday Kumar Bondhugula Reddy	Honorary Mention - ACM India Early Career Research Award 2020
Arkaprava Basu	Pratiksha Trust Young investigator award

Centre for Sustainable Technologies

Division of Mechanical Sciences

Name	Awards
Monto Mani	Research Council Member of CSIR Central Building Research Institute (Roorkee) for three years

Electrical Communication Engineering

Division of EECS

Name	Awards
Vaibhav Katewa	2020 IEEE Control Systems Letters Outstanding Paper Award
Neelesh B Mehta	Chair of the 4-member Steering Committee that oversees the IEEE Transactions on Wireless Communications
Neelesh B Mehta	Co-chair of Meetings and Conference Committee (MCC) of the Asia Pacific Board of IEEE ComsSoc
Neelesh B Mehta	Member of Awards Committee for Asia-Pacific Board Young Researcher Award
Neelesh B Mehta	Member of the IEEE ComSoc Awards Committee
Gaurab Banerjee	Abdul Kalam Technology Innovation National Fellowship
Rahul Singh	Best Paper Award Runners-up ACM Mobihoc 2020
Debdeep Sarkar	Young Investigator Award by Infosys Foundation, Bangalore
Raghunathan Varun	IEEE senior membership
Raghunathan Varun	Optical Society of America senior membership
Anandi Giridharan	Chair, WiE AG, IEEE Bangalore Section
Anandi Giridharan	Execom Member& Past Chair, IEEE CIS Bangalore Chapter
Anandi Giridharan	Branch Counselor, IEEE IISc Student Branch
Chandra Murthy	Appointed as senior area editor for the IEEE Transactions on Signal Processing
Chandra Murthy	My proposal titled "Physical Layer Enhancements for 5G in the Indian Context" made it to the top 100 in the 5G Hackathon organized by the Department of Telecommunications, Govt. of India.
Chandra Murthy	The solution Learned Chesterâ for mmWave channel estimation submitted (jointly with Eurecom, France) from the ECE department (headed by Prof. Chandra R. Murthy) to the ITU AI/ML in 5G challenge won the third place.
Balajisundar Rajan	J.C. Bose National Fellowship was extended for the second term: 2021-2025.
Vijaykumar Panganamala	Plenary Speaker for the International Conference on Signal Processing and Communications (SPCOM 2020), IISc
Himanshu Tyagi	INSA Medal for Young Scientists
Himanshu Tyagi	Senior Member, IEEE
Chockalingam Ananthanarayanan	Alumni Award for Excellence in Research in Engineering, 2020, IISc, Bangalore.

Electronic Systems Engineering

Division of EECS

Name	Awards
Umanand L	Fellow of INAE
Shayan Garani Srinivasa	Chairman, IEEE Data Storage
Shayan Garani Srinivasa	Jury Member, IEEE 2020 Globecom awards
Hardik J Pandya	ISSS Award 2020 under the Young Scientist Award Category

Instrumentation and Applied Physics

Division of Physical and Mathematical Sciences

Name	Awards
Baladitya Suri	Infosys Young Investigator
Sai Siva Gorthi	Best Product Award for MITR Labs by Dept of Information Technology, Biotechnology, Science & Technology, GoK as part of Smart Bio Awards 2020
Sai Siva Gorthi	MITR Labs won the Award in the Diagnostics category at the National Start-up Conclave 2020
Asha Bhardwaj	Infosys young investigator award
Sanjiv Sambandan	Winner, National Bio Entrepreneurship Competition 2020

Neuroscience

Division of Biological Sciences

Name	Awards
Kavita Babu	Janaki Ammal National Woman Bioscientist Award (young category, 2020-2025)
Kavita Babu	BK Bachhawat Travel award (co-recipient, travel in 2020-postponed to 2021)
Kavita Babu	Wellcome Trust -DBT India Alliance Senior Fellowship (2020-2025)

Inorganic and Physical Chemistry

Division of Chemical Sciences

Name	Awards
Partha Sarathi Mukherjee	Elected fellow of the Indian Academy of Sciences
Partha Sarathi Mukherjee	Membership of the International Advisory board of The Chemical Record, a journal published by the Wiley and Jpan Chemical Society
Partha Sarathi Mukherjee	Invited Fellow of the Royal Society of Chemistry under Leaders in the Field Category
Sampath Srinivasan	Fellow, The World Academy of Sciences
Sampath Srinivasan	Sastra-CNR Rao Award for Chemical Sciences
Puspendu Kumar Das	None
Geetharani Kalimuthu	SERB-Women Excellence Award
Thilagar Pakkirisamy	joined the Editorial Board of Aggregate and the Editorial Advisory Board of journals published by Wiley-VCH
Mugesh Govindasamy	Dr. Ghanshyam Srivastava Memorial Award, Indian Chemical Society
Mugesh Govindasamy	Prof. W. U. Malik Memorial Award, IIT Roorkee
Mugesh Govindasamy	SASTRA-CNR Rao Award in Chemistry & Materials Science
Arunan Elangannan	Alumni Award for Excellence in Research by IISc
Binny Joseph Cherayil	2019-2020 Fulbright-Nehru Academic and Professional Excellence Fellowship Award
Jemmis Eluvathingal Devassy	Golden Jubilee Commemoration Medal (Chemical Sciences) by the Indian National Science Academy
Jemmis Eluvathingal Devassy	Sir Devaprasad Sarvadhikari Medal, Calcutta University, 2020

Molecular Biophysics Unit

Division of Biological Sciences

Name	Awards
Rishikesh Narayanan	Elected as a Fellow of the Indian Academy of Sciences, Bangalore
Rishikesh Narayanan	Joined the editorial board of Frontiers in Cellular Neuroscience
Aravind Penmatsa	EMBO Global Investigator
Somnath Dutta	NIL

Materials Engineering

Division of Mechanical Sciences

Name	Awards
Kamanio Chattopadhyay	Patron, Electron Microscope Society of India
Vikram Jayaram	Lifetime fellow of Electron Microscopy Society of India - 2020
Rajeev Ranjan	Fellow of the Indian Academy of Sciences
Suryasarathi Bose	Swarnajayanti Fellowship 2020
Suryasarathi Bose	Kaushal Kishore Memorial Award 2020
Ashok M Raichur	Platinum Jubilee Award Lecture, 107th Indian Science Congress, Bengaluru
Govind S Gupta	Fellow in Indian Institute of Metals (FIIM)
Govind S Gupta	Guest Editor of Trans IIM journal

Microbiology and Cell Biology

Division of Biological Sciences

Name	Awards
Dipshikha Chakravortty	Fellow, Indian Academy of Sciences
Dipshikha Chakravortty	Prof SK Chatterjee Award, 2020
Umesh Varshney	J N Tata Chair Professorship
N. Ravi Sundaresan	2019-National Bio-science Award for Career Development from Department of Biotechnology, India
N. Ravi Sundaresan	2019-Winner, NASI-Scopus Young Scientist Award 2018, Category: Biomedical Research and Healthcare
N. Ravi Sundaresan	2016-Torrent Pharmaceuticals Young Scientist Award
N. Ravi Sundaresan	2014-Ramalingaswami Re-entry fellowship from Department of Biotechnology, India
Samay Pande	Wellcome Trust-DBT India Alliance Intermediate Fellowship
Utpal Nath	None
Usha Vijayraghavan	Chair, Research Council, CSIR-CIMAP
Usha Vijayraghavan	Editor, Journal of Experimental Botany, Oxford University Press
Usha Vijayraghavan	Convenor of INSA Sectional Committee

Mathematics

Division of Physical and Mathematical Sciences

Name	Awards
Apoorva Khare	SwarnaJayanti Fellowship in Mathematics, for 2019 (DST and SERB, Govt. of India)
Subhojoy Gupta	Associate of the Indian Academy of Sciences
Purvi Gupta	Inducted as an associate of the Indian Academy of Sciences
Venkatesh Rajendran	Infosys Young Investigator award
Venkatesh Rajendran	Two years Research grant from Infosys foundation
Mahesh Kakde	SwarnaJayanti Fellowship
Tirthankar Bhattacharyya	FNA

Mechanical Engineering

Division of Mechanical Sciences

Name	Awards
Pramod kumar	Conferred with INAE Fellowship of Indian National Academy of Engineers
Susmita Dash	Infosys Young Investigator Award
Koushik Viswanathan	Invited speaker at VAIBHAV summit Advanced Manufacturing Vertical
Pradip dutta	J. R. D. TATA Chair Professorship
Saptarshi Basu	Elected as Fellow of Royal Society of Chemistry

Molecular Reproduction, Development and Genetics

Division of Biological Sciences

Name	Awards
Sandhya Visweswariah	MR Das Memorial Lecture Award from INSA
Anu Rangarajan	Elected Fellow of National Academy of Science, India (NASI)
Anu Rangarajan	Elected member of Guha Research Conference
Srimonta Gayen	Infosys young Investigator

Materials Research Centre

Division of Chemical Sciences

Name	Awards
Bikramjit Basu	Fellow, International Union of Societies for Biomaterials Science and Engineering
Bikramjit Basu	Fellow, International Academy of Medical and Biological Engineering
Bikramjit Basu	Fellow, Indian Academy of Sciences
Bikramjit Basu	Distinguished Alumnus Award 2020, National Institute of Technology, Durgapur, India
Abhishek Kumar Singh	JSPS Invitation Fellowship
Abhishek Kumar Singh	Distinguished Lectureship Award of Chemical Society of Japan

Management Studies

Division of Interdisciplinary Sciences

Name	Awards
Balachandra Patil	Ranked among top 2% of the Energy Scientists in the World
Bala Subrahmanya Mungila Hillemane	Best Paper Award in ASIP Innovation Conference 2020 held in Korea.
Yadnyvalkya	NIL
Yadnyvalkya	NIL
Yadnyvalkya ()	NIL
Yadnyvalkya ()	NIL

Robert Bosch Centre for Cyber Physical Systems (RBCCPS)

Division of Interdisciplinary Sciences

Name	Awards
Shishir Nadubettu Yadukumar Kolathaya	Won the best presentation for the paper "Imitation Learning for High Precision Peg-in-hole Tasks" in ICCAR 2020.

Organic Chemistry

Division of Chemical Sciences

Name	Awards
AT Biju	Advisory Board, Org. Chem. Front.
AT Biju	International Advisory Board, Asian J. Org. Chem.
Uday Maitra	Acharya J.C. Ghosh Memorial Lecture Award, Indian Chem. Soc. 2018 (lecture given in 2020)
Santanu Mukherjee	AV Rama Rao (AVRA) Young Scientist Award for the year 2019
Garima Jindal	Rekha Rao Young Investigator Award

Physics

Division of Physical and Mathematical Sciences

Name	Awards
Arindam Ghosh	Infosys Prize
Arnab Rai Choudhuri	Invited to deliver the Science Day Lecture at TIFR Mumbai
Jaydeep Kumar Basu	Fellow of Indian Academy of Sciences Bangalore
Vijay Balakrishna Shenoy	Distinguished Alumnus Award 2020, Indian Institute of Technology Madras, Chennai
Prabal Kumar Maiti	Associate editor PCCP (RSC Journal)
Anil Kumar P S	CNR Rao Bangalore India Nanoscience Award

Supercomputer Education and Research Centre

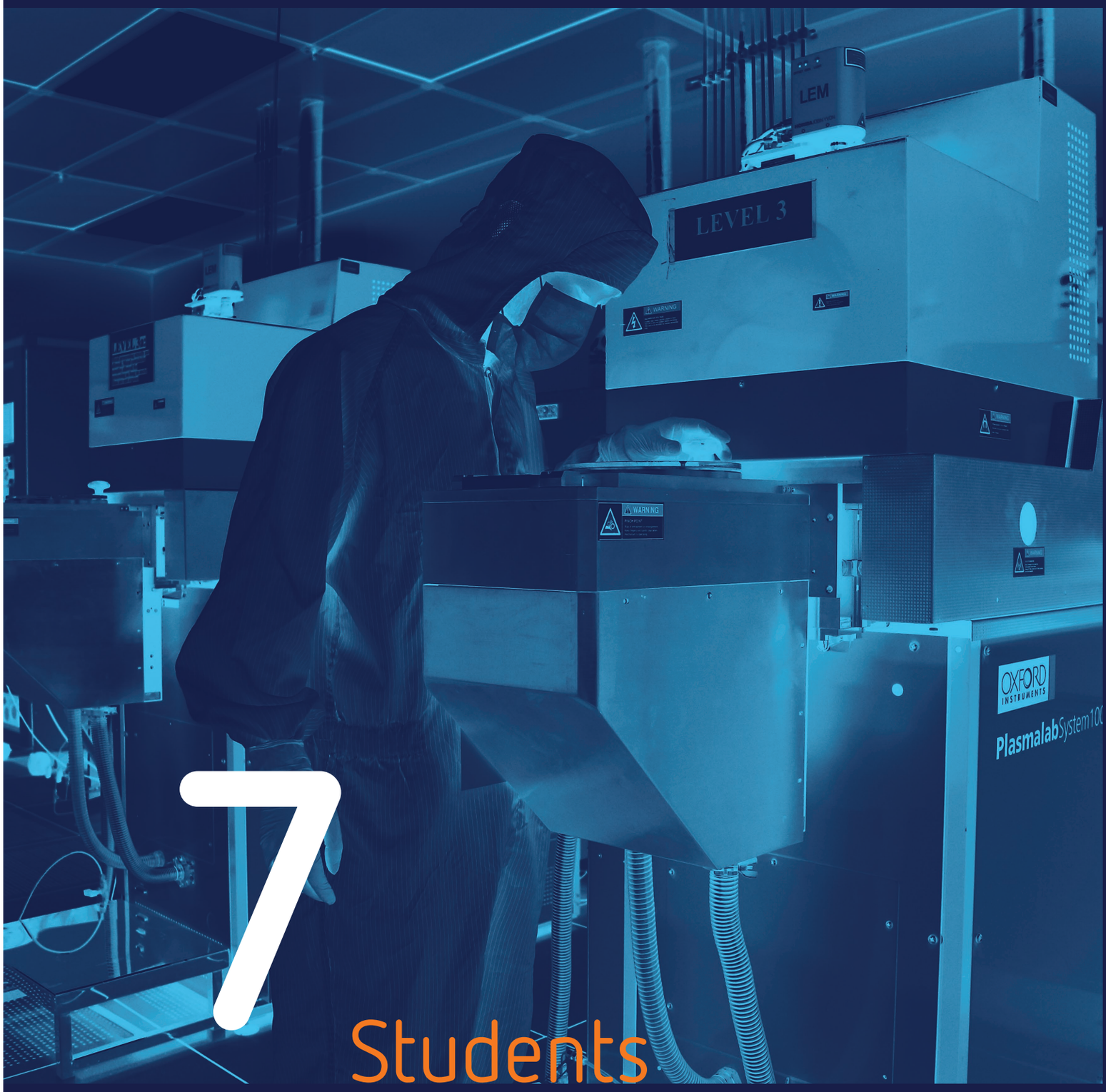
Division of Interdisciplinary Sciences

Name	Awards
Lakshmi Jagarlamudi	Cray Dr. A.P.J Abdul Kalam HPC Award 2020

Solid State and Structural Chemistry

Division of Chemical Sciences

Name	Awards
Natarajan	Professor Swaminathan 60th birthday commemoration lecture award (INSA)
Natarajan	Professor Rustom Chokshi award for excellence of research (IISc)
Vivek Tiwari	Infosys Young Investigator
Satish Patil	Fellow, Indian Academy of Sciences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7 Students

7.1 ADMISSIONS AND ON ROLL

During the year, 1040 students (316 for research 33 for Integrated PhD, 560 for course programmes and 131 under graduate programme) joined the Institute taking the number on roll to 4750 (2838 students in research, 367 in Int. PhD, 992 in post graduate and 553 in under graduate course programme).

7.2 SC/ST STUDENTS

40 students belonging to SC/ST in research, 89 in the course programme and 25 in the under-graduate programme joined the Institute in the current year.

ADMISSIONS

Research: Out of 978 applicants, 761 were called for an interview; 54 were offered admission and 40 joined.
Int. PhD: Out of 113 applicants 25 of them were short-listed and called for an interview, 9 were offered admission and 6 joined.

COURSES

MTech/MMgt/MDes: Out 861 applicants, 147 were offered admission and 89 joined.
Bachelor of Science (Research): Out of 1690 applicants, 51 were offered admission and 25 joined

7.3 SCHOLARSHIPS / FELLOWSHIPS

The students participating in research and course programmes are granted scholarships at the Institute ranging from 12,000/- to 70,000/- depending on the programme. Those students who are granted fellowships by agencies like UGC/CSIR and other bodies are not eligible for scholarships awarded by the Institute.

7.4 STUDENTS ASSISTANCE PROGRAMME

Needy students have offered their services in selected Institute activities and have secured additional finances under the "earn-while-you-learn" scheme.

Students Aid Fund: This is a co-operative scheme to assist needy and deserving students through loans, to meet tuition fees, study tour expenses, cost of books, thesis expenses and maintenance at the Institute.
During the period 2019-20, students availed themselves of the loan to the extent of Rs.17,00,000/-.

7.5 STUDENTS COUNCIL

The Students Council (an elected body from among the student community) provides an effective channel of communication between the Director, faculty and students. Through dialogue and discussion on various student matters, problems relating to the students are resolved by initiating appropriate action. The Students Council is

also responsible for certain welfare measures initiated by the student community. The publication of 'SCAMPUS', a campus magazine and newsletter of the students is one of its main activities.

7.6 HOSTELS

The Students Hostel consists of 16 men and 4 women hostel blocks. Students, research associates, and short-term workers totaling 2825 (2077 men and 748 women) are provided accommodation in the Hostel blocks.

Four dining halls (2 vegetarian and 2 Composite) provide a variety of food items in clean and hygienic conditions for all the boarders.

The hostels and dining halls are managed by the Council of Wardens.

7.7 AWARD OF MEDALS

Medals for the year 2019-20 for the Best Course Students (M Tech /Mgt / MDes) M Tech Program

Name of the Medal	Awardee
Dr. N Narayanamurti Medal	Arnab Mukherjee
Prof. N S Lakshmana Rao Medal	Ashmita Bhattacharya
The Computer Society of India (Bangalore Chapter) Medal	Thankey Bhargav Deepakkumar
The K K Malik Medal	Apurba Roy
S V Sastry Memorial Medal	Mohamed Adil T
The N R Khambhati Memorial Medal	P V Harisyam 04-03-00-10-51-18-1-15503 66 Credits 9.8 CGPA A+ Grade 26 Students
Prof. S V C Aiya Medal	S Chandrasekhar
Motorola Medal	Shriram R
The DESE Design Medal	Syam Krishnan C R
H R BabuSeetharam Medal	Aditya Shukla

M Des. Program

Name of the Medal	Participating Dept.	Awardee
The Institute Medal	PD	Alornekar Adersh Raghunandan

M Mgt.

Name of the Medal	Participating Dept.	Awardee
Prof. B. G Raghavendra Memorial Medal	MG	Thejas M Bhat

Research Program: (Ph D)

Name of the Medal	Awardee
Prof. A K Rao Medal	Dr.Anjaly P
Prof. N R Kuloor Memorial Medal	Dr.Sagar B
Prof. B K Subba Rao Medal	Dr.SantanuPramanik
Prof. K P Abraham Medal	Dr. Syed Idrees Afzal Jalali
The Alumni Medal (Research)	Dr. Shikhar Vashishth
The SeshagiriKaikini Medal	Dr.Geethu Joseph
Prof. D J Badkas Medal	Dr.ChiranjeevYarra
Prof. N S Govinda Rao Medal	Dr. Ketan Bajaj
MAA Communications Medal	Dr. P S Suvin
Prof.Giri Memorial Medal	Dr. Matta Srujan Kumar
Mrs. C V Hanumantha Rao Medal	Dr.DivyaSridharan
The ShamraoKaikini Medal	Dr. Madhura Sham Amdekar
The M Sreenivasaya Medal	Dr. R Venkataraman
Prof. B H Iyer Medal	Dr. Poonam Mishra
Dr. J C Ghosh Medal (Physical Chemistry)	Dr. Ramesh Naidu Jenjeti
Prof S Soundarajan Medal (Inorganic Chemistry)	Dr.Bijnaneswar Mondal
The Guha Research Medal	Dr.Karunakaran
The Toulouse Medal	Dr. Aishwarya Abhisek Mohapatra
The Martin Forster Medal	Dr.Anwoy Maitra
Prof. Anil Kumar Memorial Medal (Experimental Physics)	Dr. Saurav Islam
Kumari L A Meera Memorial Medal (Theoretical Physics)	Dr.Mit H Naik
The Sudborough Medal	Dr.RinkleJuneja
Dr.Srinivasa Rao Krishnamurthy Medal	Dr.Punyabrahma Panda
The Roddam Family Medal	AngshumanModak
Tag Corporation Medal	Dr. Bhavani Shankar
The Institute Medal	Dr. Anupam Banerjee
The Institute Medal	Dr. Anamika Singh Pratiyush
The Institute Medal	Dr. Khushboo Pandey
The Institute Medal	Dr. Aakash K Agrawal

M Tech (Research) Program

Name of the Medal	Participating Dept.	Awardee
Dr. M N S Swamy Medal	CS	Ms. Megha Byali
The Hay Medal	EE	Mr. Sayan Paul
The P S Narayana Medal	CE	Mr. Akash Gupta
NetApp Medal	CDS	Mr. Navaneet K L

For Integrated Ph D (M.S. Level)

Name of the Medal	Division	Awardee
Prof. P L Bhatnagar Medal	Mathematical Sciences	Aakanksha Jain
Dr. R K Maller Memorial Medal	Biological Sciences	Shraddha Sansidha Mohanthy
Dr. A Nagaraja Rao Medal	Chemical Sciences	Naveen Goyal
Kumari L A Meera Memorial Medal	Physical Sciences	Shreya Kumbhakar

For Bachelor of Science (Research)

Name of the Medal	Major	Awardee
The Institute Medal	Biology	Raj Magesh Gauthaman
The Institute Medal	Chemistry	Shounak Nath
Sitaram Jindal Foundation Medal	Materials Science	Rohith K M S
The Institute Medal	Mathematics	Shabarish C H
The Institute Medal	Physics	Jeevan Chandra N

7.8 AWARDS & DISTINCTIONS CONFERRED ON STUDENTS

Aerospace Engineering

Division of Mechanical Sciences

Student Name	Award
Saarthak Gupta	ASME young engineer travel award
Aditya Anand	Prime Minister Research Fellowship for PhD studies
Anjaly P	Medal for Best PhD Thesis in AE Dept
Manu Mohan	Best paper award in NAPC 2020
B Sudershan	Best paper presentation in IIT Madras

Biochemistry

Division of Biological Sciences

Student Name	Award
Dr. Srujan Kumar Matta	Giri Memorial Award: Best Ph.D. thesis award in the Biochemistry department-2020
Anumeha	Runner-Up-I of the "Dr. K V Rao Research Awards' (Biology)
Amarendra Kumar	SBC (I) Best Poster Award
Humaira Siddiqua	Best Poster presentation

Biosystems Science and Engineering

Division of Interdisciplinary Sciences

Student Name	Award
Kaamini MD	Best oral presentation, Current Innovations and the Future of Therapeutic Developments â€" 2020
Preeti Sharma	Best Poster Presentation at the Controlled Release Soceity, India Chapter, International Symposium
Jayashree V Raghavan	Society for Leukocyte Biology Video Abstract Spotlight Awardee
Atchuta Srinivas Duddu	Prime Minister Research Fellowship
H A S Shri Kishore	Best Poster Award, BSSE Annual Symposium 2020
H A S Shri Kishore	Best Poster Award, International Conference on
Subbalakshmi A R	Runner-up, International Poster Presentation Competition (INYAS)

Atmospheric and Oceanic Sciences

Division of Mechanical Sciences

Student Name	Award
Angshuman Modak	Roddam Family Medal
Jayakrishnan	PMRF
Rajat Masiwal	PMRF
Shikhar Srivastava	PMRF

Computational and Data Sciences

Division of Interdisciplinary Sciences

Student Name	Award
Srinivas Karthik V	Honorable Mention for Outstanding Doctoral Thesis, CSA
Aditya Rastogi	PMRF
Naveen Paluru	PMRF
Rahul John Roy	GE Healthcare M.Tech. Fellowship
Sravanti Addepalli	Google PhD fellowship 2020
Jogendra Nath Kundu	Qualcomm Innovation Fellowship 2020
Konda Reddy Mopuri	Best Doctoral Dissertation Award at SPCOM 2020
Konda Reddy Mopuri	IUPRAI Best Doctoral Dissertation Award for 2018-19
Ravi Kiran S Sarvadevabhatla	Sir Vithal N Chandavarkar Memorial Medal for Ph.D Thesis
Aditya A Prasad	PMRF
Shriram Ramesh	Motorola Medal for Best CDS M.Tech.(CDS) Thesis
Shikhar Vashishth	2021 ACM India Doctoral Dissertation Award

Chemical Engineering

Division of Chemical Sciences

Student Name	Award
Khantesh Agrawal	Young Scholar Award, EIHE 2020

Earth Sciences

Division of Mechanical Sciences

Student Name	Award
Pratyusha Chanda	PMRF
Yogaraj Banerjee	MOEST postdoc fellowship Taiwan

Computer Science and Automation

Division of EECS

Student Name	Award
Vishakha Patil	Google PhD Fellowship
Vishakha Patil	PMRF Fellowship (declined)
Nidhi Rathi	IBM Fellowship
Anand Krishna	PMRF
Ashish Panwar	PMRF
Stanly John Samuel	Cisco PhD Fellowship for 2020-21
Nishat Koti	Cisco Ph.D Fellowship 2020-2021
Divya Ravi	Second prize at the 10th IDRBT Doctoral Colloquium, 2020
Divya Ravi	Student Best Paper Award at EECS Research Students
Divya Ravi	Selected for Women in Theory Workshop, 2020
Ajith Suresh	selected to participate in the 8th Heidelberg Laureate Forum
Megha Byali	Swamy medal for the best M.Tech. Research thesis
04-04-00-10-42-18-1-16040	Co-winner of best MTech thesis award given by Mcafee India.
04-04-00-10-42-18-1-16040	Institute medal for best MTech CSA student of the batch 2018-20.
Ashish Panwar	PMRF
Vishakha Patil	Honorable Mention for Best. M.Tech. (Resaerch) Thesis in the Department of CSA
Vishakha Patil	Google Ph.D. Fellowship
Shivika Narang	TCS Ph.D. Fellowship
Anand Krishna	PMRF

Ecological Sciences

Division of Biological Sciences

Student Name	Award
Satyajeet Gupta	Graduate Student Representative (Animal Behavior Society) 2020
Satyajeet Gupta	The scent of life: Intraspecific vehicle discrimination in phoretic nematodes based on physiological state of a vehicle; Winter Conference of the Association for the Study of Animal Behavior Society (ASAB) (Virtual meeting), December 2020
Satyajeet Gupta	Which vehicle to ride on? Hitchhiker's dilemma in an ephemeral microcosm; 57th Annual Conference of the Animal Behavior Society (Virtual meeting), August 2020
Satyajeet Gupta	Webinar Talk: The enemy of my enemy is my friend: Trophic cascade (past, present & future; Institute of Electrical and Electronics Engineers (IEEE) AcSIR CISO Student Branch, Chandigarh & IEEE Power & Energy Society, April 2020
Tanveen Kaur Randhawa	PMRF
Dilip Naidu	Grantham Fellowship

High Energy Physics

Division of Physical and Mathematical Sciences

Student Name	Award
Sreemayee Aditya	PMRF
Samudra Sur	PMRF

Product Design and Manufacturing

Division of Mechanical Sciences

Student Name	Award
L R D Murthy	Selected for ACM IUI 2020 Student Consortium with Travel Grant $1300
Vinay Krishna Sharma	Robert Bosch Centre for Cyber Physical Centre PhD Fellowship
Anubhav Patel	Student Best Paper Award Finalist (IEEE ICCAS 2020 S Korea)
Puneeth Kannaraya	CII MILCA Platinum Award for best low cost automation in Industry 4.0

Civil Engineering

Division of Mechanical Sciences

Student Name	Award
Kanneganti Bhargav Kumar	PMRF
Sneha Santy	Grantham Fellowship
Gowri R	Grantham Fellowship
Aitichya Chandra	PMRF Fellowship
Ketan Bajaj	Prof. NS Govindrao Medal for Best Ph.D
Oindrila Kanjilal	Alexander von Humboldt Research Fellowship
Sreeparvathy Vijay	Virtual Berkner Travel Fellowship to participate in the 2020 American Geophysical Union (AGU) Fall Meeting, 1-17 December 2020 (Online). [Received Grant of $2500 USD towards various expenses].
Sreeparvathy Vijay	Roland Schlich travel support grant for participating in the European Geosciences Union (EGU) General Assembly 2020 [EUR 340]
Bollapragada Lakshmi Vara Prasad	PMRF

Nanoscience and Engineering

Division of Interdisciplinary Sciences

Student Name	Award
Vivek Singh	SITARE-Gandhian Young Technological Innovation Appreciation
Suryansh Upadhyay	Best Poster Award, ICEE 2020
Nishta Arora	DCMP Graduate Student Travel Award for APS 2020 March Meeting in Denver.
Viphretuo Mere	Best student paper award (2nd place) in IEEE Sensors 2020 conference
Santosh Aparanji	Tata Trusts Travel Grant to present paper in SPIE Photonics West 2020
Santosh Aparanji	SPIE Travel Grant to present paper in Photonics West 2020
Roopa Prakash	DST SERB Travel Grant to present paper in SPIE Photonics West 2020 (San Jose)
Disha Chugh	PMRF

Sustainable Technologies

Division of Mechanical Sciences

Student Name	Award
Roshan R Rao	Bhavans Fellowship
Suchi Priyadarshini	PMRF

Electrical Communication Engineering

Division of EECS

Student Name	Award
Rooji Jinan	RBCCPS Fellowship
Ajay Badita	Cisco CNI Fellowship
V. Arvind Rameshwar	PMRF
V. Arvind Rameshwar and Aashish Tolambiya	Qualcomm Innovation Fellowship (QIF)
Geethu Joseph	SPCOM 2020 Best PhD Dissertation Award
Geethu Joseph	Finalist for Indian National Academy of Engineering Innovative Student Projects Award
Pooja Nayak Muralidhar	PMRF
Kanishak Vaidya	PMRF
Anjana Mahesh	Qualcomm Innovation Fellowship
ROBIN FRANCIS	CISCO CNI Master Scholarship award
Sujata Sinha	Centre for Networked Intelligence Masters Scholarship Award, 2020
Tushar Gaur	PMRF

Instrumentation and Applied Physics

Division of Physical and Mathematical Sciences

Student Name	Award
Sukanta Nandi	KVRSS First Prize
Rajesh Srinivasan	Gandhian Young Technological Innovation (GYTI) Award
Shweta Pant	SITARE- Gandhian Young Technological Innovation (GYTI) Award 2020

Electrical Engineering

Division of EECS

Student Name	Award
Ruturaj Gavaskar	Hay Medal (Best MTech Research Thesis in EE)
Tanuka Bhattacharjee	PMRF
Girija Ramesan Karthik	RBCCPS PhD Fellowship 2020-21
Manthan Sharma	MTech CPS research grant 2020-21
Aditya Shankar Kar	Student Best Paper Award in EECS Research Students' Symposium
Anusree Rajan	Robert Bosch Centre for Cyber Physical Systems fellowship
Sushmit Mazumdar	Masters Thesis Award (POSOCO 2019) from Ministry of Power, GOI.
Harisyam PV	The N.R.Khambhati Memorial Medal-best Mtech student in EE discipline
Sayan Paul	The Hay Medal-best M.Sc(Engg)/M.Tech(Res) thesis in EE Dept

Electronic Systems Engineering

Division of EECS

Student Name	Award
Priya J. Nadkarni	IEEE best researcher award, Bengaluru section, 2020
Priya J. Nadkarni	Invited speaker at IEEE SPCOM 2020 in quantum special session
Anil Vishnu GK	SRISTI-Gandhian Young Technological Innovation awards 2020 for the project on A Portable Diagnostic Platform for Rapid Label-free Phenotyping of Breast Cancer
Arjun BS	PMRF
Sumitkumar Pramanick	INAE young scientist

Mechanical Engineering

Division of Mechanical Sciences

Student Name	Department	Award
Manoj N. Dixit	ME	PMRF
Kuppuraj	ME	INAE best PhD thesis award

Inorganic and Physical Chemistry

Division of Chemical Sciences

Student Name	Award
Bijnaneswar Mondal	Best thesis award in Inorganic Chemistry
Prodip Howlader	Alexander von Humboldt Fellowship, Germany
Namrata Singh	IUPAC-SOLVAY International Award
Aishani Ghosal	Pikovsky Valazzi Matching Scholarship of Tel Aviv University
Umar Rashid	PMRF
Geetanjali Bhatia	Carl Strom International Diversity Award to attend Gordon Research Conference

Materials Engineering

Division of Mechanical Sciences

Student Name	Award
Sriram Bharath G.	PMRF
Sushma Indrakumar	PMRF
Aditi Jain	Best oral presentation in the Indo-UK Virtual Conference on Current Innovations and the Future of Therapeutic Developments 2020
Aditi Jain	selected to attend the 70th Lindau Nobel Laureate Meeting 2020 in Lindau, Germany
Santanu Ghosh	DST National Postdoctoral Fellowship
Sushma Kumari	DST National Postdoctoral Fellowship
Rajesh Kotcherlakota	C.V. Raman Postdoctoral Fellowship
Syed Idrees Afzal Jalali	Best Oral Present Award, SICE-2020
Syed Idrees Afzal Jalali	K P Abraham Best Thesis Award
Syed Idrees Afzal Jalali	Best Contributed Paper at SICE 2020 Organized by IIT Bombay
Shrutee L	Submitted PhD thesis

Molecular Biophysics Unit

Division of Biological Sciences

Student Name	Award
Hitesh Verma	Best Thesis Award
Priyanka Lahiri	Best poster Award, GRC of peptides, CA, USA
Divyansh Mittal	Scientific research work selected for presentation at COSYNE, 2020, Denver, USA (Travel grant of USD 1000 from COSYNE for attending)
Niranjan Kumar	Best oral presentation award at NMRS 2020
Kavyashree Nadig	PMRF
Suman Mishra	In-House Symposium NuBS 2020

Microbiology and Cell Biology

Division of Biological Sciences

Student Name	Award
Dipasree Hajra	SPM Fellowship (CSIR)
Mr. Sangeeth Saji	2nd Prize in oral presentation (ICAPHS â€" 2020)
Venkantaraman Ravi	Institute medal for Best PhD thesis in Microbiology and Cell Biology
Saheli Saha	Best poster prize in Microbial Ecology and Evolution meeting 2020
Jyotsna Kalathera	Best poster prize in Microbial Ecology and Evolution meeting 2020
Mr. Vishwadeep mane	Travel award (Â£1000) by the British Ecological Society (BES) for presenting research at its Annual Meeting in Belfast, Northern Ireland, UK (December 10, 2019)
Mr. Vishwadeep Mane	EMBO Corporate Partnership Registration Award for presenting independent research at Gender roles and their impact in Academia (virtual conference) organized by EMBO, EMBL and HHMI (October, 13, 2020)
Shachee Swaraj	PMRF
Oyahida Khatun	AWSAR Award
Richa Mishra	ACS young scientist best poster award at India Embo symposium
Shalini Singh	BBA Young Investigator Award
Parijat Bandyopadhyay	CS young scientist best poster award at India Embo symposium

Materials Research Centre

Division of Chemical Sciences

Student Name	Award
Swati Sharma	SBAOI Bajpai-Saha Student Award for Best Student Paper Presentation
Krishnakanth Sada	Newton-Bhabha PhD Placement Fellowship
Krishnakanth Sada	KVRSS Research Award (Chemistry Runner Up I)
Lalit Sharma	ECS F.M. Becket Summer Fellowship

Molecular Reproduction, Development and Genetics

Division of Biological Sciences

Student Name	Award
Priyanka Biswas	Best Poster Award in the EMBO Workshop on Mycobacterial heterogeneity and host tropismâ
Sakshi Gupta	PMRF
Saurav Kumar	Mrs. C.V. Hanumantha Rao Medal
Simran Srivastava	PMRF

Organic Chemistry

Division of Chemical Sciences

Student Name	Award
Mr Sayan Shee	PMRF
Pankaj Kumar Chaturvedi	PMRF
Aditya Chakrabarty	PMRF
Dr. Santhosh Rao	The Guha Research Medal

Physics

Division of Physical and Mathematical Sciences

Student Name	Award
Prerana Biswas	Best Poster (Extragalactic Astronomy), Annual Meeting of the Astronomical Society of India
Saurav Islam	Nomination for Best Thesis Award
Alankar Dutta	PMRF
Sourav Bhadra	PMRF

Solid State and Structural Chemistry

Division of Chemical Sciences

Student Name	Award
Anumita Bose	PMRF
Ayan Banerjee	PMRF
Antarip Halder	DBT postdoctoral fellowship
Aiswarya Abhisek Mohapatra	Toulouse Medal

7.9 PLACEMENT

An attractive Placement Brochure was prepared by OCCaP to be circulated with potential recruiters. A large number of potential recruiters were contacted with an intent for Campus Association for recruiting the students. Brochures were shared, and many responded positively with good number of work opportunities for our students for Final placements. This has added on to the list of our Eminent Recruiters those visited last year on Campus. On Campus and Off Campus interest to hire our students was shared by the companies.

A modern and fully functional Placement Portal has been set up for students and recruiters. The portal enables companies to register and post their hiring requirements. Students can register, apply for jobs, and manage interface with recruiters. The portal facilitates Emails and SMS alerts to selected set of students, and to disseminate information quickly.

About 50 % of students who pursued internship from batch 2020-21 received direct pre-placement full time offers (PPO) during internship season 2020. Pre-Placement Talks (PPT's) for UG/Master/ PhD/ Post Doc students was scheduled where companies interacted with students to discuss prospective job opportunities. 180 companies participated for full time hiring. During this Campus Interviews total students placed is 294 with highest of 95.3 Lakhs (Japanese Yen) as highest international offer and INR 61.2 Lakhs as highest domestic offer.

**Placements for season 2020-21 was in a virtual mode from pre-placement talks, tests to interview process

7.10 EXTERNAL REGISTRATION PROGRAMME

Sl. No	Organization	Number of Students
1	24 - 7 Customer Private Limited	1
2	ABB Corporate Research Center	1
3	Accenture Technology Labs	1
4	ADE- DRDO	1
5	Aeronautical Development Agency	3
6	Aeronautical Development Establishment DRDO	1
7	Amrita School of Engineering	1
8	Atomic Mineral Directorate for Exploration and Research	1
9	Bangalore Integrated Systems Solutions P Ltd.	1
10	Bloom Energy I Pvt Ltd	1
11	BrahMos Aerospace	1
12	BRAHMOS AEROSPACE - JV MINISTRY OF DEFENCE	2
13	CDD Society	1
14	Center for Science Technology and Policy	1
15	Center for Study of Science Technology and Policy	1
16	CENTRAL RESEARCH LAB	1
17	Central Research Laboratory Bharat Electronics Limited	1
18	Centre for Artificial Intelligence and Robotics	1
19	COMSOL Multiphysics Pvt. Ltd	1
20	CSIR- National Aerospace Laboratories	1
21	DEFENCE METALLURGICAL RESEARCH LABORATORY	2
22	DEFENCE RESEARCH AND DEVELOPMENT ORGANISATION	5
23	Defence Research and Development Organization	3
24	Defense Research and Development Laboratory	1
25	DRDO	2
26	EY	1
27	Gas Turbine Research Establishment	3
28	GE Power Systems	1
29	Generl Electric India Technology Centre	1
30	HAL	1
31	HEMVATI NANDAN BAHUGUNA GARHWAL UNIVERSITY	1
32	HINDUSTAN AERONAUTICS LIMITED	6
33	Hindustan University	1
34	Honeywell Tech Sol Pvt Ltd	1
35	Honeywell Technology Solutions Lab	1
36	Honeywell Technology Solutions Pvt. Limited	1
37	IBM India Pvt. Ltd.	1
38	IBM Research	1
39	Indian Space Research Organisation	8

40	Indian Space Research Organization	3
41	Indira Gandhi Centre for Atomic Research	1
42	Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam	1
43	Infosys Limited	1
44	Infosys Ltd.	1
45	Innomantra Consulting Pvt Ltd	1
46	Institute of Ayurveda and Integrative Medicine Foundation of Revitalization of Local Health Traditions	1
47	Intel Technology India Pvt Ltd	1
48	Intel Technology India Pvt Ltd.	1
49	ISRO	3
50	ISRO Satellite centre	6
51	ISRO Satellite Centre - Indian Space Research Organization	1
52	ISRO Sattlite Centre, Blore	1
53	ISRO TELEMETRY TRACKING AND COMMAND NETWORK	1
54	Liquid Propulsion Systems Center	1
55	Liquid Propulsion Systems Centre	1
56	Microwave Tube Research and Development Centre DRDO	2
57	Nagarjuna Fertilizers and Chemicals Ltd	1
58	National Aerospace Laboratories	6
59	National Centre for Earth Science Studies	1
60	NSTL.DRDO.Ministry of Defence	1
61	NTRO PMO GOVT OF INDIA	1
62	Nuclear Fuel Complex	1
63	Organisation	1
64	Praxair India Pvt Ltd	1
65	Programme AD - Research Center Imarat	1
66	Ramaiah Insitute of Management	1
67	RDE ENGINEERS DRDO	1
68	RESEARCH CENTRE IMARAT. RCI. DRDO	1
69	ROBERT BOSCH ENGINEERING AND BUSINESS SOLUTIONS LIMITED	1
70	Robert Bosch Engineering and Business solutions private Limited	1
71	Samatvam Science And Research Center	1
72	Samsung R and D Institute India Bangalore Pvt Ltd	1
73	Samsung R D Institute Bangalore	1
74	Sigma Quant Technologies Pvt. Ltd.	1
75	SOLID STATE PHYSICS LABORATORY	1
76	Tata Consultancy Services Limited	1
77	Texas Instruments India Pvt Ltd	2
78	Triveni Turbine Limited	1
79	Vikram Sarabhai Space Centre	1
80	WEBFIL LIMITED - DIGITAL SYSTEMS DIVISION	1
	Grand Total	**121**

8 Events

8.1 INSTITUTE LECTURES

SPECIAL LECTURES

PROF. RODDAM NARASIMHA ENDOWMENT LECTURE

On "Laboratory Studies of free Convective Turbulent Transport of Heat and Moisture." By Prof. Jaywant H Arakeri, Department of Mechanical Engineering. On 27th August 2020 at 4.00 p.m.

M J THIRUMALACHAR AND M J NARASIMHAN ENDOWMENT LECTURE

On " New and Emerging technologies: Key Drivers of Bioeconomy Growth" by Dr. Renu Swarup, secretary, department of Biotechnology on 18th January 2021 at 4.00 P.M.

IISc Colloquium

Institute Colloquium on "How Crystal Growth Enables Your Electronics World: If Only we could make Diamonds! By Prof: Srinivasan Raghavan, CeNSE on 28th May 2020 at 4.00 P.M.

Institute Colloquium on "Making Weak Bonds, Breaking Strong Bonds and Defining All Bonds: Experiments with Supersonic Waves!" by Professor E.Arunan, Department of Inorganic and Physical Chemistry, on 25th November, 2020 at 4. 00 PM.

Institute Colloquium on "Schrodinger's Cat and Cauchy's Dog" by Professor S. Thangavelu of Mathematics, on 29th December, 2020 at 4.00 PM.

Institute Colloquium on "The Ocean beneath a hole in the monsoon: Results from the BoBBLE (Bay of Bengal Boundary Layer Experiement) by Prof. P.N.Vinaychandran, Centre for Atmospheric and Oceanic Sciences, (CAOS) on 28th January 2021 at 4.00 P.M.

Institute Colloquium on "From the specific to the general and back: HIV-Aids, Covid – 19, and beyond" by Prof. Narendra M Dixit, Chair, centre for Biosystems Science and Engineering, & department of chemical engineering on 25th February 2021 at 4.00 P.M.

Institute Colloquium on "The role of Interference in the Design of Next Generation Wireless Communication Systems" by Prof. Neelesh B. Mehta, ECE Department on 19th March 2021, at 4.00 P.M

BIOLOGICAL SCIENCES

- Designer Enzymes, 24-01-2020 (BC)
- Restriction Enzymes ushered in the Biotechnology revolution, 29-02-2020 (BC)

- Gordon Research Conference on Predator-Prey Interactions, 26-01-2020 (CES)
- Seed dispersal in the Anthropocene, 02-03-2020 (CES)
- Introduction to molecular phylogenetics, 2020 (CES)
- Applications of molecular phylogenetics, 2020 (CES)
- International Conference on Autophagy and Lysososmes, 2020 (MRDG, MCB, CNS)
- INSTRUCT-ERIC workshop, 16-01-2020 (MBU)
- Organized MBU In House symposium NuBS symposium 2020, 2020 (MBU)
- Cryo-EM Workshop in IISc, 2020 (MBU)
- Biological Transactions: From molecules to organisms, 2020 (MCB)
- International conference on Autophagy and Lysosomes: function, signaling and disease, 16-01-2020 (MCB)
- Combating COVID-19, 2020 (MCB, CIDR)
- Mycobacterial heterogeneity and host tropism, 2020 (MCB)
- Discussion meeting on Structural Biology, 16-01-2020 (MBU, MRDG)
- Electron Cryo-Microscopy Workshop, 10-02-2020 (MBU, MRDG, NCBS)
- Phenotypic Heterogeneity as a Driver of Cancer Progression, 05-01-2020 (MRDG)
- Conference and Workshop on Phenotypic Heterogeneity as a driver of Cancer Progression, 05-01-2020 (MRDG)

CHEMICAL SCIENCES

- 100 Years of Hydrogen Bonding, 09-01-2020 (IPC)
- Convenor, 30th SBAOI Annual Meeting and 13th STERMI Annual Meeting, & International Conference on Biomedical Materials Innovation 2020, Bharathiar University, Coimbatore, 06-12-2020 (MRC)
- Workshop Chair and Mentor, Recent Trends in Biomedical Engineering, NIT Durgapur, 03-01-2021 (MRC)
- Symposium Chair, Frontiers of Science Symposium: Materials for Society, Indian Academy of Sciences, 01-10-2020 (MRC)
- Workshop Chair, Regenerative Engineering: Biomaterials for Regulating Cell Function AIChE Annual Meeting, 20-11-2020 (MRC)
- Workshop Chair, Challenges in Antimicrobial Biomaterials Development, World Biomaterials Congress, 11-12-2020 (MRC)
- One Day NMR Users meeting, 2020 (NRC)
- ICOC-2020, 07-03-2020 (OC)
- Pfizer Symposium on Organic Chemistry, 19-02-2020 (OC)

ELECTRICAL, ELECTRONICS AND COMPUTER SCIENCES

- Stochastic Approximation and Reinforcement Learning Session inIndian Control Conference 2020, 16-12-2020 (CSA)
- Computational Thinking in India, 08-08-2020 (CSA)
- Workshop on Research Highlights in Programming Languages, 15-12-2020 (CSA)
- Multi-party Computation: Theory and Practice, 19-01-2020 (CSA)
- Research Highlights in Programming Languages, 15-12-2020 (CSA)
- Fairness, Accountability, Transparency And Ethics in Machine Learning, 09-01-2020 (CSA)
- Indo-French Seminar on Artificial Intelligence, 27-10-2020 (CSA)
- Indo French Seminar, 27-01-2021 (CSA)
- Theory and Practice of Blockchains, 27-05-2020 (CSA)
- EECS Symposium, 11-07-2020 (CSA, EECS)
- Workshop on Advanced Networks, 10-07-2020 (CSA, EECS)
- EECS YRM, 17-07-2020 (CSA, EECS)
- 2020 International Symposium on Information Theory and Its Applications, 24-10-2020 (ECE, JITS)
- ECE webinar series, 01-10-2020 (ECE)
- CyPhySS, 2020 (ECE, RBCCPS)
- CONECCT 2020, 02-07-2020 (ECE)
- B-HTC 2020, 08-10-2021 (ECE)
- Cyber-Physical Systems Symposium (CyPhySS-2020), 2020 (ECE, RBCCPS)
- Current Trends in Quantum Information processing, 24-07-2020 (PHY, ECE, DESE)
- Quantum Computation and Quantum Information, 20-07-2020 (ECE)
- SPCOM 2020, 19-07-2020 (EE)
- Image Processing & Computer Vision, 01-01-2020 (EE)
- SPCOM2020, 19-07-2020 (EE, ECE, CDS)
- Deep Learning Theory and Practice, 07-01-2020 (EE)
- Workshop on embedded systems and IOT, 07-12-2021 (ESE, DESE)
- Workshop on embedded systems and IOT, 03-06-2020 (ESE, DESE)
- IoT-Enabled Analog System Design, 13-01-2020 (DESE)
- Blockchain Technology, 15-09-2020 (ESE, CMTI)

INTERDISCIPLINARY SCIENCES

- Phenotypic Heterogeneity as a Driver of Cancer Progression, 05-01-2020 (BSSE)
- Measuring and modeling the epithelial-mesenchymal plasticity, 05-10-2020 (BSSE)
- Digital Health and Imaging, Aug 1st 2020 – Jan 1st 2021 (CDS)
- IISc "Russian Academy of Sciences-Novosibirsk State University Meeting to Discuss Collaborative Research on Intelligent Systems and their Applications", 24-02-2020 (CDS)
- SPCOM 2020 19th July – 24th July, 2020 (CDS)
- Special session on â€œDeep Learning for Computer Visionâ€-, International Conference on Signal Processing and Communications (SPCOM), 19th July-24th July, 2020 (CDS)
- Special session on â€œNeuromorphic Signal Processing and Applicationsâ€-, International Conference on Signal Processing and Communications (SPCOM), 19th July – 24th July, 2020 (CDS)
- International Conference on Multimedia Big Data (BigMM) 24th Sep – 26th Sep, 2020 (CDS)
- EECS Symposium 10th July – 12th July, 2020 (CDS)
- ACM Winter School, 9th Jan – 14th Jan, 2020 (CDS)
- EIH-2020 (CeNSE)
- Electron and Ion on Helium 2020, 25-01-2020 (CeNSE)
- 5th International Conference on Emerging Electronics (ICEE), 26-11-2020 (CeNSE)
- Interaction between transportation-related emissions and air quality in urban areas in India, 07-01-2020 (CiSTUP)
- A Short Course on Advanced Choice Modelling Methods in an Evolving Urban Travel Behaviour Landscape, 03-02-2020 (CiSTUP)
- AI and IoT for Flow Modeling (MS)
- Robot Learning and Control, 02-11-2020 (RBCCPS)
- CyPhySS 2020, 11-07-2020 (RBCCPS)
- EECS Symposium, 10-07-2020 ((RBCCPS)

MECHANICAL SCIENCES

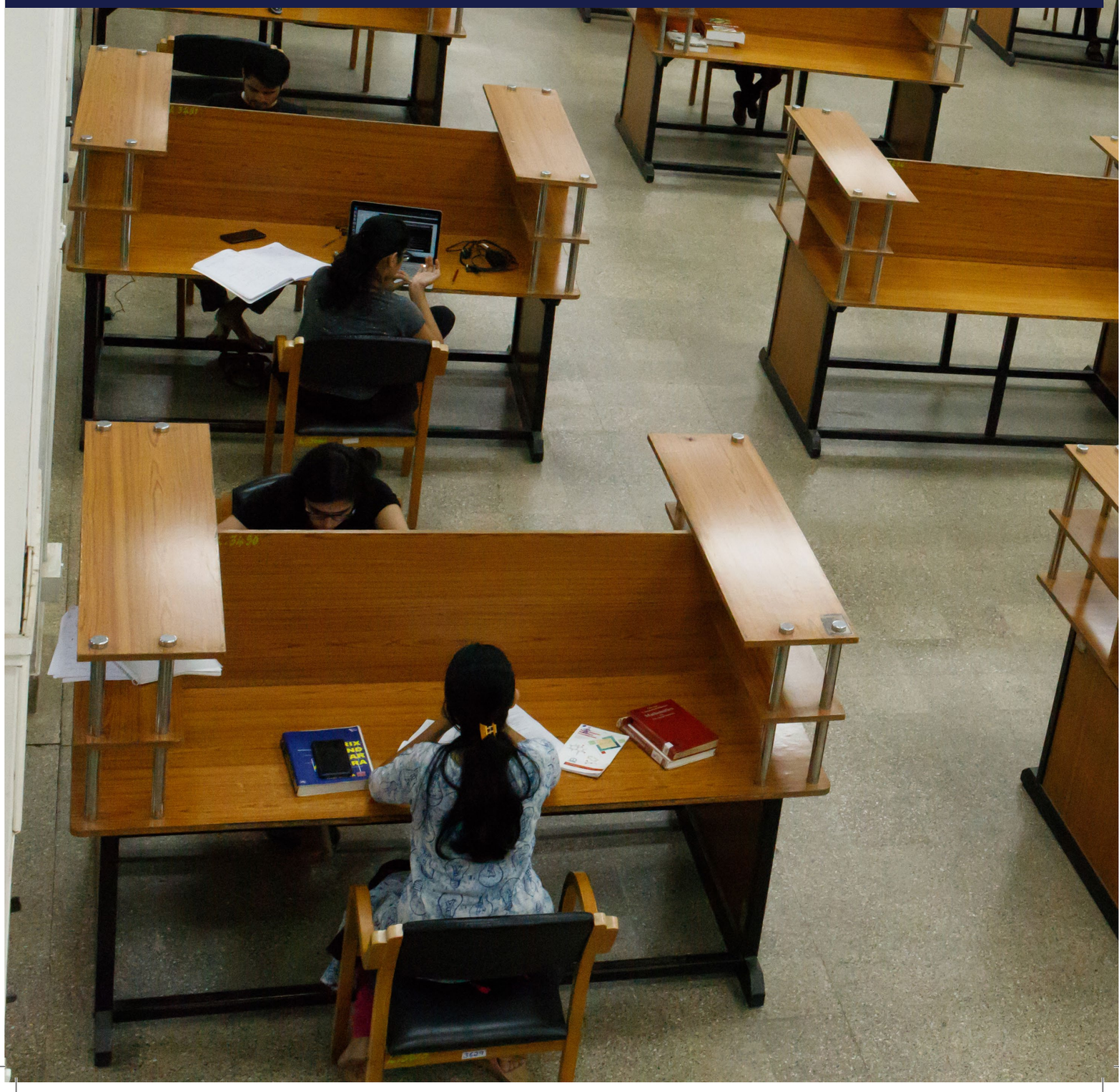
- Satish Dhawan Centenary Lecture Series 2020, (AE)
- SSWR-IMechE Seminar Series on Artificial Intelligence and Application, 03-02-2020 (AE)
- SSWR Seminar on Shock Waves, 15-09-2020 (AE)
- SSWR Manoj Prakash Memorial Lectures, 05-12-2020 (AE)
- Aerospace Vertical, Vaishwik Bharatiya Vaigyanik Summit (VaiBhaV), Oct 10th - Oct 28th, 2020 (AE)
- Professor Roddam Narasimha Endowment Lecture, 2020, (CAOS)
- Third Annual Meeting of the Ocean Predict Science Team, Dec 7th – Dec 10th, 2020 (CAOS)
- A Program on Climate and Environment", 09-01-2020

- Digital Solutions To Acclerate Adaptation to Climate Change in Agriculture Jan 13th – Jan 14th 2020 (CAOS)
- Training of Trainers, 8th Feb – 9th Feb, 2020 (CAOS)
- Inter-School Quiz Competition, 24-08-2020, (CAOS)
- Future Earth South Asia Governing Council Meeting, 06-10-2020 (CAOS)
- International Conference on Himalayan Cryosphere, 19th Oct – Oct 21st 2020 (CAOS)
- Climate Resilient Agriculture, 3rd Dec – 4th Dec (CAOS)
- Decadal variations of Monsoon, 27-12-2020 (CAOS)
- Wednesday Webinars on Mechanics of Materials 16th Sep – 16th Dec, 2020 (CIE)
- Advanced Technologies for Water Resources Management 9th March 2020 – Jan 15th 2021 (CIE)
- Advanced Technologies for Water Resources Management 9th March – 13th March, 2020 (CIE)
- Governance and Mobility 4th March – 6th March, 2020 (CIE)
- "Modelling and Simulation of Pedestrians for Scientific Decision Support" 24th Feb – 28th Feb, 2020 (CIE)
- Application of Dielectric Spectroscopy to problems in Agriculture, Environmental Physics and Engineering, 2020(CIE)
- DCC 2020, 14th Dec – 16th Dec, 2020 (CPDM)
- Bigathon + : Transforming India 5th Aug – 12th Aug, 2020 (CST)
- High Temperature Materials, 3rd Dec – 6th Dec, 2020 (MAT Eng)
- Materials and Metallurgy Curriculum, 5th March – 8th March, 2020 (MAT Eng)
- 5th National Executive Committee, 2020, (MAT Eng)
- YRM 27th July – 29th July, 2020 (ME)
- Virtual Symposium on Experimental Mechanics 27th July – 29th July, 2020 (ME)
- Young Researchers Meet, 27-02-2020 (ME)
- Virtual Symposium in Experimental Mechanics, 28th July – 31st July, 2020 (ME)
- Soft Matter Young Investigator Meeting, 3rd Dec – 5th Dec, 2020 (ME)
- Virtual Symposium on Experimental Solid Mechanics 28th July – 29th July, 2020 (ME)

PHYSICAL AND MATHEMATICAL SCIENCES

- Current Trends in Quantum Information Processing, 24-07-2020, (CHEP)
- The 9th International Conference on New Frontiers in Physics (ICNFP 2020) 4th Sep – 12th Sep, 2020 (CHEP)
- National Symposium on Instrumentation (NSI-42), 2020 (IAP)
- Combinatorics and Random Processes 27th Jan – 31st Jan (MA)
- Workshop on Finite Elements for Nonlinear and Multiscale Problems, 2020 (MA)
- Algebra Symposium, 2020 (MA)
- Discussion Meeting on Representation Theory 2020 (online) (MA)

- Algebra & Combinatorics Seminar, 2020 (MA)
- Weekly seminars on "BGG Category O", 2020 (MA)
- IISc Geometry/Topology Seminar, 5th Oct – 14th Dec, 2020 (MA)
- Symmetry, Thermodynamics and Topology in Active Matter 16th March – 29th May, 2020 (PHY)
- QMAT3, 7th Sep – 11th Sep, 2020 (PHY)
- Indian Statistical Physics Community Meeting 2020. 19th Feb – 21st Feb, 2020 (PHY)
- Turbulence: Problems at the Interface of Mathematics and Physics, 7th Dec – 18th Dec, 2020 (PHY).



9 Other Institute Units


FOUR SEASON

9.1 OFFICIAL LANGUAGE UNIT

CHARIPERSON: RAJEEV RANJAN

Hindi Teaching Scheme: An In-Service Hindi Training is offered to the staff to train them in the Official Language. The Institute takes the responsibility of providing class-rooms, and study material. Classes are organised during office hours. This is year too Institute staff were trained and they were also trained to use Hindi software on computer.

Hindi Workshop: The Institute regularly organises Hindi Workshops on various aspects of the use of Hindi in Central Government Offices and conversation session for the benefit of the Institute staff. Staff from different Sections/Units of Institute takes part in these workshops and are utilizing the same in their offices. This year in view of the strict Covid protocols, online workshop and discussion was organised. Disussions were mainly on the how to effectively implement Official Language in various administrative Units.

Hindi Competitions: In order to encourage the use of Hindi language by the staff in Official work, Official Language Unit & Hindi Samiti jointly organised several competitions such as General Quiz, Dictation, Extempore Speech, Cross Word, Dumb Charades, Memory Test, Antakshari, Creative Writing, Poetry Recitation. Staff and students of the institute participated in large numbers in these competitions. As has been indicated above due to the ongoing pandemic, few competitions were conducted online.

Hindi Day: "Hindi Day" Celebration was held in the Institute on 22nd September 2020 in the Council Chamber. The Online function was presided by Prof. Govindan Rangarajan, Director, IISc, Bangalore, Prof. Rajeev Ranjan, Chairperson of the Official Language Unit delivered the welcome address.

The function was streamed on social media. Faculty members, employees and students of the Institute participated in large numbers. Winners of these competitions were honoured by the Chief Guest and The Director. As a mark of appreciation and encouragement Institute has awarded Rs.2000.00 Cash Prize to the children of the faculty and staff members who have scored 80% or high marks in Hindi Language in the 10th Std & 12 Std (SSLC, ICSE and CBSE) and 2nd PUC during the academic year 201-2020. This year, totally 5 students of 10th Std (CBSE and SSLC) and 1 student from II PUC were given cash awards.

TOLIC Competitions: The Institute had organised a Webinar in Hindi on " Uttarkhand Tragedy: Possible Reasons" by Prof. Anil V. Kulkarni, Distinguished Scientist Divecha Centre for Climate Change, IISc, Bangalore on 10.03.2021. The Institute had also organised Science Quiz in Hindi On 18.03.2021 under the auspices of Town Official Language Implementation Committee (O-2). Participants from TOLIC (O-2), TOLIC (Bank) and TOLIC (PSU) attend the Webinar and Quiz competition in large numbers. Rs. 500.00 for every correct answer was distributed online to the quiz competition winners.

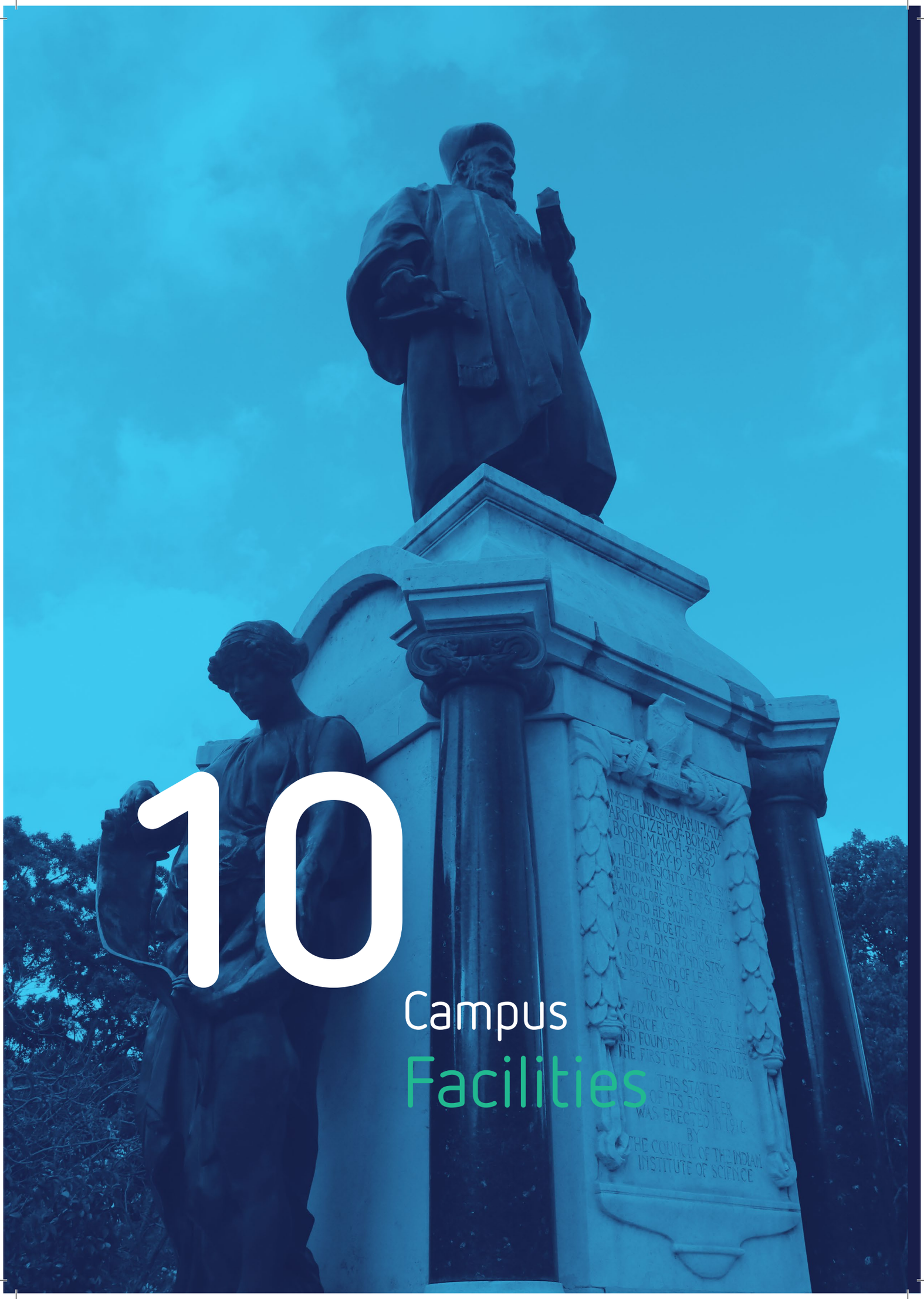
Newsletter & Magazine: Hindi Newsletter "Darshini" is regularly published. For the year Jan- Mar, Apr-Jun, Jul-Sep 2019 was published. In addition to this Monthly journal KERNEL is being translated and published in Hindi. Soft copies of the same have been uploaded on the Institute webpage.

Translation:

- Translation of the annual Report of the Institute in Hindi
- Translation of Annual Accounts in Hindi
- Hindi translation of other administrative manuals, forms and routine correspondence.

9.2 PUBLIC INFORMATION OFFICE

Right to Information Act, 2005: The Institute adopted the Right to Information Act, 2005 in the year 2006. The Institute has disseminates information through its website, which is accessible to the public. During the year, the public have made around 360 requests seeking information and prompt action has been taken and the applicants have been informed accordingly.



10 Campus Facilities

10.1 HEALTH CENTRE

- A fully equipped Clinical laboratory, Digital X-Ray, Ultrasonography, ECG and a fully equipped Physiotherapy Unit are some of the services available.
- Specialist consultants in General Medicine, Gynecology, ENT, Ophthalmology, Dermatology, Dentistry and Psychiatry are available on appointment basis.
- There is a Pharmacy which stores and distributes most of the required medicines.
- There is an Operation Theatre where minor surgical procedures can be carried out efficiently.
- For cases requiring hospitalization for major illnesses, patients are referred to external hospitals for admission and treatment. All the permanent employees are their family members, retired employees and their spouses, and family pensioners are covered by Group Mediclaim Insurance policy under the Contributory Health Service Scheme (CHSS).
- OPD consultation is available for Institute employees and students.
- There are experienced doctors residing on campus and Area Medical Officers cater to the institute fraternity that resides off campus in the city.
- The Health Centre provides Ayurvedic health care by recognized Ayurvedic practitioners based on referrals.
- Emergency care is available round the clock. There is a fully equipped ambulance also.
- The Health Centre provides professional counseling as well. This service is available on the first floor of the Faculty Club.
- Covid-19 response: The Health Centre is providing support to the Institute members including retired employees and their families during the pandemic.
- Timing of Health Centre:
  (i)9 AM – 2 PM (4 doctors)
  (ii)2 PM to 7 PM (1 doctor)
  (iii)8 PM to 8 AM (1 doctor)
- Ambulance contact: 2293 2390 (Nursing 24/7)/2227 (Reception)

10.2 RECREATIONAL FACILITIES

10.2.1 GYMKHANA

The spacious and well-designed Gymkhana is the nodal centre for sports and cultural activities of the students and employees. It offers facilities for many outdoor and indoor games and has a well-equipped gymnasium, badminton court, billiards and a swimming pool. In addition, the Gymkhana houses the Nature club, Dance club, Dramatic club, Literary, Fine Arts and Photographic club, and a well-equipped modern music room. The Ranade Library in Gymkhana offers light reading material in English and in many Indian languages. Other features include periodic coaching classes in games and athletics such as Basketball, Tennis, Swimming, Kung Fu, Archery, Badminton, Athletics, Aerobics and Dance. The Football/Hockey and Tennis grounds are fitted with floodlights. The Raja Ramanna Student's Activity Centre (SAC) is open for cultural activities.

Due to COVID-19 pandemic some of the sports activities were conducted at the Gymkhana. The outdoor game clubs held annual tournaments. The Institute's Cricket team, Football team, Hockey team and Volleyball team participated in Club matches. The Gymkhana has also conducted Inter Departmental / Open matches for the students.

10.2.2 FACULTY CLUB

The Faculty Club is a place for recreational, social and cultural activities.

The Library has some books and magazines for the member to read very peacefully in the club longue. Some of the books have been added to enhance the reader's interest. The Caroms, Billiards, table-tennis, TV, the Gym facilities is available to exercise the body. Also, the music concert performed by some blind orphan children's during the club retiring event.

The dining facilities for the faculties or Club members with a fresh and healthy vegetarian meal served every day and the tea, coffee and different snacks are served on the various days of the week during the working hours of the club with covid pandemic norms and also the cleanness were improved to facilitate the peaceful environment to sit and talk about the research work ideas during the stay in the club.

The club has hosted the every year New Year Lunch to the entire IISc Club members along with their family members which is the time for the entire families, children's to get together and celebrate and also regularly felicitated the retiring club members with their family members hosted the high-tea in the presence of our Institute Director except during the covid-19 pandemic situations due to the pandemic restrictions in the Institute.

The audit of the Faculty Club accounts for the 2019-2020 and 2020-2021 has been done by the external auditor of an agency and the accounts were perfectly alright by the auditor with the accounts books of the faculty club. The new building with ultra-modern kitchen and facilities for the Faculty Club proposal requested to the Institute administration to create better facilities for the benefit of its members.

10.2.3 TATA MEMORIAL CLUB

This Club provides the space and facilities for various games and cultural activities for the supporting staff of the Institute.

In addition to organizing outdoor and indoor games, its activities cover swimming coaching, computer training, Abacus class, creative camps, dance training, musical instrument training. Yoga / Meditation classes, and Sloka classes for members, students & their dependents. Tuition classes are conducted with the support of student volunteers for needy dependents and children. The club also provides Engineering and Medicine text books for needy children of the Institute community. The mini-multi gym facility is open to the Institute community. The club also maintains a Library.

10.3 AUDITORIA

10.3.1 NATIONAL SCIENCE SEMINAR COMPLEX

The magnificent National Science Seminar Complex, situated in the IISc Campus, is the first of its kind in India. The complex is open for seminars, symposia, workshops and conferences organized by recognized scientific societies, educational institutions and professional bodies. The total built up area measures around 5750 sq. meters.
This is fully air conditioned complex, houses the JN Tata Auditorium with a seating capacity of 750 and 3 mini

seminar halls, Hall- A with 120 seating capacity, Hall- B with 90 and Hall- C with 60 seating capacity. It is having an Exhibition ground to conduct poster sessions and exhibitions. Interactive concourses at the basement and ground level with excellent light and sound facilities are part of the seminar complex. The dining area at basement is available for catering. The complex has facilities for photo copying, and secretarial assistance.

10.3.2 PROF. SATISH DHAWAN AUDITORIUM

Located on the first floor of the Centre for Scientific and Industrial Consultancy (CSIC), this is a medium sized auditorium, which is having a seating capacity of 250. It is having fixed seats and a dais suitable for conferences and the complex is open for seminars, symposia, workshops and conferences organized by recognized scientific societies, educational institutions and professional bodies. It is fully air-conditioned and is adequately equipped with sound, lighting and projection equipment.

10.3.3 RUSTUM CHOKSI HALL

Located close to the entrance of the Institute, with a seating capacity of 120, the interior of the hall and its surroundings provide the right environment for intellectual inquiry and cultural activities.

10.3.4. FACULTY AND RECEPTION HALL

The Faculty Hall with a seating capacity of 275 is located in the east wing, on the first floor of the tower building. The Reception Hall is in the west wing. These are used for formal events.

10.4 AMENITIES

The following amenities located in different parts of the campus make day-to-day life smoother and more comfortable. In fact, these facilities have made IISc a totally self-contained Campus.

- Travel Agencies (Domestic & International Travel) (2)
- Beauty Parlors (1)
- Gents Hair Stylists (2)
- Diary outlet (2)
- Bakeries (2)
- Laundry and Dry Cleaners (3)
- Tailoring Shops (3)
- Food Courts (2)
- Fruit Stall & Juice Centre (1)
- STD Courier & Mobile Services shop (1)
- Photocopying and DTP Centers (2)
- General Stores (3)
- Student council store (1)
- Fruits & vegetables Shop (1)
- Campus Book Store (1)
- Photo Studio (1)
- Cable Network Providers (2)
- Internet Service Providers (1)
- Restaurants (1)
- Play School (1)
- Super Market (1)
- Cycle repair shops (2)
- Medical Shop (1)
- Creche (2)

Communications: Post Office (Science Institute, Bangalore – 560 012), Telecom Centre and STD booths. The Institute is connected by the Centrex Exchange from BSNL with 2400 extensions. In addition, there are nearly 250 direct lines to different department and centers.

Centralized electronic franking takes care of outward postage. The CMC section maintains a fleet of service vehicles through approved travel agencies.

Bank: Canara Bank and State Bank of India have fully computerized branches with many facilities including foreign exchange transactions and ATM machines.

11

Endowed Chairs

11.1 Endowed Chairs for Faculty

A number of Endowed Chairs have been instituted in recent years to recognize the outstanding contribution of Institute faculty members.

YEAR	NAME	DEPARTMENT
ABB CHAIR		
2012–15	P S Sastry	EE
2015-18	K Gopakumar	ESE
2018-21	L Umanand	ESE
AMRUT MODY CHAIR		
2015-18	Binny J Cherayil	IPC
2018-21	Aninda J Bhattacharyya	SSCU
ASTRA CHAIR		
2012-15	Sandhya S Visweswariah	MRDG
2015-18	C Jayabaskaran	BC
2018-21	Dipshikha Chakravortty	MCB
HAL CHAIR		
2017-18	K P J Reddy	AE
2018-21	Debasish Ghose	AE
J N TATA CHAIR		
2017-20	D D Sarma	SSCU
2020-21	Umesh Varshney	MCB
JRD TATA CHAIR		
2017-20	V Kumaran	Ch. Eng.
2020-21	Pradeep Dutta	ME
HOMI BHABHA CHAIR		
2017-20	Sriram Ramaswamy	PHY
2020-21	S K Satheesh	DCCC
KSIIDC CHAIR		
2012-15	P P Mujundar	Civil
2015-18	T G Sitharam	Civil
2018-21	S Gopalakrishnan	A.E.
MSIL CHAIR		
2012–15	Chanda J Jog	PHY

2015-18	B Ananthanarayan	CHEP
2015-18	Vasant Natarajan	PHY
2018-21	S Asokan	IAP
SATISH DHAWAN CHAIR		
2012–15	KPJ Reddy	AE
2015-18	Ranjan Ganguli	AE
2018-21	D Nagesh Kumar	CEaS/CiE
TATACHEM CHAIR		
2012–15	P Vijay Kumar	ECE
2015-18	N Surya Prakash	NMRC
2018-21	Vinod Sharma	ECE
RAMAKRISHNA RAO CHAIR		
2014-17	Srinivasan Raghavan	CeNSE
2017-20	Ambarish Ghosh	CeNSE
2020-21	Shankar Kumar Selvaraja	CeNSE
PRATT & WHITNEY CHAIR		
2016-18	Gopalan Jagadeesh	AE
2018-21	R V Ravikrishna	M.E.
REVATI & SATYANADHAM ATLURI CHAIR		
2018-21	Rishikesh Narayanan	MBU
MINDTREE CHAIR		
2018-21	Vijay Natarajan	CSA
DRDO CHAIR		
2018-21	D Roy Mahapatra	AE

11.2 Endowed Visiting Chairs

A number of Endowed Visiting Chairs have been instituted to facilitate the visits of celebrated researchers from all over the world.

YEAR	NAME	DEPARTMENT
BRAHM PRAKASH CHAIR		
2015	Tamas Ungar	Eotvos University, Budapest, Hungary
2015-16	Kannan M Krishnan	University of Washington, Seattle, USA

2016	Jiang-Zhong Jiang	Zhejiang University, Hangzhou, PR China,
2016	Tamas Ungar	Eotyos University, Budapest, Hungary
2016	David P Field	Washington State University, Pullman, USA
2017-18	Surya R Kalidindi	George W Woodruff School of Mechanical Engineering, Atlanta, USA,
2017	Jerzy Antoni Szpunar	Univ. of Saskatchewan, Saskatoon, Canada
2017	David P Field	Washington State Univ., Pullman, USA
2017-18	Sridhar Seetharaman	Colorado School of Mines Golden, USA
2018	Hamish L Fraser	Dept. of Materials Science & Engg, The Ohio State University, Columbus
2018	Manoj Gupta	National University of Singapore
2019	Sergii Divinskyi	University of Munster, Germany
2019	Werner Skrotzki	Dresden University of Technology, Germany
2019	Shervanthi Homer-Vanniasinkam	University College London, UK
2020	Teresa Perez-Prado	IMDEA Matrials Institute Madrid, Spain
2021	Apparao Mohan Rao	Clemson University Clemson, South Carolina

SATISH DHAWAN CHAIR		
2015	Tribrikram Kundu	University of Arizona, Tucson, AZ
2016	P Guruswamy	Ames Research Center, California, USA
2016-17	D S Naidu	University of Minnesota, USA
2017	Garry L Brown	Princeton University, Princeton, NJ
2017	Rama K Yedavalli	The Ohio State University, Columbus, USA

SATISH DHAWAN (IoE) CHAIR		
2019	Siva Athreya	Indian Statistical Institute, Bangalore
2019	Arun Shukla	Univ. of Rhode Island, USA
2019	Murugesu Sivapalan	Univ. of Illinois at Urbana-Champaign, USA
2019	Prasad Tetali	Georgia Institute of Technology, USA
2019	Rajesh P N Rao	Univ. of Washington, USA
2019	Rao R Tummala	Georgia Institute of Technology, USA
2019	Sajal K Das	Missouri Univ. of Science and Technology
2019	Ramachandra Guha	Historian and Sociologist
2020	Sargur N Srihari	University of Buffalo, USA
2020	Daniel Wyler	University of Zurich, Switzerland
2020	Giancarlo D'Ambrosio	INFN Sezione di Napoli

SUNDARARAJAN CHAIR		
2015	Uma Das Gupta	Kolkata
2019		
2020	Chintan Vaishnav	MIT Sloan School of Management, Cambridge

PRATT & WHITNEY CHAIR		
2015-16	Ravi N Banavar	IIT Bombay
2018-19	A M Rajendran	University of Mississippi, USA
DST-IISc CENTENARY CHAIR		
2015	Ramesh Narayan	Harvard University, USA
2015	Jainendra K Jain	Pennsylvania State University, USA
2015	William A Goddard	Caltech, California, USA
2017	Allan Peter Young	Univ of California, USA
2017	Richard N Zare	Stanford University, Stanford, CA
BHARAT ELECTRONICS CHAIR		
2016		
Goutam Chattopadhyay	Jet Propulsion Lab, USA	
SMT. RUKMINI – SHRI GOPALAKRISHNACHAR DISTINGUISHED CHAIR		
2015	Michael L Norman	University of California, San Diego, USA
2016	Rakesh Agrawal	Microsoft Research, Redmond, USA
2018	Sargur M Srihari	State University of New York, Buffalo, NY, USA
K VAIDYANATHAN DISTINGUISHED VISITING CHAIR		
2015-2020	Shihab Shamma	University of Maryland, USA
SMT SUDHA MURTHY DISTINGUISHED VISITING CHAIR		
2016-2019	Vasant Honavar	Pennsylvania State University, USA
PRATIKSHA TRUST DISTINGUISHED VISITING CHAIR		
2018	Christos H Papadimitriou	Columbia University, New York, ny, USA
INFOSYS VISITING CHAIR		
2016-2020	Jainendra K Jain	Pennsylvania State University, USA
	Susanne C Brenner	Louisiana State University, USA
	Aneesh V Manohar	University of California, USA
2018	Xerxes Tata	Dept. of Physics & Astronomy, Univ. of Hawaii at Manoa, USA
2018	Harald Upmeier	Dept. of Mathematics and Computer Science, Philipps-Universitat Marburg, Germany.
2019	Harald Upmeier	Dept. of Mathematics and Computer Science, Philipps-Universitat Marburg, Germany.
2019	David Logan	Physical and Theoretical Chemistry Laboratory, Univ. of Oxford, UK
2019	Guy Theraulaz	Centre de Recherches sur la Cognition Animale, Universite Paul Sabatier, France.
2019	Vyjayanthi Chari	University of California, USA

2019	Girish S Agarwal	Texas A&M University, USA
2020	Ueli Grossniklaus	University of Zurich
2020	Ashoke Sen	Harish-Chandra Research Institute, Allahabad
2020	Ramanujan Hegde	MRC Laboratory of Molecular Biology, Cambridge, UK.
GORE SUBRAYA BHAT CHAIR		
2021-22	Siva Sai Gorthi	IAP

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