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RESEARCH SPECTRUM

A COMPENDIUM OF GRAPHICAL ABSTRACTS ILLUSTRATING RESEARCH AT IIT INDORE

Editors:
Dr. Ankur Miglani
Prof. Pavan Kumar Kankar
Dr. Shailesh I. Kundalwal

Research Spectrum

(A Compendium of Graphical Abstracts Illustrating Research at IIT Indore)

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Director's Message

It gives me immense pleasure to write a foreword to the third issue of first volume of *Research Spectrum*. This publication will showcase high-quality research work, done by the faculty members and students of IIT Indore, in a graphical form. As we say '*a picture is worth a thousand words*,' we want to present a pictorial abstract of our complex research in a most simplified way through this endeavour of *Research Spectrum*.

It may be noted that majority of the research works presented in the *Research Spectrum* have been bestowed with the Best Research and/or Best Technology awards of the Institute. It also includes some of the prominent research works that were considered for the award. Further, to recognise the professors who have won the awards in a year, they have been requested to be the editors of the periodic volumes of *Research Spectrum* coming out during the year.

We sincerely wish that the readers will find *Research Spectrum* containing graphical abstracts of the research work of IIT Indore faculty and students easy to understand and will further help disseminate the novel research ideas depicted therein amongst the avid researchers and lovers of technology.

With best wishes,

Prof. Suhas S Joshi
Director

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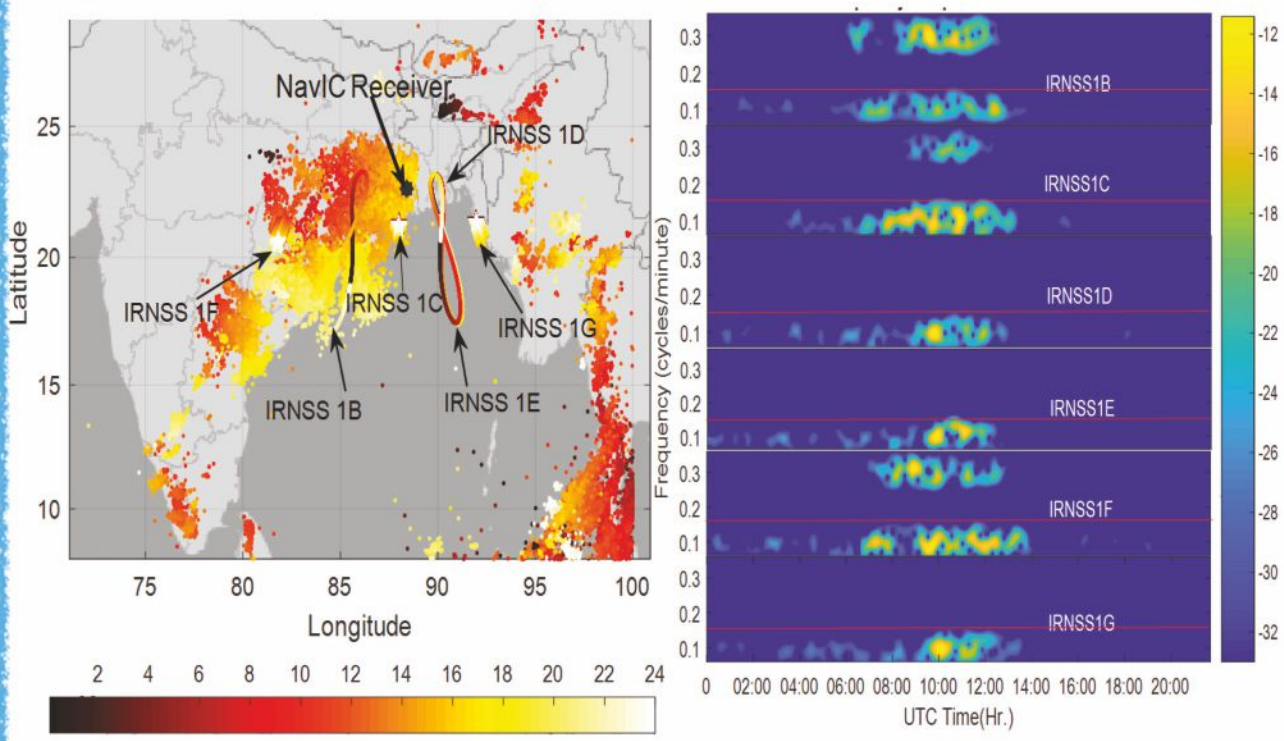
First detection of Acoustic and Gravity Wave by Indian Navigation satellite NavIC

Soumen Datta[1] and Saurabh Das[1]

Department of Astronomy, Astrophysics, and Space Engineering,, Indian Institute of Technology Indore, Indore, India



Left Fig.: Lightning strikes and the NavIC satellites foot print on ionosphere on a sivere lightning day. The colure bar indicates the UTC Hr. **Right Fig.**: Frequency response of the waves (red line indicates the Brunt Vaisala frequency before gravity wave dissipation altitude)

Tropical thunderstorms are major source of low frequency atmospheric waves such as acoustic and gravity waves. Acoustic waves are usually not detected over low-latitude regions due to the atmospheric conditions. These waves propagate to the upward direction by atmospheric filtering and dissipation process. A significant number of waves can manage to reach the ionospheric altitude and causes perturbation in ionospheric TEC variation. This study is based on first time detection of thunderstorm induced both acoustic and gravity waves by Indian navigation system IRNSS/NavIC signal.

The work has been published in the Advances in Space Research: Datta et al., ASR (2023), DOI: 10.1016/j.asr.2023.09.018

Dorzolamide suppresses PKCδ -TIRAP-p38 MAPK signaling axis to dampen the inflammatory response

Sajjan Rajpoot[1], Ashutosh Kumar[2], Vadim Gaponenko[3], Teresa LM Thurston[4], Dolly Mehta[5], Syed M Faisal[6], Kam YJ Zhang[2], Hem C Jha[1], Gajanan N Darwhekar[7], & Mirza S Baig[1]

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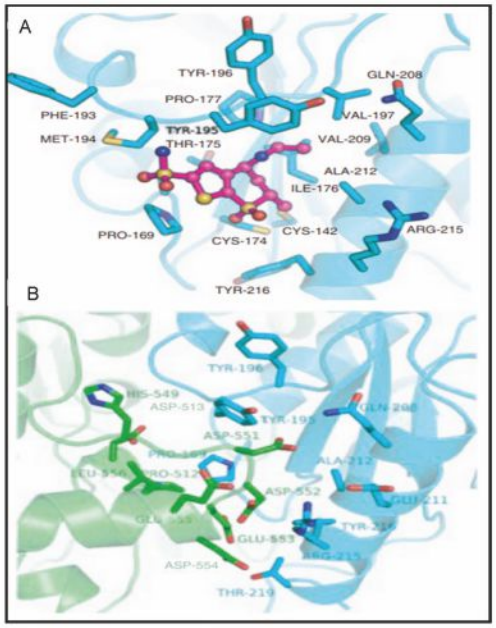
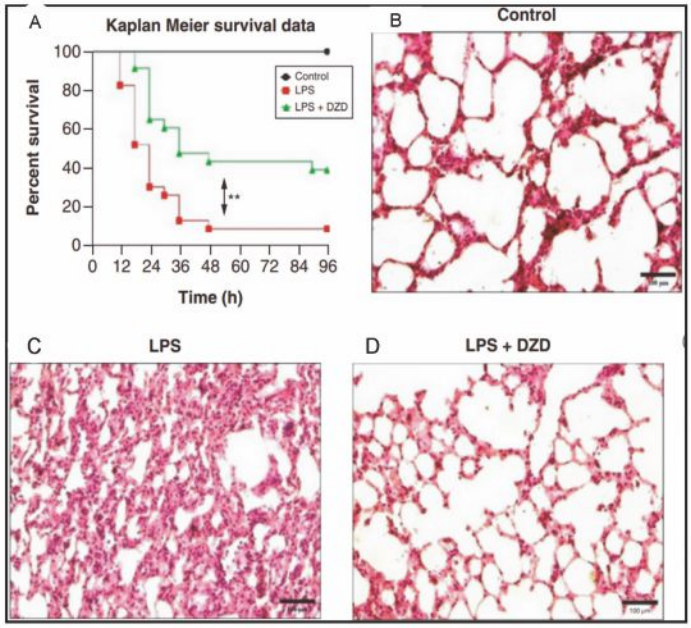




Left Fig.: PKCδ and TIRAP interacting interface near DZD binding site. **Right Fig.**: DZD in mice protects the septic mice mortality and alleviates the lung injury induced by LPS.

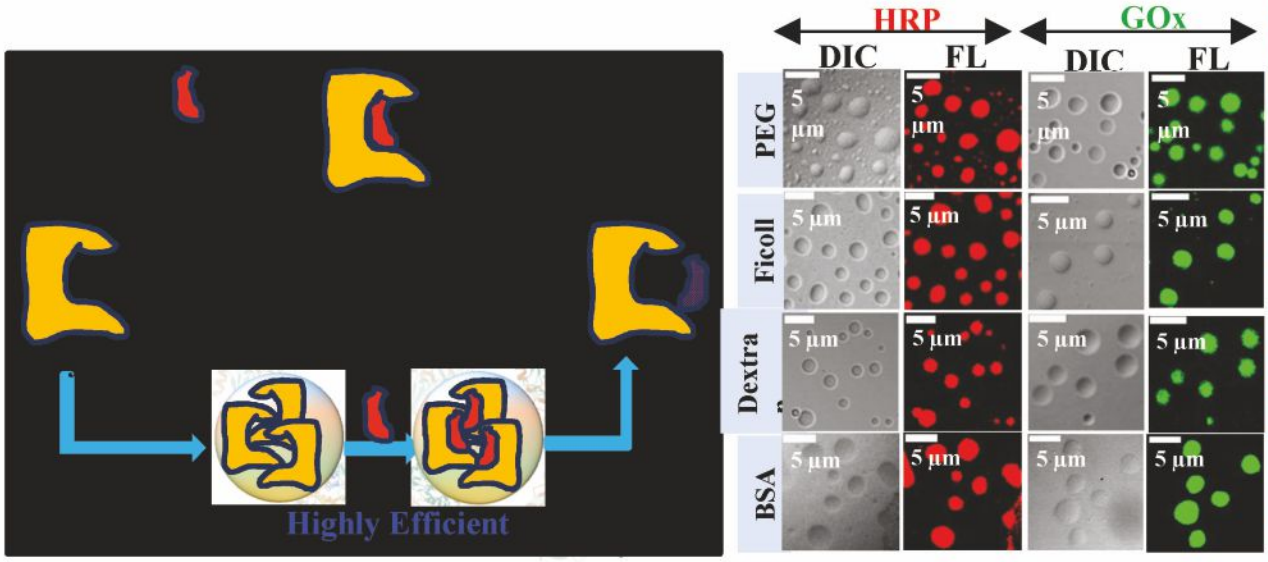
Chronic inflammation is the body's natural defense against injury and infection, but it can also cause severe damage and long-term health problems. There is an urgent need to identify suitable targets in inflammation pathways and to develop target-specific drugs. The importance of TIRAP in inflammatory signaling has increased recently due to its role in modulating and trans-activating the TLR4/TLR2 signaling mediators. Our research has uncovered a new pathway of the TIRAP–PKCδ-p38 MAPK signaling axis, which could be further investigated. We have repurposed Dorzolamide (DZD) to target TIRAP–PKCδ and inhibit downstream inflammatory pathways, thereby dampening chronic inflammatory diseases.

The work has been published in the Future Medicinal Chemistry: Rajpoot. et al. Future Med. Chem. (2023) 15(6), 533–554.

Biomolecular Condensates Regulate Enzymatic Activity under a Crowded Milieu: Synchronization of Liquid-Liquid Phase Separation and Enzymatic Transformation

Bhawana Saini[1] and Tushar Kanti Mukherjee[1]*

Department of Chemistry, Indian Institute of Technology Indore, Simrol, Indore 453552, Madhya Pradesh, India



Left Fig.: Schematic illustration of enzymes and its activity in the absence and presence of crowders. **Right Fig.**: Confocal images of RBITC-labeled HRP and FITC-labeled GOx droplets formed in the presence of different crowders.

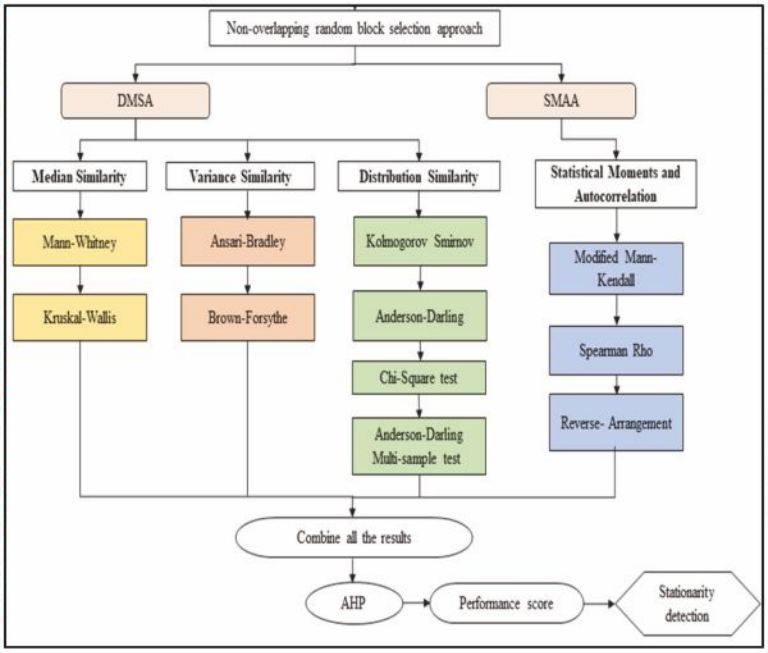
Cellular crowding regulates the enzymatic activity in physiological conditions, which is difficult to realize in the dilute phase. The present work, demonstrates the first report of macromolecular crowding induced liquid−liquid phase separation (LLPS) of enzymes via formation of liquid-like condensates and thereby increases the intrinsic catalytic efficiencies of enzymes like HRP and GOx. Our findings reveal an unprecedented enhancement (91- to 205-fold) in the catalytic efficiency (k_{cat}/K_m) of HRP at pH 4.0 within the droplet phase relative to that in the bulk aqueous phase in the presence of different crowders.

The work has been published in the Journal of Physical Chemistry B: Saini. et al. J. Phys. Chem. B (2023) 127, 180−193.

Nonoverlapping Block Stratified Random Sampling Approach for Assessment of Stationarity

Ramesh S. V. Teegavarapu[1] and Priyank J. Sharma[2]

[1]Dept. of Civil, Environmental and Geomatics Engineering, Florida Atlantic Univ., Boca Raton. [2]Department of Civil Engineering, Indian Institute of Technology Indore, Indore, India.



***DMSA-** Distribution and Median Similarity Assessment
***SMAA-** Statistical Moments and Autocorrelation Assessment
***AHP** – Analytical Hierarchy Process

Fig.: Stationarity detection using nonoverlapping random sampling blocks

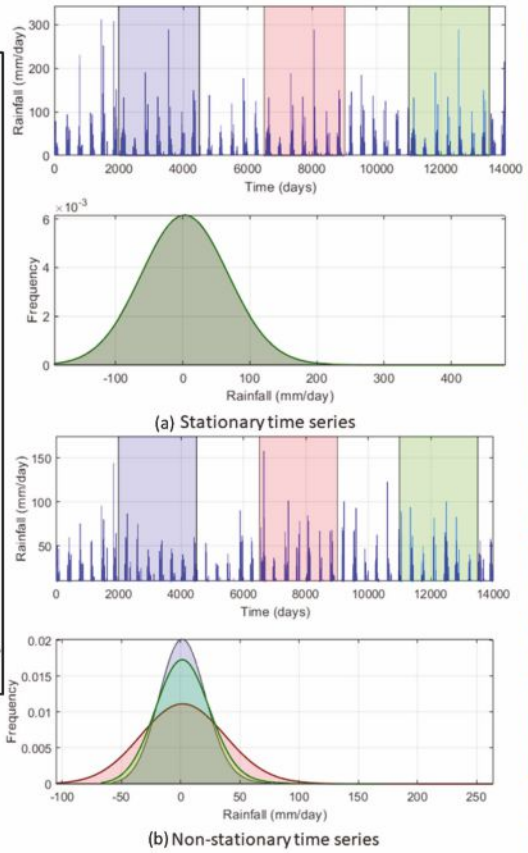


Fig.: Stationary vs Non-stationary time series

The study introduces an innovative approach, utilizing nonoverlapping stratified random sampling blocks and nonparametric tests. It comprehensively assesses various time series characteristics, including distributional, median, and variance similarities, invariance of statistical moments, and autocorrelation at different lags. The method, proven robust through extensive simulations with real-world and synthetic datasets, accurately identifies weak and strict stationarity. Compared to traditional unit root and trend tests, this conceptually simple approach offers a superior and comprehensive evaluation of stationarity using multiple nonparametric tests.

The work has been published in the Journal of Hydrologic Engineering: Teegavarapu, R. et al., J. Hydrol. Eng. (2021) 26.7: 04021020

Secured Convolutional Layer IP Core in Convolutional Neural Network Using Facial Biometrics

Anirban Sengupta[1] and Rahul Chaurasia[1]

[1]Department of Computer Science and Engineering, Indian Institute of Technology, Indore, India.

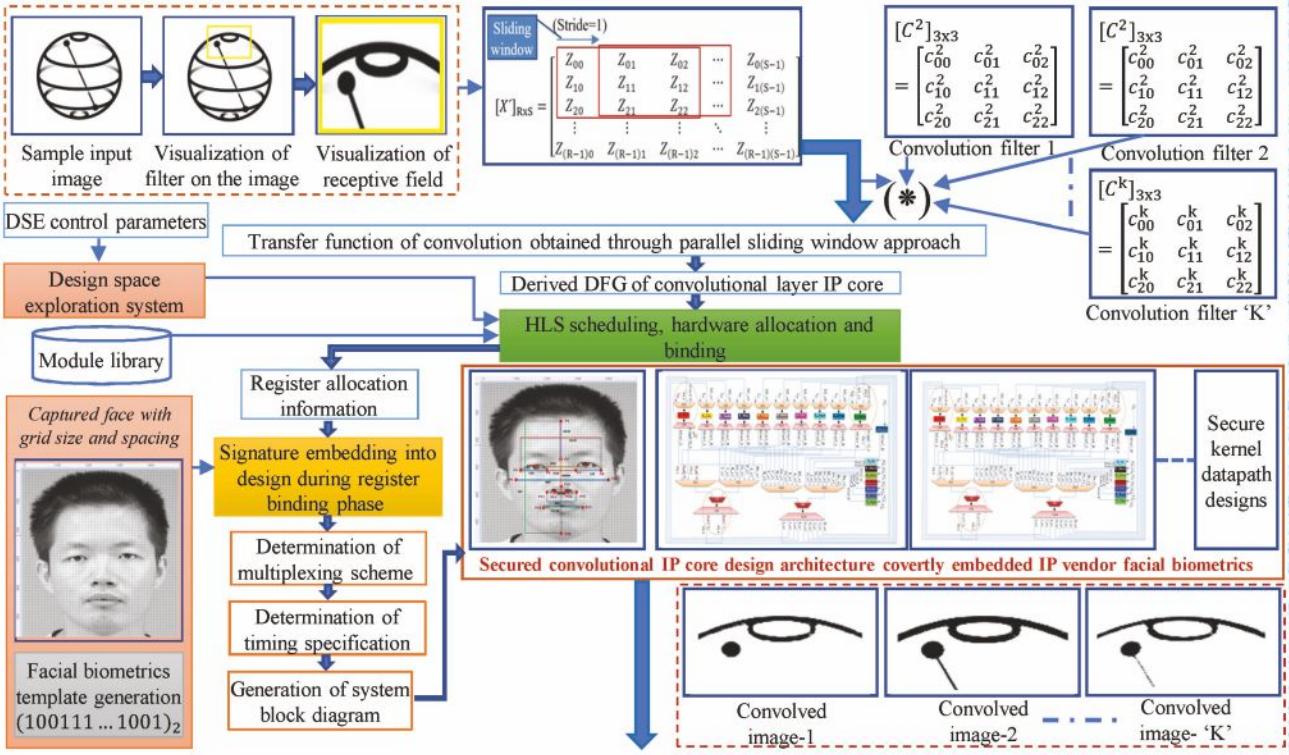


Fig.: High-level synthesis (HLS) based approach for designing convolutional hardware IP (for hardware-based computation of pixels corresponding to output feature/activation map) secured with facial biometrics of IP vendor . *Note: DSE: Design space exploration, DFG: data flow graph*

Developing secure hardware intellectual property (IP) cores for machine learning applications is essential to ensure their accelerated and dependable performance. This research delves into utilizing HLS to design secure convolutional hardware IP with embedded facial biometrics, used in convolutional neural networks (CNN). The design methodology introduces a new perspective on designing secure custom hardware IPs for machine learning applications and establishes a robust detective control mechanism against pirated design versions at zero design cost overhead.

The work has been published in IEEE Transactions on Consumer Electronics: Sengupta et al. IEEE Trans. Consum. Electron., (2022) 68, 291-306.

CrowdFormer: Weakly-Supervised Crowd Counting With Improved Generalizability

Siddharth Singh Savner[1] and Vivek Kanhangad[1]

[1]Department of Electrical Engineering, Indian Institute of Technology Indore, Indore, India.

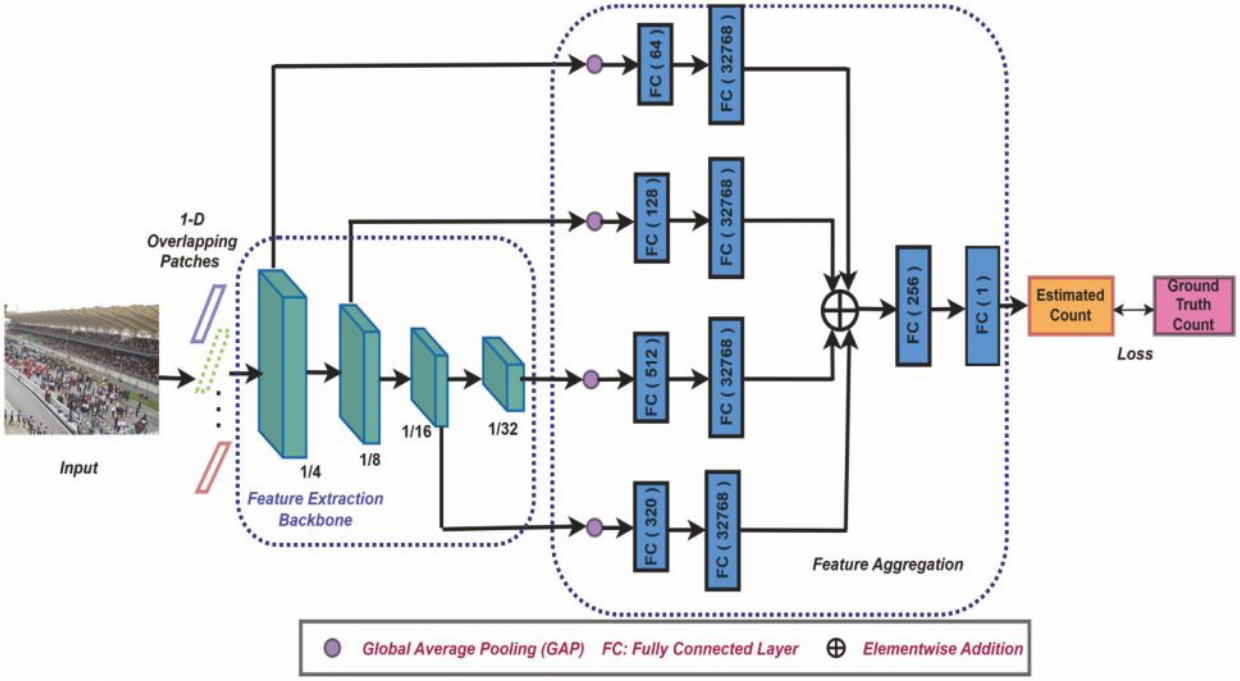


Fig.: The Proposed Model for Crowd Counting.

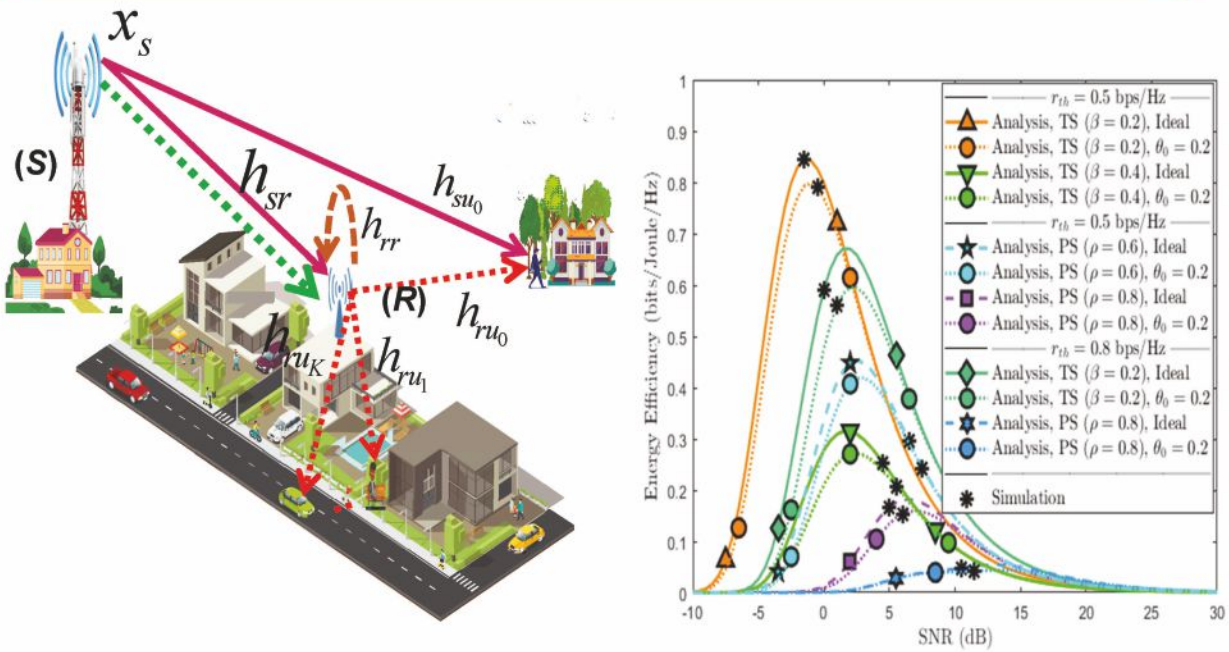
Automated crowd counting is a crucial subtask involved in crowd management to ensure public safety and security. While CNN-based methods excel in various computer vision tasks, including crowd counting, they lack global context. Vision transformers, capable of capturing global context, are underexplored in crowd counting. This work proposes a weakly-supervised method employing a pyramid vision transformer-based end-to-end model for crowd counting in a weakly-supervised setting. The transformer backbone extracts multi-scale features with global context and effectively captures the semantic crowd information. The MLP-based feature aggregation and regression head combine all the features effectively and regress the crowd count. Evaluations on benchmark crowd datasets demonstrate the effectiveness of the proposed method in crowd counting and its generalizability.

The work has been published in the Elsevier Journal of Visual Communication and Image Representation: Savner et al. J. Vis. Commun. Image Represent. (2023) 94, 103853.

Overlay Cognitive IoT-Based Full-Duplex Relaying NOMA Systems with Hardware Imperfections

Chandan Kumar Singh[1] and Prabhat Kumar Upadhyay[1]

[1]Department of Electrical Engineering, Indian Institute of Technology Indore, Indore, India.



Left Fig.: System model for full-duplex overlay cognitive NOMA (OCNOMA) system.
Right Fig.: Energy efficiency plot for FD OCNOMA in IoT network.

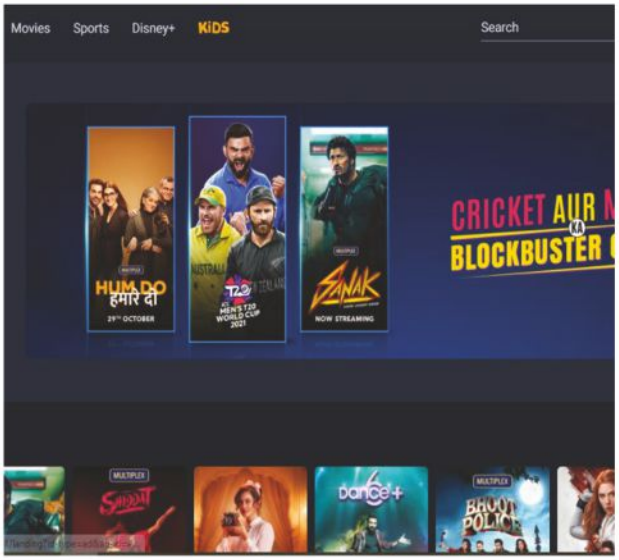
This work focuses on enhancing the spectral and energy efficiency of IoT networks using cognitive radio and NOMA techniques through an overlay cognitive NOMA (OCNOMA) system. It features a primary network and a secondary network with an energy-harvesting full-duplex (FD) secondary transmitter (ST) using a time-switching (TS)/power-splitting (PS) protocol to support its operations. The proposed cooperative spectrum-sharing transmission (CSST) scheme addresses FD self-interference, NOMA interference, and hardware impairments. Performance is analyzed under Nakagami-m fading, evaluating on outage probability, OCNOMA power allocation, throughput, and energy efficiency. The results highlight the proposed scheme's advantages for cognitive IoT networks and provide design guidelines for future-generation wireless communication systems.

The work has been published in the IEEE Internet of Things Journal: Singh et al., IEEE Internet Things J. (2022) 9, 6578-6596.

A Critical Political Economy Perspective on Indian Television: STAR, Hotstar, and Live Sports Streaming

Mahima Singh[1] and Akshaya Kumar[1]

[1] School of Humanities and Social Sciences, Indian Institute of Technology Indore, Indore, India.



Years	Broadcast Rights	Value	Digital Rights	Value
2012- 2018	Star Network (Star Sports)	$750 million	-	-
2018- 2023	Star Network	$944 million	Star Network	Inclusive

Table 3.1 The ownership of television rights for Indian cricket

(Home matches of the national team)

Years	Broadcast Rights	Value	Digital Rights	Value
2018- 2022	Star Network	$2.40 billion	Star Network	Inclusive
2023- 2027	Star Network	$3.05 billion	Viacom 18	$3.02 billion

Table 3.2 The ownership of television rights for IPL

Years	Broadcast Rights	Value	Digital Rights	Value
2015- 2023	Star Network	$ 1.9 billion (appx)	-	-
2024- 2027	Star Network	$ 3 billion (appx)	Star Network	Inclusive

Table 3.3 The ownership of television rights for ICC Matches

Left Fig.: The Hotstar homepage, featuring the IPL, representing the intrinsic value attributed to live sports streaming within the OTT market. **Right Fig.**: The ownership of broadcast rights for Indian Cricket, ICC matches and IPL representing Star TV's dominance in sports broadcasting.

The rise of OTT platforms has also resulted in a shift in Indian sports broadcasting, with live sports streaming emerging as a new way to watch sports events. There is a symbiotic relationship between sports and media. On the one hand, sports provide a great source of quality programs for media institutions; on the other hand, media assure them of the most reliable revenue stream. This study shows that while changes in the television ecosystem have occurred due to the launch of OTT platforms, television's political economy's fundamental structure has remained resilient. Despite the challenges posed by Internet distribution, legacy media conglomerates like Star continue to hold significant advantages that act as a barrier to diversity, particularly in sports broadcasting.

The work has been published in tripleC: Communication, Capitalism & Critique: Singh et al., triple C, (2023) 21 (1) 18-32.

Multistability, Chaos and Mean Population Density in a Discrete-time Predator-prey System

Rajni[1] and Bapan Ghosh[1]

[1]Department of Mathematics, Indian Institute of Technology Indore, Indore, India.

Model from the published paper[1]:

$$x_{n+1} = x_n + rx_n\left(1 - \frac{x_n}{K}\right) - \frac{\alpha x_n y_n}{h + x_n} - q_1 e_1 x_n \text{ and } y_{n+1} = y_n + \frac{\beta x_n y_n}{h + x_n} - m y_n - q_2 e_2 y_n$$

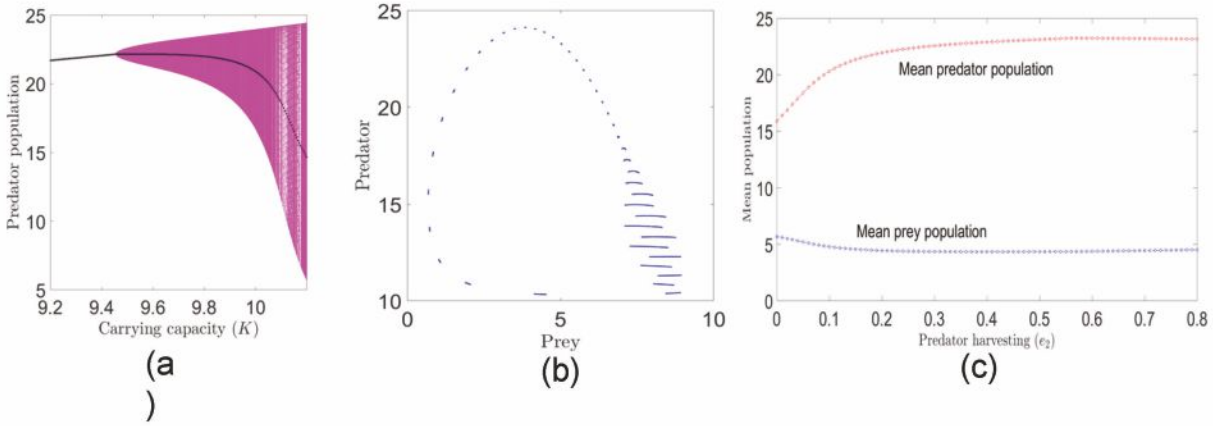


Fig: (a) Bifurcation diagram (in magenta color) and mean predator population (in black color). **(b)** Chaotic attractor. **(c)** The mean population of both species with increase in mortality rate of the predator.

This paper uses the forward Euler discretization scheme to investigate a discrete-time predator-prey system derived from the continuous-time Rosenzweig-MacArthur model with harvesting. Variations in the carrying capacity of the prey species reveal a Neimark-Sacker bifurcation, leading to destabilization of the system and showing complex behaviors like quasiperiodicity, periodic windows, period-bubbling, multistabilities, and chaos. The sufficient increase in nutrient supply to the prey species may paradoxically lead to predator on the verge of extinction, known as the "paradox of enrichment". Subjecting the system to prey and predator harvesting stabilizes the system, showcasing a counterintuitive "hydra effect" where predator biomass increases despite mortality.

The work has been published in Chaos, Solitons & Fractals: Rajni et al., Chaos Solit. Fractals, (2022) 162, 112497.

Enhanced rate performance and specific capacity in Ti-substituted P2-type layered oxide through structural modifications

Hari Narayanan Vasavan[1], Manish Badole[1], Sushmita Dwivedi[1], Deepu Kumar[2], Pradeep Kumar[2], and Sunil Kumar[1,*]

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[2] School of Basic Sciences, Indian Institute of Technology Mandi, Mandi, 175005, India.

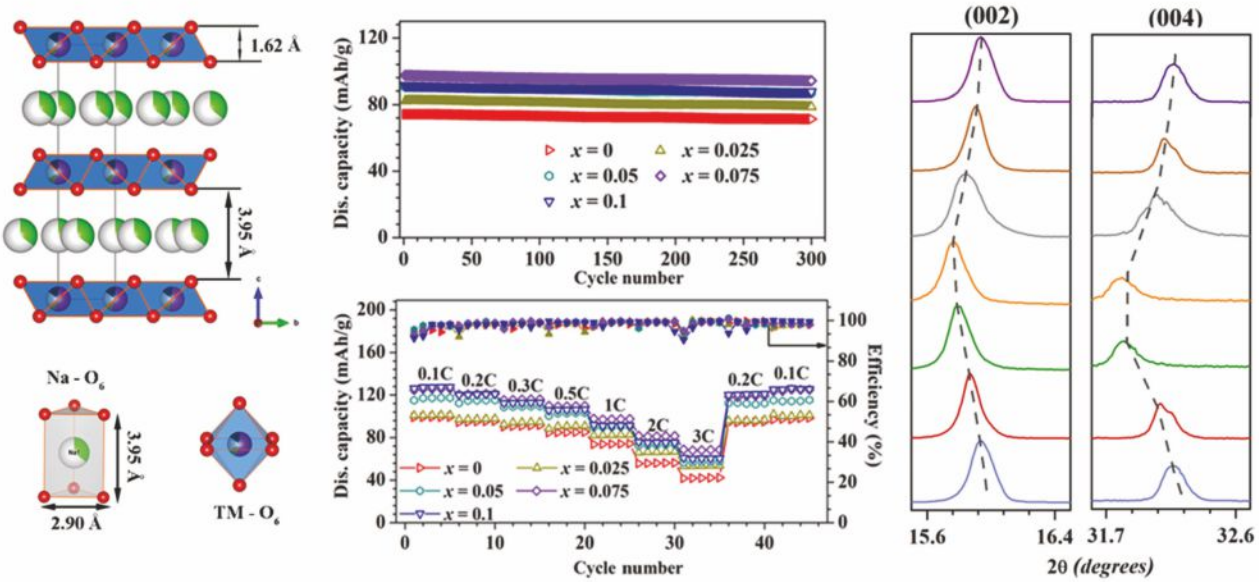


Fig. A representative image of the structure, electrochemical performance, and structural evolution of Ti-substituted P2-type layered oxide cathode during cycling.

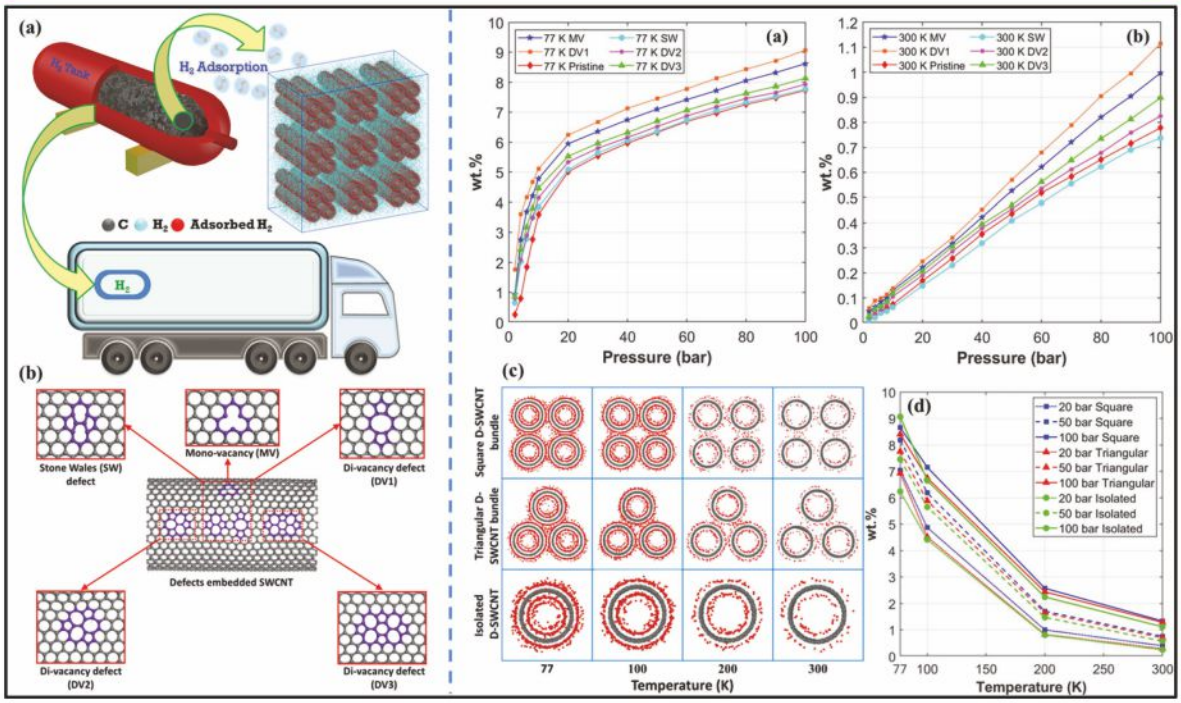
Through the modifications in crystal structure and particle morphology introduced by Ti substitution, a faster Na-ion diffusion was achieved in P2-$Na_{0.70}Ni_{0.20}Cu_{0.15}Mn_{0.65}O_2$, which significantly improved specific capacity and rate performance. At discharge rates of 0.1C and 1C $Na_{0.70}Ni_{0.20}Cu_{0.15}Mn_{0.575}Ti_{0.075}O_2$ showed a specific capacity of ~ 126 mAh/g and ~ 97 mAh/g, respectively, and retained ~ 96 % of its initial capacity even after 300 cycles at 1C. Excellent electrochemical properties and moisture-stable nature make these materials attractive candidates as cathodes for low-cost Na-ion batteries.

The work has been published in the Chemical Engineering Journal: Vasavan. et al., Chem Eng J (2022) 448, 137662.

Topological Defects Embedded Large-Sized Single-Walled Carbon Nanotubes for Hydrogen Storage: A Molecular Dynamics Study

Saurabh Mishra[1], Shailesh I. Kundalwal[1]

[1]Department of Mechanical Engineering, Indian Institute of Technology Indore, Indore, India.



Left Fig.: **(a)** An artistic illustration of a solid-state H_2 storage system using carbon nanotubes (CNTs), **(b)** schematic illustration of studied topological defects. **Right Fig.**: **(a)** & **(b)** Calculated H_2 adsorption isotherms of isolated CNTs, **(c)** equilibrium snapshots showing distribution of adsorbed H_2, **(d)** gravimetric H_2 density of DV1-defected CNT bundles.

Experimental studies found that CNTs typically contain many topological defects due to the intrinsic limitations of synthesis and purification processes. This work reports the H_2 adsorption metrics of large-sized defected CNTs (D-CNTs) and their bundles using molecular dynamics simulation implemented with a novel potential energy distribution method. Despite having reduced mechanical properties, D-CNTs have a higher H_2 storage capacity than their pristine counterparts, owing to increased porosity and the emergence of narrow cavities surrounding defective sites.

The work has been published in the International Journal of Hydrogen Energy: Mishra et al., Int. J. Hydrog. Energy, (2022) 47(86) 36605-36621.

Performance prediction of an axial piston pump with increasing severity of leakage fault in single and multiple cylinders

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[2]Microfluidic and Droplet Dynamics Lab, Department of Mechanical Engineering, Indian Institute of Technology, Indore, Madhya Pradesh 453552, India

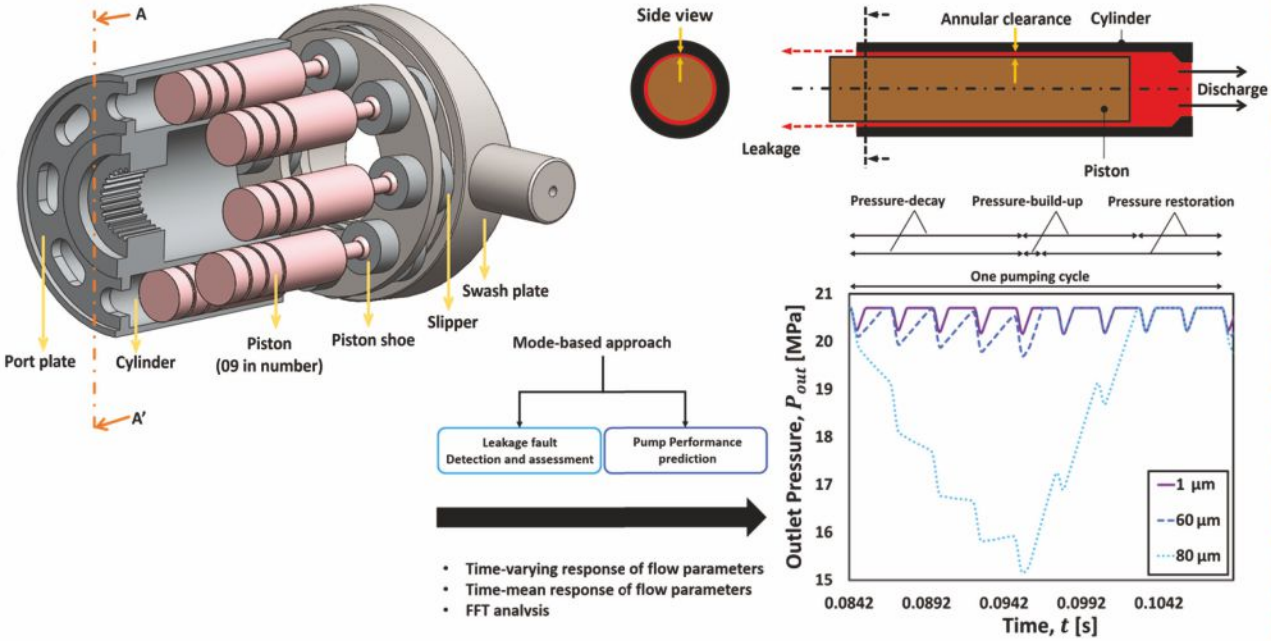

Fig: An iso-view of the axial piston pump with 9 cylinders (Left). The methodology for leakage fault diagnosis of the pump is shown on the (Right).

Wear-induced leakage past the piston-cylinder clearance significantly impairs the performance of axial piston pumps (APPs) in various forms. The study simulated oil leakage faults in single and multiple cylinders, revealing a deepening concave dip in the pressure waveform with increasing fault severity. Simulations covered three fault severity levels (5 µm, 100 µm, and 200 µm) and four external load levels (5 MPa, 10 MPa, 15 MPa, and 23.5 MPa). Results highlight the efficacy of frequency analysis of discharge pressure signals for fault identification. A more evenly distributed leakage fault among cylinders corresponds to reduced amplitude pressure fluctuations at the discharge.

The work has been published in The Journal of Dynamic Systems, Measurement, and Control; Gupta et al., J. Dyn. Sys., Meas., Control,145(2): 021001 Paper No: DS-21-1265.

Raman Spectroscopy as a Simple yet Effective Analytical Tool for Determining Fermi Energy and Temperature Dependent Fermi Shift in Silicon

Chanchal Rani[1], Manushree Tanwar[1], Tanushree Ghosh[1], Suchita Kandpal[1], Devesh K. Pathak[1], Anjali Chaudhary[2], Priyanka Yogi[3], Shailendra K. Saxena[4] and Rajesh Kumar[1,5]

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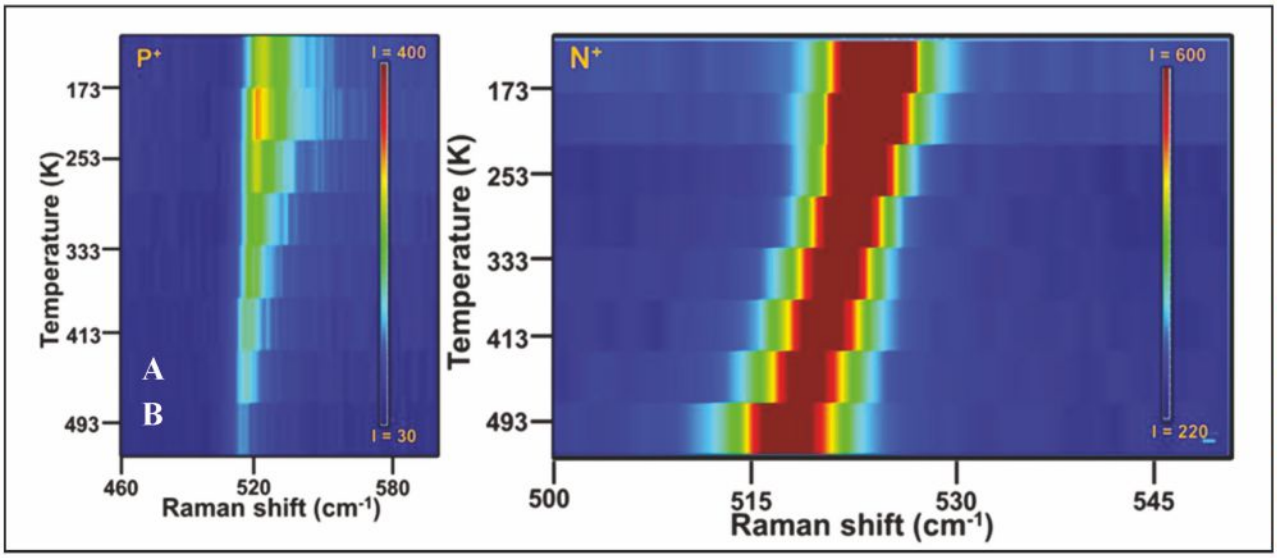


Fig.: Thermal Raman map from heavily doped (A) p-type silicon and (B) n-type silicon wafer

Fermi energy depends on doping concentration and temperature. Raman spectroscopy proves to be an effective tool to determine the position of Fermi level. It can be estimated using Raman spectroscopy if one can deconvolute the association between the Fermi energy and Fano interaction strength. Raman lineshape from a system having Fano resonance is asymmetrically broadened and often shows atypical temperature dependence which can be utilized for calculating the value of Fermi-energy.

The work has been published in Analytical Chemistry: Rani et al., Anal. Chem., 94 (2022) 1510.

Inauguration of 'Centre for Translation Research' & Launch of 'A Handbook of Ideas, Innovations and Technologies of IIT Indore'

IIT Indore celebrated its 15th Foundation Day on 17th February 2024. On this occasion, Centre for Translation Research was inaugurated by Dr. Abhay Karandikar, Secretary, Department of Science & Technology.

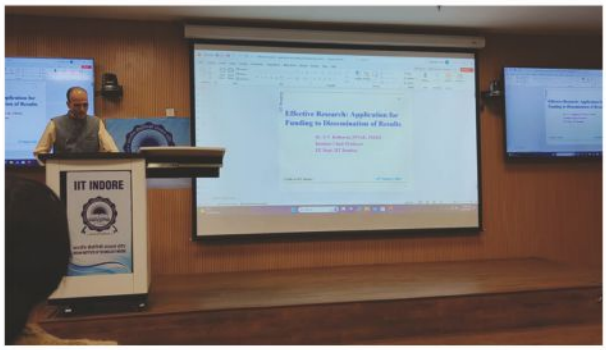
The centre has been established to formalize the translation research ecosystem and extend the commercialization of technology from research to the product stage.

Five translational research fellowships have been awarded for upgrading the current technologies to Higher TRLs to bring out market-ready products which were showcased.

On this occasion, *'A Handbook of Ideas, Innovations and Technologies of IIT Indore'* was also launched by Dr. Karandikar. This handbook consists of around 120 technologies which are at different level of Readiness.

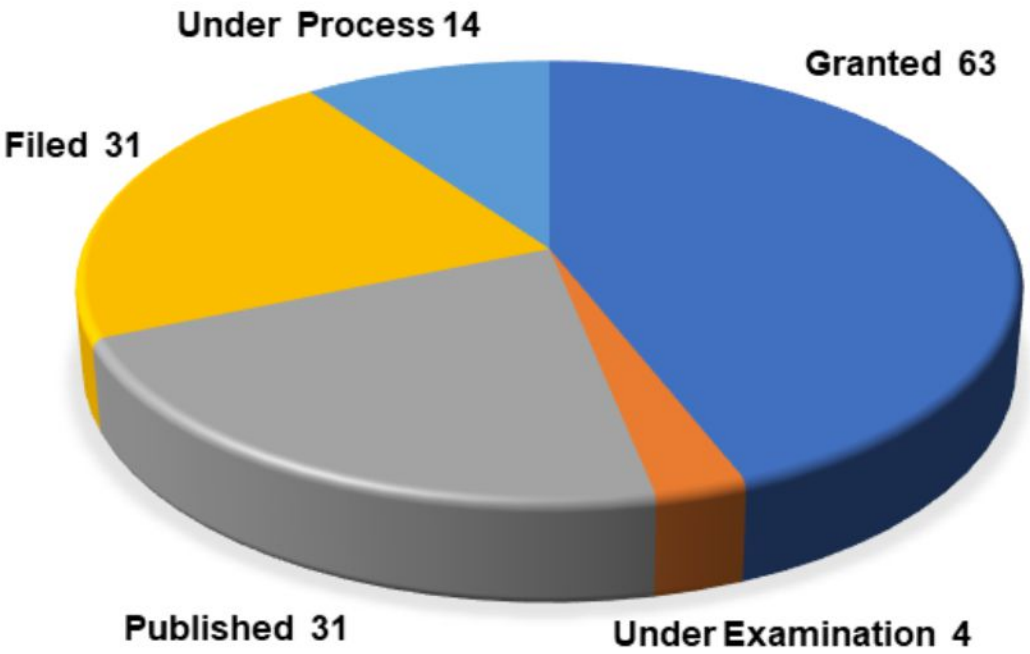
Research Initiatives by IIT Indore

Office of Research & Development organized an expert talk by Prof. S.V. Kulkarni (Institute Chair Professor, Department of Electrical Engineering, IIT Bombay) titled "Effective Research: Application for funding to Dissemination of Results" on 12th January 2024. In his talk, Prof. Kulkarni enlighten about writing an effective research proposal and research ethics.



Office of Research & Development organized a Workshop on "Research Protection and Dissemination: IPR Fundamentals and Management in Academia" on 03 February 2024. The resource person for the workshop was Dr. Padma Satish IIT Bombay. Dr. Shatish discussed about the Types of IPRs and ways of their protection; Effective use of IPRs in Academia and Dos and Don'ts during Patent drafting and filing.

Patents by IIT Indore



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