RESEARCH SPECTRUM

A COMPENDIUM OF GRAPHICAL ABSTRACTS ILLUSTRATING RESEARCH AT IIT INDORE

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Prof. Avinash Sonawane
Prof. Shaibal Mukherjee
Dr. Surya Prakash

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 fourth 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 the 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 members 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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SWASTi-SW: Space Weather Adaptive SimulaTion Framework for Solar Wind and Its Relevance to the Aditya-L1 Mission

Prateek Mayank[1], Bhargav Vaidya[1], D. Chakrabarty[2]

[1] Department of Astronomy, Astrophysics and Space Engineering, Indian Institute of Technology Indore, India. [2] Space and Atmospheric Sciences Division, Physical Research Laboratory, Ahmedabad, India.

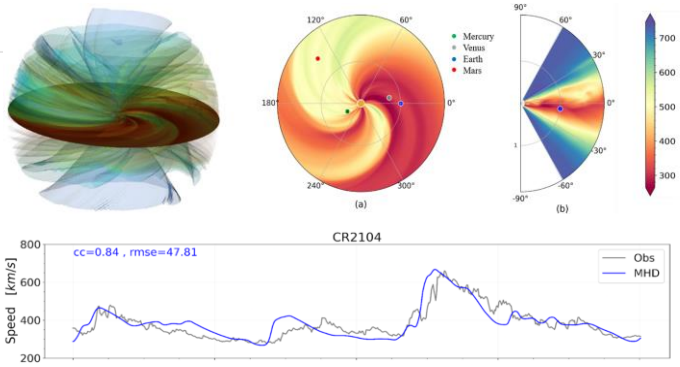


Fig. 1: 3D and 2D views of simulated solar wind structure using SWASTi framework. The shown colormap is for solar wind speed whose comparison with observation has been shown in bottom subplot.

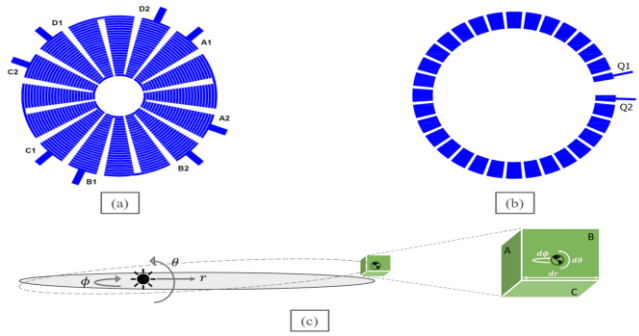


Fig. 2: Schematic diagrams of (a) THA-1, (b) THA-2 of SWIS-ASPEX ADITYA L1, and (c) the computational surfaces (A, B, and C) covering the openings of detectors. Surfaces A and B cover the THA-1, and C covers the THA-2.

This work introduces an indigenous 3D solar wind model (SWASTi-SW) that combines a semiempirical coronal model with a physics-based inner heliospheric model to study and forecast solar wind properties. By refining the WSA relationship, it estimates solar wind speeds at 0.1 AU using synoptic magnetograms. These inputs determine solar wind plasma properties for the heliospheric model, which predicts conditions from Mercury to Mars and beyond up to 2.1 AU. Validation covers multiple Carrington rotations, examining variations in specific heat ratio and stream interaction regions (SIRs), providing multidirectional SIR features and synthetic measurements for ISRO's Aditya-L1 mission payload.

The work has been published in The Astrophysical Journal Supplement Series: Mayank et al., ApJS (2022) 262:23.

Small Molecule Screening Discovers Compounds that Reduce FMR Poly-G Protein Aggregates and Splicing Defect Toxicity in Fragile X-Associated Tremor/Ataxia Syndrome

Arun Kumar Verma, Eshan Khan, Subodh Kumar Mishra, Amit Kumar

Department of Biosciences and Biomedical Engineering, Indian Institute of Technology Indore, India.

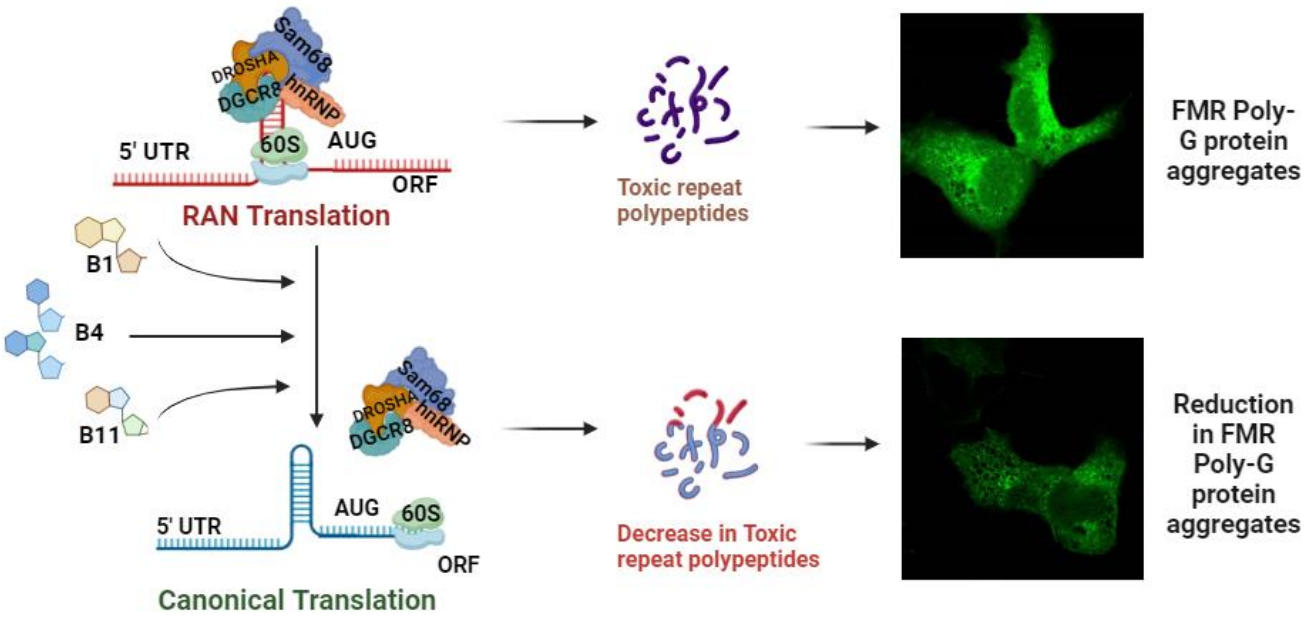


Fig: Flow diagram defining the working and functionality of the small molecules against Fragile X-associated tremor/Ataxia Syndrome.

The study utilized a small chemical library of around 2,50,000 members from the National Cancer Institute (NCI) to search for potential compounds that reduces toxic CGG RNA-mediated pathogenesis. The screened compounds were subsequently evaluated for their affinity and selectivity towards toxic CGG repeats RNA. Next, these lead small molecules addressed pre-mRNA alternative splicing abnormalities while retaining global splicing efficacy. They also inhibited FMR1 Poly-G protein aggregation without influencing the gene's downstream expression. Through this study, we explored compounds - B1, B4, and B11 as prospective lead molecules for developing novel FXTAS therapies. We thus found a potential candidate that improves pre-mRNA splicing defects and reduces FMR1polyG aggregations.

The work has been published in the Journal of Molecular Neurobiology: Verma et al., Mol. Neurobiol. (2022) 59, 1992-2007.

Self-assembled Benzoselenadiazole-capped Tripeptide Hydrogels with Inherent *In Vitro* Anticancer and Anti-inflammatory Activity

Tapas Ghosh,[1] Shu Wang,[2] Dharmendra Kashyap,[3] Rohit G. Jadhav,[1] Tanmay Rit,[1] Hem Chandra Jha,[3] Brian G. Cousins,[2] Apurba K. Das*[1]

[1]Department of Chemistry, Indian Institute of Technology Indore, India. [2]Department of Chemistry, Loughborough University, Loughborough LE11 3TU, UK. [3]Department of Biosciences and Biomedical Engineering, Indian Institute of Technology Indore, India.

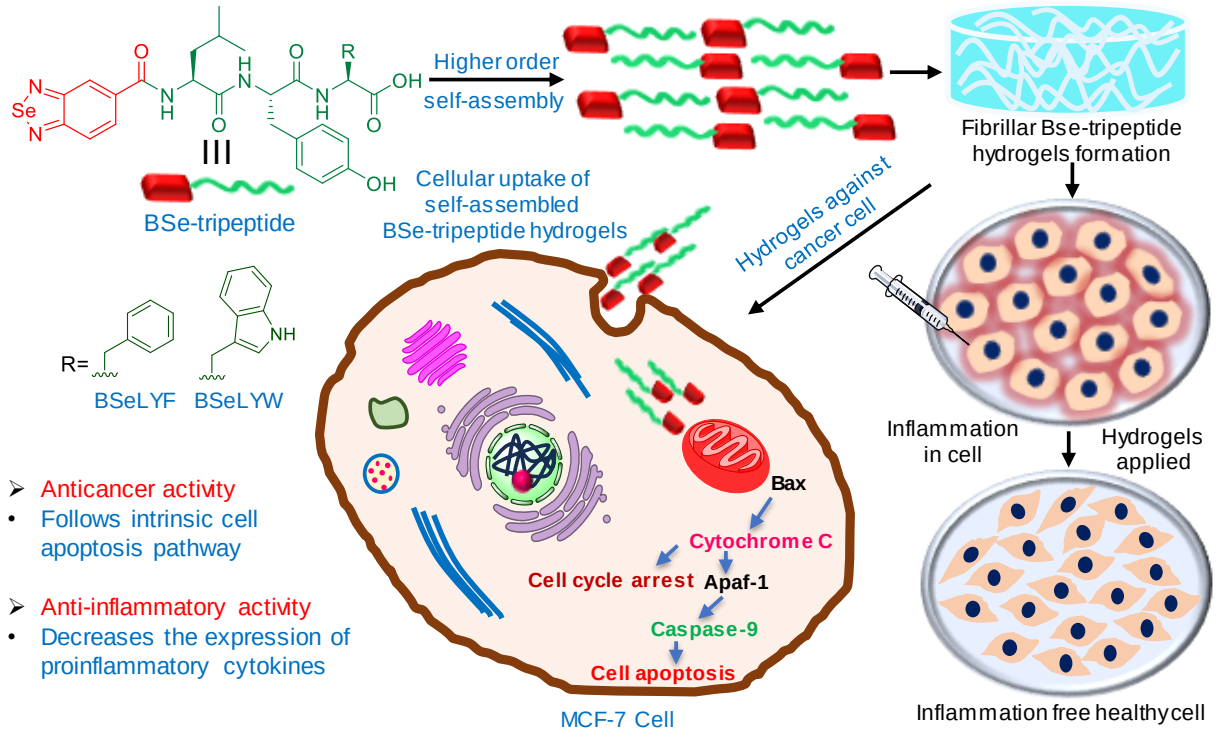


Fig.: Graphical presentation of the formation of nanofibrillar hydrogels by self-assembled BSe-capped tripeptides and their anticancer and anti-inflammatory activities.

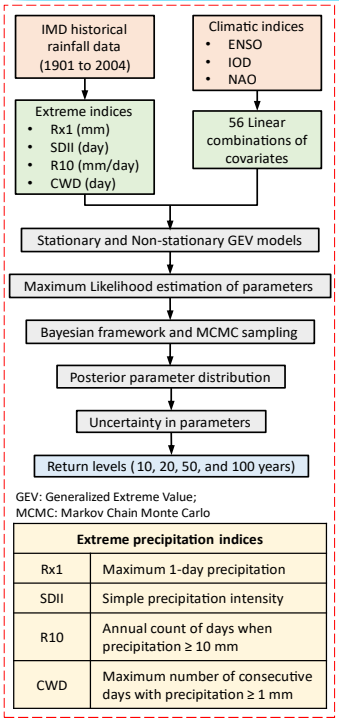
Cancer and related mortality are one of the most alarming situations for the mankind worldwide. Malignant tumor cells are prone to develop resistance to chemotherapy drugs, which creates hurdle in the cancer treatment. In this study, we developed benzoselenadiazole-capped tripeptide hydrogels (BSeLYF and BSeLYW) and investigated their anticancer and anti-inflammatory activities. These hydrogels cause cancer cell death through an intrinsic pathway and suppress the levels of proinflammatory cytokines (*TNF-α* and *IL-6*), demonstrating anti-inflammatory activity.

The work has been published in the Chemical Communications: Das et al., Chem. Commun. (2022) 58, 7534-7537.

Climate Change Impact on Precipitation Extremes Over Indian Cities: Non-stationary Analysis

Manish Kumar Goyal[1], Anil Kumar Gupta[2], Srinidhi Jha[1], Shivukumar Rakkasagi[1], Vijay Jain[1]

[1]Department of Civil Engineering, Indian Institute of Technology Indore, India. [2]National Institute of Disaster Management, New Delhi, India.



Extreme precipitation indices	
Rx1	Maximum 1-day precipitation
SDII	Simple precipitation intensity
R10	Annual count of days when precipitation ≥ 10 mm
CWD	Maximum number of consecutive days with precipitation ≥ 1 mm

Fig.1: Schematic flowchart depicting the methodology.

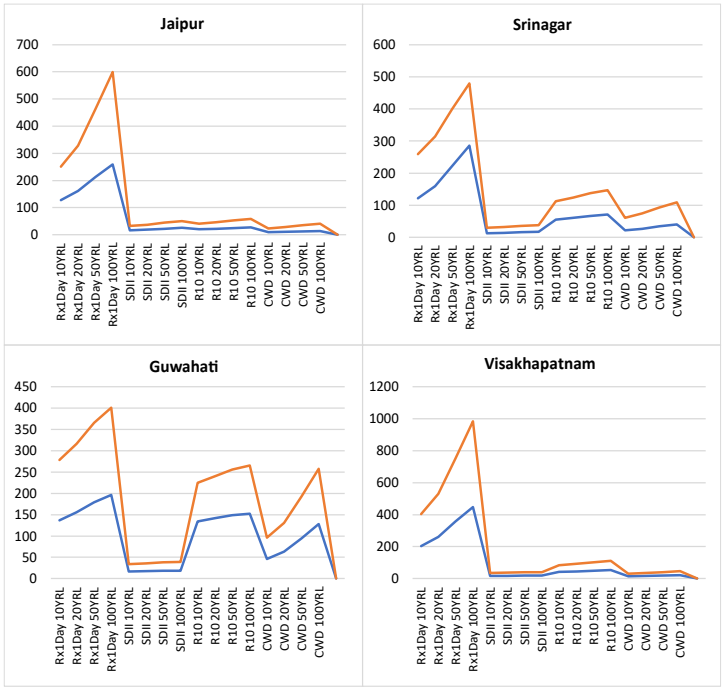


Fig. 2: The return levels for stationary and non-stationary conditions over each city during 10-, 20-, 50-, and 100-year periods.

This study attempts a city-level analysis of projected extreme precipitation events to enhance urban flood resilience. This study represents a novel application of non-stationary extreme value analysis integrated with the Bayesian uncertainty approach to examine extreme precipitation at a city level in India. The comparison between stationary and non-stationary analysis revealed increased extreme precipitation events in these cities. This deeper understanding of the relationship between large-scale climate oscillations and heavy rainfall can improve risk assessment and policymaking to protect vulnerable populations from extreme events.

The work has been published in the Technological Forecasting and Social Change: Goyal et al., Technol. Forecast. Soc. Change (2022) 180: 121685.

Adaptation of Pair-Polar Structures to Compute a Secure and Alignment-Free Fingerprint Template

Vivek Singh Baghel[1], Syed Sadaf Ali[2], Surya Prakash[1]

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

[2]ETIS, ENSEA, CY Cergy Paris Université, CNRS, Cergy, France.

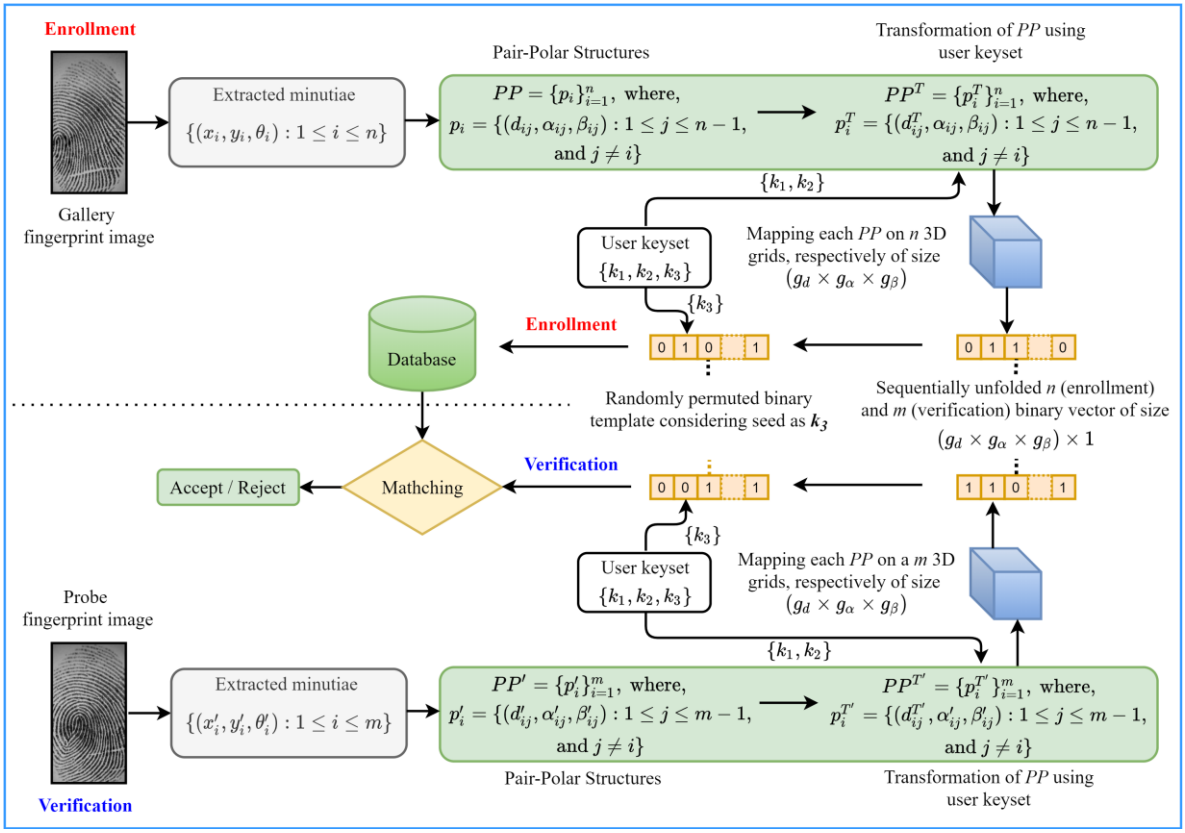


Fig.: A schematic diagram of the proposed secure fingerprint authentication system.

This work proposes a novel approach to generate the non-invertible fingerprint template utilizing the alignment-free features extracted from the pair-polar structures of minutiae. In the proposed approach, the generated secure fingerprint templates are in the form of binary vectors. The computation of binary vectors has been performed by many-to-one mapping of transformed features into 3D grids. The proposed approach has been evaluated considering revocability, unlinkability, security, and performance on publicly available fingerprint databases. The obtained results demonstrate the robustness and effectiveness of the proposed approach.

The work has been published in the IEEE Transactions on Industrial Informatics: Baghel et al., IEEE Trans. Indust. Inform. (2023) 19 (2): 1947-1956.

IoT Enabled Real-Time Monitoring NO_2 Gas Sensor

Chandrabhan Patel[1], Sumit Chaudhary[1], Mayank Dubey[1], Shaibal Mukherjee[1,2,3]

[1]Hybrid Nanodevice Research Group, Department of Electrical Engineering, Indian Institute of Technology Indore, India. [2]Centre for Advanced Electronics, Indian Institute of Technology Indore, India. [3]Centre for Rural Development and Technology, Indian Institute of Technology Indore, India.

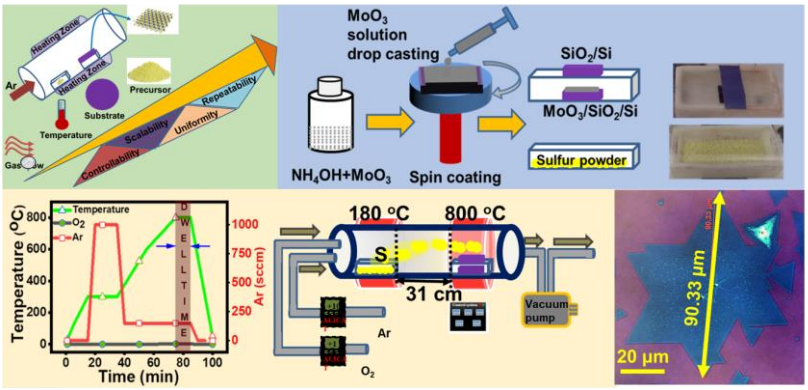


Fig.1: Realizing quantum sensing material via optimized commercially feasible growth recipe in a CVD system.

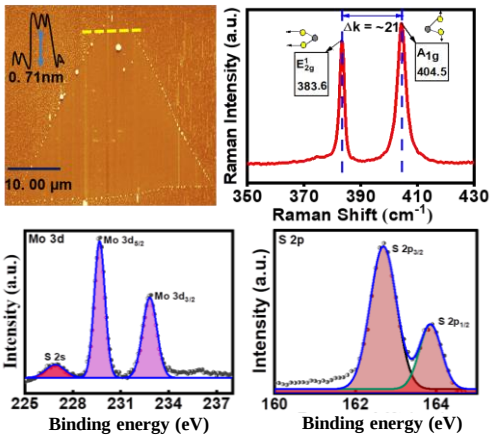


Fig.2: Validation of quantum material via AFM, Raman and XPS.

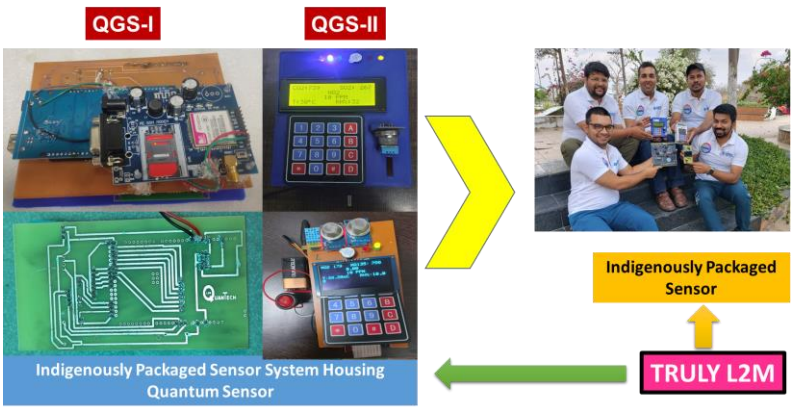


Fig.3: In-house developed IoT-based architecture delving in a lab-to-market approach.

Fig.4: Developed android mobile application for real-time monitoring.

The work delves into the synthesis of a uniform and repeatable quantum sensing material via CVD, which is still a major bottleneck owing to strong dependence on diverse associated growth parameters. In this work, we have proposed the most viable recipe which is suitable for controlling the nucleation density and producing upto 90 µm-long monolayer crystal and (695×394.8) μm^2 large monolayered films on SiO_2/Si substrate. The sensing performance has been thoroughly investigated for NO_2 exposure at room temperature, affirming ultra-sensitivity of the films. Further, an IoT-enable architecture is designed and developed for real-time monitoring of the sensors.

The work has been published in the ACS Applied Nano Materials: C. Patel et al., ACS Appl. Nano Mater. (2022) 5: 9415-9426.

Optical Reflecting Surface-Assisted Optical Space Shift Keying-Based MIMO-FSO System

N. Vishwakarma[1], Swaminathan R[1], P. D. Diamantoulakis[2], G. Karagiannidis[2]

[1]Department of Electrical Engineering, Indian Institute of Technology Indore, India, [2]Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece.

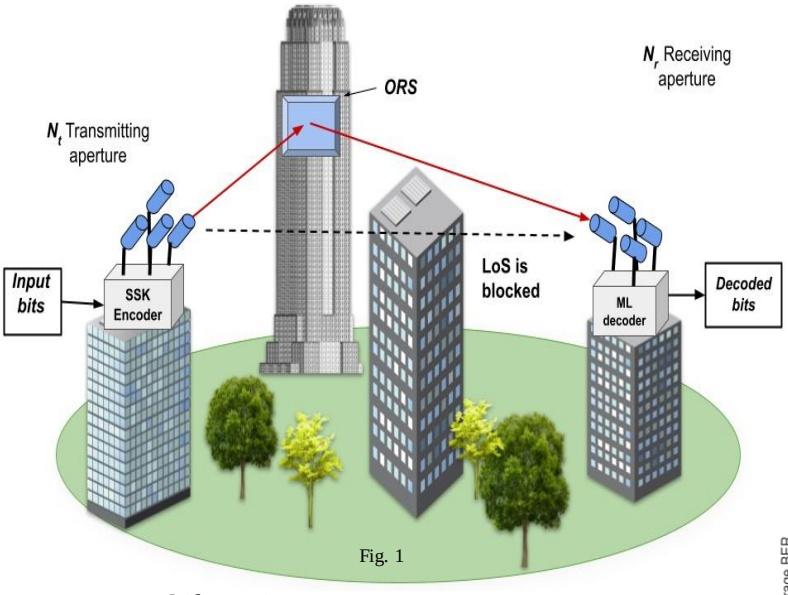


Fig. 1

SSK - Space Shift Keying
ML Decoder – Maximum Likelihood Decoder

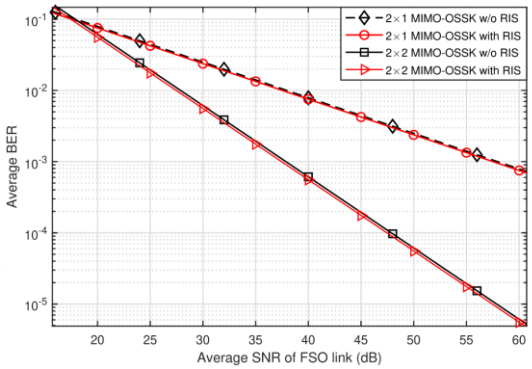


Fig. 2(a)

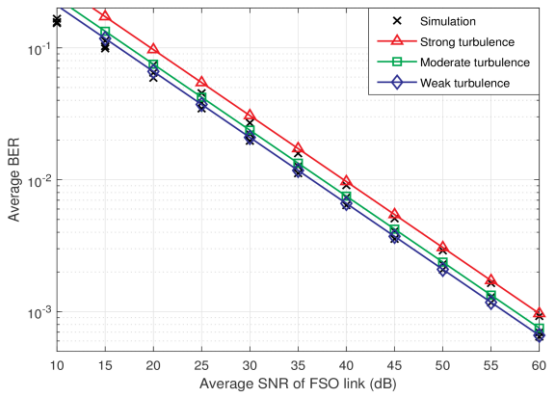


Fig. 2(b)

Fig.1: ORS-assisted OSSK-based FSO system.
Fig.2(a): BER comparison with and without ORS.
Fig.2(b): BER with different turbulence conditions.

Optical reflecting surface (ORS) is a promising technique to provide an alternate path for free space optical (FSO) data transmission with enhanced coverage if a line-of-sight (LoS) link is blocked due to obstacles. In this study, we propose an ORS-assisted FSO communication system based on optical space shift keying (OSSK) technique and investigated the performance in terms of average bit error rate (BER) and ergodic capacity. It is observed that in the absence of the LoS link, the proposed system can create a virtual LoS link with better performance than the FSO system without ORS.

The work has been published in the IEEE Transactions on Communications: Vishwakarma. et al., IEEE Trans. Commun. (2023) 71 (8), 4751-4763.

Assessing District-level Climate Vulnerability in Madhya Pradesh, Central India: An Integrated Environmental and Socio-economic Approach

Amit Kumar, Mohanasundari T.*

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

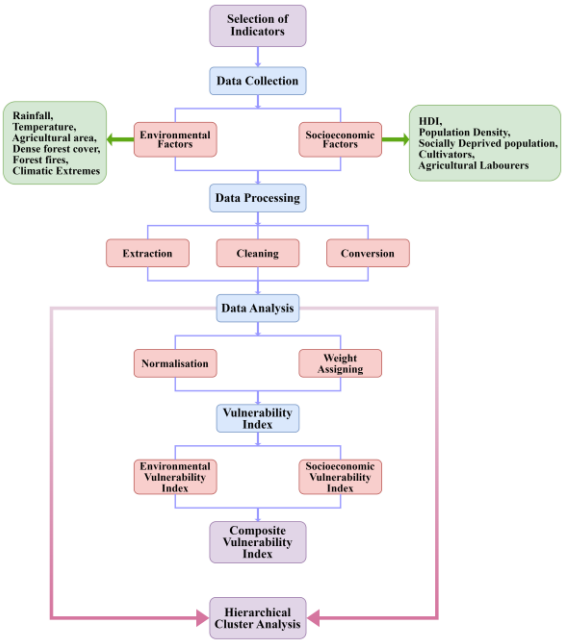


Fig.1 :Comprehensive methodology Flowchart.

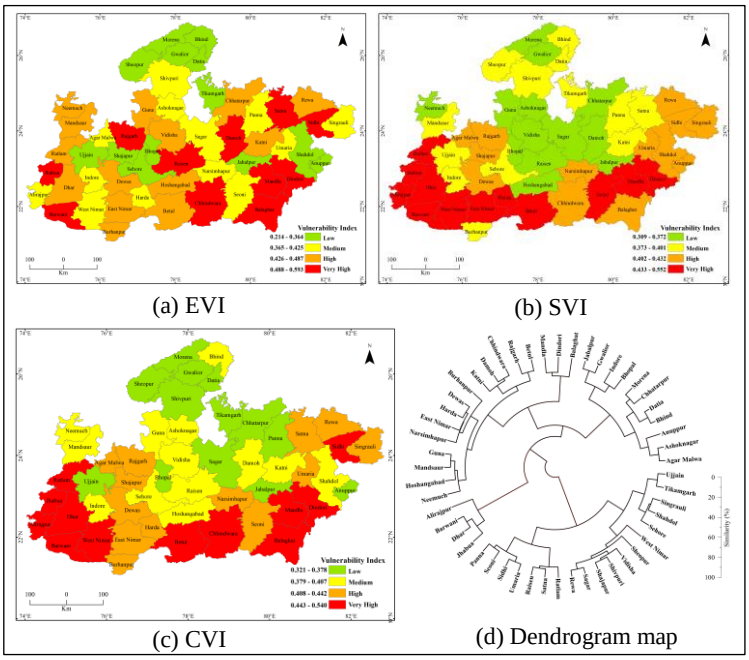


Fig.2: District-wise Vulnerability map and Cluster map; (a) Environmental (EVI), (b) Socio-economic (SVI), (c) Composite (CVI), (d) Dendrogram.

This study evaluates district-level climate vulnerability in Central India by integrating Environmental and Socio-economic factors. Using 8 environmental and 5 socio-economic indicators, it employs a multidimensional approach to develop the Environmental Vulnerability Index (EVI), Socio-economic Vulnerability Index (SVI), and Composite Vulnerability Index (CVI). Lower CVI districts like Gwalior, Jabalpur, and Bhopal exhibit decreased vulnerability, while higher CVI districts like Narsimhapur and Barwani face notable susceptibility due to factors such as agricultural dependence and social deprivation. Hierarchical cluster analysis validates vulnerability classifications, emphasizing the need for comprehensive vulnerability assessments to guide adaptive strategies.

The work has been published in Theoretical and Applied Climatology: Kumar et al., Theor. Appl. Climatol. (2024) 155, 3449–3471.

Pseudospectra and Stability Radii and their Relationship with Backward Error for Structured Nonlinear Eigenvalue Problems

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Department of Mathematics, Indian Institute of Technology Indore, India.

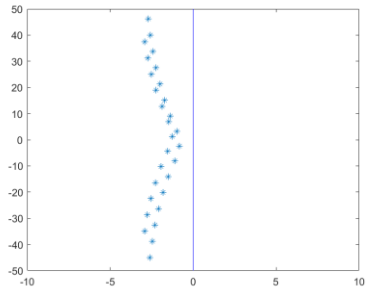

Fig.: Spectrum of delay problem.

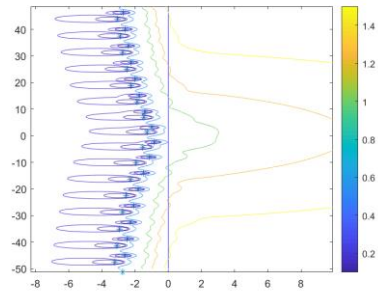

Fig.: Unstructured pseudospectra of delay problem.

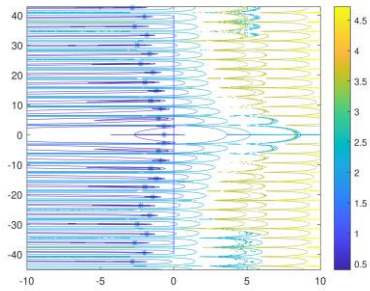

Fig.: Hermitian pseudospectra of delay problem.

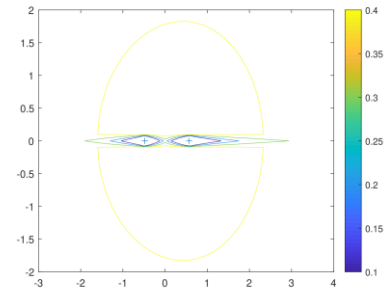

Fig.: Hermitian pseudospectra of matrix pencil.

This paper discusses pseudospectra and stability radii for structured nonlinear matrix functions, such as Hermitian, skew-Hermitian, H-even, H-odd, complex symmetric, and complex skew-symmetric. To compute pseudospectra and stability radii, eigenvalue backward error is required. Hence, we initially present the structured eigenvalue backward error. Subsequently, we compute the structured pseudospectra using the obtained results for the eigenvalue backward error of a class of structured nonlinear matrix functions. Finally, we discuss the stability radii of the above-structured problems arising in different applications. The paper also generalizes the results on the eigenvalue backward error of matrix polynomials in the literature for the above structures.

The work has been published in the Journal Mathematical Methods in the Applied Sciences: Ahmad et al., Math. Meth. Appl. Sci. (2024) 1-25.

Understanding the Deformation Behavior of Metallic and Nano-glasses using Indentation

Abhinav Sharma[1], Horst Hahn[2], S.H. Nandam[2,3], Eswara Prasad Korimilli[1]

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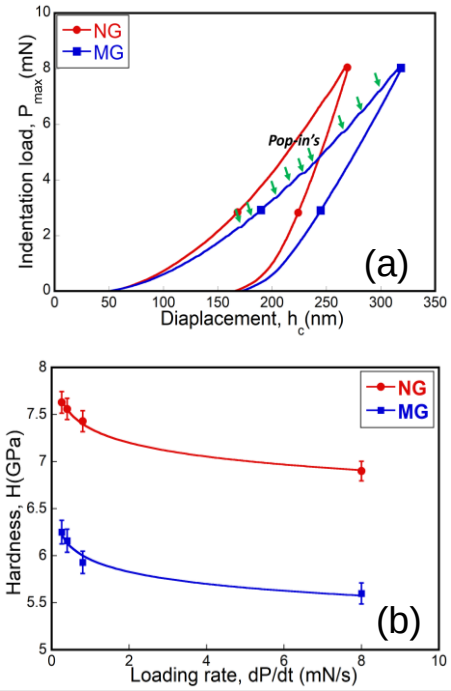

Fig. 1: (a) Representative nano-indentation load *vs.* displacement curves of a binary MG and NG and (b) their hardeness variation with loading rate.

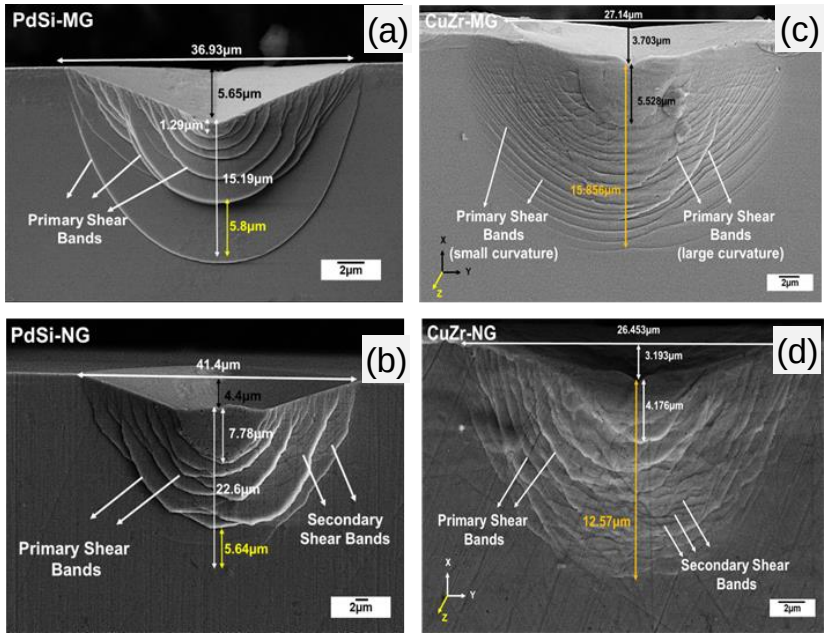

Fig. 2: Subsurface deformation zones of Pd-Si based MG and NG presented respectively in (a) and (b) while Cu-Zr based MG and NG in (c) and (d), respectively emphasizing the differences in shear band mediated plastic flow.

The study emphasizes the differences in the deformation behavior of Nanoglasses (NGs) (a new class of amorphous alloys) and their conventional metallic glass (MG) analogs. NGs contain unique microstructure with amorphous grains surrounded by amorphous interfaces. Nanoindentation experiments on NGs and MGs reveal that NGs exhibit a higher hardness. The plastic flow underneath the indentation of NGs and MGs having identical composition is analyzed using bonded interface indentation clearly shows that the strain partitioning into a large number of shear bands is the possible reason for the enhanced plasticity of these in NGs as compared to MGs.

The work has been published in the Scripta Materialia: A. Sharma et al., Scr. Mater. 191 (2021) 17–22.

Solar Energy Harvesting using Lead-free Pyroelectric Bulk Ceramics: A Simulation Study

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[1]Department of Mechanical Engineering, Indian Institute of Technology Indore, India. [2]School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798, Singapore.

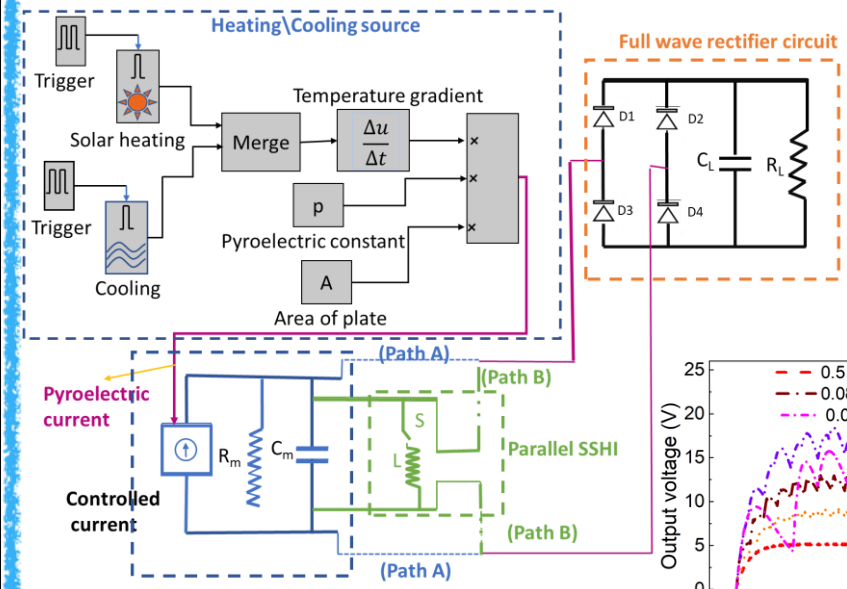

Fig.2: Schematic of the solar energy harvesting based electrical equivalent circuit of pyroelectric material for full-wave rectifier circuit (FWR) path A and parallel synchronized switch harvesting on inductor (P–SSHI) with FWR path B.

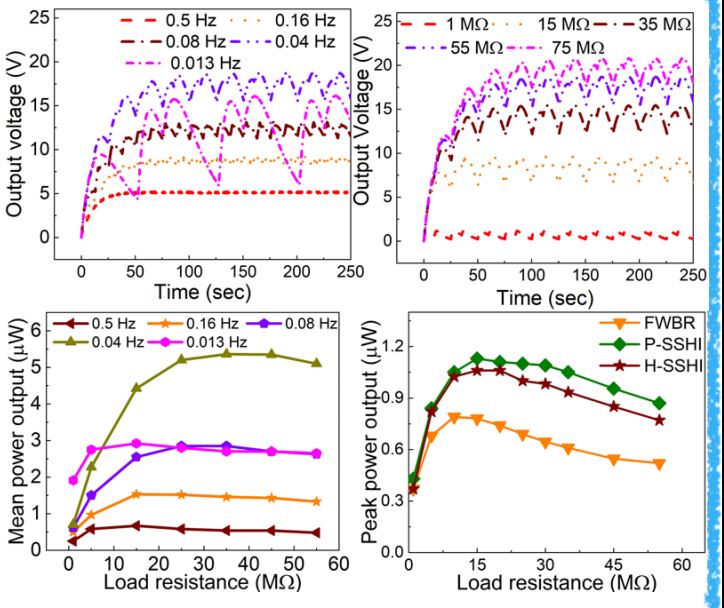

Fig.1: Variation of output voltage (a) at different frequencies (35 MΩ and 1 μF) (b) at different R_L at 0.04 Hz and 1 μF, peak power versus different load resistance (R_L) (c) at various frequency (FWR) and (d) different power-enhancing circuits (0.5 Hz and 1 μF) La-NBT-BT-Ta.

The current study evaluates various lead-free pyroelectric materials for solar energy harvesting. Solar radiation was employed as a heat source, while natural airflow rate produced the necessary heating/cooling operations. La-NBT-BT-Ta is the most effective pyroelectric material providing a maximum voltage of 35 V at 1 μF under no-load conditions. The effect of frequency, load resistance, capacitance and nonlinear electrical circuit were analyzed to enhance power. Thus, these approaches can potentially improve effectiveness of pyroelectric materials-based solar energy harvesting materials.

The work has been published in the Journal of Science: Advanced Materials and Devices: Saurabh et al. JS: AMD (2023) 8.1: 100527.

Unraveling the Magnetic Ground State and Local Lattice Distortion in Z_2XY-type Full Heusler Compounds: An EXAFS Study

Tamalika Samanta[1], Velaga Srihari[2], P. A. Bhobe[3*]

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[2]High Pressure and Synchrotron Radiation Physics Division, Bhabha Atomic Research Centre, Mumbai, India.
[3]Department of Physics, Indian Institute of Technology Indore, India.

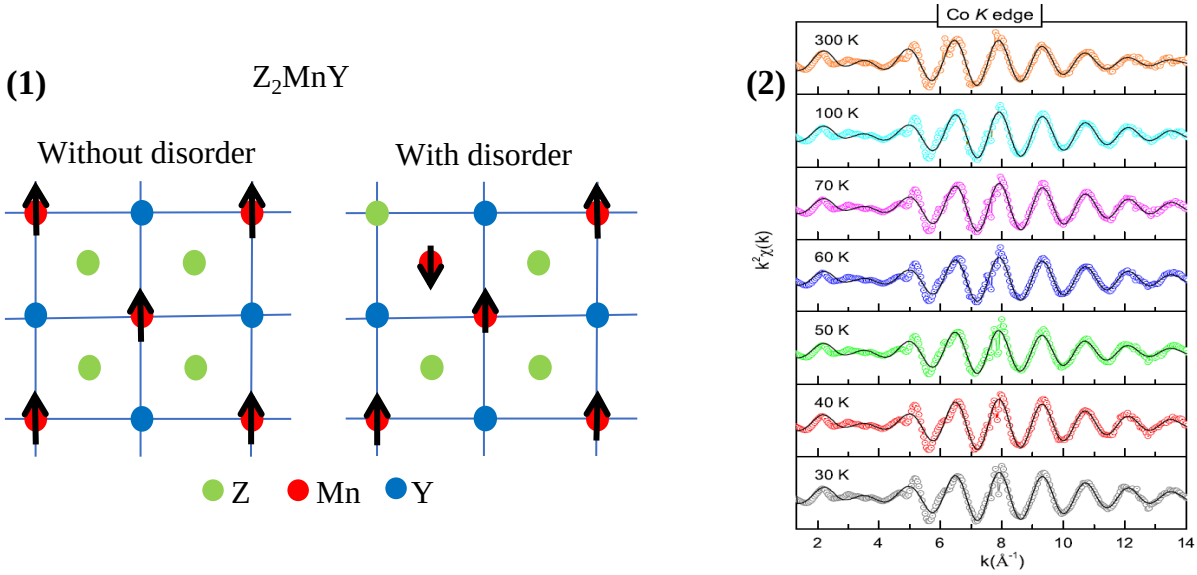

Fig.1: Schematic representation of arrangement of atoms in Heusler alloys and corresponding magnetic integrations.

Fig.2: Temperature dependent EXAFS of Ga_2MnCo for Co-edge.

This is a study of the relationship between magnetic properties and local structural order in non-traditional Heuslers, achieved by reversing its chemical formula from X_2YZ to Z_2XY. Our findings indicate that these systems do not adopt the typical FCC crystal structure with ferromagnetic ordering. Instead, a highly unusual re-entrant cluster glass magnetic state is observed. As the magnetic order is driven by the RKKY-type interaction that strongly depends on the separation between the X/Y atoms, we undertook a study of its local crystal structure using EXAFS.. We find unusual anti-site disorder between X/Y atoms, that leads to competing FM and AFM, and the resultant glassy magnetism.

The work has been published in the Journal of Physical Chemistry C: Samanta et al., J. Phys. Chem. C (2022) 126, 17670−17679.

Inauguration of 'Centre for Experiential Learning on Innovation, Technology and Entrepreneurship (C-ELITE)'

As part of the upcoming campus at Ujjain, IIT Indore inaugurated three state-of-the-art labs under *Centre for Experiential Learning on Innovation, Technology and Entrepreneurship (C-ELITE)* in Ujjain Engineering College on 8th March 2024. The inauguration was done by Dr. Mohan Yadav, Honorable Chief Minister of Madhya Pradesh.

The labs include Makers' Space, Heritage and Innovation Centre in Astronomy and Space Engineering (HICASE) and Laser Engineering.

The upcoming campus at Ujjain aligns with the National Education Policy-2020 and envisions a Deep Tech Research and Discovery Campus built on the pillars of research and innovation. The campus will include Deep Tech Research Laboratories, a Discovery Center, a Lab-to-Market Center, and a Center for New and Emerging Technologies, supporting real-life products through Lab-to-Market Incubation and entrepreneurship center, benefitting engineering students from state colleges.

In another initiative, Shri Dhamendra Pradhan ji, Honorable Cabinet Minister for Education and Skill Development and Entrepreneurship, Government of India inaugurated '*JPN Center Excellence in Humanities*'.

IPR Chair Professor

Prof. Ruchi Sharma, Professor, School of Humanities and Social Sciences has been elected as IPR Chair Professor under the Scheme for Pedagogy & Research in IPRs for Holistic Education and Academia (SPRIHA), formulated by the Department of Industrial Policy & Promotion (DIPP), Government of India.

Under this scheme, IPR Chair Professors have been appointed in various institutes across the country to encourage the study and research on Intellectual Property Rights (IPR). Such Chairs will deliberate on developing credit as well as specialized courses on IPR, organize seminars and workshops on IPR matters, develop inputs, and research on IPR matters.

World Intellectual Property Day

To mark World Intellectual Property Day, Indian Institute of Technology Indore planned a series of events on 26th and 27th of April 2024. Remarkable events featuring insightful discussions and expert lectures on the importance of intellectual property (IP) in fostering innovation and creativity were planned. This year's theme emphasized on *"IP and the SDGs: Building our Common Future with Innovation and Creativity"*.

The event was graced by the presence of notable dignitaries including Chief Guest Dr. Akhilesh Gupta (Senior Advisor and Head PCPM, DST) and Guest of Honour Prof. Sujit Bhattacharya (Chief Scientist, CSIR-NIScPR).

The event also featured insights from IP attorneys and IP practitioners, further enriching the discussions with practical perspectives on intellectual property in today's research and innovation arenas.

भारतीय प्रौद्योगिकी संस्थान इंदौर
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