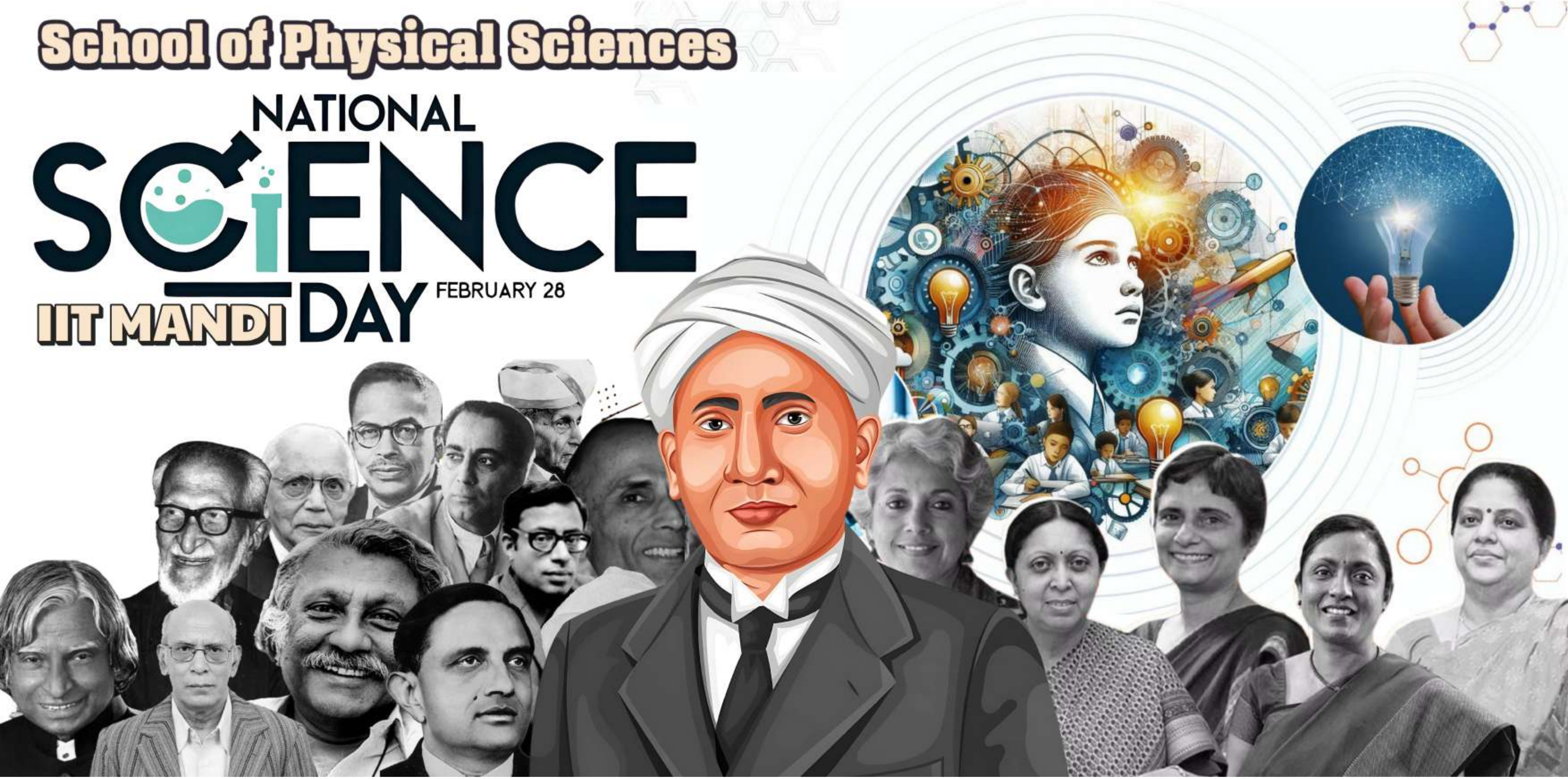
School of Physical Sciences
NATIONAL
SCIENCE
DAY
FEBRUARY 28
IIT MANDI

Science Day Schedule

28 Feb, A1 NKN

9:15 AM-9:45 AM	**Inauguration with lamp lighting and Sarasvati Vandana**
9:45 AM-10:00 AM	**Address by the Chair of SPS, IIT Mandi**
10:00 AM-10:30 AM	**Address by Director, IIT Mandi**
10:30 AM- 11:30 AM	**Talk by Guest of Honor Prof. Subhash Chaturvedi** **Title:** Features of quantum mechanics underlying quantum technologies
11:30 AM-12:00 PM	**Tea and Snacks**
12:00 PM-12:45 PM	**Session Chair: Dr. Pradyuman Pathak** **12:00 PM-12:15 PM** — Finite temperature spin-dipole oscillations in coherently coupled condensates **Sunil Kumar** **12:15 PM-12:30 PM** — Correlated Emission Lasing in a Single Quantum Dot Embedded Inside a Bimodal Photonic Crystal Cavity **Lavakumar Addepalli** **12:30 PM-12:45 PM** — Kibble-Zurek scaling and statistics of defect formation in binary Bose-Einstein condensates **Subhadeep Patra**
12:45 PM-2:25 PM	**Lunch, Poster Session, and Group Photo**

2:25 PM-4:35 PM	**Session Chair: Dr. Prabhakar Palni**	
	2:25 PM-2:35 PM	**Science Activity-I**
	2:35 PM-2:50 PM	Constraining Statistical Isotropy using 21cm Power Spectrum and Bispectrum **Bhuwan Joshi**
	2:50 PM-3:05 PM	Inclusive-jet photoproduction using PYTHIA for Electron-Ion Collider **Abhas Rathi**
	3:05 PM-3:20 PM	Development of Ultra-Thin LGADs with Enhanced Timing Capabilities and Radiation Hardness for Future Collider Applications **Jaideep Kalani**
	Session Chair: Prof. C. S. Yadav	
	3:20 PM-3:35 PM	Coupling of magnetism and transport properties to the lattice degrees of freedom in $NdBaCo_2O_{5+\delta}$ (δ = 0.65) **Himanshu Pant**
	3:35 PM-3:50 PM	Phonons and quasi-particle excitations in a putative quantum spin liquid candidate **Vivek Kumar**
	3:50 PM- 4:05 PM	Raman Tensor Analysis of Single Crystal Bismuth Telluride **Aditya Singh**

	4:05 PM-4:20 PM	A Motile Rod in an Active Nematic Medium: Caging, Orientational Trapping and Anomalous Diffusion **Abhishek Sharma**
	4:20 PM-4:35 PM	Basics of Supercooled liquid theory and Breakdown of Hydrodynamic laws **Devanshu Chakraborty**
4:35 PM-5:00 PM	**High Tea and Poster session**	
5:00 PM-5:30 PM	**Science Activity-II**	
5:30 PM-5:35 PM	**Announcement of new Physics Club**	
5:35 PM-6:05 PM	**Prize distribution and Vote of Thanks**	

List of Talks

Finite temperature spin-dipole oscillations in coherently coupled condensates

Sunilkumar V[1], Arko Roy[1]

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We examine the role of thermal fluctuations on spin-dipole oscillations in cigar-shaped coherently coupled mixtures of dilute atomic gases. To this end, we use the Hartree-Fock-Bogoliubov theory with the Popov (HFB-Popov) approximation to investigate the low-lying spin-dipole mode at zero as well as finite temperature. Experimentally, the spin-dipole mode can be excited by the application of a differential potential to the coherently-coupled condensate. With a linear ramp acting in an opposite way to each of the component, we perform a numerical real-time simulation of the coupled Gross-Pitaevskii equation to corroborate the HFB prediction at zero temperature. The finite temperature damping of the spin-and density-dipole oscillations is to be carried out by employing the Stochastic Gross-Pitaevskii equation.

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Correlated Emission Lasing in a Single Quantum Dot Embedded Inside a Bimodal Photonic Crystal Cavity

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Abstract: We investigate the phenomenon of correlated emission lasing in a coherently driven single quantum dot (QD) coupled to a bimodal photonic crystal cavity, utilizing a master equation to describe the system dynamics. To account for exciton-phonon interactions, we incorporate a non-perturbative approach through a polaron transformed master equation. By analyzing fluctuations in the Hermitian operators associated with relative and average phase, we demonstrate that correlated emission suppresses quantum noise in the presence of exciton-phonon interaction at low temperature.
Keywords: Correlated emission, Master equation, Polaron transformation.

1. Introduction

In a correlated emission laser (CEL), coherence between the upper levels in a three-level atomic system leads to correlated spontaneous emissions into the cavity modes. This correlation suppresses quantum noise in the laser, driving it towards the vacuum noise limit (VNL). CEL has been proposed in various atomic-level configurations, such as the 'V' type system employed in quantum beat lasers, Hanle lasers, and three-level cascade systems. Realizing the CEL in semiconductor cavity QED systems is particularly exciting. As these scalable devices hold great promise for developing on-chip quantum technology due to their integrability with photonic networks. In this work, we propose CEL using a single quantum dot (QD) embedded in a photonic bimodal cavity.

We consider a single QD with 'x' and 'y' excitons, each driven by separate external coherent fields, and coupled to two orthogonally polarized cavity modes as shown in Figure 1. Using the quantum optics toolbox [1], we solve the master equation numerically to analyze the steady-state dynamics of the system and examine fluctuations in the relative and average phase Hermitian operators. The Hamiltonian of the system is given by,

$$H = \omega_x \sigma_1^+\sigma_1^- + \omega_y \sigma_2^+\sigma_2^- + \omega_{c_1} a_1^\dagger a_1 + \omega_{c_2} a_2^\dagger a_2 + g_1\left(\sigma_1^+ a_1 + a_1^\dagger \sigma_1^-\right) + g_2\left(\sigma_2^+ a_2 + a_2^\dagger \sigma_2^-\right) + \eta_1\left(\sigma_1^+ e^{-i\omega_{Lx}t} + \sigma_1^- e^{i\omega_{Lx}t}\right) + \eta_2\left(\sigma_2^+ e^{-i\omega_{Ly}t} + \sigma_2^- e^{i\omega_{Ly}t}\right) + H_{ph} \quad (1)$$

where a_i is the annihilation operator for the i-th cavity mode, g_1, g_2 are the $|g\rangle \leftrightarrow |x\rangle$, $|g\rangle \leftrightarrow |y\rangle$ transitions coupling strength to the 1st and 2nd cavity modes. QD operators are given by, $\sigma_1^+ = |x\rangle\langle g|$, $\sigma_2^+ = |y\rangle\langle g|$. The coherent pumping strengths are η_1, η_2 for $|g\rangle \leftrightarrow |x\rangle$, $|g\rangle \leftrightarrow |y\rangle$ transitions respectively. The exciton-phonon interaction Hamiltonian is given by, $\mathrm{H_{ph}} = \hbar\, \Sigma_k \omega_k\, \mathrm{b}_k^\dagger \mathrm{b}_k + \hbar \Sigma_{i=x,y} \Sigma_k \lambda_k^i\, |i\rangle\langle i| \left(\mathrm{b}_k^\dagger + \mathrm{b}_k\right)$. Here, b_k is the annihilation operator for the k-th phonon bath mode. Further, to consider the exciton-phonon effects to all orders non-perturbatively, we make polaron transformation[2], $H' = e^S H e^{-S}$, where $S = \Sigma_{i=1,2} \sigma_i^+ \sigma_i^- \Sigma_k \frac{\lambda_k}{\omega_k}\left(b_k^\dagger - b_k\right)$. Thereafter, we derive the master equation for the system after making Born-Markov approximation for the residue terms after polaron transformation [3].

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Kibble-Zurek scaling and statistics of defect formation in binary Bose-Einstein condensates

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We present the study of defect formation and validate the Kibble-Zurek (KZ)[1,3] scaling laws associated with a quasi 2D homogeneous miture of Bose-Einstein condensates at finite temperature. To this end we use Stochastic (Projected) Gross-Pitaevskii formalism which provides a grand canonical description of the condensate field where the thermal cloud (reservoir) assumes to be in local equilibrium with chemical potential μ and temperature T. KZ mechanism predicts the spontaneous formation of defects across a continuous phase transition and which follows a universal scaling law for defect density $\rho \sim \tau_Q^{\,-2\nu/1+z\nu}$, where ν and z are the critical exponents. In the mean field regime, KZM predicts $\nu = 1/2$ and $z = 2$. Quenching μ linearly with a rate τ_Q induces continuous phase transition and we study the formation of point defects in the form of vortices in the miscible phase revealing the KZ scaling laws for the defect density and the statistics of the defect distributions which go beyond KZM. Furthermore, In the immiscible phase, we study the evolution of line defects (domain walls), mean domain area, number of domains and their spatial distributiuon along with the associated universal scaling laws.

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Constraining Statistical Isotropy using 21cm Power Spectrum and Bispectrum

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The Cosmological Principle states that the universe is statistically isotropic and homogeneous on large length scales, typically $\gtrsim$ 70Mpc. A detection of significant deviation would help us falsify the simplest models of inflation. In this regard, there are potential indications of departures from this principle, e.g., observations from WMAP and Planck show signs of a preferred direction in the temperature fluctuations known as hemispherical asymmetry in CMB. Phenomenologically, this has been studied using a dipole modulation model. In addition to this, a number of possible mechanisms have been proposed in the literature to explain this anomaly. Some of these scenarios generate dipolar asymmetry or predict quadrupolar asymmetry in the primordial power spectrum of curvature perturbations. In this paper, we study both these asymmetries. To fulfill the objective, we employ 21cm intensity mapping technique post during post reionization era, i.e., $z \lesssim 7$. We apply Fisher formalism to constrain dipolar and quadrupolar anisotropy parameters using both 21cm power and bispectra and give forecasts for three intensity mapping surveys: SKA-Mid, HIRAX and PUMA. Although 21cm intensity mapping is a very promising cosmological probe, the signals are severely affected by foregrounds. To mitigate the foreground effects, we use foreground avoidance approach. For the interferometer mode of operation, we also include the wedge effect. From our analysis, we find that PUMA, on account of its high redshift range is able to constrain both dipolar and quadrupolar parameters to better than $\sim 10{-}3$ for redshifts $z \gtrsim 1$. This is one order of magnitude better constraints as compared to those provided by the latest CMB surveys. We also find that as compared to power spectrum, the constraining power of bispectrum is more sensitive towards foregrounds.

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Development of Ultra-Thin LGADs with Enhanced Timing Capabilities and Radiation Hardness for Future Collider Applications

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Abstract

This study investigates Low Gain Avalanche Detectors (LGADs) for future par- ticle collider experiments, aiming to improve timing resolution ($<$ 20 ps) under very high-radiation environments. Using the WeightField2 simulation program, we opti- mized an n-in-p type LGAD design, focusing on ultra-thin sensors ($\sim<$ 50 μm) with p-doped Silicon bulk. Our results show that a 20 μm thick sensor achieves optimal performance. Simulations were performed under High Luminosity LHC conditions (temperature ≈ -15 $^\circ$C, luminosity $\approx 7 \times 10^{34}$ cm^{-2} s^{-1}), taking into account ra- diation damage, gain quenching, and lattice defects. Further studies were extended to Silicon Carbide (SiC) bulk material due to its superior properties, such as a wide band-gap and high atomic displacement energy, which provide strong resistance to ir- radiation. Its high electron saturation drift velocity and thermal conductivity make it a fast-responding detector with lower thermal sensitivity. After irradiation, the study in- vestigates fast charge collection, breakdown voltage and radiation tolerance, comparing these with conventional Silicon-based LGADs. These findings underline the potential of optimized LGADs in maintaining performance under high radiation regime.

Keywords: LGAD, timing resolution, radiation hardness, ultra-thin sensors, Silicon Car- bide, WeightField2 simulation

Inclusive-jet photoproduction using PYTHIA for Electron-Ion Collider

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Inclusive-jet photoproduction at HERA has shown to be a favourable ground for verifying perturbative QCD with the obtained jet cross-section. Monte-carlo event generator PYTHIA8 is used to compare the data of ZEUS collaboration [1], aiming for high-precision measurements of α_s at HERA. Inclusive-jet photoproduction in the reaction $e^++p \rightarrow e^++jet+X$ with beam energies E_p = 920 GeV, E_e = 27.5 GeV, and centre-of-mass energy $\sqrt{s}$ = 318 GeV is analysed using different parton distribution functions (PDFs) and jet reconstruction algorithms such as k_T, anti-k_T, and SIScone. A better fit for parton content of photon is required for precision phenomenology at the Electron-Ion Collider, the successor of HERA that will be colliding spin-polarised electrons and ions at energy scales from 29 to 141 GeV. The framework developed from the validated results is used in making predictions for differential cross-section at EIC with different centre-of-mass energies (28.6, 63.2, and 140.7 GeV) at low and high photon virtualities. This study further aims to explore the multi-parton interaction from the hadronic fluctuation of the exchanged photon.

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Coupling of magnetism and transport properties to the lattice degrees of freedom in $NdBaCo_2O_{5+\delta}$ ($\delta = 0.65$)

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We have studied the origin of zero volume expansion below the Curie temperature (T_c), variable range hopping (VRH) behavior using structural, magnetic, transport and thermal studies on the oxygen deficient double perovskite $NdBaCo_2O_{5+\delta}$ ($\delta = 0.65$). The valence state of Co ions and the possible properties exhibited by such compound were studied using electronic structure calculations for $\delta = 0.75$. Careful investigation of structure shows that the compound stabilizes in tetragonal structure (P4/mmm) having $2a_p$ x $2a_p$ x $2a_p$ (222) superstructure, where a_p is the cubic perovskite lattice parameter. The compound exhibits a minimum in resistivity, ferromagnetic (FM) and ferrimagnetic (FeM) transitions around 375 K, 120 K (T_c) and 60 K, respectively with signature of Griffiths phase above T_c. Our detailed structural analysis suggests signature of the onset of the above magnetic transitions at temperatures well above its stabilization at long range level thereby leading to VRH behavior. The observed zero thermal expansion in volume below T_c appears to be due to competing magnetic interactions within and between the magnetic sublattices. Our electronic structure calculations in FM and FeM configurations show (a) Co ions stabilize in intermediate spin (IS) state, having oxidation state less than +3 (b) half metallicity, (c) the behavior of the density of states is in line with the resistivity results, and (d) unusually high orbital angular moment in Co ions with inclusion of spin orbit coupling (soc). Our results show the possibility of coupling between magnetism and ferroelectricity. We believe that our results, especially on the valence state of the Co ion, zero thermal expansion in volume, short range magnetic orderings and the connection between different degrees of freedom will be helpful in clearing the ambiguities existing in literature on the nature of magnetism and thereby aiding in designing new functionalities by maneuvering the strength of soc.

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Phonons and quasi-particle excitations in a putative quantum spin liquid candidate

Vivek Kumar[1,*], Deepu Kumar[1], Birender Singh[1], Yuliia Shemerliuk[2], Mahdi Behnami[2], Bernd Büchner[2,3], Saicharan Aswartham[2], and **Pradeep Kumar**[1]

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**DI-1702*

Quantum spin liquid, a state in which strong quantum fluctuations prevent any long-range magnetic order even at absolute zero temperature. Such a phase was first proposed by P.W. Anderson in 1973 which does not involve any spontaneous symmetry breaking and local order parameter, and to understand it is beyond conventional phase transition theory. This state of matter exhibits phenomena like long-range entanglement and fractional quantum excitations, which are believed to hold great potential for quantum communication and computation. However, in 2006 Alexei Kitaev proposed an exactly solvable model for S=1/2 on a honeycomb lattice which significantly advanced the field. Kitaev spin liquids are characterized by exotic low energy fractionalized excitations where spins fractionalize into Majorana fermions and form a highly entangled topological ground state, is still elusive experimentally and may be gauged via indirect experimental signatures. Remnants of Quantum spin liquid phase may reflect in the spin dynamics as well as quanta of lattice vibrations, i.e., phonons, via the strong coupling of phonons with the underlying fractionalized excitations. I will discuss the Raman spectroscopic results on a putative quantum spin liquid candidate which evidences the spin fractionalization into Majorana fermions.

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Raman Tensor Analysis of Single Crystal Bismuth Telluride

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Light-matter interaction helps to understand the many body physics and fundamentals of the electron and phonon coupling in Bi_2Te_3. High-quality single crystals of Bi_2Te_3, a well-known topological thermoelectric material, is prepared by Bridgman technique. The structure is confirmed by X-Ray diffraction, Transmission electron microscopy and Selected area electron diffraction, which shows crystal is oriented along the c-axis. Bi_2Te_3 crystallizes in a rhombohedral crystal structure with five atoms (quintuple layer) in one unit cell, which gives 15 phonon modes having 3 acoustic and 12 optical vibrations. The crystalline unit cell comprises of three slabs of quintuple layers stacked with vdW forces. Raman spectra analysis of characteristic modes have been carried out to estimate the tensor elements, which suggests a higher differential polarizability along the c-axis leading to anisotropic light matter interactions. The interplay of electron-photon-phonon interactions is crucial for understanding the lattice dynamics of Bi_2Te_3, which helps to advance the applicability as thermoelectric materials with unique topological properties.[1-5]

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A Motile Rod in an Active Nematic Medium: Caging, Orientational Trapping and Anomalous Diffusion

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We investigate the dynamical and statistical properties of a fore-aft asymmetric polar rod embedded within a vibrated granular medium composed of fore-aft symmetric rods. Our study reveals distinct directional memory effects and transport behaviors depending on the phase of the surrounding medium. In the nematic phase, the polar rod exhibits strong directional memory, whereas in the isotropic phase, it experiences a noisier environment, leading to a more transient memory of its past direction. At high packing fractions, where the medium forms a periodic nematic order, the polar rod undergoes caging behavior perpendicular to the nematic alignment, accompanied by orientational trapping. Additionally, in the nematic phase, the translational diffusivity of the polar rod along the nematic alignment increases with rod concentration. In contrast, in the isotropic phase, both translational and rotational diffusion of the polar rod follow normal diffusion. These findings provide insights into the interplay of medium-induced constraints in driven granular systems.

Reference:

Basics of Supercooled liquid theory and Breakdown of Hydrodynamic laws

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We present a study of translation and rotational(reorientation) dynamics of a binary mixture of FENE dumbbell molecular liquid and monatomic molecule where the non-bonding interatomic potential is that of a well-known glass-forming binary mixture. In the extended model of the glass forming system with rotational motion, we find many signatures of glass transition, such as dramatic slowdown of density relaxation, decoupling of the translational and rotational relaxation and breakdown of basic hydrodynamic laws like Stoke-Einstein relation and Stoke-Einstein-Debye relation . A comparison of variations in the signature of glass transition at higher and lower densities shows that translational-rotational decoupling at lower density is more due to the formation of cavities.

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List of Posters

Poster # 1

Local Structural distortions and their impact on Physical properties of $La_{0.4}Sr_{0.6}MnO_3$

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We investigated the relationship between local structure and physical properties of $La_{0.4}Sr_{0.6}MnO_3$ (LSMO60) by analyzing X-ray diffraction, Extended x-ray absorption fine spectra (EXAFS), X-ray absorption near edge spectroscopy, specific heat capacity and DFT calculations. Our results show that the local structure of LSMO60 differs from its global structure. We could identify the features of XAS by comparing the unoccupied states of density of states (DOS) and match the XANES features with FEFF calculations. Our results suggest that e_g orbitals of Mn-3d states play a crucial role in determining the physical properties of LSMO60.

References:

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Poster # 2

Study of magnetic and structural behaviour of Cr doped $Ca_{0.7}Sr_{0.3}RuO_3$ ruthenates

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$SrRuO_3$ is infinite layer Ruddlesden Popper series compound. This compound stabilizes in the orthorhombic Pbnm space group and has Tc around 160K (1). Ca doped SrRuO3 shows the smeared quantum phase transition from ferromagnetic to paramagnetic behaviour (2). The smeared quantum phase transition could be due to the disorder induced in the system as the Ca is doped on Sr site. We synthesised the compound $Ca_{0.7}Sr_{0.3}Ru_{1-x}Cr_xO_3$ (x=0,0.05,0.1) by using solid state method and XRD measurements were done using 9 kW Rigaku Smart lab X ray diffractometer with Cu Kα radiation in the Bragg Brentano focusing geometry. Rietveld refinement is done for all the three compounds which suggest the compounds stabilize in single orthorhombic Pbnm space group and is in single phase. The magnetic measurements M vs T, there is a peak around 15K which could be the signature of the T_c. In the χ^{-1} vs T, a downturn is observed in all the above compounds which could be due to the Griffith regime around the critical point. To relate the observed magnetic behaviour with theory, we did the DFT for spin polarized (FM phase and A-type, C-type and G-type) on $Ca_{0.75}Sr_{0.25}RuO_3$ using the lattice parameters of Ca0.7Sr0.3RuO3 and thus we calculated the magnetic exchange constant (J)(3) and found the values of J are positive which shows that the compound possess the ferromagnetic interaction.

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Poster # 3

Impact of Layer Number on the Spin Dynamics in Two-Dimensional Ruddlesden-Popper Perovskites

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ABSTRACT

Nowadays, two-dimensional (2D) metal halide perovskites have emerged as a highly promising class of spintronics materials due to their exceptional spin-dependent photophysical properties. [1] The presence of heavy metal induces a large spin-orbit coupling, which in the presence of structural inversion asymmetry lifts the spin degeneracy of both the conduction and valence bands, resulting in observable Rashba and Dresselhaus type band splitting.[2] In this study, we elucidate how the number of inorganic layers affect the spin relaxation mechanism and spin decoherence time in mixed-phase 2D Ruddlesden-Popper (RP) perovskites, $(TEA)_2(MA)_{n-1}Pb_nI_{3n+1}$ (n=1−4), using circularly polarization-resolved transient absorption (TA) spectroscopy. The difference between same and opposite pump-probe signal indicates the initial creation of spin polarization and provides insight into the decay and formation kinetics of spin populations with distinct polarization states. Our results indicate a gradual transition in the spin depolarization mechanism shifting from the Maialle–Silva–Sham (MSS) process [3] for n=1 to the Elliot–Yafet (EY) mechanism [4] for n=∞, via polaronic screening mechanism, observed for n=2-4. Interestingly, the longest spin decoherence time is observed in the n=2 sample at room temperature which is ~ 25 times larger than that of n=1. Hence, our findings offer valuable insights into the different spin relaxation mechanisms in mixed phase RP perovskite and pave the way for advancements in the development of spintronic devices.

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Poster # 4

Spectroscopic investigation of charge carrier dynamics in Germanium selenide

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Abstract

Germanium selenide (GeSe) is emerging as a promising two-dimensional material for photovoltaic[1] and photodetection applications[2] because of its closely spaced direct and indirect bandgaps that overlap well with solar spectrum. Additionally, it exhibits broken structural symmetry which gives rise to two non-equivalent in-plane crystal orientations categorized as armchair (AC) and zigzag (ZZ). The anisotropic atomic arrangement along the principal in-plane crystallographic directions results in modification of fundamental properties, such as absorption, carrier mobility, effective mass, dielectric constant, refractive index.

We employed transient absorption (TA) spectroscopy to investigate the charge carrier dynamics in GeSe film excited well above (410 nm) and near the band edge (820 nm). A global and target analysis approach is applied to deconvolute the different spectral components present in TA spectra[3]. We find that decay profiles are mainly associated with the three decay components of increasing lifetimes and assigned to free carriers cooling to the band edge, in-gap trap state and ground state, and finally long-lived recombination mechanisms occurring from hundreds of ps to ns, respectively. The presence of two different valleys within the band structure is proposed because of two bleach bands in VIS and NIR regions, respectively.

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Poster # 5

2D Perovskite-based Flexible Memristors for Neuromorphic Applications

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The big data revolution has increased the demand for efficient storage and processing, revealing the limitations of traditional computing, particularly the von Neumann bottleneck. New technologies like resistive random-access memory (ReRAM) and neuromorphic computing are merging memory and processing to create energy-efficient systems. [1, 2] Various materials, such as transition metal oxides, dichalcogenides, perovskites are being explored for their memristive properties, which are key to advancing neuromorphic computing.[3] Here we present a 2D perovskite-based artificial synapse on a flexible substrate with the structure Al/ $(4\text{-FBA})_2PbBr_4$/ITO. The device shows strong performance, including over 340 cycles of endurance, an on/off ratio of 10^3, and excellent retention of memory states for over 10^4 seconds. It also demonstrates key functionalities like short-term potentiation and depression, mimicking biological synaptic behavior. This device enhances memory and processing efficiency, advancing flexible neuromorphic systems.

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Poster # 6

Signature of point nodal superconductivity in the Dirac semimetal PdTe

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Topological semimetals are materials with special electronic properties, featuring topologically nontrivial bulk band crossings and robust surface states [1]. When combined with superconductivity, these materials become even more interesting, leading to intrinsic topological superconductivity. Recent discoveries of materials that show both topological semimetal behavior and superconductivity have advanced this research, providing new ways to explore the interaction between topology and superconductivity. PdTe is a 3D Dirac semimetal, exhibiting type- II superconducting behavior with a transition temperature (T_c) ~ 4.5 K [2,3]. Recent angle-resolved photo-emission spectroscopy (ARPES) experiments have revealed the coexistence of bulk-nodal and surface-nodeless cooper pairings in PdTe [4]. However, the low-temperature thermal-conductivity measurements on PdTe single crystals suggest that PdTe has multiple nodeless superconducting gaps, which contradicts the bulk-nodal gap claim [5]. We carried out electronic and thermal transport experiments on PdTe single crystals. Our field-dependent specific heat data down to temperatures ~ 58 mK shows a power-law field dependence, which differs from the usual linear behavior expected for an isotropic fully gapped s-wave superconductor [6]. Additionally, our zero-field specific heat data reveal a clear ~ T^3 temperature dependence at low temperatures ($T < T_c/3$), suggesting the presence of bulk point nodes in the superconducting order parameter of PdTe. A weak-coupling BCS-type order parameter with p-wave symmetry and point nodes fits the zero-field data well. These bulk specific heat measurements indicate that PdTe is likely an odd-parity p-wave superconductor [7].

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Poster # 7

Transport properties of AM_4X_8 Type Tetrahedral Cluster Compounds

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The family of lacunar spinel compounds AM_4X_8 (A = Ga, Ge; M = V, Nb, Ta; X = S, Se) are are well known for its different thermal and electronic transport properties. Here we had synthesized polycrystal GaV_4Se_8 using the sold state reaction method and confirmed single phase with powder XRD. It is skyrmion hosting, having a Mott insulating ground state with a structural phase transition from cubic to rhombohedral at a temperature of T_S =41K and magnetic ordering from paramagnetic to ferromagnetic at a temperature of T_C =17.5K. The resistivity vs temperature plot of the compound reveals a Variable Range Hopping behavior while fitting with Mott's VRH. The Seebeck coefficient of the compound, measured up to 70K helps in obtaining the activation energy $E_a^S = 0.065eV$. This compound is getting more explored because of its topologically protected skyrmion hosting property , which is helpful in the field of memory devices, AI and quantum computing.

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Poster # 8

Low temperature Electrical and Thermal transport studies of $NbSe_2$ crystals

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Transition metal dichalcogenides (TMDCs) have the formula MX_2, where M is a transition metal like V, Nb, or Ta, and X is a chalcogenide such as S, Se, or Te.These materials are known for their layered structures and interesting properties, including charge density waves (CDW) and superconductivity [1,2]. This study focuses on 4H-$NbSe_2$ which is a polymorph of well known 2H-$NbSe_2$ [1,3]. We have synthesized both polycrystalline and single-crystal forms of 4H $NbSe_2$. The polycrystalline material was obtained using a solid-state chemical reaction [1,2,3], while the single crystals were grown using the chemical vapor transport method with iodine as a transport agent. Structural characterization through powder X-ray diffraction (XRD) confirmed the phase purity and hexagonal nature of the samples. We performed temperature-dependent measurements of electrical resistivity and the Seebeck coefficient at low temperature. Our findings revealed a superconducting transition at T ~ 6.4 K. Evidence from Seebeck coefficient measurement suggests the possibility of CDW transition at ~ 43 K. We'll present detailed electrical and thermal transport properties of the 4H- $NbSe_2$. These studies have the potential to advance our understanding of its potential applications in quantum technologies and thermoelectrics.

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Poster # 9

Optimizing Thermal Transport: The Influence of Atomic Mass Contrast on Optical Phonons

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The development of effective thermal management strategies in electronic devices such as semiconductors, sensitive thermal sensors, and optoelectronics leads to increased efficiency, reliability, and longevity and decreased energy consumption. Thermal conductivity of materials is mainly regulated by the lattice dynamics of the phonon transport[1]. Mostly heat is carried by the acoustic phonon due to their high group velocity. Atomic mass contrast[2] plays a significant role in scattering mechanisms. Over the recent period, optical phonons are of great interest due to their highly dispersive behaviour. The change in the atomic masses influences the optical phonon transport, which hereby shows the different dispersive behaviour resulting in more contribution to thermal conductivity. This effect can be crucial for thermoelectric materials, where incorporated electronic conductivity is suppressed while thermal conductivity is favourable for efficiency. Thus, the optical phonon engineered by the atomic mass contrast for low thermal conductivity could be of great interest for thermoelectric materials.

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Poster # 10

Investigation of Structural Phase Transition in α-In_2Se_3 Using Raman Spectroscopy

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Chalcogenide materials have received a considerable attention for their exceptional physical, electrical, and optical properties, which made them ideal candidate for next-generation optoelectronic devices. [1, 2] Raman spectroscopy is an advanced technique for characterizing materials and comprehending microscopic changes, such as soft chemical bonds associated with vibrational modes and electronic transitions. In this regard, In_2Se_3, is a well-known layered material, which has a considerable polymorphic structure that can change with external parameters such as temperature, pressure, and magnetic field. [3] Such external stimulations make it an ideal material to understand the phonon dynamics. In this work, we have obtained thin layer of In_2Se_3 using mechanical exfoliation and emphasized on the structural phase transition through temperature dependent Raman spectroscopy.

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Poster # 11

Cryogenic technique for assembling chemically sensitive van der Waals heterostructures

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Assembling atomic layers of van der Waals materials (vdW) combines the physics of two materials, offering opportunities for novel functional devices. Realization of this has been possible because of advancements in nanofabrication processes which often involve chemical processing of the materials under study; this can be detrimental to device performance. To address this issue, we have developed a modified micro-manipulator setup for cryogenic exfoliation, pick up, and transfer of vdW materials to assemble heterostructures. We use the glass transition of a polymer PDMS to cleave a flake into two, followed by its pick-up and drop to form pristine twisted junctions. To demonstrate the potential of the technique, we fabricated twisted heterostructure of $Bi_2Sr_2CaCu_2O_{8+x}$ (BSCCO), a van der Waals high-temperature cuprate superconductor. We also employed this method to re-exfoliate $NbSe_2$ and make twisted heterostructure. Transport measurements of the fabricated devices indicate the high quality of the artificial twisted interface. In addition, we extend this cryogenic exfoliation method for other vdW materials, offering an effective way of assembling heterostructures and twisted junctions with pristine interfaces.

Keywords : van der Waals heterostructures, High-temperature superconductors, 2D materials, PDMS, Cryogenic exfoliation

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Poster # 12

A study of Cosmic No Hair Conjecture for Bianchi Type-VII space-time Geometries

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Cosmic no hair Conjecture tells about the general solutions to Einstein’s field equations with a positive cosmological constant that will always evolve towards a de-Sitter space, proposed by Gibbons and Hawking.We were motivated by Wald's paper \cite{PhysRevD.28.2118}, in which he partially proved the Cosmic No-Hair Conjecture for Bianchi-type universes, except Bianchi IX. In our study, we conduct a literature survey and perform various tests related to the Cosmic No-Hair Conjecture. Our initial focus is on investigating a potential approach to solving this conjecture for a specific Bianchi Type VII geometry. This approach is relevant to local geometry rather than global geometry. Our broader objective is to extend this work to Thurston geometries, though they are not included in our current study. Here, we discuss anisotropic and homogeneous geometries and explore how these geometries evolve into isotropic and de Sitter-like structures. However, we do not address the transition from inhomogeneous and anisotropic conditions to a homogeneous and isotropic universe.

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Poster # 13

Understanding the basics of Lorentz Invariance Violation using Chern Simon theory

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We present a basic understanding of Lorentz invariance violation (LIV) and explore the one from the possible ways to detect it, using a theoretical framework based on Chern-Simons theory. Introducing a Chern-Simons term in the electromagnetic lagrangian, modifies the standard physical laws, leading to a phenomenon known as cosmic birefringence, where the polarization plane of electromagnetic waves rotates as they propagate. This effect provides a potential observational signature of LIV, which can be tested through precision cosmological and astrophysical measurements. By studying these signatures, we aim to gain insights into the fundamental nature of physics .

Poster # 14

Quantum Walk Teleportation in 2D and 3D Lattices

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A quantum walk, the quantum analog of a classical random walk [1], allows particles to exist in superposition across multiple locations. A "coin" degree of freedom determines movement direction at each step [2]. Quantum walk teleportation exploits the entanglement naturally generated in quantum walks [2]. A general teleportation circuit (Fig. 1) consists of a position space at Alice's side and coin spaces at both Alice's and Bob's ends. The process involves quantum walk steps, measurements by Alice, and unitary corrections by Bob. For two-qubit teleportation in

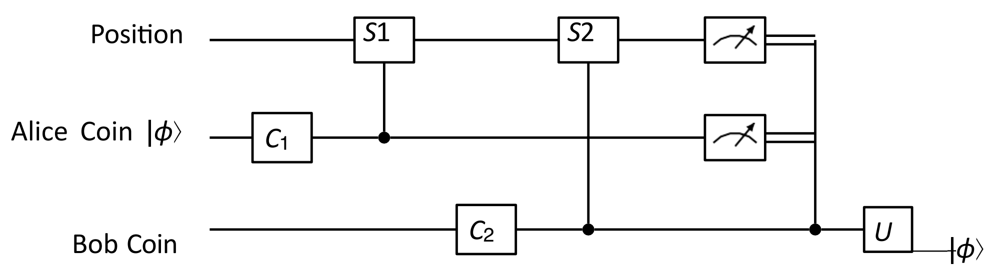

Fig. 1: General quantum walk teleportation circuit

a 2D square lattice, Alice's two-coin state $|\varphi\rangle = \alpha|00\rangle + \beta|01\rangle + \gamma|10\rangle + \delta|11\rangle$ is teleported using two quantum walk steps. The shift operators $\hat{S}_1, \hat{S}_1^\dagger, \hat{S}_2, \hat{S}_2^\dagger$ define walker movement, followed by Hadamard operations. Alice's position and coin measurements reduce the state, and Bob applies unitary operations to recover $|\varphi\rangle$. The cyclic case follows a similar protocol with modifications in shift operators and measurement mappings. For three-qubit teleportation in a 3D lattice, an extension of the 2D protocol, we use an initial position $|000\rangle$ and six coins (three each for Alice and Bob). Eight shift operators define movement. Bob applies 216 unitary operations in the standard 3D case and 64 in the cyclic case. Ququad (d = 4) teleportation in a 2D square lattice modifies the two-qubit protocol by using 4-level coin states and a ququad Hadamard gate in the second walk step. Bob's unitary operations for 36 measurement outcomes are determined similarly. Qutrit teleportation is implemented in a 2D hexagonal lattice using two distinct shift operators corresponding to the two lattice site types. The teleportation process follows analogous steps, concluding with Bob's unitary corrections.

We systematically generalize single-qubit quantum walk teleportation to multi-qubit and higher-dimensional qudit states in 2D and 3D lattice structures. Future work includes extending these methods to other geometries and deriving general formulae for n-qubit and qudit teleportation.

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