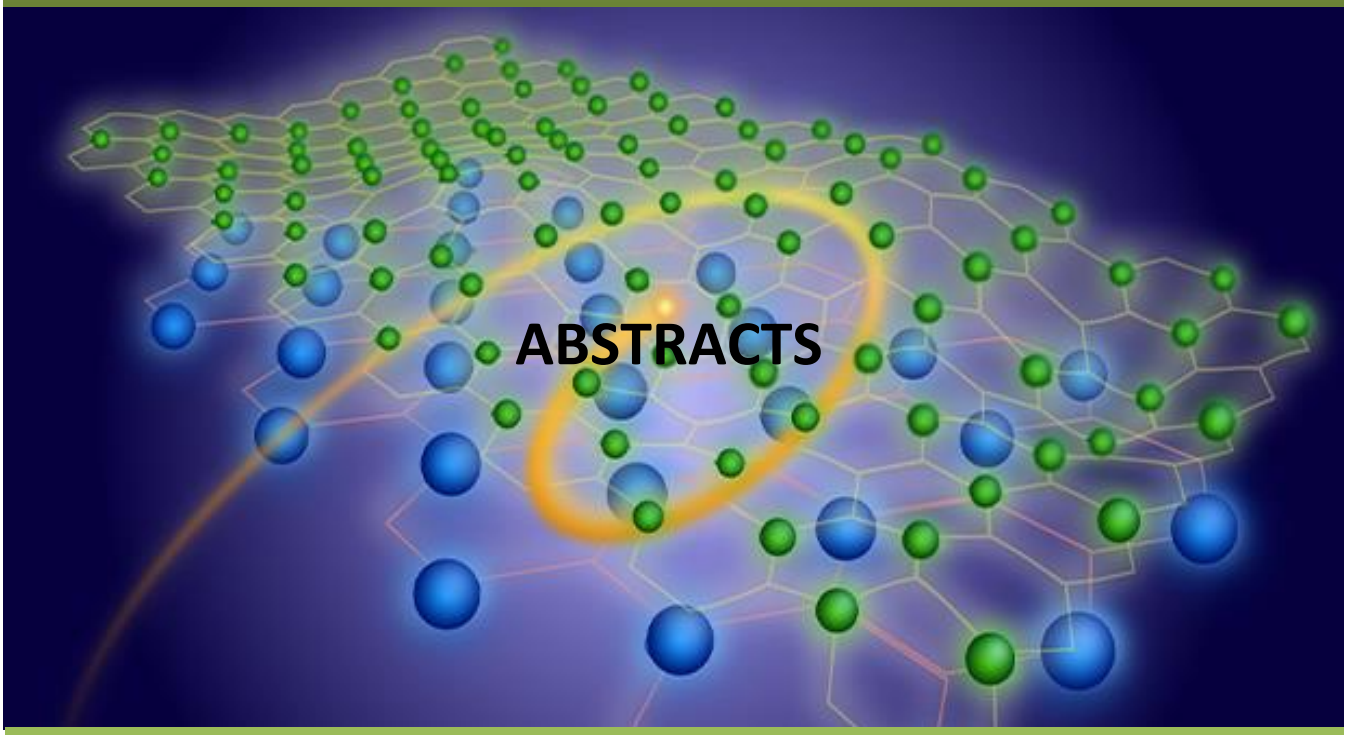
Recent trends in Condensed Matter Physics related to Quantum Materials, 2024

15th & 16th February, 2024

Indian Association for the Cultivation of Science



ABSTRACTS

ORGANIZED BY

School of Physical Sciences,

Indian Association for the Cultivation of Science

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"If you aren't confused by quantum mechanics, you haven't really understood it."

—Niels Bohr

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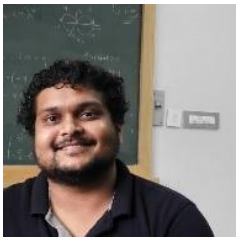
IIT Bombay



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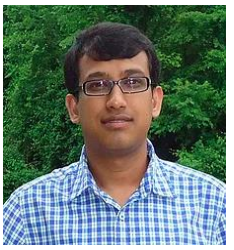

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PROGRAM SCHEDULE

DAY 1

FEBRUARY 15TH, THURSDAY

9:00 – 10:00	REGISTRATION	
10:00 – 10:15	HIGH TEA	
10:15 – 10:30	WELCOME ADDRESS	
SESSION 1: CHAIR: PROF. INDRA DASGUPTA		
10:30 – 11:00	PROF. ARTI GARG (SINP KOLKATA)	Many-body Localization: Current status
11:00 – 11:30	PROF. SUVANKAR CHAKRAVERTY (INST MOHALI)	Anomalous Shubnikov-De Haas oscillations and Room temperature spin polarizations at Oxide interfaces
11:30 – 11:45	TEA BREAK	
SESSION 2: CHAIR: PROF. KRISHNENDU SENGUPTA		
11:45 – 12:15	PROF. YASIR IQBAL (IIT MADRAS)	Dynamics of $K_2Ni_2(SO_4)_3$ governed by proximity to a 3D spin liquid model
12:15 – 12:45	PROF. SUBHABRATA DHAR (IIT BOMBAY)	Valley Polarization Properties of Monolayer MoS2 Grown by Chemical Vapor Deposition
12:45 – 13:15	PROF. ARIJIT HALDAR (SNBNCBS KOLKATA)	Higher-order topology in quantum spin models
13:15 – 14:45	LUNCH BREAK	
SESSION 3: CHAIR: PROF. DURGA BASAK		
14:45 – 15:15	PROF. PRAVAT KUMAR GIRI (IIT GUWAHATI)	Optical Studies on Many-body Effects in 2D Tungsten Disulfide and Single Photon Emission from 2D Hexagonal Boron Nitride

15:15 – 15:45	**PROF. DEBRAJ CHOUDHURY (IIT KHARAGPUR)**	**Resistive-state switching in some Titanate-spinel compounds**
15:45 – 16:00	**TEA BREAK**	
SESSION 4: CHAIR: PROF. MINTU MONDAL		
16:00 – 16:15	**RITWIK DAS (IACS KOLKATA)**	**In-plane magnetization orientation driven topological phase transition in $OsCl_3$ monolayer**
16:15 – 16:30	**MOHAMAD NUMAN (IACS KOLKATA)**	**Interplay between Lattice and Magnetism: Insights into the Multiferroicity in distorted diamond spin chain compound $Cu_3Nb_2O_8$**
16:30 – 16:45	**SOMSUBHRA GHOSH (IACS KOLKATA)**	**Hilbert space fragmentation: en route to Real Eigenvalues in Non-Hermitian Systems**
16:45 – 17:00	**SHAMEEK MUKHERJEE (IACS KOLKATA)**	**Linear magnetoelectric coupling without long-range magnetic order and rare-earth-free large magnetocaloric effect in $Co_3V_2O_8$**
17:00 – 18:30	**POSTER SESSION**	
19.30 – 22.30	**BANQUET DINNER**	

DAY 2

FEBRUARY 16TH, FRIDAY

SESSION 5: CHAIR: PROF. SUBHAM MAJUMDAR		
10:00 – 10:30	**PROF. AKSHAY NAIK (IISC BANGALORE)**	**2D Nanomechanics: Beyond precision sensors**
10:30 – 11:00	**PROF. SUMIRAN PUJARI (IIT BOMBAY)**	**Punctured-Chern topological invariants for semi-metallic band structures**
11:00 – 11:30	**PROF. SRIMANTA MIDDEY (IISC BANGALORE)**	**Quantum fluctuations lead to glassy electron dynamics in the good metal regime of electron doped $KTaO_3$**
11:30 – 11:45	**TEA BREAK**	
SESSION 6: CHAIR: PROF. SAURAV GIRI		
11:45 – 12:15	**PROF. SAMBUDDHA SANYAL (IISER TIRUPATI)**	**Quantum Matter in pyrochlore magnets**
12:15 – 12:45	**PROF. DEBANGSU ROY (IIT ROPAR)**	**Spin-orbit torque integration with static field: a generalized method to achieve initialization-free multistate memory behavior of SOT induced magnetization switching**
12:45 – 13:15	**PROF. ABHRADEEP PAL (IIT BOMBAY)**	**Superconducting devices with ferromagnetic insulators**
13:15 – 14:45	**LUNCH BREAK**	
SESSION 7: CHAIR: PROF. ARNAB SEN		
14:45 – 15:15	**SAIKAT DAS (IIT KHARAGPUR)**	**5d Transition Metal Oxide-based Quantum Materials for Spintronics**

15:15 – 15:30	**MOUMITA INDRA (IIT BOMBAY)**	**Double roton-minima in bosonic fractional quantum Hall states**
15:30 – 15:45	**SK KALIMUDDIN (IACS KOLKATA)**	**Exceptionally Slow, Long Range, and Non-Gaussian Fluctuations Anticipate the Critical Singularity Far Away from the Charge Density Wave Transition**
15:45 – 16:00	**TEA BREAK**	
SESSION 8: CHAIR: PROF. SUBHADEEP DATTA		
16:00 – 16:15	**INDRAJIT SAU (IACS KOLKATA)**	**Sublattice scars and beyond in two-dimensional U(1) quantum link lattice gauge theory**
16:15 – 16:30	**KUSAMPAL YADAV (IACS KOLKATA)**	**Tuning anomalous Hall effect in strain coupled epitaxial ferromagnetic thin film heterostructures**
16:30 – 16:45	**SOURAV MONDAL (IACS KOLKATA)**	**Excitonic Rydberg States in a Tri-layer to Monolayer H2-Aided CVD-Grown Large-Area MoS2 Film with Excellent UV to Visible Broad Band Photodetection Applications**
SESSION 9: CHAIR: PROF. DEVAJYOTI MUKHERJEE		
16:45 – 17:00	**TANIMA KUNDU (IACS KOLKATA)**	**Modulation of Structural and Electronic Phases in Two-dimensional PdSe2**
17:00 – 17:15	**ANIRBAN DAS (IACS KOLKATA)**	**Stability of Discrete Time Crystal without disorder in the thermodynamic limit**
17:15 – 17:30	**SUBHAM PARAMANIK (IACS KOLKATA)**	**Formation of Dual Bands in Mixed-Halide Perovskites during Photoinduced Halide Segregation**
17:30– 17:45	**SUDIPTA CHATTERJEE (SNBNCBS KOLKATA)**	**Destabilization of a correlated insulator**
17:45 – 18:00	**PRIZE DISTRIBUTION FOLLOWED BY CONCLUDING REMARKS**	
18.00 – 18.30	**HIGH TEA**	

INVITED TALKS

Many-body Localization: Current status

Arti Garg

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Many-body localization (MBL) is a fascinating phenomenon where disorder renders general interacting quantum systems insulating. Characterizing this intriguing insulating state and understanding the nature of the transition from the delocalized phase to the insulating MBL phase, which does not follow the standard paradigm of statistical physics, is a subject of intense research. In this talk I will provide an overview of the field of MBL, realization of the MBL phase in experiments, and recent discrepancies about the stability of the MBL phase.

Anomalous Shubnikov-De Haas oscillations and Room temperature spin polarizations at Oxide interfaces

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In recent times, momentum dependent splitting of spin-bands in an electronic system, the "Rashba effect", has gained a lot of interest because of its applications in future generation spintronic devices.[1,2] The Rashba effect is important not only because it has tremendous potential for technical applications, but also because it is a hunting ground for emergent physical properties owing to the linear dispersion relation at the crossing point of the two spin bands.[3] In this work, we present the observation of emergent phenomena arising at the interface of two insulating perovskite oxides due to Rashba spin-band splitting. In our first work, we improvise a novel conducting interface by juxtaposing KTaO3 (KTO) with another insulator, namely LaVO3 (LVO).[4] This heterointerface exhibits strong spin-orbit coupling which is the highest among perovskite oxide heterostructures reported so far. The system is also found to show the signature of topological chiral anomaly via observation of planar Hall effect (PHE) and anomalous in-plane magnetoresistance (AMR) similar to that observed for topological systems. [5] In addition, surprising quantum oscillations have been observed in magneto-resistance. A nonlinear dependence of Landau index as a function of the inverse of applied magnetic field has been observed. In our next work, we show the realization of a spin polarized optically transparent interface. The quest for realizing highly spin-polarized conduction in materials at room temperature is one of the central themes of material physics. We report the realization of a conducting interface of two insulating perovskite oxides namely LaFeO3 (LFO) and SrTiO3 (STO) that demonstrates the signatures of spin-polarization, namely negative magnetoresistance, and anomalous Hall resistivity above 150 K and even up to the room temperature. However, the same system shows positive magnetoresistance and normal Hall effect at temperatures below 150 K. The origin of this could be understood phenomenologically as magnetic proximity and a topological effect of Berry's phase originating from the nonlinear spin arrangement in the system due to thermal fluctuations at high temperatures. In addition, this interface appears to be almost transparent in the entire range of visible light. Our observation is not only of interest to fundamental science but is also viewed as a step towards "room-temperature transparent oxide-spintronics."

References: [1] S. Datta, and B. Das, Appl. Phys. Lett., 56, 665 (1990). [2] Y.A. Bychkov, and E.I. Rashba, JETP Lett. 39, 78 (1984). [3] H. Murakawa, M.S. Bahramy, M. Tokunaga, Y. Kohama, C. Bell, Y. Kaneko, N. Nagaosa, H. Hwang, and Y. Tokura, Science 342, 1490 (2013). [4] N. Wadehra, R. Tomar, R.K. Gopal, Y. Singh, S. Dattagupta, and S. Chakraverty, Nature Communication, 1, 874 (2020). [5] A.A. Taskin, H.F. Legg, F. Yang, S. Sasaki, Y. Kanai, K. Matsumoto, A. Rosch, and Y. Ando, Nat. Commun. 8, 1340-1 (2017).

Dynamics of $K_2Ni_2(SO_4)_3$ governed by proximity to a 3D spin liquid model

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Quantum spin liquids (QSLs) have become a key area of research in magnetism due to their remarkable properties, such as long-range entanglement, fractional excitations, pinch-point singularities, and topologically protected phenomena. In recent years, the search for QSLs has expanded into the three-dimensional world, where promising features have been found in materials that form pyrochlore and hyper-kagome lattices, despite the suppression of quantum fluctuations due to high dimensionality. One such material is the S=1 $K_2Ni_2(SO_4)_3$ compound, which belongs to the langbeinite family consisting of two interconnected trillium lattices. Although magnetically ordered, $K_2Ni_2(SO_4)_3$ has been found to exhibit a highly dynamical and correlated state which can be driven into a pure quantum spin liquid under magnetic fields of only $B \simeq 4$~T. In this article, we combine inelastic neutron scattering measurements with pseudo-fermion functional renormalization group (PFFRG) and classical Monte Carlo (cMC) calculations to study the magnetic properties of $K_2Ni_2(SO_4)_3$, revealing a high level of agreement between the experiment and theory. We further reveal the origin of the dynamical state in $K_2Ni_2(SO_4)_3$ by studying a larger set of exchange parameters, uncovering an `island of liquidity' around a focal point given by a magnetic network composed of tetrahedra on a trillium lattice.

Reference: arXiv:2308.11746 (2023)

Valley Polarization Properties of Monolayer MoS_2 Grown by Chemical Vapor Deposition

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Two-dimensional transition-metal dichalcogenides (TMDs) offers valley degree of freedom, which can be exploited to design next-generation valley-based electronics or 'valleytronics'. The broken inversion symmetry, together with strong spin-orbit coupling, results in the valley-dependent optical selection rules in monolayer (1L)-MoS_2. This property enables an exciton to sustain its valley character throughout the time of its existence. In fact, valley polarization approaching 100% has been reported in exfoliated 1L-MoS2 samples, whereas 1L-MoS_2 films grown by the chemical vapor deposition (CVD) technique, which is frequently used to grow large area films on different substrates, show only moderate polarization values (less than 50%). Since large area coverage of the monolayer film has to be ensured for any practical application of the material, it is imperative to understand the reason for the moderation of valley polarization in CVD-grown 1L-MoS_2. Note that the optical and electrical properties of CVD grown layers often suffer from the presence of a high density of sulfur vacancy defects (VS) and the residual strain. Since the valley and spin properties are closely related to the crystal symmetry, both the strain and the defects are expected to have certain impacts on the valley polarization (VP) property of 1L-MoS_2 grown by the CVD technique. Involvement of small wavelength phonons in valley depolarization of 1L-MoS_2 is an unsettled issue. A recent theory suggests that the long-range part of the electron-hole exchange interaction can virtually transfer excitons between K to K' valleys without directly involving any phonon [1]. In this process, the momentum scattering of the excitons can influence the spin flip scattering rate through Maialle-Silva-Sham (MSS) mechanism. The presence of defects can influence the momentum relaxation rate of the excitons and hence can affect the valley depolarization. Here, our temperature dependent polarization resolved photoluminescence spectroscopic study experimentally demonstrates, the above mechanism as the most dominant intervalley exciton transfer process in CVD grown monolayers, where momentum scattering of excitons by the air molecules attached to VS plays significant role [2]. Interestingly, the momentum scattering rate is found to be proportional to the cube root of the defect density. Intervalley scattering of excitons through Γ-valley also contributes to the valley de-polarization process specially when the layer has tensile strain or high density of VS defects as these perturbations reduces K to Γ-energy separation. Band-structural calculations carried out within the density functional theory framework confirm this finding. Experimental results further suggest that exchange interactions with the physisorbed oxygen molecules can also result in the intervalley spin-flip scattering of the excitons and this process becomes important when the defect density is sufficiently high.

References: [1] T. Yu and M. W. Wu, Physical Review B 89, 205303 (2014).

Higher-order topology in quantum spin models

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The concept of free fermion topology has been generalized to d-dimensional phases that exhibit (d − n)-dimensional boundary modes, such as zero-dimensional (0D) corner excitations. In this talk, I will first briefly introduce the notion of Higher-order topological (HOT) phases. Following the introduction, I will talk about extending HOT phases to spin systems and discuss the theoretical prediction of HOT-triplons in quantum paramagnets formed by interacting spin dimers.

Resistive-state switching in some Titanate-spinel compounds

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I will discuss some of our experimental results on the volatile resistive-state switching in doped $MgTi_2O_4$ spinel system. $MgTi_2O_4$ spinel oxide exhibits a rare concomitant magnetic (spin-singlet), structural and orbital-ordering (tetramer orbital ordering) transition driven by Jahn-Teller active $Ti^{3+}(3d^1)$ ions. In presence of a complimentary Jahn-Teller active ion ($V^{3+}(3d^2)$) doping, V-doped $MgTi_2O_4$ spinel exhibits a rare mixed-valent (containing Ti^{3+}, V^{3+}, Ti^{4+} and V^{2+} ions) ground state. We will discuss the transport results revealing that both V-doped and vacancy-doped $MgTi_2O_4$ exhibits current/voltage -induced breakdown of their Mott insulating state to give way to a low-resistive state in presence of extremely-small threshold electric fields. Further lowering of the threshold fields for resistive-state transition can be realized by suitable tuning of the magnetic ground-state of the $MgTi_2O_4$ spinel by replacing the non-magnetic Mg-site with magnetic Mn^{2+} ions.

Quantum Matter in pyrochlore magnets

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The term "quantum matter" is typically used to describe many-body systems with emergent macroscopic properties that are intrinsically quantum mechanical. A theoretical description of "quantum matter" is beyond the scope of the two most successful many-body physics paradigms: symmetry breaking and the notion of the integrity of electrons as quasi-particle.

2D Nanomechanics: Beyond precision sensors

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Mechanical resonators are powerful tools for precise measurements at the nanoscale. The ability to interact with wide variety of stimuli makes them important in many different applications including quantum technology. Furthermore, the prevalence of nonlinear effects at nanoscales positions these resonators as optimal tools to probe both individual nonlinear responses and collective behaviours.

Punctured-Chern topological invariants for semi-metallic band structures

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Topological insulator-based methods underpin the topological classification of gapped bands, including those surrounding semi-metallic nodal defects. However, multiple bands with gap-closing points can also possess non-trivial topology. We construct a general wave function-based ``punctured-Chern'' invariant to capture such topology. To show its general applicability, we analyze two systems with disparate gapless topology: 1) a recent two-dimensional fragile topological model to capture the various band-topological transitions and 2) a three-dimensional model with a triple-point nodal defect to characterize its semi-metallic topology with half-integers that govern physical observables such as anomalous transport. This invariant also gives the classification for Nexus triple-points as Z×Z.

Quantum fluctuations lead to glassy electron dynamics in the good metal regime of electron doped $KTaO_3$

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One of the central challenges in condensed matter physics is to comprehend systems that have strong disorder and strong interactions. In the strongly localized regime, their subtle competition engenders glassy electrons, which ceases to exist well before the insulator-to-metal transition is approached as a function of doping. In this talk, I will present our recent finding of glassy electron dynamics deep inside the good metal regime of an electron-doped quantum paraelectric system: $KTaO_3$. We reveal that upon excitation of electrons from defect states to the conduction band, the excess injected carriers in the conduction band relax in a stretched exponential manner with a large relaxation time, and the system evinces simple aging phenomena - a telltale sign of glass. Most significantly, we observe a critical slowing down of carrier dynamics below 35 K, concomitant with the onset of quantum paraelectricity in the undoped $KTaO_3$. Our combined investigation using second harmonic generation technique, density functional theory and phenomenological modeling demonstrates quantum fluctuation-stabilized soft polar modes as the impetus for the glassy behavior. This study addresses one of the most fundamental questions regarding the potential promotion of glassiness by quantum fluctuations and opens a route for exploring glassy dynamics of electrons in a well-delocalized regime.

This work has been carried out in collaboration with Shashank Kumar Ojha, Sankalpa Hazra, Surajit Bera, Sanat Kumar Gogoi, Prithwijit Mandal, Jyotirmay Maity, Andrei Gloskovskii, Christoph Schlueter, Smarajit Karmakar, Manish Jain, Sumilan Banerjee, Venkatraman Gopalan.

Optical Studies on Many-body Effects in 2D Tungsten Disulfide and Single Photon Emission from 2D Hexagonal Boron Nitride

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Ultrathin two-dimensional (2D) materials are excellent platforms for studying many-body effects due to strong coulombic interactions. Monolayer and few-layered transition-metal dichalcogenides (TMDs) form tightly bound electron–hole pairs (excitons) with binding energies up to hundreds of meV, which is much larger than that in conventional bulk semiconductors. The strongly bound excitons produce a variety of interesting multiparticle excitations, such as charged excitons (trions), biexcitons, and exciton–trion complexes. In this talk, first, we will discuss about the manipulation of excitons, trions, and biexcitons in 2D monolayer WS_2 (1L-WS_2) at room temperature using a sandwich-type ZnO/WS_2/ZnO quantum well (QW) structure. We explore the quantum confinement and doping effect and the tuning of the photoluminescence (PL) emission from the 1L-WS_2 film. We adopted excitation power-dependent and temperature-dependent PL spectroscopy as tools to understand the contributions of neutral excitons, trions, biexcitons, and defects in the tuneable PL from the sandwich structure. Unlike a typical quantum-well case, here, the larger bandgap ZnO injects photo-excited carriers onto the 1L-WS_2, which leads to the conversion of trions and biexcitons to neutral excitons. The biexciton emission becomes dominant at low temperatures and high laser powers for monolayer WS_2, limiting the QW-induced excitonic PL enhancement. Next, I will discuss about our preliminary results on the single photon (quantum) emission from hBN nanoparticles and 2D hBN quantum dots at room temperature. Quantum emitters in 2D materials have attracted significant attention due to their potential applications in quantum technologies. These emitters, such as specific point defects, can emit high-purity single photons, making them crucial components in quantum information processing, quantum communication, and quantum sensing devices. We study the effect of high-temperature oxygen annealing to understand the origin of single photon emission from hBN and improve upon the emission at room temperature. Implications of these results will be discussed for future development in the field.

Spin-orbit torque integration with static field: a generalized method to achieve initialization-free multistate memory behavior of SOT induced magnetization switching

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The integration of modern artificial intelligence (AI) into various sectors has outpaced advancements in contemporary computing hardware which is based on Von Neumann architecture and leads to notable power consumption and latency issues. Analog computing, with its network of multistate memory elements, addresses these concerns by allowing parallel computing within the memory itself. Due to their non-volatility and low power consumption, spin-orbit Torque (SOT)-based memory devices are promising candidates for analogue computing[1,2].In SOT based memory element current through a heavy metal layer can generate SOTs which can manipulate the magnetic orientation of adjacent ferromagnetic layer[3,4]. However, mechanisms for achieving multistate behaviour in SOT memory elements are often material or device-specific. In this study, we explore the combined symmetry of SOT and a static DC field to stabilize multistate behaviour. Our observations focus on the Pt/Co/Pt stack, where spin Hall effect (SHE) generates the SOT while similar interfaces about Co layer mitigate other interface generated effects[4]. Moreover, Pt/Co/Pt is one of the earliest model systems for perpendicular magnetic anisotropy (PMA) studies, thereby expanding the potential applicability of our findings. Using macrospin framework and subsequent micromagnetic analysis we reveal that the integration of a static field while current induced switching can manipulate SOT generated effective field. Further, we verified experimentally that SOT manipulation through a static field yields multiple intermediate saturation states, characterized by the magnitude and polarity of the static field. Observed intermediate states correspond to domain states where domain dynamics is governed by the chirality broken Neel domain walls. Further, each intermediate state is reproducible with a high retention. Our findings suggest that this multistate memory phenomenon is induced by both SOT and external field simultaneously. Furthermore, our measurements aim to resolve the initialization problem of modern analogue memory devices through the experimental demonstration of initialization-free multistate memory. Lastly, this method is applied to other PMA stacks to verify the generality of method. Therefore, static field induced manipulation of SOT could serve as a mechanism for achieving highly dense and power-efficient analogue computing memory elements.

References: [1] S. Fukami, C. Zhang, S. DuttaGupta, A. Kurenkov, and H. Ohno, Magnetization switching by spin–orbit torque in an antiferromagnet–ferromagnet bilayer system, Nature Materials 15, 535 (2016). [2] J. Grollier, D. Querlioz, K. Y. Camsari, K. Everschor-Sitte, S. Fukami, and M. D. Stiles, Neuromorphic spintronics, Nature Electronics 3, 360 (2020).

Superconducting devices with ferromagnetic insulators

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A thin Superconductor (S) proximity coupled to a Ferromagnetic Metal (FM) is an experimentally well studied system which has demonstrated intriguing phenomena such as an oscillatory Tc with ferromagnet thickness, zero to pi transitions in ferromagnetic weak link Josephson junctions and the possibility of generation of spin polarized Cooper pairs using conventional s-wave superconductors. However, despite some early studies from Meservey, Tedrow and Moodera in MIT – the proximity coupling of a Ferromagnetic Insulator to a superconductor is relatively less explored. The primary feature of proximity coupling in FI/S systems is the appearance of an effective exchange field in a thin S layer, which is distinctly different from that of the stray field emanating out of the FI layer. In this talk I will discuss three different kind of devices using FIs which has been developed at the Quantum Materials and Devices Laboratory at IIT Bombay. The first is an FI/S bilayer, which we demonstrate as a system that allow application and tuning of local magnetic fields. The second is a FI/S/FI spin valve where several novel switching phenomena, and possible control of magnetism using superconductivity is found. Both these devices are in Current In-Plane (CIP) geometry, that harness the induced exchange fields for their functionality. In Current Perpendicular to Plane (CPP) geometry, using S/FI/S Josephson junctions – we demonstrate devices with nonreciprocal Josephson effect (Josephson Diode) and non-volatile Josephson memory with reasonably high characteristic voltage.

5d TransitionMetal Oxide-basedQuantumMaterials for Spintronics

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Spin-orbit coupled systems offer a promising pathway for developing spintronic devices and technologies likespin-orbit torque-based non-volatile memory and magnetoelectric spin-orbit logic.The prerequisite, however, is the charge-to-spin current interconversion, which has been achieved traditionally using spin-orbit materials like heavy metals, topological insulators, and heterointerfaces hosting a high-mobility twodimensional electron gas. In this regard,the exploration of oxide-basedquantum materials containing heavy elements arestill in its infancy. In this talk, I will discuss 5dtransitionmetal oxide-based quantum materials, $Bi2WO_6$ and $SrIrO_3$, aspotential candidatesfor linear and non-linear charge-to-spin current interconversion, respectively. In particular, I willfirst discuss thecurious case of $Bi2WO_6$ thin film growthusing pulsed laser deposition, which sensitively depends on the presence of oxygen vacancies on the substrate surface. [1] Subsequently, I will discuss the spin-orbit torque ferromagnetic resonance characterization of high-quality Bi_2WO_6 and $Ni_{0.8}Fe_{0.2}$-based heterostructures, demonstrating a charge-to-spin current conversion at the interface. Such charge-to-spin current inter-conversion may be linked to the spin-orbit proximity effectenabled Rashba-Edelstein effect. [2] Further, I will briefly discussthe observation of non-linear spin-charge conversion in thin films of Dirac semimetal $SrIrO_3$.[3]

Reference

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CONTRIBUTED TALKS

Exceptionally Slow, Long Range, and Non-Gaussian Fluctuations Anticipate the Critical Singularity Far Away from the Charge Density Wave Transition

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$(TaSe_4)_2I$ is a quasi-one-dimensional compound long-known to have a charge-density wave (CDW) transition at around 263 K. We experimentally establish that this transition, unlike what is seen in other CDW compounds such as TaS_2, is a second-order critical transition. Critical fluctuations in the CDW condensate, which couple to the dissipative normal carriers, are slow enough to survive the thermodynamic limit and dominate the low-frequency resistance noise. Around the transition region, we find a rapid increase in their relaxation time, as well as a shift of the spectral weight of fluctuations to lower frequencies. These are direct signatures of the critical slowing down on account of the softening at the hydrodynamic amplitude modes. Critical opalescence on the account of diverging isothermal susceptibility is also seen in the very sharp growth of the variance. The distribution of fluctuations in the transition region is skewed and strongly non-Gaussian. This is on account of the breakdown of the validity of the central limit theorem as the diverging coherence volume becomes comparable to the macroscopic sample size. The temperature window, where the fluctuations manifest as slow and extended hydrodynamic modes is found to be very wide ($\delta\epsilon \approx \pm 0.1$, where ϵ is the reduced critical temperature) but consistent with the Ginzburg criterion.

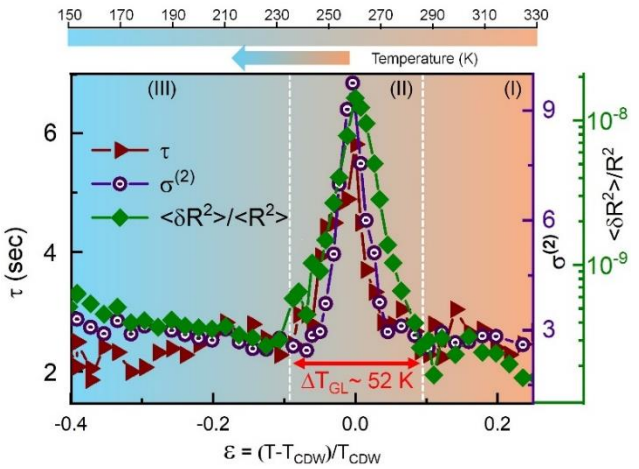

Fig: Fluctuations around the CDW singularity; *Variation of the relaxation time τ (wine triangle), the relative variance $\langle\delta R^2\rangle/R^2$ (green rectangular), and the second variance $\sigma^{(2)}$ (violet circle) of the resistance noise with reduced temperature $\epsilon = (T - T_{CDW})/T_{CDW}$, where T_{CDW} = 263 K. This combined plot clearly reveals three distinct fluctuation regions, marked (I), (II), and (III) respectively.*

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Tuning anomalous Hall effect in strain coupled epitaxial ferromagnetic thin film heterostructures

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Anomalous Hall effect mediated by interfacial strain coupling has been investigated in epitaxial thin film heterostructures. Using the combined pulsed laser deposition and sputtering techniques, epitaxial NiFe/LSMO heterostructures were grown on single crystal MgO (100) substrates with and without $BaTiO_3$ (BTO) sandwich layers. In-depth x-ray diffraction and x-ray spectroscopic analyses revealed the single-crystalline nature and stoichiometric growth of the heterostructures. Temperature dependent x-ray diffraction revealed a first-order-type phase transition near 350 K in the NiFe/LSMO heterostructure. Temperature dependent magneto-optic Kerr effect (MOKE) measurements revealed a ferromagnetic phase transition in the epitaxial NiFe/LSMO thin film. A non-trivial interplay between the intrinsic and extrinsic spin orbit effects in these heterostructures has been observed from anomalous hall effect, which can be tuned using LSMO base layer. A metal-insulator transition induced by LSMO layer has been observed in NiFe/LSMO/MgO film, which may be attributed to the enhanced double exchange behavior in the same. This work extends a better understanding between magnetism and spin-orbit coupling in multilayered heterostructures.

Formation of Dual Bands in Mixed-Halide Perovskites during Photoinduced Halide Segregation Presenting

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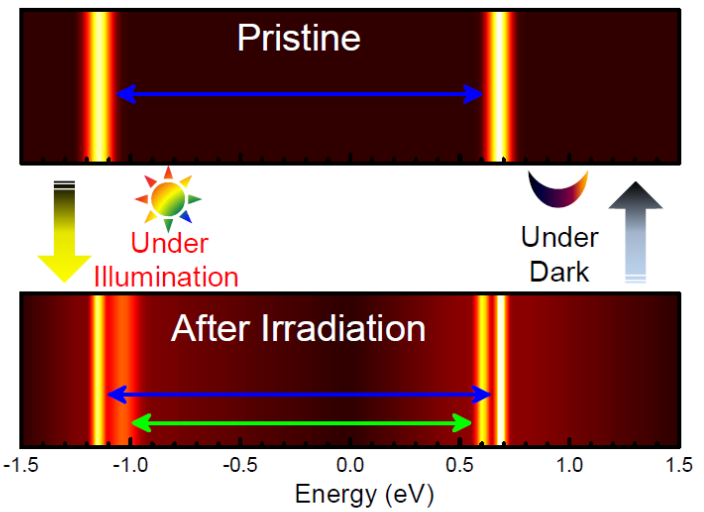
In mixed-halide perovskites, photoinduced halide segregation is known to occur, leading to the formation of segregated domains and thereby an additional low-energy photoluminescence emission. Here, we probe an archetypical mixed-halide perovskite from the perspective of band energies at the microscopic scale. Through optically-coupled scanning tunneling spectroscopy, we determine the band energies of halide-segregated domains, namely iodide-rich and bromiderich ones. We estimate the composition of the phases and identify energy-levels associated with them as would be "seen" by charge carriers in devices. The appearance of dual bands due to the segregation process is explained in the light of molecular orbitals involved in forming the bands. Kelvin probe force microscopy upon illumination provide the local map of the contact potential difference throughout the sample surface, leading to the inference that the grain boundaries act as active sites for iodide migrations, that is, the low bandgap iodide-rich domains formed at the grain boundaries.

ToC Graphics



Modulation of Structural and Electronic Phases in Two-dimensional $PdSe_2$

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Tuning the ambipolar behavior in charge carrier transport via defect-engineering is crucial for achieving high mobility transistors for nonlinear logic circuits. Here, we present the electric-field tunable electron and hole transport in a microchannel device consisting of highly air-stable van der Waals (vdW) noble metal dichalcogenide (NMDC), $PdSe_2$, as an active layer. Pristine bulk PdSe2 constitutes Se surface vacancy defects created during the growth or exfoliation process and offers ambipolar transfer characteristics with a slight electron dominance recorded in field-effect transistor (FET) characteristics showing an ON/OFF ratio <10 and electron mobility ~21 $cm^2/(V \cdot s)$. However, transfer characteristics of $PdSe_2$ can be tuned to a hole-dominated transport while using hydrochloric acid (HCl) as a p-type dopant. On the other hand, the chelating agent EDTA, being a strong electron donor, enhances the electron-dominance in PdSe2 channel. In addition, p-type behavior with a 100 times higher ON/OFF ratio is obtained while cooling the sample down to 10 K. μ-focused angle-resolved photoemission spectroscopy also resembles the p-type band structure of $PdSe_2$ single crystal at low temperature. In addition, the pressure-induced structural modulation associated with metallization were also investigated by high pressure X-ray diffraction and Raman spectroscopy study. $PdSe_2$ undergoes an orthorhombic to pyrite (cubic) structural transition around 4.7 GPa. The interlayer vdW gap reduces under compression resulting in a 2D to 3D type structural crossover. Ab initio electronic structure calculations at the transition pressure regime resemble the interlayer charge transfer along with a semiconducting to metallic transition. Raman spectroscopy shows a direct correlation between the anomalous phonon mode softening and weakening of the bond strength of Se-Se dumbbells in $PdSe_2$. Such an anisotropic and highly auxetic vdW architecture may open up new possibilities towards next-generation electronics as well as exotic superconducting phases under external perturbation.

Linear magnetoelectric coupling without long-range magnetic order and rare-earth-free large magnetocaloric effect in $Co_3V_2O_8$

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The crystal structure of $Co_3V_2O_8$ features cobalt atoms arranging themselves into kagome staircase lattices. Through our low-temperature synchrotron diffraction studies, we have verified a distortion in the kagome lattices along the [010] direction, correlated with an unusual thermal expansion of the unit cell volume below ~180 K. This temperature marks a structural transition to a polar Aba2 space group from the high-temperature structure, a shift further confirmed by Raman spectroscopy and associated with ferroelectric order at 180 K (TFE). Despite the onset of long-range magnetic order below ~11 K, a noteworthy linear magnetoelectric (ME) coupling is observed below TFE. Consequently, ME coupling is tied to the distortion in the kagome lattice structure formed by the Co atoms. These connections present an opportunity for manipulating ME coupling at higher temperatures. The compound displays a highly promising magnetocaloric effect near its magnetic order, offering another appealing outcome. This feature holds significance in the exploration of rare-earth-free magnetocaloric materials.

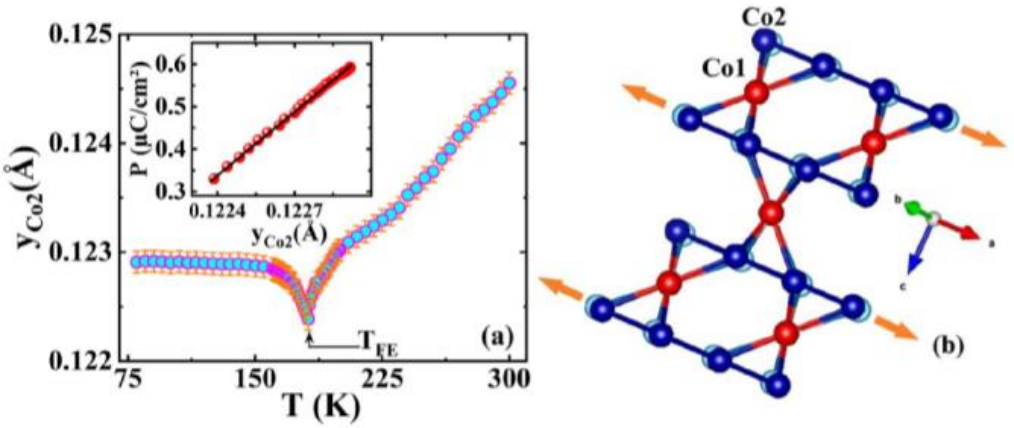

FIG: (a) Thermal variations of the y positions of the Co2 atom; the inset shows the variation of P against the y positions of the Co2 atom. (b) Distortion in the kagome staircase lattice below the structural transition.

In-plane magnetization orientation driven topological phase transition in $OsCl_3$ monolayer

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The quantum anomalous Hall effect resulting from the in-plane magnetization in the $OsCl_3$ monolayer is shown to exhibit different electronic topological phases determined by the crystal symmetries and magnetism. In this Chern insulator, the Os-atoms form a two-dimensional planar honeycomb structure with an easy-plane ferromagnetic configuration and the required nonadiabatic paths to tune the topology of electronic structure exist for specific magnetic orientations based on mirror symmetries of the system. Using density functional theory (DFT) calculations, these tunable phases are identified by changing the orientation of the magnetic moments. We argue that in contrast to the buckled system, here the Cl-ligands bring non-trivial topology into the system by breaking the in-plane mirror symmetry. The interplay between the magnetic anisotropy and electronic band-topology changes the Chern number and hence the topological phases. Our DFT study is corroborated with comprehensive analysis of relevant symmetries as well as a detailed explanation of topological phase transitions using a generic tight binding model.

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Hilbert space fragmentation: en route to Real Eigenvalues in Non-Hermitian Systems

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For the past few years, Hilbert space fragmentation (HSF) has been proposed as an avenue to evade thermalization in isolated quantum systems. In this talk, I shall discuss another unexplored consequence of HSF, namely to yield real eigenvalues of non-Hermitian systems. Such reality of eigenvalues cannot be explained by taking into account global symmetries (like PT symmetry) alone. I shall consider the interacting Hatano-Nelson chain as an example and show that the reality of eigenvalues at large interaction strengths is a consequence of HSF and protection by global symmetries.

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Destabilization of a correlated insulator

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We have observed that an introduction of disorder in a controlled way using 1 MeV argon ion irradiation, suppresses the correlation-driven MIT in $NdNiO_3$ thin films. The film makes a crossover to a heavily disordered conductor governed by weak localization (WL) and at ever higher disorder, an Anderson localized state. We show that the pristine films of $NdNiO_3$ demonstrate an MIT with the electrical conduction process being governed by variable range hopping (VRH). For disorders up to 1%, the conduction in the film exhibits WL behavior with finite conductivity at temperature $T \rightarrow 0$. At higher fluences ($\sim$ 2%) the conductivity decreases significantly but the electrical conduction follows a power-law temperature dependence with a small but finite zero temperature conductivity σ (T = 0) which is expected in a solid with electrons that are Anderson localized. A similar experiment has been performed in $Nd_{0.7}La_{0.3}NiO_3$ thin films. We also observe a significant suppression of non-Gaussian resistance fluctuations in the irradiated films, elucidating the suppression of the correlated nature of the charge carrier dynamics. Raman spectroscopy and x-ray measurements demonstrate that the basic integrity of the NiO_6 octahedra is conserved and the structure preserves its crystallinity.

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Double roton-minima in bosonic fractional quantum Hall states

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Collective excitation of strongly correlated fractional quantum Hall (FQH) fluids is an insightful investigation in a two-dimensional electron system (2DES). Strongly correlated many-body quantum phenomenon, such as the fractional quantum Hall effect can be explained with the concept of quasi-particles known as composite fermions (CFs). Rapidly rotating BEC, trapped in a a two-dimensional (2D) harmonic potential [1] creates a fictitious magnetic field (B), perpendicular to the 2D-plane that resembles like 2DES in perpendicular magnetic field. In such an interacting system there is formation of Landau levels (LLs) of the electrons as well as the quasi-particles. Jain, Regnault, and other theoretician [2] studied the interacting bosons using CF theory and considered short-ranged δ-function like interaction between the Bose particles. The correlated FQH-states produced in rotating BEC may be explained by the weakly-interacting CFs of Bose atoms, which are the bound states of Bose atoms and the odd number of flux quanta (or quantized vortices). The Bose-CFs experience a reduced magnetic field

$$B* = B - p\rho\phi 0$$

here, B represents fictitious magnetic field, $\phi 0$ is the magnetic flux quantum; while the number density of the Bose atoms is ρ, and p = 1, 3, 5, is the odd number of flux quanta attached. The LL filling fraction of the Bose atoms (ν) can be related with the LL filling fraction of Bose-CFs (assumed to be an integer n) as

$$\nu = n/np+1.$$

We calculated the collective spin-conserving excitation spectra in rotating diluted ultra-cold Bose atoms following D. Das et. al. [3]. Double roton-minima have been observed in the FQH states for the two filling fractions (ν = 1/4, 1/6) of the first series of Jain's CF sequences. The obtained roton-minima for ν = 1/4 are at the wave-vectors 1.26 and 2.38 and the roton-minima for ν = 1/6 have been shifted to 1.08 and 2.06. Such shift of roton-minima is attributed due to strong correlation between the particles in bosonic FQH-system. Moreover, the number of roton-minima observed depends upon number of attached fluxes as well as the ranges of interaction between the particles.

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Stability of Discrete Time Crystal without disorder in the thermodynamic limit

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We have shown realization of discrete time crystal (DTC) without disorder in 1D non-integrable spin chain and have discussed about its stability in the thermodynamic limit. Stability of the discrete time crystal is maintained by Dynamical Freezing which violates Floquet-ETH. In this work we use the same mechanism to realize the Non-equilibrium steady signature of DTC and test it's stability against various kind of perturbations. We show that beyond a certain threshold of the longitudinal field present in the Hamiltonian, one can realize a stable DTC-signature. To do that, We perform unitary evolution of simple product states via Exact diagonalization and iTEBD and show the persistence of DTC-signature. To probe into the infinite time behaviour we study Floquet eigenvectors of the Floquet Unitary operator where the eigenvector emerges as cat-like states. We compare the finite-length infinite-time behaviour with infinite-length and large finite-time behaviour, and show that these two limits nicely sits in agreement. We also show emergence of other stable approximately conserved laws in our work.

Excitonic Rydberg States in a Tri-layer to Monolayer H_2-Aided CVD-Grown Large-Area MoS_2 Film with Excellent UV to Visible Broad Band Photodetection Applications

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The diverse nature of optoelectronic properties of few-layer or monolayer MoS_2 is generally dominated by A and B excitons. Occasionally, strong Coulombic interactions within the 2D monolayer led to the creation of hydrogen-like Rydberg states of excitons in MoS_2 similar to other 2D monolayers. In this paper, a simple process is used to convert trilayer MoS_2 films to a monolayer by introducing H_2 gas during chemical vapor deposition. Remarkably, alongside the usual A, B excitons, and A- trion, appearance of the Rydberg states is evidenced by photoluminescence (PL) spectra even at room temperature; also, there is an increase in their areal percentage with an increase in H_2 content. The s-type excited Rydberg states up to the 4th order (n = 5) and 3rd order (n = 4) of A and B excitons respectively have been probed from the PL spectra at 93 K. Unprecedentedly, the first order derivative of room temperature photocurrent spectrum reveals the Rydberg states concurrently and elaboratively. Furthermore, the large area MoS_2 films exhibit photoresponse in a broad UV to visible region with excellent photosensitivity (~10^2) towards both UV and visible lights. Not only does this provide a profound understanding of the excitonic Rydberg states, but also highlights the considerable potential of large area monolayer MoS_2 overcoming the difficulty of tiny flake related 2D device endeavors.

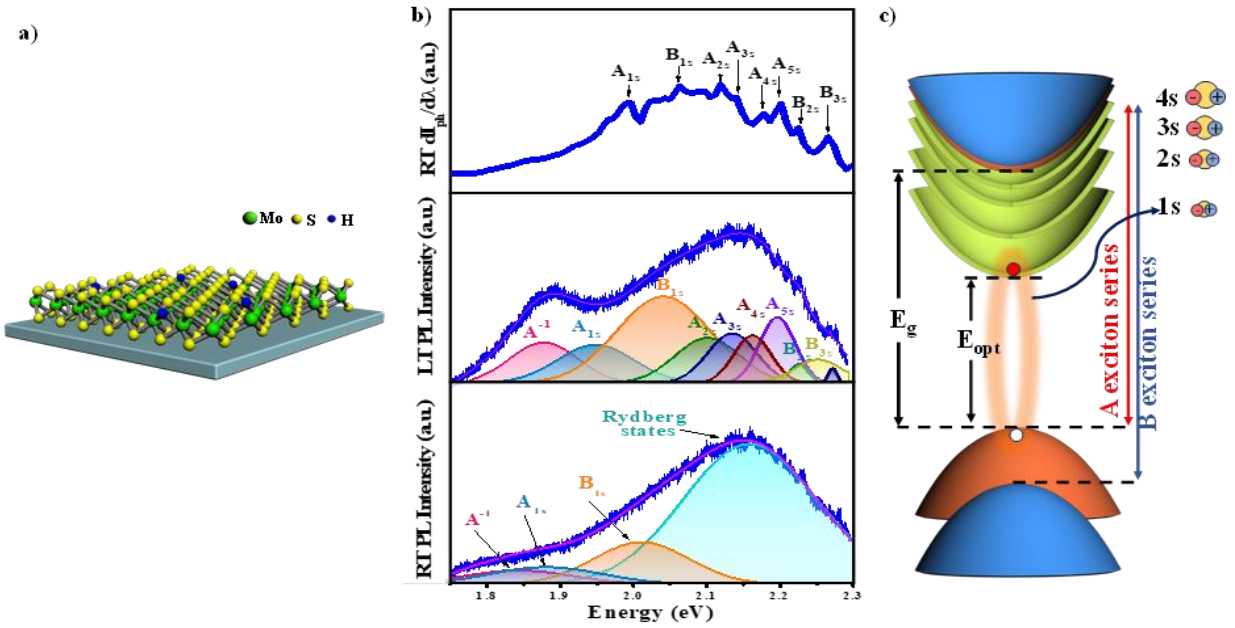

Figure: a) Schematic representation of H_2-aided monolayer MoS_2, b) Probing excitonic Rydberg states of H_2-aided monolayer MoS_2 from deconvoluted PL spectra at Room temperature and at 93 K and $dI_{ph}/d\lambda$ spectra of H_2-aided monolayer MoS_2. c) Schematic representation of energy band diagram of excitons and their Rydberg states.

Sublattice scars and beyond in two-dimensional U(1) quantum link lattice gauge theory

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We have elucidated the structure and properties of a class of anomalous high-energy states, known as quantum many-body scars, of matterfree U(1) quantum link gauge theory Hamiltonian using numerical and analytical methods. Our starting Hamiltonian is H = Okin + λOpot, where λ is a real-valued coupling, and Okin (Opot) are summed local diagonal (off-diagonal) operators in the electric flux basis acting on the elementary plaquette □. The spectrum of the model in its spin- 1/2 representation on Lx×Ly lattices reveal the existence of sublattice scars, |ψs⟩, which satisfy Opot,□|ψs⟩ = |ψs⟩ for all elementary plaquettes on one sublattice and Opot,□|ψs⟩ = 0 on the other, while being simultaneous zero modes or nonzero integer-valued eigenstates of Okin. We demonstrate a "triangle relation" connecting the sublattice scars with nonzero integer eigenvalues of Okin to particular sublattice scars with Okin = 0 eigenvalues. A fraction of the sublattice scars have a simple analytic description in terms of emergent "short-singlets". We further construct a long-ranged parent Hamiltonian for which all sublattice scars in the null space of Okin become unique ground states.

Interplay between Lattice and Magnetism: Insights into the Multiferroicity in distorted diamond spin chain compound $Cu_3Nb_2O_8$

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$Cu_3Nb_2O_8$ is an atypical type-II magnetic multiferroic, where the direction of the electric polarization does not conform to the conventional spin current model. It exhibits a unique crystal structure, where Cu atoms arrange themselves into a distorted diamond chain along the crystallographic a-axis, leading to quasi-one-dimensional behavior with the presence of nonmagnetic Nb atoms between these chains. To understand its multiferroic character, we employed a combination of temperature-dependent powder x-ray diffraction, x-ray absorption spectroscopy, and magnetization measurements. Anomaly in lattice parameters is observed below the magnetic transition temperature (*TN*), and the low temperature crystal structure lacks inversions symmetry. The near edge of the x-ray absorption spectra confirms 2+ valence state of Cu, which remains unaltered down to 20 K. Extended x-ray absorption fine structure analysis reveals significant alterations in the Cu-O bond lengths within the first shell subsequent to *TN*. The pre-edge intensity increases sharply below *TN*, which justifies the increase in local distortion of the Cu-O coordination. Notably, our analysis of magnetic susceptibility data indicate stronger interaction between the shorter diagonal Cu atoms in the diamond chain than that of predicted by Density Functional Theory. The work sheds new light on the interplay between structure and magnetism in $Cu_3Nb_2O_8$ and it contributes to understand this multiferroic materials.

Poster Presentations

Weyl Point Mediated Anomalous Hall Conductivity in Magnetic Inverse Heusler Alloy

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The exploration of novel quantum materials and the study of topological principles in condensed matter physics have been vibrant areas of research in recent years. Among these, Weyl semimetals (WSM) appear as a distinct class, emerging in crystals with broken inversion (P) or time-reversal (T) symmetry, hosting bulk emergent Weyl fermions and surface Fermi arcs connecting Weyl nodes of opposite chirality. Notably the magnetic WSMs with broken-T, offer an expanded realm to explore the interplay between topological ordering, magnetism and electron correlation compared to their non-magnetic counterparts. In inversion symmetric magnetic WSMs, the broken-T induced persistent Berry curvature along with intrinsic magnetism results in remarkably large anomalous Hall conductivity (AHC). Realization of non-centrosymmetric magnetic Weyl semimetals is anticipated to exhibit anomalous transport properties stemming from the interplay of unusual bulk electronic topology and magnetism. In this work, we present a nontrivial AHC in the compensated ferrimagnetic inverse Heusler alloy using symmetry arguments and first-principles calculations. Nonzero components of AHC are determined based on the magnetic space group of inverse Heusler. The nature of the Berry curvature is responsible for the intrinsic origin of the AHC which is consistent with the experimental value. Our results highlight the inverse Heusler compounds as promising platform to realize magnetic Weyl semimetals.

***Work done in collaboration with** Arnab Bhattacharya, Afsar Ahmed, Prof. Biswarup Satpati, Dr. Samik Duttagupta, and Prof. Indranil Das from CMP Division, Saha Institute of Nuclear Physics, Kolkata, India and Prof. Indra Dasgupta from School of Physical Sciences, Indian Association for the Cultivation of Science, Kolkata.

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STRAIN-ENGINEERED ENHANCEMENT OF INTERFACIAL EXCHANGE BIAS IN SUPERMALLOY AND OXIDE THIN FILM HETEROSTRUCTURES

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Ferromagnetic-antiferromagnetic thin film heterostructures composed of supermalloy (NiFeMo) and supermalloy oxide (NiFeMoO) were deposited on c-cut sapphire Al_2O_3 (0001) substrates utilizing a commercial sputtering technique. X-ray diffraction revealed the epitaxial relationship between the cubic $Ni_{80}Fe_{16}Mo_4$ (111) and $Ni_{0.80}Fe_{0.16}Mo_{0.04}O$ (111) planes with the underlying c-cut Al_2O_3 (0001) planes in the heterostructures. Magnetic measurements, conducted with temperature variation using magneto-optic Kerr effect (MOKE), exhibited a noticeable exchange bias present at the interface between the NiFeMo and NiFeMoO layers within the heterostructures. A close co-relation between the residual stress in the epi-layers and the ensuing exchange bias effect was established. This study introduces an innovative approach for strain engineering to manipulate exchange bias effects in the technologically significant supermalloy material, offering potential applications in the field of spintronics.

Spin-orbit coupling induced novel spin textures in non-centrosymmetric half-Heusler alloys

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The spin-orbit coupled electronic structure of two representative nonpolar half-Heusler alloys, namely 18- electron compound CoZrBi and 8-electron compound SiLiIn, has been studied in detail. An excursion through the Brillouin zone of these alloys from one high-symmetry point to the other revealed rich local symmetry of the associated wave vectors resulting in nontrivial spin splitting of the bands and consequent diverse spin textures in the presence of spin-orbit coupling. Our first-principles calculations supplemented with the lowenergy k · p model Hamiltonian revealed the presence of the linear Dresselhaus effect at the X point having D2d symmetry, and the Rashba effect with both linear and nonlinear terms at the L point with C3v point group symmetry. Interestingly we have also identified nontrivial Zeeman spin splitting at the non-time-reversal invariant W point and a pair of nondegenerate bands along the path to L displaying vanishing spin polarization due to the non-pseudo-polar point group symmetry of the wave vectors. Further, a comparative study of CoZrBi and SiLiIn suggests, in addition to the local symmetry of the wave vectors, the important role of the participating orbitals in deciding the magnitude of the spin splitting of the bands. Our calculations suggest that half-Heusler compounds with heavy elements displaying diverse spin textures may be ideal candidates for spin valleytronics, where spin textures can be controlled by accessing different valleys around the high-symmetry k-points.

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An elementary investigation of Burstein-Moss shift in Quantum Physics of Semiconductor Materials

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We study the Burstein-Moss shift and related properties for band-tailed degenerate n-type semiconductors. We do this by taking into consideration the wave vector dependency of the optical matrix element and applying a recently established electron dispersion rule. Since our dispersion law can be used to easily obtain physical entities for heavily doped semiconductors, like the thermoelectric power, effective electron mass, specific heat, and Einstein relation, the dispersion relation for heavily doped semiconductors, thus derived in a simplified manner, is crucial. Using n-InSb as an example for numerical computations, it is observed that the optical activation energy increases with increasing carrier concentration. Moreover, the present theory shows better agreement with experimental results than the conventional approach, which is based on the optical matrix element's wave vector independence, which is further controlled by the $E-\vec{K}$ relation.

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Sub mm Size MoS_2 Synthesis on Different Substrate and It's Transport Characteristics

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Transition metal dichalcogenides (TMDs) have emerged as promising material for next-generation electronic and optoelectronic devices due to their characteristic electronic structure and finite band gap residing in the visible range. Among them, molybdenum disulfide (MoS_2) has gained significant attention during the last decade for its two-dimensional nature and remarkable semiconducting behavior. Chemical vapor deposition (CVD) has proven to be a versatile and scalable technique for the synthesis of high-quality monolayer and few-layer MoS_2 films. In this study, we focus on MoS_2 synthesized by CVD, exploring its growth process on different substrates. Further, we fabricate Field Effect Transistor (FET) devices using optical lithography and investigate its electronic transport behavior down to 77K. While the device exhibits a nonlinear IV characteristics and higher on/off ratio (10^4) at room temperature, the mobility was rather small (~0.8 cm^2/Vs). The temperature dependent transport reveals that the electron transport is dominated by the variable range hopping as reported earlier. Thus our study demonstrates a systematic large area growth, fabrication and device characterization of MoS_2 based FETs, important for futuristic applications.

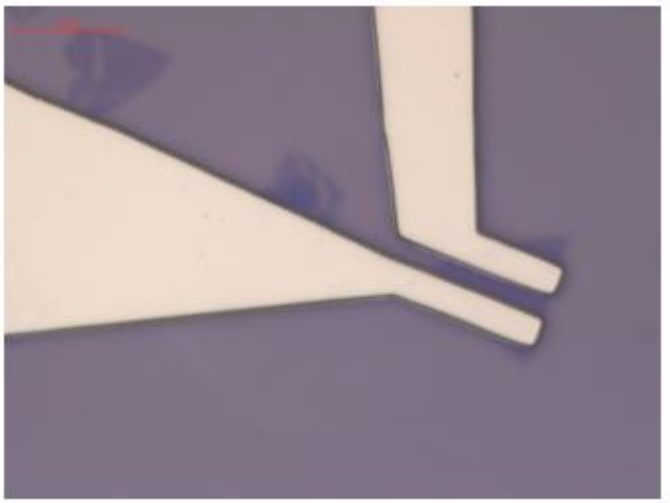

Fig 1: Optical image of FET device of monolayer MoS_2

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Compliance-Free and Forming-Free Highly Stable Digital and Analog Resistive Switching Behaviour in a Perovskite-based Artificial Synaptic Device Mimicking: Pavlov's Associative Learning for Neuromorphic Computing

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Given the swift advancement of artificial intelligence, the fusion of biological capabilities within electronic devices has become imperative for executing intricate tasks and adjusting to diverse work settings. In this context, memristive synaptic devices have emerged as crucial components in the field of bio-inspired electronics, playing a pivotal role in advancing computational applications. However, limited reports are available on the realization of a multifunctional switching behaviour, combining digital and analog switching capabilities in a single perovskite oxide-based device. In this work, to the best of our knowledge, we demonstrate analog resistive switching behaviour and all fundamental synaptic functionalities including learning experience for the first time in a $La_{0.8}Sr_{0.2}Mn_{0.62}O_{2.77}$ (LSMO)-based memristor. Notebly, both compliance-free and forming-free digital and analog resistive switching behaviour is observed in a single LSMO-based memristor which is fabricated using pulsed laser deposition tecnique. A probable current conduction mechanism for both switching behaviour in the present device is proposed. Remarkably, fundamental bio-synaptic features such as potentiation, depression, spike-time-dependent plasticity, paired-pulse facilitation, transition from short-term memory to long-term memory, and learning-forgetting-relearning behaviour are successfully emulated based on the change in device response current through analog memory behaviours. Importantly, classical Pavlov's associative learning rules is also being mimicked in the LSMO-based synaptic device for first time to our knowledge. Hence, the integration of memory and complex learning rules in a single device opens up new possibilities for in-memory computing architectures, offering advantages such as improved speed, energy efficiency, parallel processing, and enhanced capabilities for artificial intelligence applications.

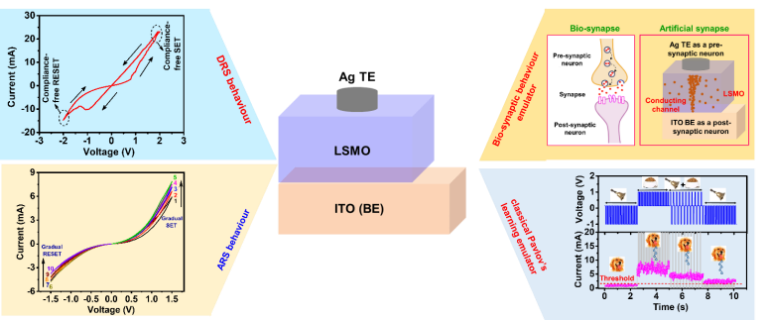

Figure: Designing a LSMO-based artificial synaptic device for advanced computing applications.

Exploring Spin Reorientation Transition & Berry Curvature driven Anomalous Hall Effect in Quasi-2D vdW Ferromagnet Fe_4GeTe_2

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Two-dimensional (2D) ferromagnetic materials have garnered significant attention due to their potential to host intriguing scientific phenomena such as the anomalous Hall effect[1,2], anomalous Nernst effect[3], and high transport spin polarization[4,5]. This study focuses on the investigation of air-stable van der Waals (vdW) ferromagnets, Fe_nGeTe_2 (F_nGT with n = 3, 4, and 5). Particular emphasis is placed on the Fe_4GeTe_2 (F4GT) compound, which exhibits a complex and fascinating magnetic behavior characterized by two distinct transitions: (i) paramagnetic (PM) to ferromagnetic (FM) around $T_C \sim 270$ K, and (ii) another spins reorientation transition (SRT) at $T_{SRT} \sim 100$ K [6-8] (See Fig.1 (a)). Scaling analysis of magneto caloric effect confirms the second-order character of the ferromagnetic transition, while the same analysis at T_{SRT} suggests that SRT is first-order phase transition[8]. Moreover, the F4GT exhibits a large anomalous Hall conductivity (AHC), $\sigma^{A}_{xy} \sim 490\ \Omega^{-1}cm^{-1}$ at 2 K[9](See Fig.1 (b)). The near-quadratic behavior of the anomalous Hall resistivity (ρ^{A}_{xy}) with the longitudinal resistivity (ρ_{xx}) suggests that a dominant AHC contribution arises from an intrinsic Berry curvature (BC) mechanism. Electronic structure calculations reveal a significant BC resulting from SOC-induced gapped nodal lines around the Fermi level, thereby giving rise to large AHC. Additionally, we reported exceptionally large anomalous Hall angle ($\simeq$ 10.6%) and Hall factor ($\simeq 0.22\ V^{-1}$) values (See Fig.1 (c,d)), the largest observed within this vdW family[9]. The findings presented here, provide valuable insights into the fascinating magnetic and transport properties of 2D ferromagnetic materials, in particular, F_nGT family.

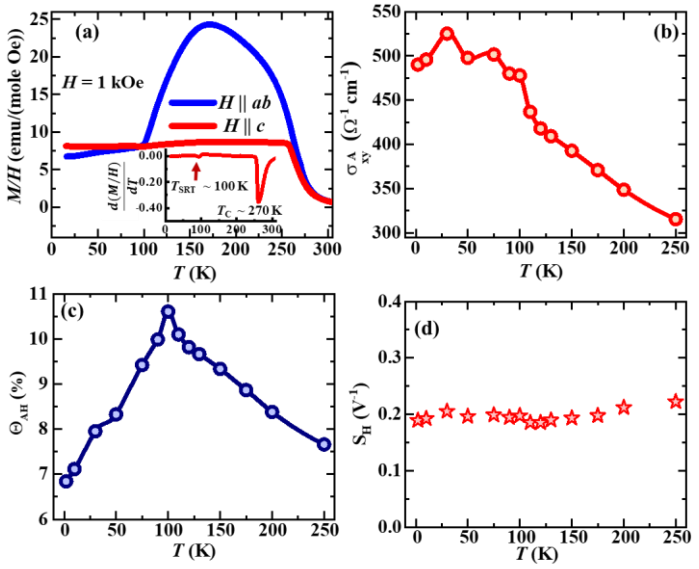

Fig.1: ***(a)*** *Temperature dependence of dc magnetization measured in the zero-field-cooled condition for applied magnetic field H = 1 kOe with H||ab and H||c, respectively. Inset shows the derivative of M, i.e., (d(M/H)/dT) vs T plot.* ***(b)*** *Temperature-dependent anomalous Hall conductivity (σ^{A}_{xy})* ***(c)*** *and* ***(d)*** *represent the Θ_{AH} and the S_H as a function of temperature, respectively.*

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Stochastic Relaxation Dynamics of a Feshbach Coupled Atomic- Molecular Bose-Einstein Condensates

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Atomic and molecular bosons are weakly coupled to one another via Feshbach detuning in the usual Bosonic Josephson Junction (BJJ). Here we study the imbalance between atomic and molecular bosons as a component of the Bloch vector. If coupling strength and detuning between the atomic and the molecular bosons are corrupted by white Gaussian noise then we get relaxation dynamics of the Bloch vector to a stable equilibrium point. In this case, the relaxation rates in the mean field (MF) are smaller than the relaxation rate of the Bogoliubov-Born-Kirkwood-Yvon (BBGKY) hierarchy. Besides this, the Particle localisation shows a jump from a molecular-heavy state to an atomic-heavy state for critical detuning in the absence of noise. This sharp jumping point is spread out in the presence of noise.

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Tuning of geometrical-magnetic-frustration and spin Jahn-Teller effect in $Mn_{1-x}CdxCr_2O_4$

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Symmetry-lowering structural transition from a cubic to a tetragonal phase (*C*-*T*) in magnetically frustrated *AB*2O4 spinel compounds is generally found indispensable to enable long-range magnetic ordering. Intriguingly, MnCr2O4, and CoCr2O4, constitute exceptions to the above general rule, as they seem to undergo long-range ferrimagnetic (FIM) ordering within their corresponding cubic phases [1, 2]. We find that MnCr2O4 (and CoCr2O4) undergo a hitherto undetected partial glassy magnetic ordering of the spiral-spin components [prior to the long-range FIM transition] at TSP, which triggers the onset of weak spin Jahn-Teller (SJT) driven structural modifications. In magnetic spinel oxides, like CdCr2O4 and FeCr2O4, where *C*-*T* structural transition occur from either a SJT effect or through JT distortions [2, 3], such a higher-temperature glassy magnetic transition is absent. Our results, thus, clearly elucidate that the structural modifications at TSP, aided with the presence of magnetic *A*-site ions, play a pivotal role in releasing the geometric-magnetic-frustration (GMF) in MnCr2O4 (and also CoCr2O4) to enable the long-range FIM ordering in these systems. On the other hand, we investigate the mechanism of tailoring the GMF and SJT effect by tuning different magnetic interactions in MnCr2O4 (which host weak GMF and weak SJT effect) through systematic doping of Cd at the Mn site, thereby, revealing the interplay among SJT effect, GMF, and long-range magnetic ordering. We find that with increasing x (i.e. Cd concentration), both frustration due to competing interaction (FCE) and GMF increase continuously up to x =0.6, and the commencement of long-range FIM ordering happens through preceding weak SJT induced structural changes within their corresponding cubic phases. Interestingly, beyond x =0.6, while FCE decreases, the GMF shoots up, which resulting in the emergence of strong SJT induced global structural transition to establish the long-range antiferromagnetic (AFM) ordering.

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Enhanced electrical transport properties of room temperature deposited RF sputtered Al doped ZnO film owing to ultrathin Zn top layer

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One of the major challenges in fabricating the flexible/wearable electronic devices is the development of affordable flexible transparent conducting film (TCF), preferably grown at room temperature (RT) or temperature not exceeding 453 K. While aluminum-doped ZnO (AZO) is recognized as the most promising substitute for the widely used tin-doped indium oxide, attaining a stable and low sheet resistance value for the AZO film grown at room temperature (RT) remains a significant challenge.

This study explores the interaction between an ultrathin Zn surface passivation layer and a RT-deposited AZO film, resulting in significantly improved electrical transport properties. The conductivity of the simple AZO film steadily decreases over time in ambient conditions (from 50 to 3 $(\Omega\cdot cm)^{-1}$). However, the introduction of a 4 nm Zn layer on top of the AZO film stabilizes the conductivity at 219.3 $(\Omega\cdot cm)^{-1}$, increasing further to 416.7 $(\Omega\cdot cm)^{-1}$ with a 5.3 nm Zn overlayer. RT Raman and X-ray photoelectron spectroscopy studies suggest that a few Zn species diffuse into the AZO films, passivating Zn vacancies (V_{Zn}) and forming Zn interstitials (Zn_i), as well as Zn_i-V_O donor complexes. This results in a significant improvement in electrical stability and conductivity values of the AZO films. Temperature-dependent conductivity measurements reveal the semiconducting behavior of AZO films with 4 and 6 nm Zn overlayers, where the transport process is governed by thermally activated band conduction (TABC) at and below RT (up to ~247 K). As the temperature decreases, the mechanism shifts to nearest-neighbor hopping (NNH) and Mott variable range hopping (VRH). The 5.3 nm Zn-coated AZO film exhibits metallic behavior at RT and undergoes a metal-to-semiconductor transition (MST) ~220 K, deviating from the Boltzmann conduction process due to electron-electron interaction (EEI) and weak localization (WL) phenomena.

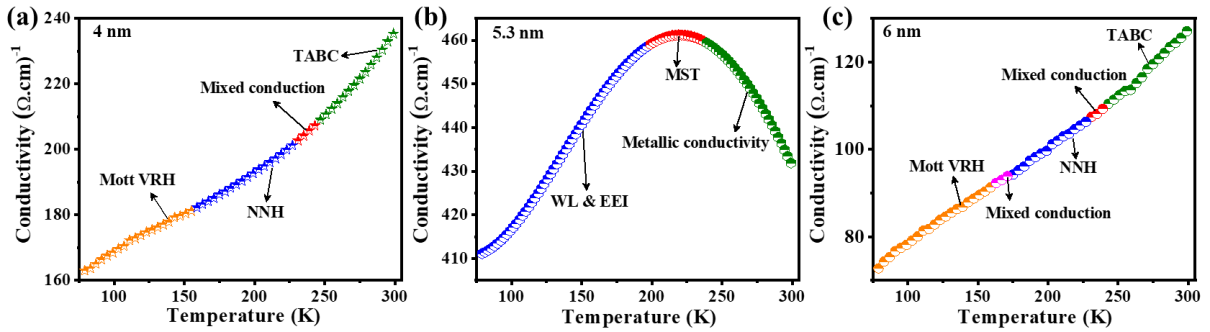

Figure: Various carrier conduction processes of AZO films with (a) 4, (b) 5.3 and (c) 6 nm Zn over layer in the temperature range of 300-79 K.

Correlation between Edge and bulk states in Quantum Hall system probe by Non local measurement

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Non-local measurements have been widely used in the search for novel transport mechanisms, including dissipation-less spin and valley transport, topological charge-neutral current, helical edge modes and mixing of edge and bulk modes. Non-local transport in the quantum Hall regime shows giant non-local resistance at the plateau-to-plateau transition region. However, origin of this giant non-local resistance in graphene and other 2D systems is still debatable. Here, we present NL resistance measurement in a 2DES embedded in GaAs/AlGaAs heterostructures at milliKelvin temperatures at 3.5x106cm2/V.s. Notably, at the plateau-to-plateau transition, edge and bulk states both coexists in quantum Hall system. Here, we have observed linear dependence of nonlocal resistance RNL with distance L from the current source at 30mk to 100mK and then decay exponentially with L above 100mK at filling fraction ν = 2 to 3 (see figure below). It is reported previously that non-local resistance in GaAs/AlGaAs arises due to co-existence of edges and bulk states. Bulk current is also circulating along the sample boundary like the edges states, propagating parallel to each other, meets only at ohmic contacts. But never observed this experimentally. Our observation of Linear decay of non-local resistance RNL with distance L from the current source confirms that bulk states is circulating current like edge states at 30mk to 100mK. While at higher temperature bulk interact with the edge states not only at the ohmic contact pad but throughout the path, leads in exponential decay of nonlocal resistance with length L.

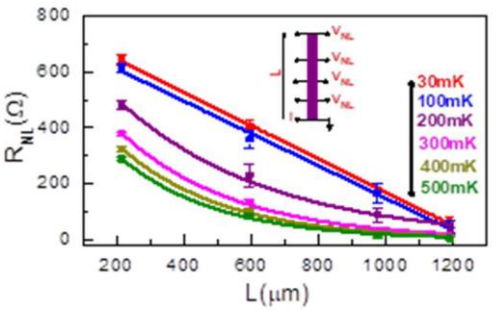

Figure 1. Experimental (points) and calculated (solid lines and curves) amplitudes of Nonlocal resistance with distance L from the current source at different temperature are shown.

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Highly Stable Artificial Synaptic Behaviour in Epitaxial Thin Film for Advance Computing Applications

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To emulate the functions of highly stable and energy-efficient advanced computing systems, which combine information storage and processing, appropriate artificial synaptic devices are needed. These devices should exhibit high retention, simple structure, and low power consumption. Here, we demonstrate that such a synaptic device is realized using an Ag/$PbZr_{0.52}Ti_{0.48}O_3$ (PZT)/$La_{0.67}Sr_{0.33}MnO_3$ (LSMO) heterostructure memristors fabricated using the pulsed laser deposition. Remarkably, an epitaxial PZT-based memristor exhibits both compliance-free and forming-free digital resistive switching behaviours. Furthermore, it successfully emulates all fundamental bio-synaptic functionalities, including potentiation, depression, spike-time-dependent plasticity, paired-pulse facilitation, and the transition from short-term memory to long-term memory behaviours. Overall, this work demonstrate a potential pathway to fabricated artificial synaptic memristors for advancing computing applications.

Investigating giant magnetoresistance and magneto-dielectric effect in multiferroic thin film heterostructure

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Artificial multiferroic heterostructure of bi-layered ferroelectric/ferromagnetic thin film such as $Ba_{0.85}Ca_{0.15}Ti_{0.9}Zr_{0.1}O_3$ (BCZT)/$La_{0.67}Sr_{0.33}MnO_3$ (LSMO) is a promising candidate for spintronic applications. A structure-property relationship governed by the substrate induced epitaxial strain has been investigated in this work. Substrate-film lattice mismatched stain gives rise to interesting magneto-transport and magneto-dielectric phenomenon. Giant magnetoresistance has been observed in film under in-plane compressive strain. Higher magneto-dielectric effect observed in film under in-plane tensile strain may be attributed to interfacial charge screening due to ferroelectric distortion at the BCZT/LSMO interface [1]. This study contributes to an improved comprehension of dielectric phenomena induced by magnetic fields in thin film heterostructures combining ferroelectric and ferromagnetic materials, achieved through the application of strain engineering.

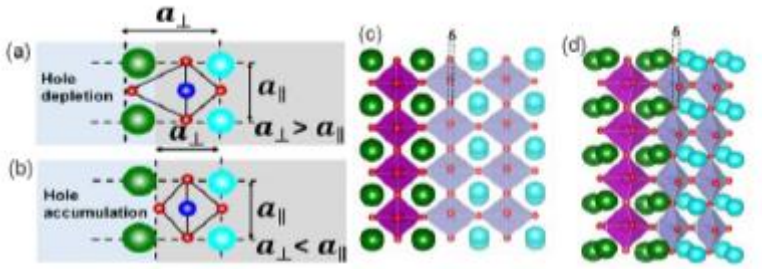

Fig. 1: BCZT/LSMO interface: charge depletion and accumulation at the interface under (a) compressive and (b) tensile strain. Displacement of ferroelectric distortion (δ) under (c) compressive and (d) tensile strain.

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Random Field to Spin Glass crossover in $SmCaCoMnO_6$ −$SmMnO_3$ composites enhancing magnetocaloric effect

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To get rid of the immense negative impact of the conventional vapor-based cooling technology on nature by reducing the use of greenhouse and hazardous, ozone-depleting chemicals [1], the future cooling technology requires a sustainable energy solution. However, the magnetocaloric effect (MCE) i.e., cooling a magnetic material by applying/removing magnetic field can sustain our nature by providing a solid-state, cost effective, reusable cooling system, but still in terms of efficiency it has a long way to go [2,3]. Here, we report an enhancement of inverse MCE at low temperature (T) due to uniform external field (H) induced random field (RF) to Spin Glass (SG) crossover in ferrimagnetic $SmCaCoMnO_6$ and antiferromagnetic $SmMnO_3$ composite systems. Among the tremendous researches done for RF to SG crossover in diluted antiferromagnet and dilute dipole-coupled Ising ferromagnetic systems [4-6], no report has yet focused on such a crossover in a ferrimagnetic double perovskite system, according to our knowledge. This is probably due to the complexity with multiple magnetic ions present in it. Here, an in-depth understanding of the RF to SG crossover is presented by investigating the evolution of the peak positions of dM/dH vs H curves under the variation of T (left inset of Fig. 1). The peak positions indicate the threshold field (H_{thresh}) required for restoring the long-range ordering, below which a short-range ordering exhibits [7]. In the $Hthresh$ vs T diagram, the displacement of T from 35 K to 15 K follows $H_{thresh} \sim a(T_0\text{-}T)^{\phi co/2}$ with the exponent, $\phi_{c0} \sim 1.5$ which is very close to the scaling behavior of RF system (Fig. 1). Nevertheless, it shows a crossover to SG under the application of higher H below T <15 K [4-5], confirmed by other measurements. This field-induced RF-SG crossover enhances H dependent entropy change ($-\Delta SM$) in SG regime, a requisite for large MCE. In SG region at ~7.5 K, a maximum $-\Delta SM$ value ~−0.65 J/Kg-K could be obtained for a change of H ~20 kOe which is almost thrice of the direct MCE (at ~65 K) in the system (right inset of Fig. 1). So, the enhancement of inverse MCE due to such crossover may circumvent the dependence on conventional yet expensive low temperature liquid cryogens.

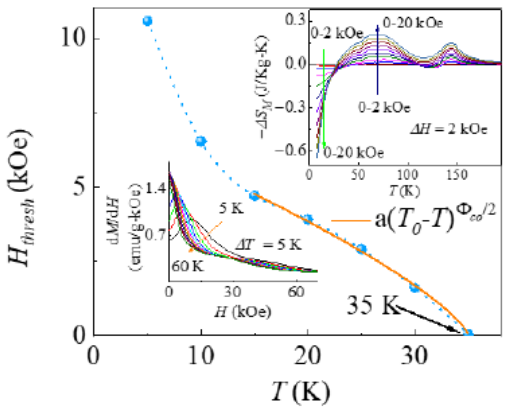

Fig. 1. H_{thresh} vs T diagram. Left inset shows dM/dH vs H curves with peaks at H_{thresh} with different T. Right inset shows $-\Delta S_M$ vs T for the change of H from 2 kOe to 20 kOe.

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Effect of carrier localization on anomalous Hall effect in structurally chiral β-Mn type $Co_7Zn_7Mn_6$ alloy

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The effect of carrier localization due to electron-electron interaction in anomalous Hall effect (AHE) is elusive and there are contradictory results in the literature. To address the issue, we have studied the detailed transport study including the Hall measurements on β-Mn type cubic compound $Co_7Zn_7Mn_6$ with chiral crystal structure, which lacks global mirror symmetry. Till now Co-Zn-Mn alloys mostly studied to explore the skyrmionic state due to their chiral crystal structure via magnetization, ac susceptibility, small angle neutron scattering and transmission electron microscopy. The alloy orders magnetically below Tc = 204 K, and reported to show spin glass state at low temperature. The longitudinal resistivity (ρxx) shows a pronounced upturn below Tmin = 75 K, which is found to be associated with carrier localization due to quantum interference effect like electron-electron interaction (EEI), weal localization (WL) and kondo effect etc. The upturn in ρxx shows a $T^{1/2}$ dependence and it is practically insensitive to the externally applied magnetic field, which indicate that EEI is primarily responsible for the low-T upturn. The studied sample shows considerable value of anomalous Hall effect below Tc, and our analysis indicates that the most likely source of the anomalous Hall effect is the intrinsic mechanism. We found that the localization effect is present in the ordinary Hall coefficient (R0), but we failed to observe any signature of localization in the anomalous Hall resistivity or conductivity. The absence of localization effect in the anomalous Hall effect in $Co_7Zn_7Mn_6$ also support the previous theoretical finding that EEI correction to AHE identically vanishes for both skew scattering and side-jump due to general symmetry reasons though it is present for system having WL effect [1,2].

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Different Phases in A Two Level Bosonic System with Rydberg Atoms

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Ultracold atoms, excited to Rydberg states with high principal quantum numbers, can lead to interesting new physical phenomena. In this work, we study a two-level bosonic Rydberg system in an optical lattice, where each lattice site supports a ground state and a Rydberg excited state. Rydberg interaction is present among the atoms in excited states of neighbouring sites in the form of a blockade. Additionally, there is on-site interaction among different bosons occupying the ground state of the same site, and this can be controlled. A Rabi coupling between the ground state and the excited state of the same site is present. The dissipative non-equilibrium dynamics of the system are probed using mean field theory, and the population differences between the ground states and the excited states are studied as functions of time. We observe that for a large amplitude of the on-site interaction strength, the Rydberg population is uniform across the lattice. However, for a lower value of the on-site interaction, the lattice emerges as two alternating sublattices in terms of the population distribution, and one can have (i) an oscillatory region (the population difference between the ground states and excited states oscillates with time), (ii) an antiferromagnetic region (the Rydberg population is fixed but has a different value for alternating sublattices). We have defined an order parameter for this system and plot this order parameter as a function of on-site interaction for a fixed time. The phase transition from uniform phase to non-uniform phase is visible in this plot.

Spin-phonon coupling in a one-dimensional spin-chain compound

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Spin-phonon coupling (SPC) represents a fascinating phenomenon in condensed matter physics, arising from the modification of phonon modes due to magnetic ordering. The exploration of SPC serves as a valuable tool for investigating a range of intriguing phenomena, including the magnetostriction effect, spin Seebeck effect, thermal Hall effect, spin-Peierls transition, and magnetoelectric effect. While the significant interplay between lattice and magnetism is recognized in spin-chain compounds, investigations into spin-phonon coupling (SPC) within such materials have largely remained unexplored. In this context, we present an extensive physical property study, especially the lattice dynamics study of a 1D spin-chain compound $MnSb_2O_4$ using temperature-dependent Raman spectroscopy. Despite its 1D nature, this compound exhibits an antiferromagnetic (AFM) LRO state below TN = 53 K. The relatively high Neel temperature (TN) of this system makes it a unique testing ground for exploring the SPC phenomenon, an aspect that has yet to be reported. Our study showed that a number of phonon modes displayed anomalous phonon softening in the vicinity of TN, which suggested a pronounced spin-phonon coupling in this system. A concurrent change in the Raman line-widths for multiple Raman modes near TN was also observed, thus indicating alterations in the phonon lifetime. Therefore, all these combined effects unanimously suggest to the occurrence of the spin-phonon coupling in this system. The presence of a short-range magnetic ordering above TN was also reflected in our lattice dynamics study.

Electric field driven conformational modifications in metal-molecule-metal junction

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Development of next generation organic electronic devices depends on understanding of charge transport mechanism at single molecular level. Single-molecule junctions, consisting of individual molecules sandwiched between two electrodes, are commonly used in charge transport studies. During past few decades rapid technical, and theoretical advances have improved our understanding of charge transport phenomena and different physical properties at the atomistic limit. Importantly in recent times, there has been a great interest of combining single-molecule junctions with different control systems to study and optimize the important physical phenomena including planarization, folding, trans-to-cis isomerization, and so forth. Our work focuses on how electric fields affect the conformation of the molecule and consequently its impact on the charge transfer to or from the molecule.

Here we show that conformational of the benzidine molecular junction can be greatly tuned by modifying bias voltage and this junction can have two distinct conductance states with conductance value either high or low. While high conductance states become more dominant with the rise of bias voltage. The effect is opposite for low conducting state. Further experiment with Benzene-1,4-diamine molecular junction reveals no such effect. Thus, our findings demonstrate that applied bias voltage is a key factor to realize the desirable configuration of the benzidine molecular junction. Increase in bias voltage leads to the change in the dihedral angel between two phenyl rings of benzidine molecule which might be reflected in bias sensitive molecular conformation. Overall, important role of electric field in the nano electro mechanics is identified through our study which enrich our knowledge for future generation nano-electronics applications.

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Dynamical phase transitions in XY model: a Monte Carlo and mean field theory study

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We investigate the dynamical phases and phase transitions arising in an anisotropic classical 2d-XY (an-XY) model under the influence of an external magnetic field which is periodically driven in time. We use acombination of classical Monte Carlo (MC) simulation (implemented within a CPU + GPU paradigm) utilizing local dynamics provided by the Glauber algorithm at a finite temperature and phenomenological mean field (MF) equation-of-motion (EOM) approach to study the model. We investigate several parameter regimes of the variables magnetic field, anisotropy, and the external drive frequency that influence the an-XY system and identify four possible dynamical phases – Ising-SBO, Ising-SRO, XY-SBO and XY-SRO. Both techniques indicate that only three of them (Ising-SRO, Ising-SBO, and XY-SRO) are stable dynamical phases in the thermodynamic sense. Within the MC framework, a finite size scaling (FSS) analysis shows that XY-SBO does not survive in the thermodynamic limit giving way to either Ising-SBO or XY-SRO. The FSS analysis further shows that the transitions between the three remaining dynamical phases either belong to the two-dimensional (2d) Ising universality class or are first-order in nature. From the perspective of the MF calculations, XY-SBO represents a transient dynamical feature that is eventually lost at late times to either Ising-SBO or XY-SRO.

Entanglement transitions in a periodically driven non-Hermitian Ising chain

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We study entanglement transitions in a periodically driven Ising chain in the presence of an imaginary transverse field γ as a function of drive frequency ω_D. In the high drive amplitude and frequency regime, we find a critical value $\gamma = \gamma_c$ below which the steady state half-chain entanglement entropy, $S_{L/2}$, scales with chain length L as $S_{L/2} \sim \ln L$; in contrast, for $\gamma > \gamma_c$, it becomes independent of L. In the small γ limit, we compute the coefficient, α, of the lnL term analytically using a Floquet perturbation theory and trace its origin to the presence of Fisher-Hartwig jump singularities in the correlation function of the driven chain. We also study the frequency dependence of γc and show that $\gamma_c \to 0$ at special drive frequencies; at these frequencies, which we analytically compute, $S_{L/2}$ remain independent of L for all γ. This behavior can be traced to an approximate emergent symmetry of the Floquet Hamiltonian at these drive frequencies which we identify. Finally, we discus the behavior of the driven system at low and intermediate drive frequencies. Our analysis shows the presence of volume law behavior of the entanglement in this regime $S_\ell \sim \ell$ for small subsystem length $\ell \leq \ell^*(\omega_D)$. We identify $\ell*(\omega_D)$ and tie its existence to the effective long-range nature of the Floquet Hamiltonian of the driven chain for small subsystem size. We discuss the applicability of our results to other integrable non-hermitian models.

Multiferroic order and large magnetic refrigeration capacity in Gd_2MnFeO_6: Significance of magnetic frustration and Jahn-Teller distortion

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We present a noteworthy finding of high-temperature ferroelectric order in a fairly unexplored Gd_2MnFeO_6 compound, characterized by a disordered double-perovskite structure. This material exhibits a remarkable cryogenic refrigerant capacity alongside the ferroelectric order, making it a rare occurrence. Notably, the refrigerant capacity of this Gd-based double perovskite surpasses that of all previously reported counterparts. Around 92 K (TFE), we observe the presence of ferroelectric order, which is significantly higher in temperature compared to the magnetic order at 4 K (TN). The involvement of dominant short-range magnetic order below TFE (≫TN) leads to a notable magnetoelectric consequence. Raman studies further support our findings, revealing a steplike octahedral distortion of $(Mn/Fe)O_6$ at TFE. This distortion aligns with a structural transition to a polar Pna21 structure at TFE, consequently inducing the ferroelectric order. The high-temperature ferroelectric order associated with the linear magnetoelectric coupling and promising magnetic refrigeration capacity are in tune with the strong magnetic frustration and significant Jahn-Teller effect in Gd_2MnFeO_6.

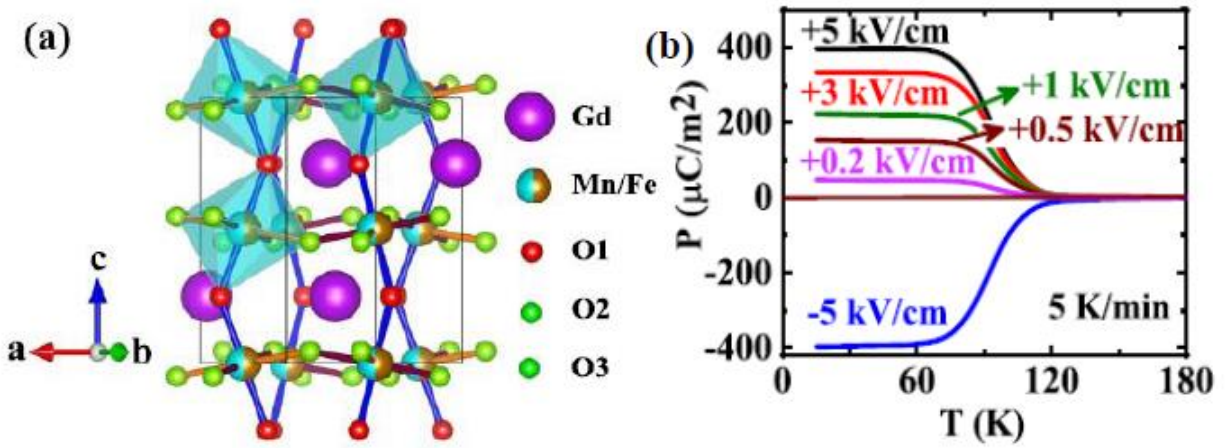

FIG. 1. (a) Connecting octahedra within the unit cell of Gd_2MnFeO_6. (b) The T variations of P at corresponding E = ±5, + 3, + 2, + 1, + 0.5 and + 0.2 kV/cm.

Pressure Induced Phase Transition in Layered Materials

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Magnetic insulators in reduced dimension are the ideal model systems to study spin-crossover (SCO) induced cooperative behavior under pressure. Similar to the external perturbations like light illumination or temperature, external pressure may provide new pathway to accelerate giant lattice collapse, and subsequently Mott transition in van der Waals (vdW) materials with diminishing effect of the third dimension. Here, we investigate room-temperature layer-dependent SCO and insulator-metal transition (IMT) in vdW magnet, FePS3, under high pressure using micro-Raman scattering [1]. Experimentally obtained spectra, in agreement with the computed Raman modes, indicates evidence of IMT of FePS3 started off with a thickness dependent critical pressure (*Pc*) which reduces to 1.5 GPa in 3-layer flakes compared to 10.8 GPa for the bulk counterpart. We have adopted a phenomenological model where a macroscopic structural change due to the variation of the effective in-plane strain with layer numbers may result in reduction of the critical pressure in few layer samples. Considering the electronic Hubbard model, using modified bandwidth (*W*) as a function of layer numbers (*N*) and pressure (*P*) with a power-law scaling stipulates the lessening effect of the third dimension on the critical pressure for IMT. Reduction of the critical pressure for phase transition in few-layer vdW magnets to 1-2 GPa marks the possibility of using nano-enclosure fit for use in device electronics where the pressure is induced due to interfacial adhesion, like in vdW heterostructure or molecules trapped between layers [2], or adapting chemical pressure [3] may open up alternative strategies towards avoiding the conventional use of diamond anvil cell (DAC).

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Ultrahigh breakdown current density of van der Waals one dimensional $PdBr_2$

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One-dimensional (1D) van der Waals (vdW) materials offer nearly defect-free strands as channel materials in the field-effect transistor devices and probably, a better interconnect than conventional copper with higher current density. We have synthesised a theoretically predicted halide based 1D few-chain atomic thread, PdBr2, isolable from its bulk which crystallizes in a monoclinic space group C2/c [1]. Liquid phase exfoliated nanowires with mean length ~ 20μm transferred onto a

SiO2/Si wafer with a maximum aspect ratio (length: width) of 5000 confirm the lower cleavage energy perpendicular to the chain direction. Moreover, an isolated nanowire can also sustain a current density of 200 MA/cm2, which is at least one-order higher than typical copper interconnects. However, local transport measurement via the conducting atomic force microscopy (CAFM) tip along the cross direction of the single chain records a much lower current density due to the anisotropic electronic transport, also confirmed by angle-resolved photoemission spectroscopy (ARPES) and density functional theory (DFT) calculations. While 1D nature of the nano object can be linked with a non-trivial collective quantum behavior, vdW nature could be beneficial for possible pathways in an interconnect fabrication strategy with better control of placement in an integrated circuit.

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Formation of atomic point contact using mechanically controlled break junction

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For future nano-electronics applications, it is necessary to understand the transport properties at the atomistic limit. Mechanically controllable break junction (MCBJ) is one of the widely accepted experimental technique in the community to study and control the atomic or molecular scale devices. Here, we present the details of the development of a piezo controlled MCBJ set up, working from cryogenic environment to ambient condition, along with its preliminary characterization with gold atomic junction. We performed conductance measurement on a macroscopic gold wire in our break junction platform, which exhibits quantized conductance plateau upon stretching the wire. At the time of controllable breaking process of notched gold wire, the number of atoms is reduced, the number of channels available for conduction also decreases and this is the reason due to which conductance drops discretely. Conductance histogram prepared from ensemble of breaking traces reveals successive peaks at integer multiple of G_0 up to ~ 12 G_0 ($G_0 = 2e^2/h$, e is the electronic charge and h being the plank's constant), in agreement with the previous observations. Emergence of plateau as well as peaks in the histogram at G_0 is the characteristics signature of gold (s metal) due to the dominance of single conductance channel at its narrowest constriction. Overall, we can conclude that our custom-designed MCBJ set up is capable of measuring quantum mechanical transport characteristics of a single atomic and molecular junction.

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Detecting Quantum Phase Transition in Periodically Driven Integrable Chain

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Quantum Phase Transition (QPT) is associated with the ground state properties of the many-body quantum systems in equilibrium, typically observed in the ground state energy of the system. But here we have shown that a quantum critical point can be detected using periodic drive in an integrable system. We employ a small amplitude drive around a fixed point deep inside a phase, and record the long-time limit of the expectation value of a local observable as the function of the drive amplitude. This quantity shows a singularity at the point where the drive field crosses the quantum critical point. We demonstrate this analytically doing a pole-structure analysis in the complex momentum plane.

Stability of Kinetically Constrained States in Quantum Many-Body Systems

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The eigenspectra of kinetically constrained systems (e.g. PXP model or East model) host numerous simple bit-string states as eigenstates of the system Hamiltonian. Consequently, the dynamics of such states are fully constrained under the action of the system Hamiltonian. In this poster, we study the ensuing dynamics of the system (starting from such states) when the constraint is slightly weakened by adding a small perturbation to the original Hamiltonian. We study the dynamics of the maximally polarized (in z) state under the action of a perturbed PXP Hamiltonian (which is nonintegrable) and find that the system exhibits non-ergodic dynamics and fidelity w.r.t. the initial state shows astounding system-size independent revivals. Results for infinite system size (obtained using iTEBD) confirm that the initial state memory stays largely intact even at Thermodynamic limit for a considerably long time. This non-ergodic behaviour can be attributed to the presence of a quantum scar in the eigenspectrum of the perturbed PXP Hamiltonian. A large weakening of the constraint leads to the disappearance of this quantum scar and the dynamics of the system becomes completely ergodic, establishing that there is a threshold to the weakening of the constraint below which the system shows pronounced non-ergodic behaviour.

Effect of residual interaction of Composite Fermions on edge reconstruction

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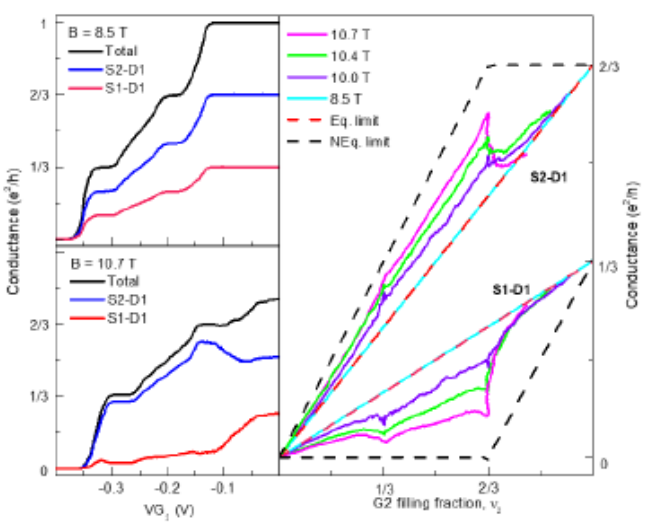
The study of fractionally charged quasi-particle in Fractional Quantum Hall system in very high magnetic field is an active area of research. The prominent fractional states are well explored and are well understood in terms of Composite Fermion theory where the new quasi-particles (called Composite Fermions, CF) are modelled as a bound state of an electron with even numbers of magnetic flux quanta. The residual interaction between the CFs which is yet to be understood, manifests many interesting phenomena including new fractional conductance plateaus. To understand the residual interaction between CFs, we have studied the electrostatic edge reconstruction for fractional fluid at filling fraction 1/2 and 3/4 which are the Fermi Sea of CF2 (two attached vortices) and hole conjugate CF4 state (four vortices). To probe the edge structure in these fractional states we selectively and individually excite the well-known three reconstructed fractional edge modes at filling fraction unity (\nu=1) and measure the transmittance of that mode through the fractional fluid region defined by top gates in a multiterminal GaAs/AlGaAs heterostructure device. Here we have observed the collapse of edge reconstruction at filling fraction 3/4 while it is intact at 1/2 filling. We speculate that strong CF-CF correlation destroys the edge reconstruction. Our result is the direct evidence of edge reconstruction collapse as the manifestation of stronger inter CF4 correlation than CF2 state.



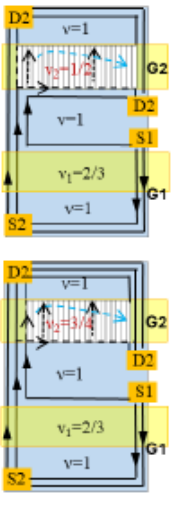


Fig: Schematics of multiterminal gated device with edge modes and combined conductance of different edge modes which gives the detail edge reconstruction picture of the interested quantum fluid.

Structural origin of room-temperature ferroelectricity in spark-plasma sintered GdCrO3, and related rare-earth chromates

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Ferroelectricity (FE) arising from off-centering displacements of non-d^0 transition metal cation is extremely promising as it can simultaneously be associated with spontaneous magnetism with a promise of strong coupling between the two order parameters. In this regard, the antiferromagnetic (AFM) RCrO$_3$ compounds (like GdCrO$_3$) constitute a promising class of multiferroic compounds, which, however, mostly become ferroelectric concomitant with AFM ordering much below room-temperature due to subtle competition between the ferroelectric off-centering mode and a non-polar antiferrodistortive rotation mode that inhibits ferroelectricity. Recently, a spark-plasma sintered GdCrO$_3$ (SPS-GCO) is found to stabilize FE of structural origin, arising from off-centering displacements of Gd and Cr ions, beyond room temperature (RT) [1]. Using a similar synthesis protocol (involving SPS), we have been able to engineer RT FE from a similar mechanism in two otherwise non-ferroelectric RCrO$_3$ (R= rare-earth) compounds, namely DyCrO$_3$ (which is reported as a quantum paraelectric) and LaCrO$_3$ (which is earlier known to be paraelectric) [2]. RT FE in SPS prepared samples is confirmed through various electrical, calorimetric, and synchrotron-based structural investigations. Out of these two emergent room-temperature FE materials, SPS-LaCrO$_3$ also undergoes a high-temperature antiferromagnetic ordering at 290 K, thus coming very close to becoming the first room-temperature multiferroic material in this promising family of RCrO$_3$ compounds.

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Edge-Rich Few Layered MoS_2

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Almost all transition metal dichalcogenides inevitably have structural defects which can bring drastic changes in the electronic properties as these can break the lattice symmetry, creating a quantum-confined environment, and modifying the electronic band structures. The defects in the form of heterogeneities affect the electron excitation, electron scattering, and also energy transfer between phonons and electrons. Therefore it is a great challenge to identify the defect types which may in turn help to correlate defects and their electronic properties, and guide the effective defect engineering. We know that the edge defects in 2D materials by large modify the properties.

In this study, we present distinctive spectra features in edge-exposed MoS_2 flakes on the silicon substrate. The flakes grown on the flat Si (100) substrate show two characteristic Raman modes of MoS_2 with Δ (A_{1g} - E^1_{2g}) values close to 25 cm^{-1} indicating the presence of few-layers in the flakes. The intensity ratio of E^1_{2g} and A_{1g} Raman peaks is 1.44 which suggests that in-plane vibration dominates in layered MoS_2. The sample grown on the edges of Si hillock, the out-of plane vibration dominates as the intensity of the A_{1g} peak increases while that of the E^1_{2g} peak decreases as the height of the hillocks increases. Therefore, the ratio of E^1_{2g}/A_{1g} further decreases monotonically from 1.44 for a non-textured substrate to a value of 0.55 as the textures on Si substrate increases to a maximum. Additionally defect related LA(M) and 2LA(M) Raman modes at 226-229 cm^{-1} and 425-470 cm^{-1} appear which are due to dangling bond at the edges. This indicates change in the growth orientation and an increase in the presence of edge-enriched MoS_2 flakes which is supported by the XRD results. Analysis of the photoluminescence spectra of the samples reveals the presence of a strong A excitonic peak of MoS_2 at 1.85 eV. However, the prominence of the A excitonic peaks decreases drastically and distinct defect related broad peak appears at around 1.77 eV which indicates dominance of the edge-related defects and non-radiative centres. Therefore, the edge-rich MoS_2 provides scope for understanding the defect related electronic properties. Details of the results will be presented in the poster.

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"If we knew what it was we were doing, it would not be called research, would it?"
— Albert Einstein

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