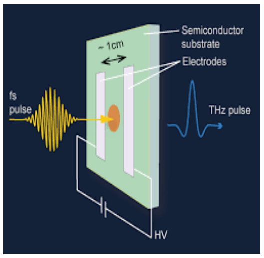
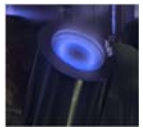
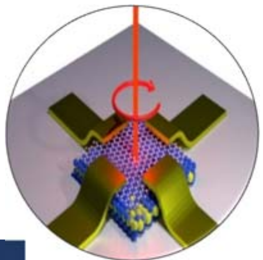
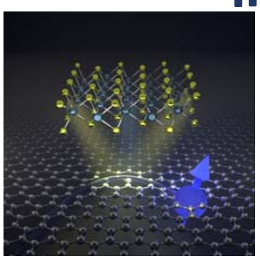




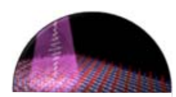


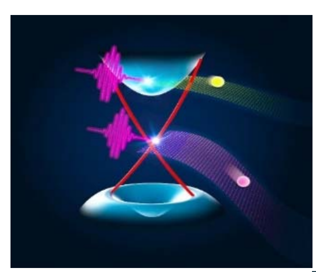


RTCMP2023

Recent Trends In Condensed Matter Physics 2023

12th and 13th January, 2023





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Quantum Design
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Recent Trends in Condensed Matter Physics 2023

School of Physical Sciences,
Indian Association for the Cultivation of Science (IACS)
2A & 2B Raja SC Mullick Road, Jadavpur, Kolkata 700032

Date: 12th and 13th January, 2023 **Venue: CV Raman Hall, IACS**

Program Schedule

Day 1

January 12th, Thursday

10:30 – 11:15	Registration & Tea	
11:15 – 11:30	Welcome address By Tapas Chakraborty (Director, IACS)	
Session 1: Chair: Saurav Giri		
11:30 – 12:15	Sunil Nair (IISER Pune)	Electrical detection of topological magnons in a pyrochlore ferromagnet
12:15 – 13:00	Sanjay Singh (IIT BHU)	Atomic ordering and Berry phase driven anomalous Hall effect in Heusler compounds
13.00 – 14.30	Lunch Break	
Session 2: Chairs: Durga Basak & Subhadeep Datta		
14:30 – 15:15	Amit Kumar (BARC)	Correlations among structural, magnetic, and electrical properties in negative magnetization materials
15:15 – 16:00	Uday Narayan Maiti (IIT Guwahati)	Single atom stabilized electronically tuned heterostructures for electrochemical water splitting
16:00 – 16:30	Tea Break	
16:30 – 17:15	Gopinadhan Kalon (IIT Gandhinagar)	Selective transport of water molecules through graphene fluidic channels
17:15 – 18:00	Nitesh Kumar (SNBNCBS Kolkata)	Anomalous transport in layered topological ferromagnets

Day 2

January 13th, Friday

Session 3: Chairs: Bimalendu Deb & Subham Majumdar		
10:30 – 11:15	Prasanta Kumar Dutta (IIT KGP)	Methods of Ultrafast Optical Characterization for Photonic, Electronic and Magnonic Applications
11:15 – 12:00	Ashis Arora (IISER Pune)	High-precision Faraday rotation and Zeeman spectroscopy investigations on 2D materials
12.00 – 12.15	Tea Break	
12:15 – 13:00	Chanchal Sow (IIT Kanpur)	FORC and IR imaging across MIT in VO2 thin films
13:00 – 13:45	Saquib Shamim (SNBNCBS Kolkata)	Kondo interactions of quantum spin Hall edge channels with charge puddles
13.45 – 14.45	Lunch Break	
14.45 – 15.30	Poster Session	
Session 5: Chairman: Indra Dasgupta		
15:30 – 16:15	Amit Agarwal (IIT Kanpur)	Novel nonlinear transport and optical phenomena in quantum materials
16:15 – 17:00	Bahadur Singh (TIFR Mumbai)	Theoretical design of atomically thin materials with topological twists
17:00 – 17:45	Victor Mukherjee (IISER Berhampur)	Many-body quantum energies
17.45 – 18.00	Concluding Remarks	

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Abstracts

Electrical detection of topological magnons in a pyrochlore ferromagnet

Sunil Nair

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Magnons -the quanta of collective spin wave excitations- have been touted to offer a platform where topology (of the magnon band structure) could manifest itself in the form of observable surface states which are distinct from the bulk. However, experimental verification is non-trivial, owing to the fact that conventional measurement techniques (like inelastic neutron scattering) are relatively insensitive to these surface magnon states. We demonstrate that a measurement geometry comprising of a heavy non-magnetic metal deposited on top of a ferromagnet can be used to infer on the presence of magnon surface states. Using a measurement geometry typically used in the past for spin-caloritronic measurements, we identify a voltage that arises as a consequence of the dragging force which surface magnons of a pyrochlore ferromagnet impart on the conduction electrons of the adjacent metal layer. This implies that magnon topology can be inferred using electrical means.

Reference:

[1] Avirup De, D. Prabhakaran, and Sunil Nair, arXiv:2210.07058 (2022)

Atomic ordering and Berry phase driven anomalous Hall effect in Heusler compounds

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Heusler compounds are promising materials for various technological applications due to their high Curie temperature, large spin polarization, large magnetization density, and exotic transport properties. The crystal symmetry and atomic ordering of these alloys are deciding factors for the observed properties. Here, we the present our recent results on the investigation of anomalous Hall effect (AHE) in a Co-based Heusler compounds using combined experimental and theoretical studies. We have used synchrotron x-ray diffraction to conform the atomic ordering in these compounds and a detailed transport and magnetic measurements are done to understand the origin of AHE in these compounds. Our results show that the anti-site disorder plays a crucial role in the modification of momentum space Berry curvature and hence the intrinsic AHE in these compounds.

References:

[1] G. K. Shukla et al., Phys. Rev. B 105, 035124 (2022).
[2] Nisha Shahi et al. Phys. Rev. B 106, 245137 (2022).
[3] G. K. Shukla et al. Phys. Rev. B 104, 195108 (2021).

Correlations among structural, magnetic, and electrical properties in negative magnetization materials

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The phenomenon of magnetization reversal or negative magnetization (NM) in magnetically ordered systems, where it does not arise due to diamagnetism, is defined as a crossover of dc magnetization from a positive value to a negative value below the magnetic ordering temperature. We have employed neutron diffraction technique to get a microscopic understanding of this peculiar magnetic phenomenon that has been observed in several magnetic systems, such as spinels, garnets, perovskites, and intermetallic compounds [1-10]. It is also interesting to study the implications of this phenomenon on other physical properties, such as exchange bias (EB) and electrical conductivity. In my talk, I will present some of our recent results in this context. We have obtained a physics understanding of the NM and EB phenomena and their correlations in the negative magnetization materials belonging to perovskites and intermetallic compounds. Particularly, anomalous behavior of EB has been correlated to the temperature/magnetic-field induced spin reorientation phenomenon. Implications of the results on electrical properties will also be discussed to highlight the intercorrelated structural, magnetic, and electrical properties of these materials.

References:

[1] A. Kumar and S. M. Yusuf, Physics Reports 556, 1-34 (2015).
[2] A. Kumar, S. M. Yusuf, C. Ritter, Physical Review B 96 (1), 014427 (2017).
[3] A. Kumar and S. M. Yusuf, J. Appl. Phys. 121, 223903 (2017).
[4] M Ghanathe, A. Kumar, S. M. Yusuf, J. Appl. Phys. 125, 093903 (2019).
[5] Deepak, A. Kumar, SM Yusuf, J. Appl. Phys. 127, 213903 (2020).
[6] M Ghanathe, A. Kumar, Ivan da Silva, and S M Yusuf, J. Magn. Magn. Mater. 523, 167632 (2021).
[7] Deepak, A. Kumar, S. M. Yusuf, Phys. Rev. Matter. 5, 124402 (2021).
[8] M Ghanathe, Amit Kumar, M.D. Mukadam, S.M. Yusuf, J. Magn. Magn. Mater. 561, 169689 (2022).
[9] Deepak, A Kumar, AK Bera, SM Yusuf, Phys. Rev. Mater. 6, 074405 (2022).
[10] Deepak, A. Kumar, S. M. Yusuf, and E. V. Sampathkumaran, J. Phys. Condens. Matter. 35, 065802 (2023).

Single atom stabilized electronically tuned heterostructures for electrochemical water splitting

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Electrolytic splitting of water is a suitable technology for the generation of green fuel hydrogen. However, high energy barriers associated with the elementary process of water splitting limit the overall efficiency of hydrogen production. In my talk, I shall present a novel selenide heterostructure ($MoSe_2$@$NiCo_2Se_4$) linked with single-atom iridium (SAC-Ir) to effectively lower these energy barriers, which serve as highly efficient water-splitting electrocatalysts. The role of extensive in-situ surface reconstruction in controlling the watersplitting process will be elaborated. The electronic origin of the high efficiency of single-atom linked catalysts will be discussed from the perspective of density functional theory (DFT) calculations.

Selective transport of water molecules through graphene fluidic channels

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When the fluidic channel dimensions approach the sizes of ions and molecules, interesting effects such as (de)hydration, steric, hydrophobic and even quantum related effects are expected to emerge. However, fabrication of atomic scale channel is considered to be extremely difficult. Here, we demonstrate that the method of mechanical exfoliation of graphene, the single layer of carbon atoms, can be utilized to create thinnest fluidic channels with a height of 0.34 nm, the thickness of graphene. Combined with lithography, this technique can yield fluidic channels of heights varying from 1 to 100's of graphene layers and very high aspect ratios of >100 without any structural collapse. We performed ion and molecular transport through channels of height ~0.34 nm, however, except protons, none of the ions permeates. The water molecules are transported with high flow rates due to hydrophobic walls resulting slip enhanced flow. This indicates the potential of 0.34 nm high channels for 100% desalination, and its performance is very similar to that of biological Aquaporin protein channels [1]. On a different route, we intercalated graphite to create atomically small fluidic channels and observed very similar properties as that of lithographically fabricated channels [2]. In this talk, some of these interesting observations will be presented.

References:

[1] K. Gopinadhan, S. Hu, A. Esfandiar, M. Lozada-Hidalgo, F. C. Wang, Q. Yang, A. Keerthi, B. Radha & A. K. Geim,Complete steric exclusion of ions and proton transport through monolayer water, Science 363, 145(2019).

[2] Selective transport of water molecules through interlayer spaces in graphite, Lalita Saini, Siva Sankar Nemala, Aparna Rathi, Suvigya Kaushik, & K. Gopinadhan* (Corresponding Author) (All IITGN affiliations), Nature communications 13, 498 (2022).

Anomalous transport in layered topological ferromagnets

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Topological features in the band structure of time reversal symmetric semimetals have direct consequences on the transport properties. This has been a topic of intense research during the last decade. Several topological semimetals such as Dirac, Weyl and nodal line semimetals were shown to exhibit exotic transport properties for example extremely large electronic mobility, ultra-high magnetoresistance, chiral anomaly induced negative longitudinal magnetoresistance etc. However, very recently it was shown that band topology in time reversal symmetry broken systems can be a source of large Berry curvature which can result in anomalous transport properties such as very large anomalous Hall conductivity. By taking some examples of layered ferromagnets such as $Co_3Sn_2S_2$, MnAlGe, $LaCrGe_3$ etc, I will show the effect of topological band structure, mainly the gapped nodal line states, on the anomalous transport properties of these materials.

Methods of Ultrafast Optical Characterization for Photonic, Electronic and Magnonic Applications

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The origin of electronic and optical properties of materials is a complex interplay between lattice, electronic and spin degrees of freedom that generally occur on a timescale that ranges from 10−18 to 10−9 s (or longer).With a revolutionary technological improvement in the field of ultrafast lasers, shorter time domain laser pulses with broader bandwidth become available for high resolution ultrafast spectroscopic techniques. Shorter the pulse become, the resolution goes higher. Experimental time resolved optical techniques to characterize the dynamic properties of photonic, electronic and magnonic systems in femtosecond time scale have transformed our understanding of these materials. In this talk, I shall be discussing about such few techniques which enable us to measure quantitates like ultrafast decay path ways of electrons, spin dynamics and absorption of low energy quasi-particles. Development and experimental intricacies of Transient absorption spectroscopy (TAS), THz-time domain spectroscopy (THz-TDS) and Time resolved magneto optical Kerr (TR-MOKE) will be discussed thoroughly along with representative data that we have published in recent years.

References:

[1] Physical Review B (APS) 103(7), 075437, (2021)
[2] Physical Review B (APS) 104(7), 075446, (2021)
[3] Applied Physics Letters (AIP)120 (2), 021101 (2022)
[4] Journal of Physics D: Applied Physics 55 (1), 014002 (2021)
[5] Scientific Reports (Nature) 9, 12138-12146 (2019)
[6] IEEE Journal of Quantum Electronics 57 (1), 1-8 (2020)

High-precision Faraday rotation and Zeeman spectroscopy investigations on 2D materials

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In this talk, first I will discuss a new technique which we have developed to perform Faraday Rotation spectroscopy at micron scales on 2D materials [1,2]. This technique enhances the spectral acquisition times by 2 to 3 orders of magnitude, compared to the state-of-the-art modulation spectroscopy methods. By performing Faraday rotation spectroscopy measurements on the hBN-encapsulated monolayers of WSe_2 and $MoSe_2$ under out-of-plane applied magnetic fields up to B = 1.4 T, we demonstrate that the plane of polarization of light shows a giant Faraday rotation of many degrees in moderate magnetic fields around the excitonic transitions [3]. This results in an ultrahigh Verdet constant (>3 x 10^7 rad/T/m) at the exciton resonance. Such giant Faraday rotation appears due to a combination of large excitonic oscillator strengths and high exciton g-factors in semiconducting transition metal dichalcogenides. Our work opens pathways to ultrathin magneto-optical technologies in the visible and infrared regions, such as optical isolators.

References**.**

[1] Review of the field at: A. Arora, J. Appl. Phys. 129, 120902 (2021)
[2] Carey et al., Small Methods (2022)
[3] Carey et al., to be submitted

FORC and IR imaging across MIT in VO_2 thin films

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Transition metal oxides exhibit unique and diverse properties such as superconductivity, ferromagnetism, colossal magnetoresistance, metal-insulator transition (MIT), etc. owing to the electron-electron interaction. Vanadium dioxide (VO_2) undergoes MIT at 340 K accompanied by a structural transition from a high-temperature rutile phase to a low-temperature monoclinic, classified as a first-order phase transition. This talk is about the comparative study of first-order reversal curve (FORC) and thermal (IR) imaging across the metal-insulator transition in PLD and sputtered grown VO_2 thin films. The grown samples are highly oriented, crystalline, and single-phase in nature. Transport data suggest that the MIT to be 334 K and 339 K for PLD-VO_2 and SPU-VO_2, respectively. FORC data for PLD-VO_2 suggests that statistically, MIT is governed by the single-domain nucleation process. Whereas for SPU-VO_2 it is governed by the multi-domain nucleation process. IR imaging across MIT also reveals that PLD-VO_2 has coherent insulator-metal phase change from a single nucleation centre whereas SPU-VO_2 has multiple nucleation centres. The origin of such difference is attributed to the growth process (crystallinity, surface roughness).

Kondo interactions of quantum spin Hall edge channels with charge puddles.

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In this talk, I will discuss some of our recent results on the quantum spin Hall effect in HgTe-based two-dimensional topological insulators. In the first part, I will show that the conductance quantization due to the quantum spin Hall effect can be observed even in the presence of magnetic impurities. Our experiments on (Hg,Mn)Te quantum wells with an inverted band structure reveal that the quantum spin Hall quantization is observed only at low temperatures (T < 400 mK), where Kondo screening of the magnetic impurities suppresses backscattering. The second part of the talk will focus on understanding the fluctuations in the quantized spin Hall conductance that has been observed in almost all realizations of the quantum spin Hall effect - including the first paper in 2007. To examine these fluctuations, we fabricate high-quality quantum spin Hall microstructures using a carefully optimized wet-etching process. We perform temperature and gate-dependent measurements in the regime of quantized conductance. The fluctuations in conductance show a characteristic temperature dependence that is related to Kondo interactions of helical edge channels with small puddles. These charge puddles - acting as Kondo correlated quantum dots due to small dimensions - arise due to fluctuations in the potential landscape in narrow gap semiconductors.

Novel nonlinear transport and optical phenomena in quantum materials

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Nonlinear responses in optical and transport phenomena are actively studied as probes of topology and band geometric properties of quantum materials. Here we discuss some prominent non-linear transport phenomena in electric and thermal responses. One specific example is the generalized theory of second harmonic generation to include Fermi surface effects in metallic systems along with finite scattering timescales. In addition to the optical second harmonic generation phenomena, we also predict other novel non-linear transport effects in materials with different symmetries. Specifically, we predict a new quantum metric-dipole induced Nonlinear Hall effect in Parity-time symmetric systems, which is a Fermi sea phenomenon. More recently, we are excited about predicting the non-linear valley Hall effect in hexagonal 2D materials, and nonlinear thermal transport phenomena in bosonic excitations such as magnons and phonons.

References:

[1] P. Bhalla, K. Das, D. Culcer, and A. Agarwal, Resonant Second-Harmonic Generation as a Probe of Quantum Geometry, Phys. Rev. Letters 129, 227401 (2022).

[2] S. Lahiri, K. Das, D. Culcer, and A. Agarwal, Intrinsic nonlinear conductivity induced by the quantum metric dipole, arXiv:2207.02178.

[3] H. Varshney, K. Das, P. Bhalla, and A. Agarwal, Quantum kinetic theory of nonlinear thermal current, arXiv:2211.01895.

Theoretical design of atomically thin materials with topological twists

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Manipulating quantum states and associated properties of two-dimensional (2D) materials under ambient conditions is necessary for developing new quantum devices with small physical dimensions. Many atomically thin materials that show substantial quantum mechanical effects over wider length and energy scales have been predicted and realized in experiments. Common to these materials is that they are exfoliated from 3D layered materials using a top-to-bottom approach. Here we discuss our recent theoretical efforts in designing new quantum materials and engineering their topological states using a novel bottom-up approach within the first-principles paradigm. Importantly, we show how passivating the high-energy surfaces of nonlayered nitrides or phosphides generate synthetic 2D materials which could be stacked to realize bulk materials. We focus on the $MoSi_2N_4$ class of synthetic 2D materials and discuss their tunable electronic and spintronic states. We also show how symmetry-lowering structural distortions in these materials can generate square and rectangular lattices with exotic topological states with large spin Hall conductivity.

Many-body quantum engines

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Design and control of many-body quantum engines are crucial for the development of quantum technologies. In this talk I shall discuss universal effects and control in quantum critical engines, and collective effects in many-body quantum thermal machines.

POSTER DETAILS

	Authors (presenter underlined)	Title
1.	Kusampal Yadav, Nasiruddin Mondal, Abhisikta Barman, Subhashree Chatterjee and Devajyoti Mukherjee*	Strain mediated enhanced Magento-Optic Kerr Effect(MOKE) and magnetization in epitaxial Py/LSMO hetrostructures
2.	Abhisikta Barman, Subhashree Chatterjee, Canlin Ou, Yau Yau Tse, Niladri Banerjee and Sohini Kar-Narayan, Anuja Datta, and Devajyoti Mukherjee*	Giant electrocaloric effect in lead-free ferroelectric Ba0.85Ca0.15Ti0.9Zr0.1O3 thin film heterostructure
3.	Satyabrata Bera and Mintu Mondal*	Unravelling the nature of spin reorientation transition in quasi-2D vdW magnetic material, Fe_4GeTe_2
4.	Soumik Das, Sujan Maity, Anudeepa Ghosh, Mainak Palit, Bikash Das, Rahul Paramanik, Tanima Kundu and Subhadeep Datta*	Spin-Phonon Coupling in Two-dimensional layered Magnetic material
5.	Subhashree Chatterjee, Abhisikta Barman, Shubhankar Barman, Tanmay Chabri, Sohini Kar-Narayan, Anuja Datta, and Devajyoti Mukherjee*	Oxygen vacancy mediated dielectric relaxor behavior in epitaxial $Ba_{0.85}Ca_{0.15}Ti_{0.9}Zr_{0.1}O_3$ thin films
6.	Pabitra Kumar Hazra, Rahul Paramanik, Bikash Das, Subrata Ghosh, Tanima Kundu, Sujan Maity, Poulomi Maji, Soumik Das, Anudeepa Ghosh, Mainak Palit, and Subhadeep Datta*	Metamagnetization and Magnetocaloric effect in 2D CrOCl
7.	Suman Mondal and Subham Majumdar*	Study of magneto-functional properties in $DyFe_2Ga$ alloy
8.	Mohamad Numan and Subham Majumdar*	Evidence of exchange striction and charge disproportionation in the magnetoelectric material Ni_3TeO_6
9.	Sourav Mukherjee, Soirik Dan, Biswajit Kundu, and Amlan J. Pal*	Spin Configuration of Manganese d-states in Diluted Magnetic Semiconductor: An Insight from Spin-polarized Scanning Tunneling Spectroscopy
10.	Subham Paramanik and Amlan J. Pal*	Negative Photoconductivity and Memristor for In-Memory Logic Operation
11.	Nasiruddin Mondal, Abhisikta Barman, Subhashree Chatterjee, and Devajyoti Mukherjee*	Influence of Twin-Crystal Structures on the Temperature Dependence of Magneto-Optic

		Kerr Effect and Magnetic Anisotropy in Epitaxial Ni Thin Films
12.	Sourav Mondal and Durga Basak*	Evolution of defects in P doped ZnO thin films judged by photophysical properties
13.	Santanu Pal and Durga Basak*	Electrical transport mechanism in RF sputtered Mo doped ZnO films.
14.	Shameek Mukherjee and Saurav Giri*	Magnetoelectric multicalorics and multiferroics in $Co_3V_2O_8$
15.	Pradeepta Kumar Ghose, Subhadeep Bandyopadhyay, Indra Dasgupta, and Saurav Giri*	Bulk Rashba Spin Splitting and Dirac Surface State in p-Type $(Bi_{0.9}Sb_{0.1})_2Se_3$ Single Crystal
16.	Tamal Kumar Dalui, Bishal Das, Aftab Alam and Saurav Giri*	Topological phase transition from semimetal to insulator in $SnBi_2Te_4$
17.	Atanu Roychowdhury and Saurav Giri*	Spin-valve-like and exchange bias effect in $Co_3Sn_{1.9}In_{0.1}S_2$ single crystal
18.	Ritwik Das, Subhadeep Bandyopadhyay and Indra Dasgupta*	Magnetization Orientation Driven Topological Phase Transition in Monolayer OsCl3
19.	Sk Kalimuddin and Mintu Mondal*	Nonlinear Coherent Light–Matter Interaction in 2D MoSe2 Nanoflakes for All-Optical Switching and Logic Applications
20.	Kunal Dutta and Indra Dasgupta*	Effect of spin-orbit couplin in non-centrosymmetric half-Heusler alloys