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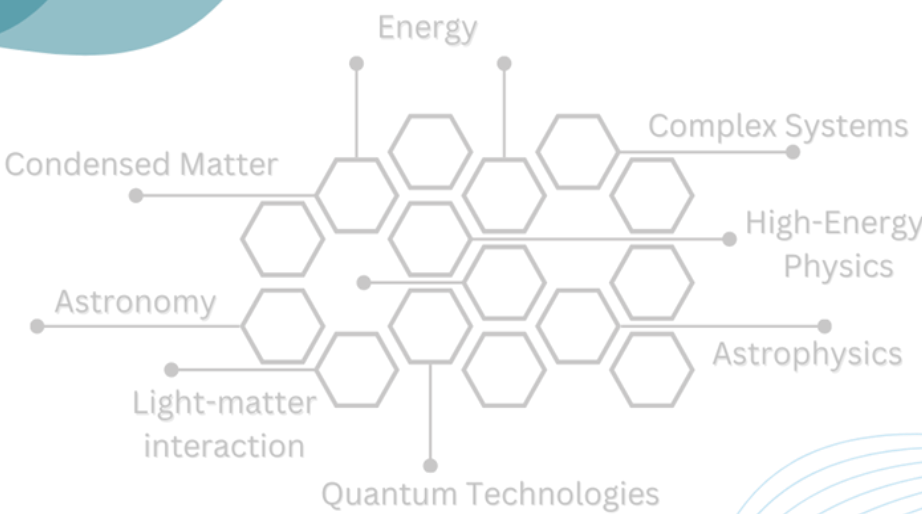

FS-PHY 2023

FRONTIER SYMPOSIUM IN PHYSICS 2023

February 24 - 26, 2023

School of Physics

IISER Thiruvananthapuram

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About FS-PHY 2023

FS-PHY 2023 is annual series of scientific meetings organized by the School of Physics, IISER Thiruvananthapuram, Kerala, India, and serves as a platform for the examination and dissemination of current and emerging research in Physics and interdisciplinary areas. Scientists and researchers from almost all sub-domains of Physical Science converge at this event to exchange innovative ideas, engage in broader impact programming, network with friends and colleagues, and contribute to the advancement of Physics.

PATRON

Prof. J. N. Moorthy,

Director, IISER Thiruvananthapuram

TITLE SPONSORS

ATOS

Atoms to Stars

Quantum Design

Programme

Day 1 **24-02-2023** Friday

Time	Session Description
13:30 - 15:30	Registration
15:00 - 15:30	High Tea
15:30 - 15:45	**Inauguration by the Director** **Prof. J. N. Moorthy**
Session 1	Chair: Anil Shaji
15:45 - 16:20	*Lecture 1* Saurabh Lodha, IIT Bombay *Topic : Few-layer 2D TMD-based photo and strain detectors*
16:20 - 16:55	*Lecture 2* Shobhana Narasimhan, JNCASR *Topic : Studying Diffusion and Sintering of Ultrasmall Supported Nanoparticles from First Principles*
16:55 - 17:15	Tea Break and Poster Session
Session 2	Chair: Ramesh Chandra Nath
17:15 - 17:50	*Lecture 3* Atindra Nath Pal, SNBNCBS *Topic : Effect of molecule-orientation in determining current flow in a single metal-molecule-metal junction*
17:50 - 18:25	*Lecture 4* Tanumoy Mandal, IISER TVM *Topic : Mind the gap: unconventional searches for new physics*
18:25 - 19:00	*Lecture 5* Sudhir K. Vempati, IISc *Topic : Novel Mechanisms for Tiny Neutrino masses*

End of Day 1

Programme

Day 2 25-02-2023 Saturday

Session 3 Chair: Joy Mitra

Time	Programme
09:00 - 09:35	*Lecture 6* Urbasi Sinha, RRI *Topic : Revealing new facets in experimental quantum information processing with photons*
09:35 - 10:10	*Lecture 7* D. V. Senthilkumar, IISER TVM *Topic : Swarmalators: Oscillators that Sync and Swarm*
10:10 - 10:45	*Lecture 8* Piyali Chatterjee, IIA *Topic : Physics of solar eruptions*
10:45 - 11:15	Tea Break and Poster Session

Session 4 Chair: Deepshikha Jaiswal Nagar

Time	Programme
11:15 - 11:50	*Lecture 9* Kasturi Saha, IIT Bombay *Topic : Magnetometry with Color Defects in Diamond*
11:50 - 12:25	*Lecture 10* Justin David, IISc *Topic : Entanglement properties of the graviton*
12:25 - 13:00	*Lecture 11* Bikas C. Das, IISER TVM *Topic : Memristor & Memtransistor: Boosting Hope for Neuromorphic Computing*
13:00 - 14:30	Lunch at CDH 3

Session 5 Chair: Soumen Basak

Time	Programme
14:30 - 15:05	*Lecture 12* Anand Jha, IIT Kanpur *Topic : Partial coherence: Applications in quantum state measurement, imaging and communication*
15:05 - 15:40	*Lecture 13* Deepak Misra, IIST *Topic : Deep learning and Machine Learning methods for computational Data Science and Engineering applications*
15:40 - 16:15	*Lecture 14* Indra Dasgupta, IACS *Topic : Spin-Orbit Coupling Induced Emergent Phases in Quantum Matter*
16:15 - 17:15	Tea Break and Poster Session

Programme

Session 6 Chair: M. M. Shaijumon

17:15 - 17:50	*Lecture 15* Sudeshna Sinha, IISER Mohali *Topic : Noise in aid of Logic*
17:50 - 18:25	*Lecture 16* K. Kishore Kumar, VSSC-ISRO *Topic : Space-borne Radars for Cloud Research: Hawks in the Sky*
18:25 - 19:05	Student Flash Talks

End of Day 2

Day 3 26-02-2023 Sunday

Session 7 Chair: Ravi Pant

09:00 - 09:35	*Lecture 17* Venugopal Achanta, NPL *Topic : Metamaterials for light-matter interaction studies*
09:35 - 10:10	*Lecture 18* Surjeet Singh, IISER Pune *Topic : Low dimensional systems with spins on chains, ladders and honeycomb structures*
10:10 - 10:45	*Lecture 19* Aveek Bid, IISc *Topic : Playing with graphene bands*
10:45 - 11:10	Tea Break

Session 8 Chair: Amal Medhi

11:10 - 11:45	*Lecture 20* Rajesh Narayanan, IIT Madras *Topic : Cloaked Quantum Griffiths Singularity in low dimensional Superconducting systems*
11:45 - 12:20	*Lecture 21* Vinayak B. Kamble, IISER TVM *Topic : AC Response Analysis of Oxide Chemiresistors: What do frequency dependent studies reveal?*
12:20 - 12:40	Valedictory Remarks

Invited Talks

Entanglement properties of the graviton

Dr. Justin David
IISc Bengaluru

Abstract

Entanglement entropy has recently emerged as a useful quantity to study in quantum field theories. The entanglement properties of the spin-2 field have only been recently studied. After a brief introduction to entanglement entropy, its applications and how it is evaluated, we present some results for the entanglement properties of the linearised graviton in 4 dimensions. This includes the evaluation of the coefficient of the logarithmic term in the entanglement of gravitons across a spherical surface. If time permits, we briefly discuss the time dependent behaviour of entanglement entropy quantum quenches due to curvature excitations.

Biography

Dr. Justin David is a Professor at IISc, Bengaluru and an accomplished theoretical string theorist. He received his Ph.D. from Tata Institute of Fundamental Research, Mumbai. He worked as a Postdoctoral fellow at the University of California, Santa Barbara, USA and at the International Centre for Theoretical Physics, Trieste, Italy.

Studying Diffusion and Sintering of Ultrasmall Supported Nanoparticles from First Principles

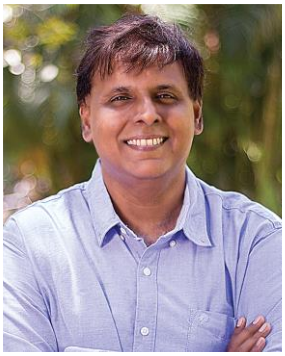
Dr. Shobhana Narasimhan
JNCASR Bengaluru

Abstract

Ultrasmall metal particles on oxide supports have many important technological applications, e.g., as nanocatalysts for several hugely important reactions. However, these nanoparticles are unstable with respect to sintering, i.e., due to thermal effects, they diffuse and coalesce. We have used ab initio density functional theory to study the processes of diffusion and sintering. We find that these nanoparticles diffuse by non-trivial mechanisms, not just simple translational motions. We also find somewhat surprising scaling relations relating diffusion barriers to the melting temperature of the bulk metal. We show that diffusion and sintering mechanisms are size- and metal-dependent.

Biography

Shobhana Narasimhan is a Professor of Theoretical Sciences at the Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru, India. She is a Fellow of the National Academy of Sciences, India. Prof. Narasimhan is a Fellow of the National Academy of Sciences, India since 2011. In 2010, she was awarded the prestigious Stree Shakti Samman Science Award of the Indian Academy of Sciences and the Kalpana Chawla Woman Scientist Award of the Government of Karnataka. Prof. Shobhana Narasimhan has been elected as an International Honorary Member to the American Academy of Arts and Sciences. She received her Ph.D. in Theoretical Physics from Harvard University in 1991. During her entire academic career, she has been a fierce advocate of women in science and has been involved with different organizations worldwide working for the same cause.



Cloaked Quantum Griffiths Singularity in low dimensional Superconducting systems

Dr. Rajesh Narayanan
IIT Madras

Abstract

Low dimensional disordered superconductors provide a veritable playground of competing orders that are triggered by an intriguing interplay of interactions and impurity physics. On the one hand, it is well known that such systems can host anomalous metallic phases circumventing the Anderson localization mechanism. On the other hand, disorder itself leads to the existence of a disorder-induced quantum Griffiths phase (QGP) triggered by the existence of disorder-induced rare superconducting puddles embedded in a non superconducting bulk. In this talk we show how such a QGP emerges in the 2D electron gas formed in the LaScO_3 /SrTiO_2 heterostructure. In particular, by using the magnetic field as a tuning parameter we show that the QGP is encoded by the divergence of the effective dynamical exponent at higher temperatures. However, at lower temperatures we argue that the divergence signalling the QGP is cut-off or Cloaked. We present plausible mechanisms that can explain this phenomenon of the emergence of the QGP and also its cloaking or cut-off. We also present arguments that the cloaking phenomenon is accompanied by the smearing of the superconducting transition.

Biography

Dr. Rajesh Narayanan is a Professor at IIT, Madras. He received his Ph.D. from the University of Oregon. He worked as a Postdoctoral fellow at Oxford University, Max Planck Institute for the Physics of Complex Systems, Institute of Nanotechnology at Karlsruhe Institute of Technology. He joined IIT Madras in 2006 as an Assistant Professor. His current research interests are Condensed Matter Theory: Quantum Field Theories applied to condensed matter systems, Quantum Phase Transitions, Strong disorder physics.

Spin-Orbit Coupling Induced Emergent Phases in Quantum Matter

Dr. Indra Dasgupta
IACS Kolkata

Abstract

Spin–orbit coupling (SOC) is a relativistic effect, which may be thought of as an interaction between the intrinsic spin moment of an electron and the magnetic field, generated in the rest frame of the electron due to its orbital motion around the positively charged nucleus. We shall illustrate that the combined effect of electron correlations and SOC leads to novel J_{eff}=1/2 Mott Insulators, bond-directional dependent exchange interactions important for the realization of Kitaev spin liquids and the possibility of Magnon Chern Insulators. In addition, we shall show emergence of Rashba and Dresselhaus spin–orbit interactions due to a gradient of electrostatic potential in non-centrosymmetric systems. Rashba-Dresselhaus systems exhibit characteristic spin textures important for spintronics research.

Biography

Prof. Indra Dasgupta completed his Ph.D. in Calcutta University in theoretical condensed matter physics. He completed his postgraduate studies in Max Planck Institute for Solid State Research. He was faculty member at various prestigious institutes including IIT Bombay, IIT Kharagpur and currently a senior professor at IACS Kolkata. His research group primarily works on strongly and weakly correlated electron systems. He is using density functional theory and different numerical methods like Quantum Monte Carlo (QMC) simulations to understand condensed matter systems. Additionally he is working in superconductivity in disordered alloys.

Novel Mechanisms for Tiny Neutrino masses

Dr. Sudhir K Vempati
IISc Bengaluru

Abstract

Neutrinos have been one of the most confounding particles of the Standard Model. They possess tiny masses established by the observation of neutrino flavour oscillations. To generate such tiny masses several mechanisms are proposed in literature including the famed seesaw mechanisms, radiative mechanisms etc. While they are excellent in their own right, novel mechanisms are being proposed. These mechanisms aim to generate large hierarchies in relevant couplings assuming O(1) parameters in the fundamental parameters of the model/theory. The ideas are influenced from both physics of extra dimensions in particle physics to Anderson localisation in condensed matter physics. The most striking of these are models based on fractal structures in theory space. After presenting these models, we discuss some possible signatures of them in various sectors like flavour factories, cosmology and direct experiments like LHC.

Biography

Prof. Sudhir K. Vempati completed his Ph.D. at the Physical Research Lab, Ahmedabad. He is a high energy physicist and a professor at the Centre for High Energy Physics, IISc, Bengaluru. His research interest lies in physics beyond the standard model and grand unified theories. He is known for his studies in neutrino physics, especially Large Hadron Collider Inverse problem. He is a member of the Indo-French Collaboration on High Energy Physics. He is recipient of the prestigious Shanti Swarup Bhatnagar Prize for Science and Technology, one of the highest Indian science awards, for his contributions to physical sciences in 2016.

Noise in aid of Logic

Dr. Sudeshna Sinha
IISER Mohali

Abstract

We present the concept of Logical Stochastic Resonance (LSR),namely the phenomenon where the behavior of nonlinear systems, in an optimal window of noise, emulates different logic operations completely consistently. We show how moderate noise is crucial for the robustness of this logic response, and discuss the emergence of LSR in nanomechanical, electronic and optical systems, as well as in chemical reaction dynamics and gene networks. Further we demonstrate how a variable bias can be used to morph the nature of the logic operation. Thus the interplay of nonlinearity and noise can yield flexible logic behavior, and the natural emergent outcome of such systems is effectively a noise aided reconfigurable logic gate.

Biography

Prof. Sudeshna Sinha is currently a professor and deputy director of IISER, Mohali. She completed her Ph.D. from TIFR, Mumbai. She was a professor at the Institute of Mathematical Sciences, Chennai till 2010. Her area of interest includes non-linear dynamics, chaos and complex systems. Her work on 'chaos-based' hardware is being developed commercially by the US-based company Chaologix. She is elected fellow of the World Academy of Sciences and recipient of many prestigious fellowships.

Few-layer 2D TMD-based photo and strain detectors

Dr. Saurabh Lodha
IIT Bombay

Abstract

In recent years, researchers have leveraged the unique physical properties of layered two-dimensional (2D) van der Waals (vdW) materials, such as a wide range of thickness-tunable bandgaps, excellent light-matter interaction and facile fabrication of heterostructures with defect-free heterointerfaces, for several optoelectronic applications. At the same time, their ultra-thin nature and high tensile strength enables the tuning of band structure parameters, and hence their optical and electronic properties, using strain. This presentation will describe recent results from our group on engineering the photo- and strain-detection performance of transistors based on 2D vdW transition metal dichalcogenide (TMD) semiconductors and their heterostructures. Photoresponsivity and speed of few-layer TMD photodetectors are fundamentally traded-off with each other by modulation of the effective trap concentration, as shown through electrostatically gated supported and suspended ReS2 photodetectors. This trade-off can be attenuated by nearly 2× using an electrostatically tunable in-plane p-n homojunction integrated laterally with a WSe2 phototransistor, enabling enhanced photoresponsivity (>100 A/W), and high detectivity (>1012 Jones) along with switching speed in the µs range at the same time. Beyond single-TMD photodetection, TMD/TMD heterostructures offer the possibilities of interlayer interface engineering for improving photodetection parameters. For instance, engineering the band alignment from type-II to type-III in a WSe2/SnSe2 p-n heterodiode helps realize a high negative responsivity of 2 × 104 A/W with a fast response time of ~1µs due to a tunneling photocurrent. Finally, an electrically actuated piezo-stack is shown to fine-tune optical and electrical parameters of MoS2 field-effect transistors with tensile as well as compressive strain, offering improved control and integration possibilities over existing mechanical methods.

Biography

Prof. Saurabh Lodha completed his PhD in electrical and computer engineering from Purdue University, USA. His group is actively involved in research of nanoelectronic devices. He is interested in Nanoelectronic devices, Advanced CMOS devices, and silicon photovoltaics. For his contributions in the development of logic transistor technologies beyond silicon and nanoelectronic devices based on two-dimensional Van der Waals materials, he received the Young Career Award in Nano science and technology by DST, Govt. of India.

Revealing new facets in experimental quantum information processing with photons

Dr. Urbasi Sinha
Raman Research Institute, Bengaluru

Abstract

In this talk, we present new facets in the domain of photonic quantum information processing.In the first and major part, we present the first loophole-free experiment wherein both the LGI and the WLGI inequalities have been decisively violated using single photons, thus providing a comprehensive refutation of the classical realist worldview along with measurements ensured to be non-invasive. Our results also demonstrate perfect matching of these observed violations with quantum-mechanical predictions incorporating experimental nonidealities, again not analysed in earlier such experiments. Our carefully designed strategies make this setup a powerful platform for harnessing this most general unambiguous signature of nonclassicality of single photon states towards various information theoretic applications wherein the single photon is a ubiquitous workhorse. In the second and shorter part of the talk, we provide a novel scheme for direct determination of different entanglement monotones used to quantify entanglement in arbitrary system dimensions using only one pair of complementary observables, as opposed to the standard d^2 measurements needed in d dimensions. Our experiment is the first direct empirical determination of the standard entanglement monotones in higher dimensions, that uses only one set of joint local measurements. This naturally motivates the question as regards the extent to which this scheme can be extended for two-qudit mixed states and what would be its ramifications. This is thoroughly studied in for different types of mixed entangled states, showing that the efficacy of this scheme is restricted to not only distillable entangled states, but extends to bound entangled states as well.

Biography

Prof. Urbasi Sinha heads the Quantum Information and Computing laboratory at RRI Bengaluru. The current research areas include experimental secure quantum communications including quantum key distribution in free space, fiber and integrated photonics, Quantum Teleportation as well as Device Independent random number generation. One of the key projects being led by the lab is a collaborative project of RRI and the ISRO called "Quantum Experiments with Satellite Technology", which is India's first funded project on satellite based long distance quantum communications. She is also an affiliated member at the Institute for Quantum Computing, Waterloo, Canada as well as the Centre for Quantum Information and Quantum Computing at the University of Toronto, Canada.

Magnetometry with Color Defects in Diamond

Dr. Kasturi Saha
IIT Bombay

Abstract

Color centers in diamond have proven to be promising candidates for not only quantum computing but also for quantum sensing. Amongst the various color defects, nitrogen-vacancy centers (NV centers) could provide a platform for precision magnetometry allowing for nanoscale magnetic imaging with applications in brain imaging, magnetotactic bacteria, quantum materials, geomagnetic fields, and many others. In this talk I will give an overview of our research towards the development of a novel scheme for optically detected magnetometry that allows for the development of low cost magnetometers. Further I will elaborate on the on-going work related to the development of a magnetic field microscope. While NV centers are routinely used for measuring static magnetic fields in a wide field of view with diffraction limited spatial resolution, dynamic widefield magnetometry has been very challenging. I will describe the first demonstration of dynamic widefield magnetometry using Nitrogen vacancy centers in diamond and its applications.

Biography

Dr. Kasturi Saha joined IIT Bombay as an assistant professor in December 2016. She did her Ph.D. in the Quantum and Nonlinear Photonics in the School of Applied and Engineering Physics at Cornell University. She did her post-doctoral fellowship in the Quantum Engineering Group at the Massachusetts Institute of Technology where she worked primarily on building a quantum spin-based gyroscope using Nitrogen-Vacancy centers in diamond. She received DST Inspire Fellowship in 2017. She is also a recipient of Young Faculty Fellowship by Indian Institute of Technology, Bombay in 2017. Currently she is the Principal Investigator at IIT Bombay. The aim of her research group 'Photonics and Quantum Enabled Sensing Technology Laboratory (P-QUEST Lab)' is to explore and push the boundaries of precision metrology, sensing and imaging using unprecedented opportunities presented by novel interdisciplinary research in fields like nano-photonics, classical and quantum information processing and life sciences.

Partial coherence: Applications in quantum state measurement, imaging and communication

Dr. Anand Jha
IIT Kanpur

Abstract

Fields with quantum correlations are resources to several quantum-information applications as they could be exploited for performing tasks that would otherwise be impossible. One of the major challenges faced in the implementation of many quantum-information protocols is the efficient measurement of quantum states and quantum correlations, especially the high-dimensional quantum states. In this talk, I will present how partial coherence properties could be utilized for efficient measurements of high-dimensional quantum states and correlations. I will also present some of our works on the applications of partially coherent light fields for imaging and communication.

Biography

Anand Kumar Jha is a Professor at Department of Physics, IIT Kanpur. His research group is Quantum Optics and Entanglement Lab. His research interest are Quantum Optics and Quantum Entanglement, Quantum Information, and Foundations of Quantum Mechanics. He pursued his Ph.D. in Optics from The Institute of Optics, University of Rochester, New York in 2009. He received the Outstanding dissertation award of the University of Rochester, USA 2010 for his thesis “Coherence properties of the entangled two-photon field produced by parametric down-conversion”.

Physics of solar eruptions

Dr. Piyali Chatterjee
IIA Bengaluru

Abstract

Solar flares and coronal mass ejections are the most energetic space weather drivers with source regions in the direct vicinity of the visible solar surface- the photosphere. They are responsible for emitting intense X-ray, gamma ray, radio emissions, magnetized plasma, shocks, and (relativistic) solar energetic particles (SEP) into the heliosphere. Modern multi-messenger solar astronomy allows us to study and interpret these signals more effectively than ever. After a brief introduction to the observational aspects of these phenomena, we will try to understand the physics behind the sudden triggers for energy release and how they might be related to the 22-year magnetic cycle of the Sun.

Biography

Dr. Piyali Chatterjee is an Associate Professor at IIA Bengaluru. Her research interests are on Space weather, solar flares, waves in magnetized media, computational magnetohydrodynamics, dynamo theory, helioseismology. She was a Reader at Indian Institute of Astrophysics, Bangalore in 2015. She pursued her PhD from Department of Physics, IISc Bangalore in 2007. She joined IISc Bangalore as IISc Research Associate at Dept of Physics in 2007. After that, she was a Visiting Fellow at Department of Astronomy and Astrophysics, TIFR, Mumbai. She was a Postdoctoral Fellow at Astrophysics group, NORDITA, Stockholm, Sweden. She was also a Post-Doctoral researcher at High Altitude Observatory, Boulder, CO, USA and at the Institute for Theoretical Astrophysics, Oslo, Norway.

Playing with graphene bands

Dr. Aveek Bid
IISc Bengaluru

Abstract

Recently, there has been a surge of interest in the topological phases of matter, both experimentally and theoretically. The interest in this field stems from the fact that these phases are robust against perturbations, with the caveat that these perturbations reserve certain symmetries. Current efforts have focused on investigating the properties of discovered topological phases and the experimental realization of theoretically predicted but undiscovered phases. A few examples of topological phases being studied are the topological insulator, topological superconductor, Quantum anomalous Hall insulator (QAHI), Quantum Spin Hall insulator, and Quantum Valley Hall phases. At the phase transition, new topological phases exist, such as Dirac or Weyl semimetal, depending on the system & symmetries. Topological phases can also be introduced by breaking the symmetries of the system with external perturbations like electric and magnetic fields. Proximity-induced effects introduced by stacking with other materials are another approach that can be used for a similar outcome. We are interested in the ability to induce transitions (either optically or electrically) between topologically non-trivial and trivial states in graphene. This is best achieved by controlling the band structure of graphene. I will discuss two approaches we have taken in our research group to achieve this – (1) proximitizing graphene with materials possessing desirable properties and (2) modulating the graphene lattice itself. I will provide examples of each approach and discuss the (possible) future directions this research will take.

Biography

Aveek Bid received his PhD in physics from Indian Institute of Science, Bengaluru and conducted postdoctoral work at the Braun Center for sub-micron Research, Weizmann Institute of Science, Israel, where he received Feinberg Graduate School Fellowship for postdoctoral studies. He joined IISc, Bengaluru in 2010 as a faculty where he is currently an Associate Professor. He was awarded "Swarnajayanti Fellowship" by DST, Govt. of India and "Shyama Prasad Mukherjee Memorial fellowship" by CSIR, Govt. of India.

Effect of molecule-orientation in determining current flow in a single metal-molecule-metal junction

Dr. Atindra Nath Pal
SNBNCBS Kolkata

Abstract

Metal/molecule interface plays a key role in determining the electronic transport through a single molecular junction. Typically, an anchoring group is used to connect an organic molecule with the metal electrodes. Presence of these anchoring groups often creates hindrance for efficient electron transport through the metal-molecule junctions. Thus, to realize highly conductive molecular junction, it is necessary to maintain strong electronic coupling between the molecule and electrodes and within the entire molecule itself. In this talk, I will discuss transport phenomena in two different molecular junctions. Firstly, I will show results from Au-Ferrocene single molecular junction, where we observe a formation of stable conducting junction at room temperature with a significantly high conductance of ~ 0.2*2e2/h, h being the Planck's constant. Transport calculations in the molecular junctions show significant transmission in the vertical geometry with metal-Fe-metal bond formation, leading to high conductance. The temperature dependent transport features reveal interesting features which has a direct correlation with the dynamic structure of the molecule. We have verified our observation by connecting Ferrocene with different anchoring groups. In another work, I will discuss the formation of one-dimensional atomic chain in Copper atomic junction by introducing Hydrogen between copper electrodes.

Biography

Dr. Atindra Nath Pal is an Associate professor at SNBNCBS. He did her PhD in Physics from IISc, Bangalore. After the postdocs from NanoPhysics Group, ETH Zurich, Switzerland and Orientals Group, Chemical Physics Weizmann Institute of Science, Israel. Faculty Dean Fellowship, he worked as an Assistant Professor in IIT Kharagpur. He joined SNBNCBS Kolkata as a faculty in 2017 where he was an Associate Professor from 2022. He is the recipient of “Young Physicist Award-2011”, from Indian Physical Society. He was awarded “Prof. Anil Kumar medal for the best experimental thesis in physics in 2011” from IISc, Bengaluru. His research mainly focuses on studies of the mechanisms of charge transport, spin transport and heat transport at the nano-scale down to single atom.

Low dimensional systems with spins on chains, ladders and honeycomb structures

Dr. Surjeet Singh
IISER Pune

Abstract

I will describe our efforts over the last several years in understanding and discovering new phenomena in low-dimensional spin systems. The talk essentially has two short parts: in part a, I will discuss the ground state of an antiferromagnetic Heisenberg spin 1/2 chain in the presence of an Ising impurity, and in part b of my talk, I will briefly discuss the controversy on the experimental evidence of Majorana fermions in the Kitaev model and our own work in this direction.

Biography

Prof. Surjeet Singh did his Ph.D. at TIFR Mumbai. Subsequently, he held postdoctoral positions at Max-Planck Institute (CPfS), Dresden, University of Paris, Orsay, and Leibniz Institute (IFW), Dresden. His research focuses on exploring the physics of quantum materials. His expertise lies in low-temperature physics and crystal growth. Currently he is a Professor at IISER, Pune where he joined as a faculty in 2009.

Metamaterials for light-matter interaction studies

Dr. Venugopal Achanta
NPL Delhi

Abstract

Metamaterials are designed structures with a combination of metal and dielectric layers or all-dielectric layers. While they have huge application potential as they can be designed with specific optical properties, they are also useful for light-matter interaction studies. After the invention of LASER, almost entire focus for about 60 years was on perturbative regime explained by Jaynes-Cummings Hamiltonian. To reach non-perturbative regimes, one needs to solve the full Rabi Hamiltonian and needs cavity systems with very high Quality factor or a large ensemble of dipoles to make use of cooperativity. There are only a handful of experimental realizations of non-perturbative regime at extreme conditions. In this talk, after introducing metamaterials, I will discuss some of their applications in quantum information and light-matter interaction in non-perturbative regime under ambient conditions.

Biography

Prof. Venu Gopal Achanta joined CSIR-NPL as Director on 21st June 2021. He obtained his Ph.D. in Physics from TIFR in 2000 for his work on Exciton dynamics in low dimensional semiconductors. In 2006, he was awarded Ph.D. in Electronics Engineering from Tokyo University for work on design and demonstration of an ultrafast all-optical switch. This work was done as a NEDO Fellow at the headquarters of Japanese National Femtosecond Technology project, FESTA Labs between 2000 and 2003. From 2003 to 2004, he worked as JST Fellow in the Quantum Information Technology group, Basic Research Labs, NEC, Japan. He joined TIFR as faculty in 2004 where he was a Professor(H) since 2018. His research interest is in classical and quantum information processing with dipolar emitters like quantum dots embedded in photonic and nanophotonic structures.

Deep learning and Machine Learning methods for Computational Data Science and Engineering Applications

Dr. Deepak Mishra
IIST-TVM

Abstract

This talk will first introduce the fundamental aspects of Machine learning and Deep learning and then discuss some critical applications of Machine learning and Deep learning in engineering, such as depth estimation, person ReId, object tracking etc.

Biography

Dr. Deepak Mishra is working as a Professor at Department of Avionics, IIST Trivandrum. He completed his Ph.D. in Electrical Engineering, (2003-2007) from Indian Institute of Technology Kanpur, India. He worked as a Postdoctoral research fellow at Health Science Center, University of Louisville Louisville, Kentucky, USA. His research interests are Computer vision, Image processing, Deep/Machine learning, Signal processing, Information Security and Biometrics, Mathematical modelling etc.

Space-borne Radars for Cloud Research: Hawks in the Sky

Dr. Karanam Kishore Kumar
SPL, VSSC, TVM

Abstract

Clouds are one of the ubiquitous features of the Earth's atmosphere, which cover its surface roughly 67% at any given time. Though the theory of cloud formation and its role in regulating climate and weather patterns is known to some extent, the accurate measurements of three-dimensional structure of these clouds and their microphysical properties are still evolving. The first space-borne precipitation radar onboard Tropical Rainfall Measuring Mission, revolutionized the way the cloud research was carried out across the globe. The recent launch of Global Precipitation Measurements satellite with dual frequency radar is also providing unprecedented information on clouds and precipitation and providing new insights into these enigmatic systems. The talk will be focusing on the need for cloud research in the present climate changing scenario, state-of-the art ground as well as space based remote sensing techniques to monitor the clouds, basics of radar backscattering, retrievals of microphysical parameters as well as current developments and future directions in the realms of space-borne radar remote sensing techniques.

Biography

Dr. Karanam Kishore Kumar is a Scientist/Engineer at Atmospheric Dynamics Branch, Space Physics Laboratory, Vikram Sarabhai Space Centre. He completed his Ph.D. from National Atmospheric Research Laboratory, Gadanki and he joined Space Physics Laboratory, VSSC, ISRO, India as a Scientist. His research interests are Middle atmospheric dynamics, Lower atmospheric dynamics, Radar and Lidar remote sensing, Design and development of atmospheric radars' signal processing algorithms, developing inversion algorithms for geophysical parameter retrievals etc.

Memristor and Memtransistor: Boosting Hope for Neuromorphic Computing

Dr. Bikas C. das
IISER TVM

Abstract

The human brain is the most efficient machine around us in size, power efficiency, self-learning capability, decision-making, data storage, and data processing. Additionally, our brain performs all operations analogously by consuming energy of about 1 – 100 fJ per synaptic event. Even though the conventional computer works much faster than the brain, the von-Neumann bottleneck and memory wall issues limit the performance and energy efficiency due to the physically separated storage and processing unit. After discovering the memristor (MR), a two-terminal device with multiple conducting states at a particular bias voltage, efforts are already underway toward developing machines similar to brain functionality. Despite massive progress in semiconductor technology, it is still challenging to mimic the functionality of synapses and neurons, the basic building blocks of our brain. Meme Transistor (memT), a gate-controlled memristor or memory transistor, is also coming up rapidly to the limelight for mimicking functionalities of synapses and neurons in a more controlled way as the building block of the artificial brain. Among various approaches, the redox-controlled MR and memT are becoming very attractive to accomplishing the desired metrics for developing efficient neuromorphic computing tools. In this talk, I will introduce a few unconventional redox reaction-dependent molecular MR and organic memT devices, which are very efficient for data storage to mimic various synaptic and neural functions electronically.

Biography

Dr. Bikas C Das is currently an Associate professor at School of Physics, IISER TVM. He obtained his doctoral degree in Physics from Indian Association for Cultivation of Science (IACS), Kolkata in 2011. He worked as post-doctoral fellows at NINT & department of Chemistry, University of Alberta, Canada and Pennsylvania State University, USA. He joined as an Assistant Professor at IISER TVM in 2015. His area of research includes device physics for emerging electronic and optoelectronic applications of various low-dimensional advanced materials. His work has been recognized by SERB early career research award (2017) Government of India.

AC Response Analysis of Oxide Chemiresistors: What do Frequency dependent Studies Reveal

Dr. Vinayak B. Kamble
IISER TVM

Abstract

Semiconducting oxide are among the most studied materials for various electronic applications including gas sensor devices although in DC electrical mode. Recently, a lot of interest has been generated in exploiting the AC mode of response in oxides to achieve better selective detection of gases which the DC mode fails to offer. In this talk, I shall discuss some temperature as well as frequency-dependent excitation of impedance in real as well as imaginary components, which reveals gas-specific frequencies and the mechanism of charge transport in air, NO 2 , ethanol, and hydrogen. We have conducted detailed compositional, structural and electrical (DC-AC) measurements to understand the nature of electronic transport and further its relevance in sensor response. In the later half, I will discuss some of similar results of frequency dependent studies of a layered compound SnO surface and probing its surface instability using AC response analysis.

Biography

Dr. Vinayak B. Kamble is working as an Assistant Professor at School of Physics, IISER TVM. He completed his Ph.D. from IISc Bengaluru. Before joining IISER TVM in 2015, he worked as research associate at materials research centre, IISc Bangalore. He is a member of various prestigious organizations like Indian National Young Academy of Science (INYAS), Materials Research Society of India (MRSI) Bangalore chapter, Institute of Physics (IOP) UK, American Chemical Society, IEEE Society, Kerala chapter. His research interests are nanostructures and thin films, surfaces and interfaces, defect induced transport properties of materials, dilute magnetic semiconductors, thermoelectric materials and solid state gas sensors.

Oscillators that Sync and Swarm

Dr. D.V. Senthilkumar
IISER TVM

Abstract

Synchronization and swarming are two distinct self-organizing behaviors, wherein the former refers to adjustment of internal rhythms (state) without changing the agent's spatial location while the latter phenomenon refers to spatial aggregation but without conspicuously altering their internal states. In contrast, swarmalators exhibit the duality wherein the internal state of the agents affect their spatial proximity and vice versa. Self-organizing collective dynamics of swarmalators may enrich our understanding on the underlying mechanisms of self-organizing behaviors of wide class of systems including cell sorting/aggregation, schooling of fishes, flocking of birds, opinion formation in social networks, self-organization of active matters, magnetic collides, microrobots, drones etc. In this presentation, I will briefly point out the state-of-the-art in the study of swarmalators and their limitations in representing the real world systems. I will introduce our model of D-dimensional swarmalators with competitive phase interactions depending on the vision radius and discuss some of the self organizing collective behaviors. Possible extension of our model to cell sorting and schooling of fishes will also be pointed out.

Biography

Dr. D.V. Senthilkumar is working as an Associate Professor at School of Physics, IISER TVM. He completed his PhD from Centre for Nonlinear Dynamics, Bharathidasan University, Tiruchirappalli in 2008. He worked as Alexander von Humboldt Postdoctoral Research Fellow at University of Potsdam, Germany during the period 2008 to 2010. He was Research Scientist at Potsdam Institute for Climate Impact Research, Germany during the period 2010 to 2013. He worked as a Senior Assistant Professor at SASTRA University, Thanjavur, Tamil Nadu. He joined at IISER TVM in 2015 as an Assistant Professor. He was awarded SERB-DST fast track young scientist project in 2014 to 2016. He was Selected in an European Union project funded by the European Commission within the Seventh Framework Programme (FP7) in the domain of Future and Emerging Technologies (FET-Open) on the realization of photonic liquid state machine based on delay-coupled Systems (PHOCUS). His research interests are Nonlinear dynamics, Chaotic dynamics, Synchronization, time-delay system and Network theory.

Mind the gap: unconventional searches for new physics

Dr. Tanumoy Mandal
IISER TVM

Abstract

To search for beyond the Standard Model resonances at colliders like the Large Hadron Collider (LHC), experimentalists generally use simple phenomenological models. Hitherto, all the searches are unsuccessful. However, there are strong reasons to believe that new physics should lie in the TeV-scale, within the reach of the LHC. The possible reason for the non-observation of any new physics so far at the LHC could be that we are not considering the correct final states into which the new resonances are decaying. Hence, we might have missed them. In this talk, I show some examples of interesting and unexplored signatures of new resonances that appear in many well-motivated models but are not considered by experimentalists.

Biography

Dr. Tanumoy Mandal is working as an Assistant Professor at School of Physics, IISER TVM from Feb 2020. He completed his PhD from Theoretical Physics Division, Institute of Mathematical Sciences, Chennai. He worked as postdoctoral fellow at Physics Division, Harish Chandra Research Institute, Allahabad, Department of Physics and Astronomy, Uppsala University, Sweden. He worked as DST-INSPIRE Fellow at University of Delhi. He worked as a researcher at Uppsala University from 2018 to 2020. He works under the field of Beyond the Standard Model theories and collider phenomenology and Matter under extreme conditions, neutron star and color superconductivity.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Poster Abstracts

Dynamics in the inner and middle Corona - Results from Coronal Sounding Experiments by Indian Mars Orbiter Mission (MOM) and Akatsuki spacecrafts

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2Physical Research Laboratory, Ahmedabad, India
3ISRO Telemetry Tracking and Command Network, Bengaluru, India

Abstract: Solar Corona is the natural laboratory that hosts some fascinating physical phenomenon, such as its unusually high temperature, the complex interplay of Magneto hydrodynamic (MHD) waves and continuous acceleration of charged particles away from solar atmosphere in the form of solar wind. However, the in-situ studies for the inner-middle region (2-10 Rʘ) pose a challenging feat. In this context, coronal radio sounding methods provide an ingenious way to explore the dynamics prevailing in the this region. Indian Mars Orbiter Mission is India's first interplanetary mission, which was inserted into Martian orbit in 2014. We analysed the downlink S-band radio signals sent from the spacecraft and received at Indian Deep Space Network, Bangalore during the May-June 2015, and September-October 2021 solar conjunction events. The experiment geometry helped us to probe the coronal region at heliocentric distances between 4 and 20 Rʘ (1 Rʘ = 676,900 Km) when the solar activity was at the post-maximum phase of the solar cycle 24, and ascending phase of the Solar cycle 25. Frequency residuals obtained from signals were spectrally analysed to study coronal plasma turbulence. It is observed that the changes in turbulence regime with respect to heliocentric distances are well reflected in spectral index values from frequency fluctuation spectrum. At a lower heliocentric distance (<10 Rʘ), the spectrum has flattened with spectral index $\alpha f \sim 0.3 - 0.5$, which corresponds to the energy source input regime. For larger heliocentric distances (> 10Rʘ), the curve steepens with spectral index $\alpha f \sim 0.7 - 0.8$, a value close to 2/3, that is indicative of inertial regimes of developed Kolmogorov-type turbulence where energy is transported through cascading. This helped us to understand the processes in the transition region where solar wind accelerates from sub alfvenic to super alfvenic speeds. This study proposes interesting insights into how solar wind properties near the coronal regions can be investigated using the radio sounding method, which is an effective method to study complex coronal physics[1].
We also utilized the various methodologies on the data acquired from coronal sounding experiments conducted by the Akatsuki spacecraft during the 2021 Venus-solar conjunction event. The single station data is analysed to study the plasma turbulence characteristics, and flow speeds measurements are based on the isotropic quasi-static turbulence models [2]. The speeds estimates were found to be in the range of 240-550 Km/sec for the given heliocentric distances. An interesting observation is tracking the evolution of fast solar wind streams with increasing heliocentric distance emanating from an extended coronal hole.

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Tuning the photoluminescence via doping and functionalization of carbon quantum dots

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Abstract: Carbon quantum dots Carbon quantum dots (CQDs) are zero-dimensional, less than 10 nm-sized carbon nanomaterials. CQDs have excellent physical properties, including high thermal and electrical conductivity, long-term fluorescence stability, and good thermal stability. Furthermore, they exhibit biocompatibility, hydrophilicity, chemical stability, and low toxicity. The different sizes and functional groups of CQDs are responsible for their broad physical and optical properties. Furthermore, their properties can be improved using various methods to tune their size, chemical and electronic structure, and surface functionality. Incorporation of appropriate functional groups and heteroatoms leads to desired tailored applicability. The
remarkable physical, photo physical, and electrochemical properties of CQDs and study their properties by various characterization techniques such as X-ray diffraction for crystallinity, scanning electron microscope, and transmission electron microscope for morphology, and the surface functionality by Fourier transform infrared (FTIR) spectroscopy, Raman spectroscopy, and X-ray photoelectron spectroscopy and the lifetime study also analysed. CQDs are generally known for luminescence property and also exhibit tunable fluorescence emission which is significant for many new applications, such as electro-optical, bio imaging, photonic materials, energy harvesting, etc. Keywords: Carbon quantum dots; CQDs; physical properties; optical properties; characterization; photoluminescence

Optical bistability and absorption characteristic of optomechanical system embedded with double quantum dot and nonlinear medium

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Abstract: In this work we theoretically study a hybrid optomechanical system embedded with two coupled quantum dots and a third-order Kerr nonlinear medium inside the cavity. The optical bistability and absorption spectrum are analyzed for the proposed system. From the Hamiltonian which describes the proposed system, a set of quantum Langevin equations are derived. Using these equations of motion, the steady-state mean field analysis is done which gives the phenomena of optical bistability. The performance of the optical switch is also analyzed in terms of gain and switching ratio. Further, the absorption spectrum of the system is derived and analyzed from the fluctuation dynamics. The optical bistability has the potential to design tunable all-optical switches. The absorption spectra display peculiar characteristics of negative absorption (transparency dip). The transparency dips are found to be strongly dependent on the frequency of the mechanical resonator. The results of our investigation reveal that the proposed system can be used as an optical switch and has numerous other applications in quantum communication systems.

Hamiltonian: $\Delta_a a^{\dagger}a + \Delta_{d1}\sigma_z^{(1)} + \Delta_{d2}\sigma_z^{(2)} + \omega m/2(p^2 + q^2) + \beta a^{\dagger}aa^{\dagger}a + \Omega_1(a^{\dagger}\sigma_-^{(1)} + a\sigma_+^{(1)}) + \Omega_2(a^{\dagger}\sigma_-^{(2)} + a\sigma_+^{(2)}) + 2M_z\sigma_z^{(1)}\sigma_z^{(2)} + \omega_D\sigma+(1)\sigma-(2) + \omega D\sigma_-^{(1)}\sigma_+^{(2)} - Ga^{\dagger}a\, q + E_p(a^{\dagger} + a) + E_s(a^{\dagger}e^{i\delta t} + ae^{-i\delta t})$.

Overcoming squeezed light optomechanical interferometer limit

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Abstract: Optical interferometers play a vital role in modern quantum technologies like quantum teleportation, quantum communication, quantum computers, quantum metrology, etc. For example, Gravitational waves are detected using a giant Michelson interferometer. However, the accuracy of these interferometers is limited by various quantum noises. While performing continuous measurements in a laser optomechanical interferometer, competition between shot noise and radiation pressure noise limits its sensitivity to standard quantum limit (SQL) [1, 2]. In addition to the SQL, there is also thermal noise which can be reduced by cooling the optomechanical mirror [3]. Thus, the classical force sensitivity in an optomechanical interferometer is limited to F_{sql}, where F_{sql} is the SQL of force sensing. The force sensitivity can be improved to $e^{-r}F_{sql}$ by using squeezed states [4,5], where r is the squeezing parameter. Squeezed states have been known for over four decades. However, the highest squeezing achieved so far is 15 dB [6] (r = 1.74). As synthesizing highly squeezed state is challenging, we propose hybridizing squeezed states technique with quantum back-action nullifying meter (QBNM) [7]. Such hybridization improves the force sensitivity of the optomechanical interferometer to $e^{-r}(\zeta/4\Delta F_{sql})^{1/2}$[8]. The cavity decay rate ζ is less than the cavity detuning Δ.

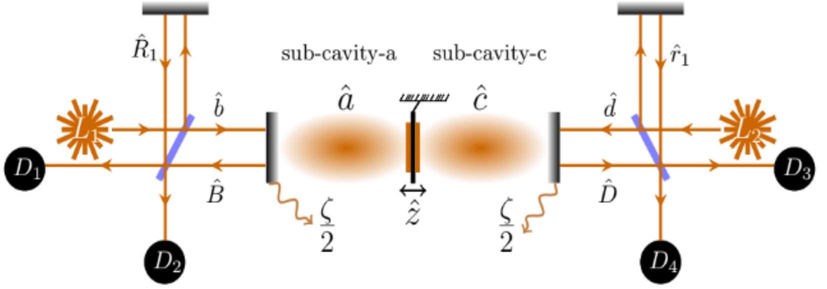

Fig. 1: An optomechanical cavity with a highly reflective mechanical mirror in the middle. The mechanical mirror divides the total cavity into two subcavities with equal length l and eigenfrequency ω_e. $\hat{a}$ and $\hat{c}$ are the annihilation operators of the subcavity fields. The subcavity fields $\hat{a}$ and $\hat{c}$ are driven by input fields with annihilation operators $\hat{b}$ and $\hat{d}$, respectively. The operators $\hat{b}$ and $\hat{d}$ are normalized such that $\hbar\omega_d\langle\hat{b}^\dagger\hat{b}\rangle$ and $\hbar\omega_d\langle\hat{d}^\dagger\hat{d}\rangle$ gives their optical powers, respectively, with ω_d as the frequency of the input fields. ζ is the cavity decay rate. The cavity detuning $\Delta = \omega_e - \omega_d$. A co-sinusoidal classical force $f\cos(\omega_f t)$ with ω_f as frequency and t as time, changes the position $\hat{z}$ of the mechanical mirror. Squeezed vacuum with annihilation operators $\hat{V}$ and $\hat{U}$ are sent into the subcavity-a and subcavity-c, respectively, through empty ports. When QBNM is implemented along vacuum squeezing the force sensitivity is given as $e^{-r_{eff}}F_{sql}$, where $r_{eff} = r + \ln(4\Delta_J/\zeta)/2$ with $\Delta_J = \Delta - J$ and J is the tunnelling rate.

Flat bands, edge states and possible topological phases in abranching fractal

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Abstract: We address the problem of analytically extracting a countable infinity of flat, non-dispersive bands in a periodic array of cells that comprise hierarchically grown branching Vicsek geometries. The structural units can, in principle, be of arbitrarily large size. Through a geometric construction, followed by an exact real space renormalization scheme we unravel clusters of compact localized states, corresponding to densely packed groups of flat bands, sometimes in close proximity with the dispersive ones, as the unit cells accommodate Vicsek fractal motifs of higher and higher generations. In such periodic arrays, energy bands close and open up at energies that are calculated exactly, and the precise correlation between the overlap integrals describing the tight binding systems has been worked out. The possibility of a topological phase transition is pointed out through an explicit construction of the edge states, weakly protected against disorder, though it is argued that the typical bulk-boundary correspondence may not hold good as the unit cells grow in size to achieve the true fractal character.

A Light shed on Lepton Flavor Universality in B meson decays

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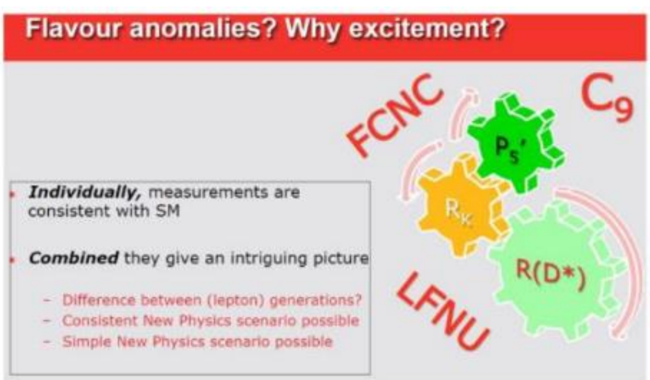
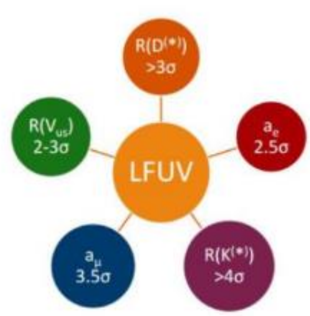
Abstract: In view of recent measurements of anomalies in semileptonic B meson decays at LHCb and several other collider experiments hinting at the possible violation of lepton flavor universality (LFU), we present a concise review of theoretical foundations of the tree- and loop-level b decays, $b \rightarrow c, l, \theta_l$ and $b \rightarrow s, l^+, l^-$ belong with the updated experimental background. We study the q^2 - dependence of form factors for the semileptonic transitions and then present the world averages, $R_{D(D^*)}$, $R_{K(K^*)}$, $R_{J/\psi,}$ and $R_{\eta c}$ in a model dependent (based on relativistic independent quark model (RIQM)) as well as model independent approach. We further provide predictions of other anomalies linked with LFU violation such as, anomalous magnetic moment of electron and muon by Fermilab (a_μ, a_e), mass of W boson by CDF collaboration, the CKM puzzle ($R(V_{us})$) in view of future high-statistics data, are also discussed. We then look over to the combined explanation of charged-current and neutral-current anomalies ($R_{D(D^*)}$, R_K), unified together in the language of effective field theory. As flavor anomalies are the strongest hints for physics beyond standard model, it is therefore expected that if the ongoing evaluation of the data of LHC Run 2 confirms the measurements of Run 1, then the statistical significance of the effect in each decay channel separately is expected to reach 5σ. Therefore the confirmation of these measurements would soon turn out to be remarkable evidence, unravelling the New Physics in the flavour fraternity, giving a better understanding on the subject, for future experimentalists and theorists.





Chaotic Time Series Prediction: Bridging the Gap with Physical Reservoir Computing

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Abstract: Chaotic time series prediction is an important and challenging task in the field of computational intelligence, with applications ranging from finance and weather forecasting to astronomy and control systems. Though traditional machine learning algorithms have improved time series forecasting by several folds, they have limitations when it comes to dealing with complex, nonlinear and chaotic signals. In this context, physical reservoir computing (pRC) emerges as a promising solution to bridge the gap between the limitations of traditional algorithms and the requirements of real-world applications. Reservoir Computing (RC) is a computational paradigm that harnesses the dynamics of recurrent neural networks to perform complex computational tasks. Physical Reservoir Computing (pRC) is are recently developed extension of RC that utilises the dynamics of physical systems instead of artificial neural networks. The architecture of PRC consists of a dynamical system, called the reservoir, which is connected to an input layer and a trained readout layer. The reservoir transforms the input signals into high-dimensional representations, which the readout then processes to produce the final output predictions. The key advantage of PRC is its ability to handle nonlinear and chaotic signals, making it well suited for the prediction of chaotic time series.

In this work, we present a comprehensive overview of the state-of-the-art pRC algorithm and its applications in chaotic time series prediction. We first introduce the fundamental concepts of pRC, including its mathematical foundations and design principles. The choice of the dynamical system to be used as the reservoir, the design of input and readout layers, as well as their interconnections play a crucial role in determining the computational capabilities of pRC. We choose a chaotic oscillator circuit as the reservoir, since they are easy to realise experimentally. Our chosen reservoir is a simple, second-order memristive circuit with striking dynamical features, which play a crucial role in the reservoir's computational capability. The potential of memristive circuits for neuromorphic computing makes this a particularly attractive choice for pRC. We explore the pRC's performance in three key tasks: (1) predicting the short-term dynamics of a chaotic time series and (2) forecasting the long-term climate of the system, and (3) inferring unseen data of the dynamical system by predicting a variable which was not given during the training phase. To get a fuller picture, we also present a detailed comparison between pRC and other RC algorithms, such as traditional ANN-based-RC and the recently developed, next-generation RC (NGRC). We employ these three different algorithms on the above tasks and compare them. The results of our experiments demonstrate the potential of pRC for a wide range of real-world applications.

Role of defect-induced shallow and deep trap levels and interphase charge transfer in nanostructured TiO_2 photocatalyst

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Abstract: Titanium dioxide (TiO_2) is widely used for waste-water treatment because of its excellent photocatalytic activity. The most common phases of TiO_2 are anatase and rutile. Among these anatase shows better photocatalytic activity while, rutile shows poor performances due to varying reasons [1], [2]. Herein, we have synthesized anatase, rutile and an anatase-rutile mixed phase and studied their microstructure, type of defects and photocatalytic activity. For this, we have employed a simple, cost-effective sol-gel technique with Titanium tetra isopropoxide (TTIP) as the titanium precursor. The structural confirmation and the phase identification were done using X-ray Diffraction (XRD) and Raman analyses. Microstrain and Urbach energy calculations indicate the presence of a shallow level oxygen defect-enriched surface structure in anatase which supports charge carrier separation in photocatalysis. XPS surface chemistry revealed the presence of Ti^{3+} defect states (shallow trap) and oxygen defects (deep trap) in the rutile sample. ESR signals support these findings. Their photocatalytic activity is compared under sunlight using a synthetic Methylene Blue dye. Anatase-rutile mixed phase shows enhanced photocatalytic activity than others. Rather than the effect of defects, interfacial charge transfer induces a synergistic effect on it. Also, phase pure rutile shows greater photocatalytic activity almost equal to that of the anatase phase because of the presence of Ti^{3+} cations. Photoluminescence emission intensity comparison gave the idea that, shallow trap levels can favour the photocatalytic activity by the charge carrier separation than recombination promoted deep trap levels.

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Exploring *In-situ* Raman Spectroscopy as a Promising Tool for Investigating Electrochemical Reactions Mechanisms

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Abstract: Operando analysis of electrochemical reactions/interfaces becoming increasingly important because it provides real-time information about the chemical changes associated with complex interfacial dynamics. *In-situ* spectroelectrochemical studies plays a vital role in understanding the electrochemical reaction intermediates as well as the interfacial reactions. Among them, powerful spectroscopic technique like Electrochemical Surface Enhanced Raman spectroscopy (EC-SERS) is considered as the most promising tool to render such complex dynamics at the solid/liquid interfaces [1]. However, it is restricted to probe the electrochemical reactions only on non-smooth plasmonic substrates like Au, Ag and Cu [2, 3].

Here, at first, we demonstrated the unintentional catalytic interference from silver nanoparticles in spectroelectrochemical studies and its mitigation using thin pinhole-free silica layer covering the silver nanoparticle ($Ag@SiO_2$), which in-term known as Shell-isolated Nanoparticle Enhanced Raman spectroscopy (SHINERS) [4]. And secondly, the application of SHINERS is employed to probe the transient potential behavior of self-organized systems which involves a sequence of mass transfer limited chemical reactions.

Our studies show the advancement of Raman spectroscopy in the field of electrochemistry, where it might be crucial in comprehending the underlying principles of any electrochemical reactions. We anticipate that the observations from this study would help SHINERS to gain more visibility among global researchers working on fundamental electrochemistry challenges such as batteries, catalytic water splitting reactions and more.

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Response of an active particle to the magnetic field

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Abstract : We consider the dynamics of a charged inertial active Ornstein-Uhlenbeck particle in a viscoelastic suspension under the action of an uniform magnetic field. With the help of both numerical simulation and analytical framework, we exactly investigate the viscoelastic response of the particle to the magnetic field by means of particle trajectories, mean displacement, and mean square displacement (MSD) calculations. The simulated particle trajectories and MSD calculations reveal that the steady state response of a confined harmonic particle to the magnetic field show interesting features due to the complex interplay of underlying physical processes such as elastic dissipation and active fluctuations in the medium. When the activity time scale of the dynamics is larger than the elastic dissipation timescale (or vice-versa), the steady state MSD shows an enhancement (or suppression) with increase in the field strength. In both the cases, for very strong magnetic field the MSD interestingly approaches the value at the equilibrium limit where the generalized fluctuation dissipation relation is satisfied and the particle behaves like an inertial passive Brownian particle. Thus, for a finite magnetic field, the system exhibits a re-entrant type transition from active to passive and then to active behaviour with persistence of elastic dissipation in the medium. Further, when the system is subjected to two active bath at different temperature along two orthogonal axes, it shows a non-zero magnetic moment even if there is no asymmetry in the confining potential, implying the effect of activity in the gyration of particle in the presence of magnetic field.

The nonleptonic decays of b-flavored mesons to S-wave charmonium and charm meson states in relativistic independent quark (RIQ) model

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Abstract: The detection of radially excited heavy meson states in recent years and measurement of heavy meson decays, particularly 14- J/'1' DS and /44, by the LHCb and ATLAS Collaborations, have aroused a lot of theoretical interest in the nonleptonic decays of b-flavored mesons. In this paper we study the exclusive two-body nonleptonic r?°, BS , B- and 1V-meson decays to two vector meson V1(nS)V2 states. Assuming factorization hypothesis, we calculate the weak-decay form factors from the overlapping integrals of meson wave functions, in the framework of relativistic independent quark (RIQ) model. We find a few dominant decay modes: B- -, D*() p-, R° -, D*+ , BS -, D;* p- , B- -, J/T K**and B -> JPPD;- with predicted branching fractions of 1.54, 1.42, 1.17, 0.53 and 0.52 (in %), which are experimentally accessible. The predicted branching fractions for corresponding decay modes to excited (2S) states, obtained in the order 0(10^{-3} - 10^{-4}) lie within the detection accuracy of the current experiments at LHCb and Tevatron. The sizeable CP-odd fractions predicted for transition particularly of Eq-meson decays to two charmful states: D'N's-) and TY°Di's5 indicate significant CP-violation in their decays that hints at the so-called new physics beyond standard model.

Emergent soliton-like solutions in the parametrically driven 1-D nonlinear Schrödinger equation

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Abstract : Solitons in open, non-integrable systems have been a subject of practical interest over the past several years. They have been realized experimentally in many physical contexts such as optics and hydrodynamics. The dissipative Kerr solitons in optical microresonators and fiber cavities are examples of solitons in open systems. Unlike the conventional solitons, the solitons in open system can only exist when there is an energy supply from an external source, in addition to the nonlinearity and dispersion. Albeit structurally similar to the conventional solitons, the solitons in open systems need not necessarily behave like conventional solitons. Here, we report the observation of a novel soliton-like solution obtained in the numerical simulation of the parametrically driven 1-D nonlinear Schrödinger equation, with a spatially periodic breather mode as the initial condition. These solitons, like conservative solitons, travel with constant amplitudes and velocities, in the absence of dissipation. However, when dissipation is introduced, the amplitude of the soliton decreases while its velocity increases which is in contrast to the conventional behaviour wherein both the amplitude and velocity decrease. Furthermore, we have investigated the stability of these solutions against random perturbations and found that the solitons are stable for sufficiently large values of perturbations.

Study of correlation between local topological ordering and chemical ordering in binary metallic glasses.

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Abstract: Bulk metallic glasses (BMGs) have gained significant attention of researchers due to their superior physical properties from the viewpoint of its uses as dental and orthopaedic transplants in human bodies. Glass-forming ability (GFA) of the metallic alloys is a key consideration for the commercially viable production of BMGs. Interplay of the structural, dynamical and thermodynamic factors governs the GFA of these systems. Atomic size mismatch and enthalpy of mixing of the constituent elements of the alloys have served as indicators for predicting its GFA. Icosahedral short- and medium-range topological ordering have been found to be the key local structural features that rapidly evolve during the supercooling of metallic alloys and glass formation. Rapid increase in the icosahedral ordering in the supercooled region has been shown to be linked to the drastic slowdown of the atomic dynamics and hence, the GFA. While a plenty of investigations of the local structure and its correlation with dynamics as well as GFA have been reported, very little attention has been paid so far on the detailed investigation of the electronic structure and bonding in the icosahedral ordering its effect on the structural heterogeneity and GFA.

In the present work, we have carried out detailed investigation of electronic structure and bonding in the icosahedral ordering in Zr-Cu alloys which exhibits composition dependence of GFA. Classical molecular dynamics simulations have been performed using LAMMPS to obtain the systems in supercooled state at desired temperature (300 K). Voronoi tessellation is used to extract the three-dimensional local structure. Electronic structure and bonding in the icosahedra are studied in terms of DOS, PDOS, charge density distribution where DFT methods are employed in Quantum Espresso. The questions that we address in this study are: (1) Is there any significant difference in the electronic structure and bonding in the icosahedra ordering in Zr-Cu alloys with different compositions? Does the electronic structure play any role in packing efficiency of icosahedra which could affect the glass formation?

Effect of the Geometry on the Magnetic Relaxation of a two-dimensional Ising Ferromagnet

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Abstract: We have studied the magnetic relaxation behaviour of a two-dimensional Ising ferromagnet by Monte Carlo simulation. Starting from all spins up configuration, the system is allowed to relax to its equilibrium state at any fixed temperature above T_c. The exponential nature of the decay of magnetization is observed. Our primary goal is to investigate the effects of the system's geometry and dynamical rules on the relaxation behaviour. How does the relaxation time (τ) change if we deform a square lattice into a rectangular one just by reducing its length along y direction (keeping length along x direction fixed)? We have studied the relaxation time as a function of the aspect ratio R (length over breadth). In the limit of a small aspect ratio, the relaxation time is almost independent of the geometrical structure. However, a power law dependence has been observed for larger values of aspect ratio. **The results are available at arXiv:2212.01858.**

Colossal cyclic endurance and low operational voltage in defect engineered ITO/$LaMnO_3$/Ag resistive switching device

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Abstract: Oxygen partial pressure in a pulsed laser deposition (PLD) chamber plays crucial role in structural and compositional modification of the deposited material. So, defect engineering (using oxygen vacancy tuning in this case) is an inevitable application of PLD process. We present enormous cyclic endurance and low operational voltage in oxygen vacancy tuned $LaMnO_3$ thin film with ITO and Ag being the bottom and top electrode, respectively. The operational voltage was achieved as low as ±1 V with lowest SET and RESET voltage which is lowest compared to previous reports on PLD grown $LaMnO_3$ thin film. Different switching windows for different oxygen partial pressure treatment show the important role played by the tuned oxygen vacancies. The switching mechanism is found to be valance change memory (VCM) type, whereas, the conduction mechanism is explained by trap-assisted space charge limited conduction (SCLC). The increasing trend of ON-OFF ratio even after 11000 plus cycles indicate the scope of neuromorphic computing using the device.

Highly Sensitive NO_2 Detection at Room-Temperature Using SnS_2/MWCNT Composite With Enhanced Recovery Kinetics using UV Activation

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Abstract : The nitrogen dioxide (NO_2) is one of the most deadly and infectious gas pollutants on this planet. Majority of the respiratory diseases and lung infections in humans are caused due to breath inhalation of NO_2 which is expanding in our environment consistently. Detecting the minute traces of NO_2 is a challenging task. Various low dimensional materials-based sensors have been used earlier to detect minute traces of such gases. Usually developed materials and subsequently the two-terminal devices suffer from either sluggish recovery and/or lower response. To address the current problem, herein, we present a high performance, cost effective, low-power consumable NO_2 chemiresistive gas sensor using SnS_2/MWCNT composite. It exhibited a relative response of about 5 % (3%) for 25 ppb (1 ppb) of NO_2 at 20 ^oC and relative humidity of 60% with complete recovery in air (10 min) and an excellent enhanced recovery rates with UV irradiation (0.3 min), see Fig.1. A theoretical limit of detection (LOD) 7 ppt is shown by the composite sensor which is considered to be the best NO_2 sensitive results shown by any SnS_2 sensing devices as compared to previously reported work in our knowledge. The improved sensing results have been assigned to the formation of nano p-n heterojunctions, which amplifies the charge carrier density and charge transfer process. The sensing mechanism is defined by using suitable surface charge reactions with consisting energy band diagram for both UV and non-UV variations. Furthermore, the sensor also exhibits good selective behaviour towards NO_2, as well as an excellent stability and long term-durability of about 6 weeks. This work will provide a new perspective on SnS_2 based composite sensors for real-world practical sensing applications.

Revisiting vacuum energy in compact spacetimes

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Abstract: The quantum fluctuations of a field are affected by the presence of nontrivial boundary conditions and extra background fields. The confinements of the field lead to the Casimir effect, and the presence of a constant background electric field leads to the Schwinger effect. These two predictions are considered the cornerstone results of standard quantum field theory. The Casimir effect occurs due to the introduction of a length scale in theory, which inevitably ties the physics of compact dimensions with the Casimir effect. Extra compact dimensions are another prediction of modern theories like string theory. The Casimir effect is experimentally validated, but the Schwinger effect and the presence of extra compact dimensions still await an experimental realization. As the vacuum energy is disturbed by boundary conditions and background fields, it is natural to study the combined effect. In this work [1], we are taking this investigation forward using the general methods of effective action. Using this method, we can bring different results in the literature into a single framework and develop new results. Using our results, we also suggest a method for the experimental realization of the Schwinger effect.

Using the effective action method, we computed the vacuum energy of a massive complex scalar field coupled to a constant electromagnetic field in arbitrary compact spacetime. The relation of extra compact dimensions and background fields with the Casimir force is derived. We observe that while the presence of a strong external magnetic field reduces the intensity of the Casimir force, the presence of an electric field enhances it. We discuss various physical cases and derive the Schwinger pair production rate in compact spacetimes. Our results show that a piston or extra compact dimensions enhance the pair production rate. These results can help in the experimental realization of the Schwinger effect.

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Entangling the laser beams using optomechanics and quantum back-action nullifying meter

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Abstract: Entanglement is an essential quantum resource for quantum technologies. While entangling distant localized modes have several applications, entangling flying modes is desired for quantum information transfer. For example, if two propagating laser beams are entangled, such entanglement can be readily transferred from one spatial point to another. Here we propose a new method to create entanglement in flying modes by entangling two spatially separated laser beams. We use optomechanics and quantum back-action nullifying meter (QBNM) [1] technique to create entanglement. Unlike conventional methods, this method does not require resolved sideband driving to create entanglement. We observe entanglement even at room temperature for parameters taken from experimental work Ref. [4].

Consider an optomechanical system as shown in FIG.1. The end mirrors m_1 and m_2 are rigidly fixed and have a decay rate ζ. The optomechanical mirror (OMM) in the middle divides the cavity into two subcavities. The OMM is perfectly reflective so that the field in sub-cavity-1 (SC1) is not mixed with the field in sub-cavity-2 (SC2) and vice-versa. The instantaneous position of the OMM is given by ˆz. SC1 and SC2 are driven by input fields with annihilation operators ˆain and ˆcin, respectively. The annihilation operators for the output fields from SC1 and SC2 are ˆa_{out} and ˆc_{out}, respectively.

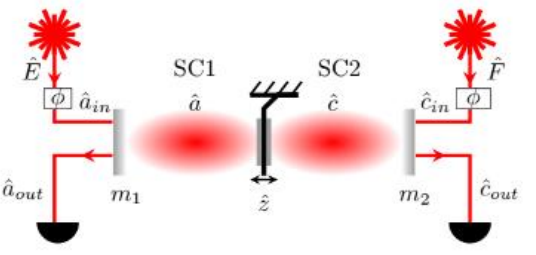

FIG. 1. Optomechanical cavity with perfectly reflective mechanical mirror in the middle. The mirrors m_1 and m_2 are rigidly fixed, while the center optomechanical mirror can oscillate.

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Memory induced transition from random self propulsion to circular motion

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Abstract: We present the theoretical realization of memory induced transition from random self propulsion to circular motion of an inertial active Brownian particle. The particle is considered to be suspended in a viscoelastic suspension with an exponentially decaying memory kernel in the viscous drag. The velocity of the particle follows the Ornstein-Uhlenbeck process, characterized by an exponentially correlated noise. From the exact solution of the dynamics, we establish a phase diagram in the parameter space, identifying the regime where the particle performs oscillation in the dynamical physical parameters like mean displacement and mean square displacements. From the simulation results, interestingly we observe that the particle takes the advantage of oscillation from the oscillatory regime of the parameter space and performs circular trajectories by fine tuning the inertial time scale and elastic dissipation time scale. For a confined harmonic particle the circular trajectories get enhanced with increase in the persistence of elastic dissipation in the medium and get squeezed with increase in the persistence of activity in the medium. This is further complemented with the mean square displacement calculation which shows enhancement (suppression) with increase in elastic dissipation (self-propulsion) time scale.

Anomalous Hall-effect in graphene-WSe_2 heterostructure

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Abstract: Proximity-induced spin–orbit coupling in graphene offers an exciting platform to probe spin-based effects in chiral Dirac fermionic systems. These systems are believed to be intrinsically time-reversal symmetric, which should ensure that the charge Hall response vanishes without a magnetic field. In contrast to this expectation, we report the first observation of anomalous Hall effect (AHE) in single-layer graphene/single-layer WSe_2 heterostructures that persists up to room temperature. The magnitude and the sign of the AHE can be tuned using an external perpendicular electric field. Our joint experimental and theoretical study establishes that the observed anomalous Hall signal arises from the combined effect of strain and spin-orbit coupling in graphene, which induces time-reversal symmetry breaking and manifests as a valley asymmetry. Our observation broadens the prospects of realizing high-temperature anomalous Hall effects in a completely new system, namely graphene-transition metal dichalcogenide based heterostructures.

Multispectral imaging in mammalian cells using a home-built LSFM system

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Abstract: Light sheet fluorescence microscopy (LSFM) works on fluorescence imaging, employing target-specific fluorescent proteins to label regions of interest in a sample. In this way, analyzing and manipulating information from different targets in a specimen requires labelling the specimen using multiple fluorophores. Multispectral imaging helps identify several target molecules simultaneously at once, thereby retrieving information from the entire volume of the sample. Here we report multispectral imaging studies on mammalian cells using our in-house built multispectral LSFM imaging system. Experimental studies were conducted on mammalian cells in alive conditions, and results are provided.

Spike and Rate-based Dynamics for Neural systems

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IISER Thiruvananthapuram

Abstract : How the brain computes has been an important question for a long time. Since then, theorists have proposed many models close to the experimental data. Networks of spiking neurons are increasingly used in neuroscience to understand phenomena observed in electrophysiology recordings. While the rate-based models are practical, they lack empirical evidence.

The dynamics of the brain are multiscale, ranging from ion channels and synapses at the molecular level to emergent behaviour, like oscillations at the scale of the entire brain. The challenge, therefore, becomes how to create predictions regarding brain dynamics while simultaneously incorporating these various dimensions.

A different starting point is to initially average over neural features to create a neural field theory that models the average dynamics of several neurons. Local instantaneous firing rates are monitored in this instance, but individual neural spike dynamics are not. These methods are substantially less computationally costly than equivalent research based on the direct computation of single-neuron dynamics. They are well suited to studying large-scale phenomena and bridging across scales. They do not, however, directly incorporate the spiking kinetics of individual neurons, as was already mentioned.

Here we try to study different spiking and rate-based neuron networks analytically and through simulations. To find out under what conditions spike-based models can favourably replace rate-based models.

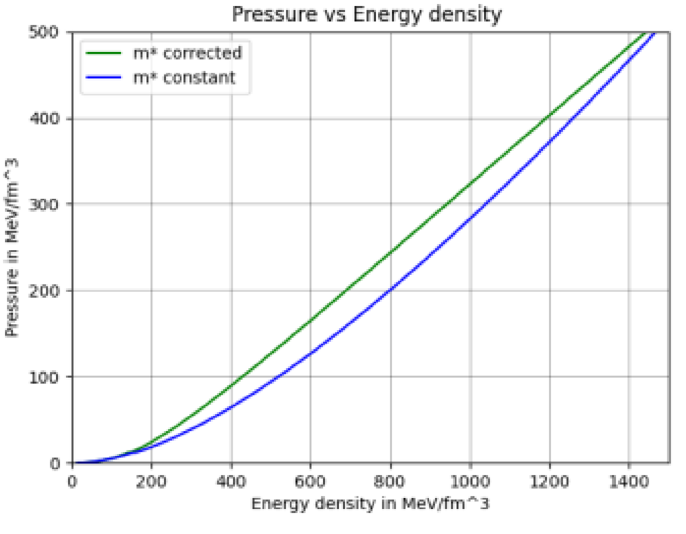
To do this, we use two well-known spiking and rate-based models, Brunel Network and the Continuous Attractor network, respectively. The Brunel network is a well-studied network of Leaky, integrated, and Fire (LIF) neurons whose network behaviour is very close to the theoretical behaviour observed in real neurons. Continuous attractor networks are used to explain one of the high-level cognitive tasks: path integration for spatial navigation in grid cells.

From Light to Heavy: Influence of Dynamic Effective Mass of Neutrons in Dark Matter Admixed Neutron Stars

Adarsh Karekkat, Tanumoy Mandal

February 2023

Abstract: Dark matter particles are notoriously elusive, and terrestrial experiments are yet to show direct detection with today's instruments and technology. Neutron stars become ideal astrophysical laboratories in such a situation, where indirect detection of dark matter becomes a viable direction. Given their extreme densities, neutron stars can capture dark matter via scattering, after which the dark matter particles can influence the observable properties of the star. Lately, models considering different interactions and mediators between Dark matter and Hadronic matter have been formulated, and relevant predictions on maximum star masses and other star properties have been made. Observational and empirical calculations can help us constrain the Equation of State at the crust level to an extent. Gravitational waves and massive pulsars like PSR J0740+6620 give upper bounds on the masses of the neutron stars as well. Any realistic model considered has to at least satisfy these constraints. In parallel, recent works have reported that the effective mass of nucleons can vary with density, temperature, and asymmetry. The relevant density ranges from nuclear saturation density to several times above it. Here we find that, for a cold neutron star, by incorporating the correction for the varying effective mass of neutrons in dark matter admixed neutron star models, we can expect significant changes to the Equation of State of the stars and hence their mass-radius relationships and other observables. We also comment on how the constraints on the mass of the dark matter particles derived from prior models can be more relaxed in this light.



Synthesis and thermal expansion studies on $YBa_2Cu_{3-x}Al_xO_{6+\delta}$ single crystals

Adarsh M Lal, Ashna Babu, Deepshikha Jaiswal Nagar

Abstract: $YBa_2Cu_3O_{6+\delta}$ (YBCO) is a high-temperature superconducting material which display superconducting transition above liquid nitrogen boiling point. $YBa_2Cu_{3-x}Al_xO_{6+\delta}$ (Al-YBCO) single crystals were synthesized using the self-flux technique in alumina crucibles. To fix the doping content of the as-grown crystals, they were subjected to annealing employing the Lindmer's phase diagram. Accordingly, annealing was done for four weeks at 300°C, two weeks at 500°C, and one week at 700°C. We measured the thermal expansion of Al-YBCO annealed at 300°C and found a two-peak anomaly which may be representing the pseudo-gap opening width. The measurements were done both on an AMI bath cryostat using liquid nitrogen in the temperature range 80 K to 270 K as well as on a closed cycle based dry Physical Property Measuring System (PPMS) cryostat. To estimate the cell effect arising due to the dilatometer in the bath cryostat, measurements were done on a standard copper sample with varying lengths of 0.5 mm, 0.97 mm and 1.97 mm. The cell effect was found to have minimal deviations from the published values. The linear thermal expansion coefficient calculated on another standard metal, silver, was found to be in accordance with published values in the literature. The pseudo-gap opening temperature was obtained for Al-YBCO using thermal expansion measurement.

Large magnetocaloric effect in the kagome ferromagnet $Li_9Cr_3(P_2O_7)_3(PO_4)_2$

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Abstract: We report the single-crystal growth, magnetic properties, and magnetocaloric effect of *S* = 3/2 kagome ferromagnet $Li_9Cr_3(P_2O_7)_3(PO_4)_2$ (trigonal, space group: $P\bar{3}c1$). The characterization is done using x ray diffraction, magnetization, and heat capacity measurements followed by band structure calculations [1]. Magnetization data suggest dominant ferromagnetic intra-plane coupling with a weak anisotropy and the onset of ferromagnetic ordering at $T_C \simeq 2.6$ K. Microscopic analysis reveals a very small ratio of interlayer to intra-layer ferromagnetic couplings (($J_\perp/J \simeq 0.02$). Electron spin resonance data suggest the presence of short-range correlations above T_C and confirms quasi-two-dimensional character of the spin system. Further, the calculation to estimate magnetocaloric effect is done from magnetization and heat capacity data [2]. A large magnetocaloric effect characterized by isothermal entropy change of $-\Delta S_m \simeq 31$ J/kg-K and adiabatic temperature change of $-\Delta T_{ad} \simeq 9$ K upon a field sweep of 7 T is observed around T_C. This leads to a large relative cooling power of $RCP \simeq 284$ J/kg for a field change of 7 T. The large magnetocaloric effect, together with negligible hysteresis render $Li_9Cr_3(P_2O_7)_3(PO_4)_2$ a promising material for magnetic refrigeration to achieve temperatures in sub kelvin range.

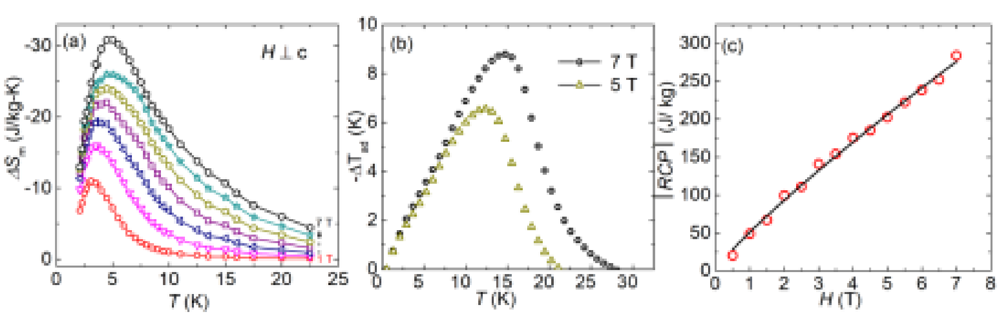

Figure 1: (a) Isothermal entropy change vs temperature calculated from isothermal magnetization data. (b) Adiabatic temperature change calculated by heat capacity data. (c) Relative cooling power as a function of field.

Understanding bulk photovoltaic effect in type-II Weyl semimetal Td-WTe_2 using polarization dependent photocurrent measurement

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Abstract: Weyl semimetals are topologically non-trivial material that are having a band touching point near the Fermi surface called Weyl nodes. Here the diverging nature of Berry curvature at the vicinity of Weyl nodes are explored in developing self-powered photodetectors at room temperature. The observed photocurrent is attributed to a combined effect of photothermoelectric effect and bulk photovoltaic phenomenon which is a non-linear optical effect that converts light into electrical current. The self-powered photoresponse at 640 nm excitation wavelength reveals the presence of a diverging Berry curvature of tungsten ditelluride (Td-WTe_2) at room temperature. The different perspective of polarization dependent photocurrent spectroscopy is used to separate the photothermal current from the shift current and the circular photo galvanic response from the linear photo galvanic response.

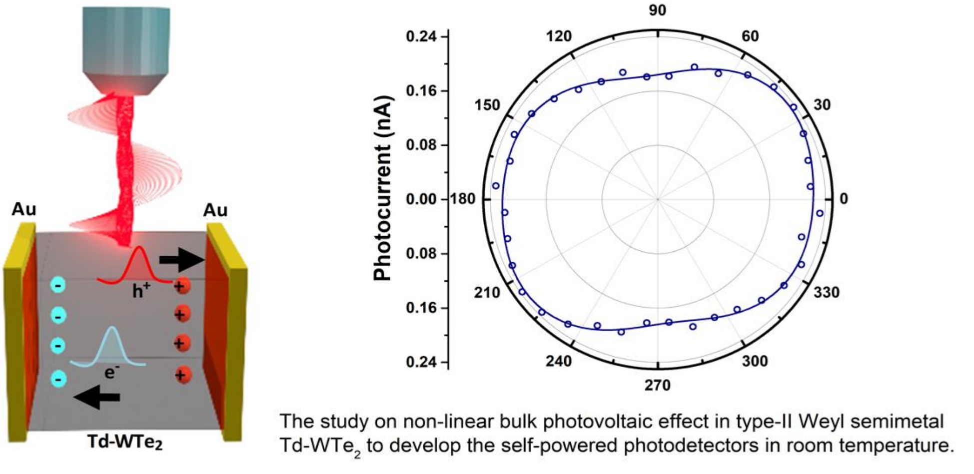

Figure 1. Schematic representing the Mechanism of bulk photovoltaic effect in Weyl semimetal and the polarization dependent photocurrent studies.

Scalable Van der Waals Josephson Junctions

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Abstract: Developments of device architecture and understanding of superconducting qubits have opened another door towards quantum computing. Basic unit of such qubits are superconducting Josephson junction which is composed of two superconductors separated by an ultrathin tunnel barrier. Aluminium oxide barriers are most commonly used in Josephson junctions in superconducting electronics. But it has been reported to have thickness inhomogeneity and defects that may affect the qubit performance. Long coherence time of two-level defects in the presence of charge noise are also observed. In such case Van der Waals materials (two Dimensional materials(2D)) can be a promising candidate for superconducting Josephson Junction because of its high crystal quality and tunable transition temperatures.

Van der Waals heterostructure which consist of Niobium Diselenide $NbSe_2$, a superconducting Transition Metal Dichalcogenide (TMDC material) which has a transition temperature T_c ~7K can be an excellent alternative for oxide free Josephson junctions . In this work $NbSe_2$ Josephson junction is fabricated by micromechanical exfoliation of layered $NbSe_2$ flakes and vertically stacking them by dry transfer technique on pre patterned Cr-Au metalized probes. Van der Waals gap can act as the insulating layer and tunnelling of cooper pair takes place between two superconducting layers through this insulating barrier.
Selective etching of the junction can be used to control the junction area and hence the properties of Josephson junction . Current Voltage characteristics and magneto transport measurements at temperatures lower than critical temperature confirms the properties of Josephson junction. Absence of hysteresis in current voltage characteristics shows the nature of overdamped Josephson junction which is the key element of superconducting quantum interference devices(SQUIDs).

So, Understanding the behaviour of 2D Single Josephson junctions is an important exercise because it is the building block of many superconducting technologies such as superconducting quantum interference devices(SQUIDs), quantum metrology, and qubits.

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Low Schottky barrier contacts to MoS_2 using Indium diffusion technique

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Abstract: MoS_2, a transition metal dichalcogenide (TMDC), has been widely researched in recent years for its use in low-power and high-performance electronic and optoelectronic applications. The ultra-low thickness, mechanical flexibility, and tunable bandgap make MoS_2 a potential candidate for making RF transistors and flexible electronics. There are theoretical as well as experimental studies on using the spin and valley states of electrostatically gated quantum dots in monolayer MoS_2 as quantum bits. The performance of all these devices is limited by the absence of clean electrical contacts to the atomically thin MoS_2 layer without damaging it[1].

The metal-semiconductor junction (MSJ) formed at the interface when MoS_2 is contacted with the commonly used metals gives rise to the Schottky barrier, hindering the charge transport across the interface. According to the Schottky-Mott rule, Schottky Barrier Height (SBH) depends linearly on the work function of metals. It is expected that we will be able to form ohmic-like contacts to MoS_2 by using metals of low work function. There are experimental reports on using low-work function metals like scandium (3.5 eV) and indium (4.1 eV) to contact MoS_2. But SBH deviates from the Schottky-Mott rule due to Fermi level Pinning (FLP), which arises due to the defects at the metal-semiconductor interface like vacancies in 2D semiconductor and interstitial atoms introduced during metal deposition, the strain caused by metal-semiconductor lattice mismatch, etc.

In this work, we have made clean indium contacts to MoS_2 using diffusion technique. Indium, when heated above its melting point (156 ^{0}C) on gold contact pads, spreads along the Au-deposited path and contact MoS_2 at the edge and bottom. We dry transferred mechanically exfoliated few-layer MoS_2 sample onto a pre-patterned Si/SiO_2 wafer with Au electrodes, which act as a path to diffuse In towards the MoS_2 flake located on the other end of the electrode. We have fabricated MoS_2 FETs with In, top Au, and bottom Au contacts on the same flake and compared their transport properties down to a temperature of 9 K. SBH is extracted from the temperature-dependent transconductance data, and it was found that In contacts show much lower SBH than Au contacts, as low as 2.3 meV. We have validated the same from DFT calculations, which gives that the low SBH can be attributed to the in-gap states of MoS_2 enhancing charge transport[2].

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Single in pair: impact on leptoquark exclusion limits

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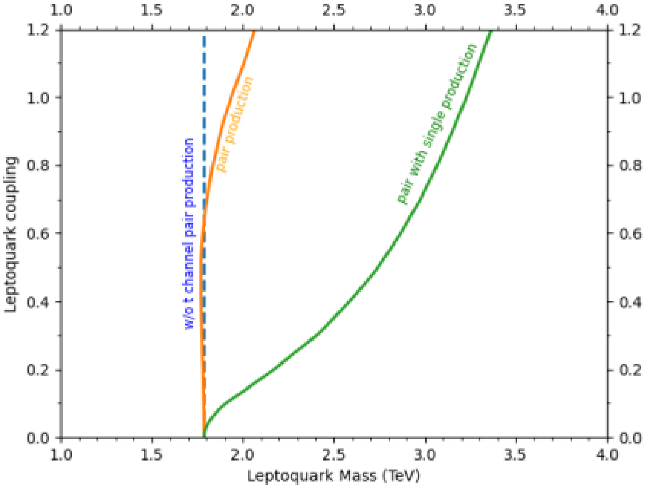
February 2023

Abstract: Recently, lepton universality violations have been observed in the rare decays of *B*-mesons by different experimental collaborations. Significant deviations from the Standard Model predictions have also been observed in the anomalous magnetic moment of the muon and the *W*-boson mass measurements. These anomalies may not be independent ones and might be intertwined at the fundamental level. One such beyond the Standard Model extensions is the leptoquark models that can simultaneously explain these anomalies. Leptoquark is a hypothetical particle that connects the quark and lepton sectors of the Standard Model and provides unique signatures at collider experiments. Search for these new physics signatures is an active program at the Large Hadron Collider experiments. The ATLAS and CMS collaborations have performed model-independent searches through the QCD-mediated pair production channels of leptoquarks leading to a dilepton-dijet final state. These model-independent searches are only sensitive to the mass of the leptoquark and its branching to a lepton-jet pair. There is a mild coupling dependency present in the pair production through the *t*-channel lepton exchange processes. It is shown in the literature that this can be used to set limits on the coupling using the apparently model-independent pair production channel. However, there are single production processes that can lead to the same dilepton-dijet final state and can potentially contaminate the pair production searches. So far, this contamination is mostly ignored in the literature. We find that by making use of this single production contamination in the pair production search, one can improve the exclusion limits on the coupling dramatically.



Exploring Axion-Like Particles as Solution to the ATOMKI Anomaly

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Abstract: This work aims to serve as the basis for the proposal of a collaborative experiment for the verification and extension of the ATOMKI experiment, to be conducted at the FRENA facility, Saha Institute of Nuclear Physics (SINP) Kolkata. The collaborators are from IISER Thiruvananthapuram, SINP and Delhi University.

Anomalous bump-like deviations of 6.8σ and 7.2σ significance were observed at 140^0 and 115^0 in the e^+e^- pair angular correlations in the nuclear de-excitations from 18.15 MeV level of ^{8}Be and 21.01 MeV level of ^{4}He respectively. These deviations, which do not have a nuclear physics- or Standard Model- based explanation, are called the ATOMKI Anomalies, and is proposed to have an intermediate particle of invariant mass ∼ 17 MeV. We present a detailed discussion of the various possible solutions to this anomaly, and we found that the pseudoscalar axion-like particles (ALPs) in the ∼ 17 MeV mass region is the best possible candidate to explain this anomaly. We find the couplings of the ALP to e^+e^- and $\gamma\gamma$ that can satisfy the various constraints from terrestrial experiments, while having a significant invisible branching fraction. From the allowed ranges of coupling constants, we have also found the possible decay length of the decay of ALP to photons, which will be helpful in the design of the proposed experiment.

Since ALPs in the 10 MeV mass range are also formed in early universe, we also check the compatibility of the proposed ALP model in surviving the astrophysical constraints from Big Bang Nucleosynthesis(BBN).

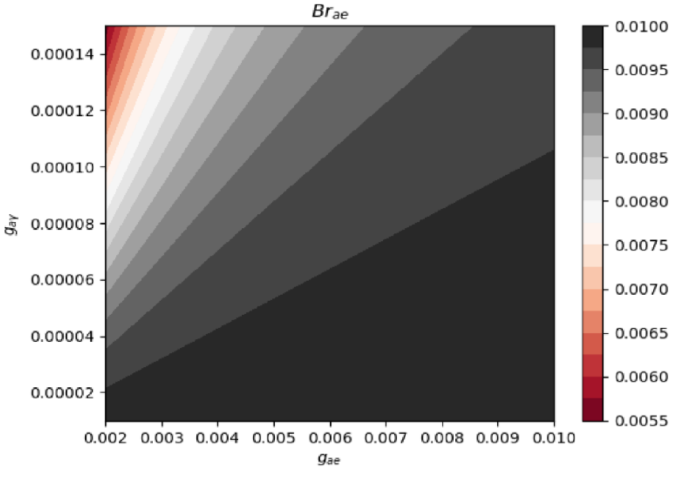

Figure 1: Allowed regions of ALP-to-photon and ALP-to-electron couplings for different Br($A \rightarrow e^+e^-$), from terrestrial experiment. Here we consider the invisible decay width to be ∼100 times that of the visible decay. All couplings are in GeV^{-1}

Magnetization studies and vortex phase diagram of oxygenated $YBa_2Cu_{3-x}Al_xO_{6+\delta}$ single crystal

Ashna Babu, Dr.Deepshikha Jaiswal Nagar

Abstract: Cuprate high temperature superconductors (HTSCs) have been intensively explored over the past several decades due to their superlattice structure of superconducting CuO2 layers. $YBa_2Cu_3O_{6+\delta}$ (YBCO), with a critical temperature of 93 K, has attracted the greatest interest due to its well-defined metal stoichiometry and variable oxygen content, which affects the carrier doping level. A vortex phase diagram for oxygenated Y $Ba_2Cu_{3-x}Al_xO_{6+\delta}$ (Al-YBCO) was analyzed from the superconducting properties. Construction of vortex phase diagrams is crucial from both a fundamental and an applied standpoint. From a technological standpoint, for such doped YBCO materials, a greater critical current density results. By measuring the field dependent magnetization of annealed single crystals of Al-doped YBCO, we were able to observe the second magnetization peak anomaly (SMP) in a vast portion of the phase diagram. In addition, we were able to observe the SMP anomaly in measurements of temperature-dependent magnetization, a first observation to our knowledge. Critical current densities were calculated using Bean's critical state model, flux jumps associated with symmetry reorientation of vortex lattice were studied, oxygen cluster distribution was also analysed, and a vortex phase diagram for oxygenated Al-YBCO single crystal was constructed by incorporating all observations.

Development of Solid Electrolytes and Interfacial Design for All-Solid-State Rechargeable Sodium Batteries.

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Abstract: The next most significant breakthrough in battery technology will undoubtedly be chemistry beyond the existing lithium-ion batteries. Sodium counterpart sharing similar chemistry with lithium has attracted the most recent research due to its earth abundance and ease of extraction. However, the safety concerns raised by conventional sodium-ion batteries employing liquid electrolytes increase the risk factor for their practical applications. Solid-state electrolytes (SEs) are promising substitutes for liquid electrolytes in terms of their improved safety, and are being extensively studied for their use in all-solid-state batteries (ASSBs) that find applications in electric vehicles[2]. Among the various available SEs, sulphide-based Na_3PS_4 has attracted great interest due to its high ionic conductivity and favorable synthesis conditions. Herein, we attempted a simple, accelerated, and energy-efficient microwave-assisted synthesis of Na_3PS_4 solid electrolytes. The electrochemical properties and the interfacial stability of the electrolyte with metallic sodium anode are thoroughly investigated and presented in our work[3]. Further, a prototype full-cell constructed using $Na_3V_2(PO_4)_3$ cathode, Na_3PS_4 solid electrolyte and modified sodium anode showed promising electrochemical properties. Additionally, our work highlighting few attempts to engineer the electrode-electrolyte interface of the NaSICON-based solid electrolyte will also be discussed in view of fabricating a lab-scale ASSB operating at room temperature.

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Bipartite entanglement via distance between the states in a one dimensional spin 1/2 dimer copper acetate monohydrate

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Abstract: We used a theoretical measure known as distance between the states, $E(\rho e)$, to determine the bipartite entanglement of a one dimensional magnetic dimer system. The calculation was compared with the well-known entanglement measure, concurrence, and found to be the same. $E(\rho e)$ was, then, expressed in terms of two thermodynamic quantities, namely, magnetic susceptibility and specific heat. Experimental verification of temperature variation of the bipartite entanglement measure in terms of magnetic susceptibility and specific heat was done on single crystals of copper acetate-an excellent one dimensional dimer system. The results showed the existence of bipartite entanglement till temperatures as high as room temperature! Large sized single crystals of copper acetate were grown by a new evaporation technique and characterised by TGA, IR and Raman spectroscopy measurements. Density functional theory calculations were done to calculate the delocalisation index which showed much lower values of $\delta(Cu, Cu)$ than other bonds, implying that the probability of direct Cu-Cu exchange in copper acetate is very small.

"Microscopic resolution ocular imaging of *Capra aegagrus hircus* eye with photoacoustic microscopy"

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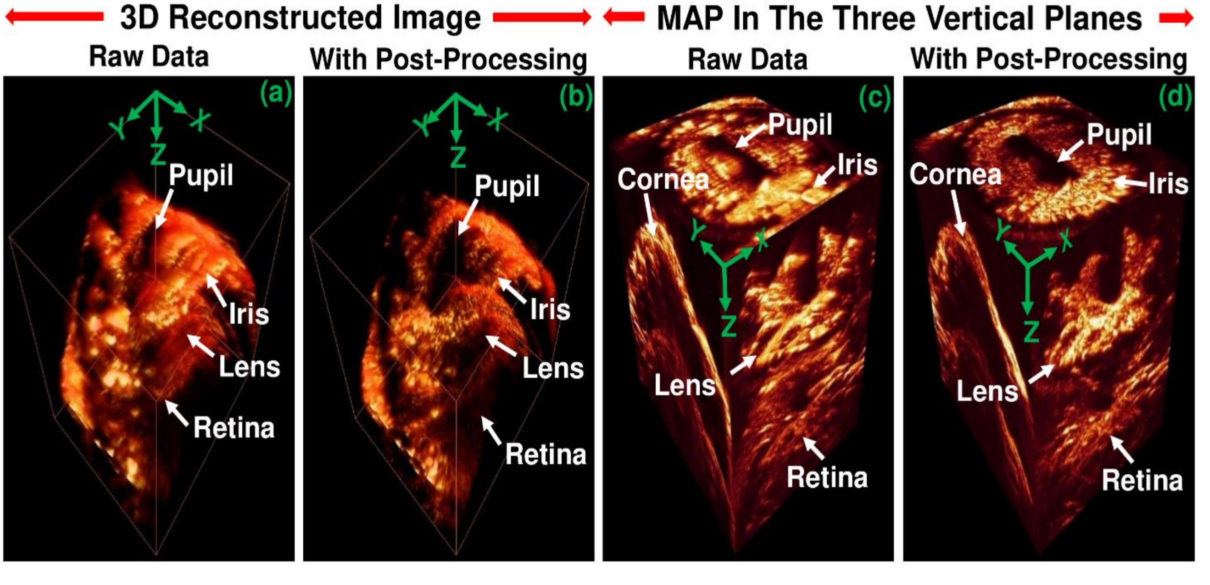
Abstract: Observation and characterization of any changes in anatomical structures of ocular components remain as the conventional technique for diagnosis, staging, therapeutic treatments, and post-treatment continuous monitoring of any ophthalmic disorders. The existing imaging technologies fail to provide imaging all of the various components of eye simultaneously at one scanning time, i.e., one can recover the vital patho-physiological information (including structure and content of biomolecules) of the different ocular tissue components only one after another. This article addresses the longstanding technological challenge by use of an emerging imaging modality (photoacoustic imaging (PAI)) in which we integrated synthetic aperture reconstruction technique (SAFT). Experimental results − with experiments being conducted in excised tissues (goat eye) − demonstrated that we can simultaneously image the entire structure of eye (~ 2.5cm) depicting clearly the distinctive ocular structures (cornea, aqueous humor, iris, pupil, eye lens, vitreous humor, and retina). In the study, we adopted several post-processing algorithms both for noise-filtering (band-pass and depth-compensation) and analysis (contrast ratio (CR) and FWHM). This study uniquely opens an avenue for promising ophthalmic (clinical) applications.



Shape Evolution study of MoS_2 flakes grown by Atmospheric Pressure Chemical Vapor Deposition

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Abstract: The layered semiconductor, molybdenum disulfide (MoS_2) monolayer with tailored size has been shown to exhibit uniform size-dependent properties and thus have potential applications in nanodevices engineering. Crystalline monolayer MoS_2 includes polygonal shapes, grown using the chemical vapour deposition (CVD) technique. However, a deep understanding of the relationship between the shape and multiple layers of MoS_2 is yet elusive. Here, we are demonstrating the CVD growth of high crystalline MoS_2 monolayer under single-zone furnace without incorporating hydrogen and growth promoter. We find that the deposition of MoS_2 flakes is highly dependent upon the spatial location on the substrate and temperature of the precursors. Systematical study of the effects of kinetic growth parameters shows the formation of different size and layer of the flakes. The Raman and PL study indicates the quality of the as grown MoS_2 which shows the crystallinity. To identify the shape and size of MoS_2 flakes, optical and SEM characterization has been carried out. Furthermore, AFM has been carried out for thickness and layer dependent studies. These results improve our understanding of the factors that influence the growth of MoS_2 domains and their size evolution.

Simulating the dynamics of a Quantum Field Theory in the light front coordinates

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Abstract: Studies on the simulation of relativistic quantum field theories and the properties of their ground states, have been successfully carried out in the recent years with the aid of quantum computers. Even though there are several challenges confronted in such an analysis, quantum simulation itself proves to be the only efficient scheme to be used for such a study in the nonperturbative regime. Still, the number of logical qubits required for the quantum simulation is prohibitively high for the present day Noisy Intermediate-Scale Quantum (NISQ) devices, hence leading to searches for alternative formulations of the theories. One such beneficial replacement is the light-front formulation by Wilson, which has been utilized in [Phys. Rev. A 105, 032418] for simulating the quantum field theory of the Yukawa model and in computing certain static quantities of the theory, on an adiabatic quantum computer. Using this formulation not only helps in considerably reducing the number of qubits required for the simulation, but also has several other merits which can be used to advantage. Hence, in this study, we are using this light-front formulation and studying the time evolution and the dynamics of a (1+1)D Yukawa model, specifically of a model consisting of the proton field interacting with the pion field, which is a step further ahead from the study of the ground state and that of the static quantities, accomplished so far in this field of research. The circuit construction and execution is done using Qiskit – IBM's quantum computing SDK, using IBM Quantum Experience cloud-based access.

CP divisible Non Markovian Dynamics

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Abstract: For an evolving open quantum system state from $\rho_S(0) \rightarrow \rho_S(t) = \Lambda_{t,0}(\rho_S(0))$, the maps $\Lambda_{t,0}\ \forall\, t \in (0, \infty)$ are completely positive(CP) if we consider initially product states between open system(S) and environment(E), $\rho_S(0) \otimes \rho_E(0)$ with a fixed $\rho_E(0) = \rho_E\ \forall\, \rho_S(0)$ [1]. To generate the complete positive divisible (CP-divisible) dynamics, $\Lambda_{t,0} = V_{t,ti}\Lambda_{ti,0}$ with $V_{t,ti}$ being complete positive, system and environment should always be uncorrelated but environment can depend on time. In case of CP-divisible dynamics, which is equivalent to Markovianity, states lost because of system-environment interaction cannot be accessed. However, we are looking at a scenario where environment's independent change (also system-dependent change) with time is faster than that of system's environment-dependent change. Hence, the lost states can be accessed. This feature is plotted in Figure.1. In a real scenario, the correlation is built between the system and the environment during the interaction. Because of this correlation, the CP condition at each intermediate time is not possible. If the correlation is kept constant then by reducing the domain of the system, the physical transformation of the state is possible. But during the dynamics, imposing any extra condition on the system, the environment, and the correlation is not always possible. Due to this, in certain scenarios, the correlation can depend on the system state too. To study such a case, we are considering the system and the environment to be in a simply-separable form. But the environment state to depends on the system state unlike the linear CP-divisible scenario. Because of this constraint, the dynamics becomes nonlinear. Since finding a transformation matrix for each system state is practically not feasible in nonlinear cases, we always try to bring the dynamics close to a linear scenario, This is possible at the initial time but at intermediate times, we can not demand it.

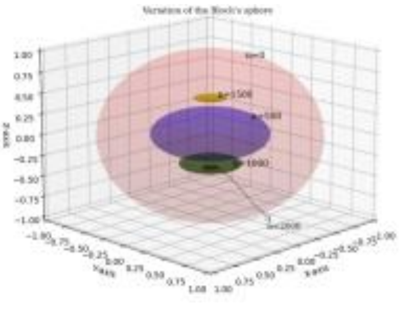

Figure 1: for a particular case when $\rho_E(t) = \frac{1}{2}(I + z_e(t)\sigma_3)$ with $z_e(t) = \cos\omega t$ and $\omega = 0.005,\ \tau = 0.1$

Hence, we have studied the condition where the nonlinear divisible dynamics can be approximated to linear divisible dynamics. To address this problem, we took a simple case of two qubits, one for the system and another for the environment. The system changes with interaction strength α used in the Hamiltonian but the environment state changes with a different interaction strength β used in the same Hamiltonian form. The different strength, β is considered so that by varying β, we can control the non-linearity. In the extreme case of β being equal to 0, the environment becomes constant and it leads to a perfect linear CP-divisible case.

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Statistical Analysis of Long GRB Prompt Emission and X-ray Flares: Multivariate Clustering and Correlations

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Abstract: The extensive observations done by the X-ray telescope on-board Neil Gehrels Swift observatory has revealed the presence of late time flares concurrent with the decaying afterglow emission. However, the origin of these flares are elusive. In this work, we made use of the large database Swift observations (2005 - 2020) of long GRBs to conduct a systematic statistical study between the prompt gamma ray emission and X-ray flares by characterising their temporal and spectral properties in terms of duration, quiescent period, peak flux, fluence, variability timescale and spectral power-law index. The multi-dimensional database of parameters, thereby, generated was investigated by the principal component analysis which revealed there is no evident correlation between the different studied parameters of the prompt emission and X-ray flares. However, the ratio of flare and prompt duration shows a negative correlation with respect to the prompt duration despite the durations being uncorrelated to each other. A positive correlation is observed between the quiescent period and the duration of flare. The consecutive flaring episodes are found to be of longer durations and less energetic in terms of peak flux than the preceding flare episodes as well as the prompt emission. The minimum variability timescale of the X-ray flare light curves tend to be longer than that of the prompt emission. The K-Means clustering of the data-set of flare properties has produced four clusters. We have generated an extensive catalogue of these different parameters characterising the prompt and flare emissions that are made available for the community.

Convolutional Restricted Boltzmann Machine (CRBM) based variational wave function for two-dimensional (2D) Hubbard model

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Abstract: We study the ground state properties of the two dimensional Hubbard model at half-filling using a variational wave function based on a convolutional restricted Boltzmann machines (CRBM). The CRBM network combines features of convolutional neural networks (CNN) with Restricted Boltzmann machine (RBM) network. We tune the network parameters by minimizing the energy for the wave function using the variational Monte Carlo (VMC) method. We compare the energy of the CRBM wave function with other commonly used Gutzwiller projected wave functions and find the CRBM energy to be considerably lower. We examine the properties of the CRBM wave function in details and show that it describes the magnetic ordering and the Mott transition in the 2D Hubbard model much more accurately compared to other conventional Gutzwiller projected wave functions.

Role of Stellar Intensity Interferometry in High Optical Resolution

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Abstract: The goal of higher optical resolution of a star's surface, environment, and internal structure are essential to astronomy. It helps to solve the puzzle related to limb-darkening, wind flow, outflow, mass transfer, a disk around the premature star, and pulsating star. Stellar Intensity Interferometry (SII) is a promising instrument to reach this goal. After the invention of this instrument by Hanbury Brown and Twiss in 1954, 32 stars were observed. It was stopped soon in need of sensitive photon detectors and good-quality photon collectors. Though, the idea behind this instrument is used in quantum optics from the beginning. After a very long gap, This idea has again entered in astrophysics for high-resolution optics. The longer/smaller baselines, large collecting areas, and sensitive photon detectors are the requirement for this instrument. The Imaging Atmospheric Cherenkov Telescope (IACT) fulfills all these requirements and does not work for gamma-ray observation during the period of moonlight so can be used as SII.

The Interplay between the Dark Matter Axion and Primordial Black Holes

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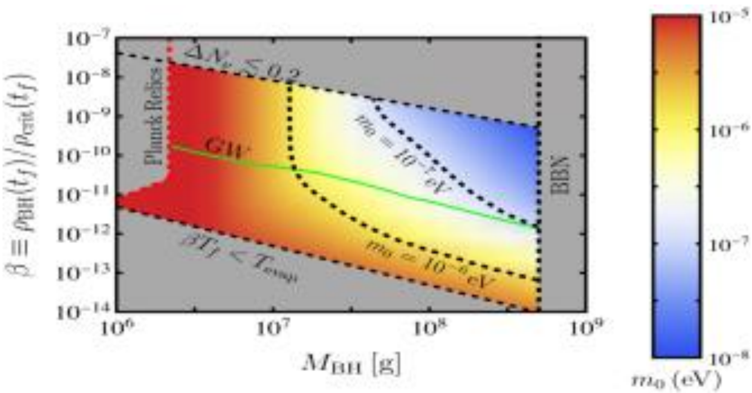
Abstract: If primordial black holes (PBHs) had come to dominate the energy density of the early Universe when oscillations in the axion field began, we show that the relic abundance and expected mass range of the QCD axion would be greatly modified. Since the QCD axion is a potential candidate for dark matter (DM), we refer to it as the DM axion. We predominantly explore PBHs in the mass range (10^6- 5×10^8)g. We investigate the relation between the relic abundance of DM axions and the parameter space of PBHs. We numerically solve the set of Boltzmann equations, that governs the cosmological evolution during both radiation and PBH-dominated epochs, providing the bulk energy content of the early Universe. We further solve the equation of motion of the DM axion field to obtain its present abundance. Alongside non-relativistic production mechanisms, light QCD axions are generated from evaporating PBHs through the Hawking mechanism and could make up a fraction of the dark radiation (DR). If the QCD axion is ever discovered, it will give us insight into the early Universe and probe into the physics of the PBH-dominated era. We estimate the bounds on the model from DR axions produced via PBH evaporation and thermal decoupling, and we account for isocurvature bounds for the period of inflation where the Peccei-Quinn symmetry is broken. We assess the results obtained against the available CMB data and we comment on the forecasts from gravitational wave searches. We briefly state the consequences of PBH accretion and the uncertainties this may further add to cosmology and astroparticle physics modeling.

Motivation: Investigate the early universe from direct and indirect searches of the dark matter particle and study the properties of the cosmological models.

Goal: Relate the mass and abundance of PBHs with the properties of the DM particle (here: axion).

Why should we care: If the range of the DM axion mass is widened, its search in new windows along with PBHs that populate the early cosmology will be motivated.

Result:



Origin of negative differential resistance and hysteresis in a charge density wave system

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Abstract: The collective transport phenomenon in charge density wave (CDW) materials can lead to interesting features such as nonlinear conductivity, negative differential resistance and hysteresis due to the depinning and sliding of CDW by an external electric field above a threshold value.[1] However, these features can also be due to extrinsic mechanisms such as the Joule-heating of the system.[2] We demonstrate negative differential resistance and hysteresis in the voltage-current characteristics of a charge density wave system, $Sr_{14}Cu_{24}O_{41}$(SCO). Using continuous and pulsed current sweeps, we unravel the competition between the sliding conductivity and Joule heating of the system. Our results indicate that the negative differential resistance observed is due to the depinning of charge density waves, and hysteresis in voltage-current characteristics is due to the Joule-heating of the system.

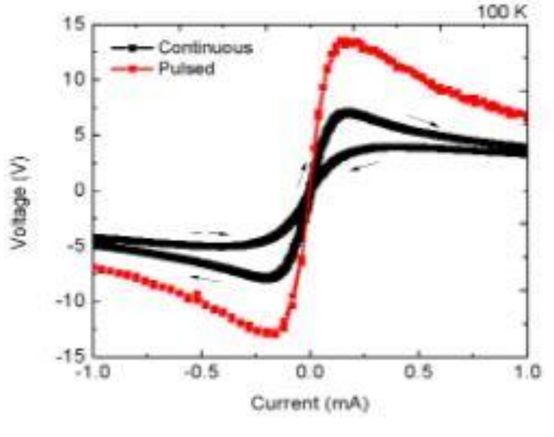

Figure 1: Comparison of continuous and pulsed V-I sweep mode of $Sr_{14}Cu_{24}O_{41}$ in its deep CDW phase at 100K (T_c = 160K). The continuous measurement consists of negative differential resistance and hysteresis, whereas the pulse mode with pulse width - 10 ms and pulse period - 5.01 s shows a negative differential resistance region with no hysteresis observed. The arrow mark indicates the direction of V-I sweep.

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Unconventional exchange bias at ferroelectric BaTiO3 and ferromagnetic $La_{0.67}Sr_{0.33}MnO_3$ interface

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(!Equal contribution first author)

Abstract : The interfaces of 3D transition-metals oxides are the fascinating playground for several atomic-scale interactions of spins. Novel physical phenomena such as magnetoelectric coupling, unconventional exchange bias (EB) coupling, domain wall motion etc., originate at such interfaces carry huge potential for advanced spintronics devices. Among them, EB holds enormous importance for device applications such as high-density memory, sensor, magnetic recording devices, etc. However, the role of such interfaces at atomic scale multiferroic in EB has not been yet fully understood due to complexities such as epitaxial strain, interface roughness, and dead layer. Here, we demonstrate EB coupling (EB shift, H_{EB}~40 Oe at 2 K) at the interface of epitaxially grown ferromagnetic (FM) $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) – ferroelectric (FE) $BaTiO_3$ (BTO) bilayer thin films on $SrTiO_3$ (STO) single crystal substrates in absence of any conventional antiferromagnetic (AFM) material. Such EB is only observed for ultralow thickness of both LSMO (<10nm) and BTO (<5 nm). We also demonstrate training effect, bias field dependency, and temperature dependency of the EB coupling. From the X ray magnetic circular dichroism (XMCD) measurement, a reversible finite magnetization on Ti atoms in BTO for LSMO/BTO heterostructure is observed at 2 K. From DFT calculations, the AFM coupling between the interfacial Mn atoms due to polarisation of Ti atoms is confirmed as a result of charge redistribution and interfacial structural distortion. A finite magnetic moment on Ti atoms is also seen attesting to experimental results. This is an important step towards creating EB coupling between FM and FE materials without conventional AFM materials, which may enable a new class of multi-state memory devices by switching magnetization, FE polarisation and EB coupling in the same device.

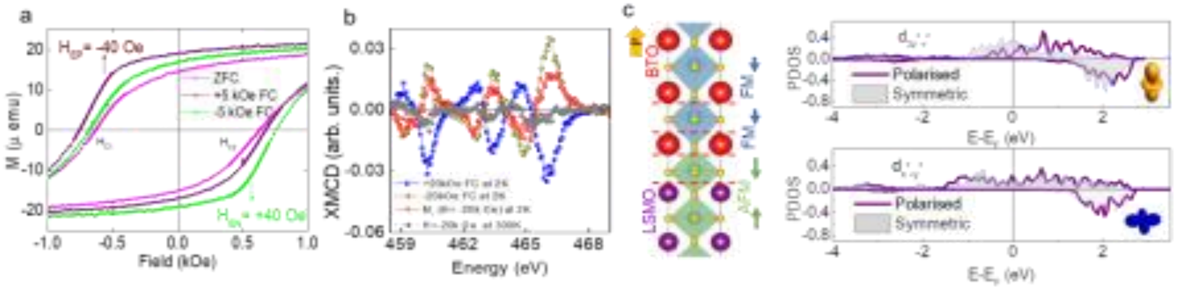

***Figure:** a. Observed unconventional EB (~40 Oe) in the LSMO-BTO bi-layer. b. XMCD measurement results shows switchable magnetism of Ti in BTO. c. Crystal structure and PDOS calculated from DFT calculations.*

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How Can Nanoconfined Water Conduct Electricity to Show a Negative Differential Resistance Effect?

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Abstract: Despite of largely explored Liquid Phase Exfoliation (LPE) of various TMDCs, high quality thin film growth via bottom-up approach are challenging for device applications. Here, we demonstrated the scalable growth of highly uniform MoS_2 thin film by the process of self-assembly at the interface of two immiscible liquids, namely hexane and water. Recently, The high electrical conductivity of water confined at the nanoscale was recently predicted theoretically and identified as an exciting new hexatic phase of water. However, the practical demonstration of such phenomena is challenging due to the complexity of characterizing water at the nanoscale. Here, The electrical characterization of the two-dimensional molybdenum disulfide (2D MoS_2) thin-film shows negative differential resistance (NDR) property under ambient conditions and at room temperature with a peak-to-valley current ratio (PVCR) of 6.3. The current-voltage (*I*-*V*) characteristics of planar two-terminal MoS_2 devices inside various controlled environments indicate that moisture is essential to display this NDR effect. The water molecules engrafted at the S-defect sites available over the 2D MoS_2 nanoflakes form monolayer-thick 2D bridges between the electrodes and show high conductivity due to the in-plane protonic conduction through water chains at the nanoscale. The protons generated from the bias-controlled electrolysis of chemisorbed water over 2D MoS_2 can flow under the favourable energy band alignment between the valence band top of MoS_2 and the metal electrode work function. At higher applied bias voltage, the depletion layer width at the Schottky junctions of MoS_2 and electrodes broaden, restricting hole transport to display the NDR effect consistently. The above mechanism of in-plane protonic conduction is further supported by the DFT studies as the intermolecular interaction of H^+ at different atomic sites of MoS_2 was found minimal compared to that of OH^- ions.

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Dynamics of Electron Relaxations to the Trap States in Zinc Oxide Using Sequential Photoluminescence Measurements

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Abstract : The dynamics of electron de-excitations has been a topic of great interest for many researchers and is an excellent source of numerous valuable information, especially in defect studies. Since the excited state is highly unstable throughout most materials, the excited electrons have a very short lifetime, typically in nanoseconds. However, in some photo-active materials, the excited electrons remain in the conduction band (CB) for a very long time and their de-excitations to the valence band (VB) or trap states are very slow. The reason behind these slow electron relaxations is still a matter of debate. The persistence of excited electrons in the CB leads to many important phenomena such as persistent photoconductivity (PPC)[1-3], slow photo responsivity [4] and so on. Understanding the mechanism of slow electron relaxations is of paramount importance while employing materials exhibiting these delayed de-excitations, for different applications. The time-dependent photocurrent measurement is considered as a yardstick for probing the electron persistence in the CB. However, standard spectroscopic techniques have not been used till date to investigate the effects of delayed electron relaxation from the CB on the optoelectronic properties of these semiconductors. We have developed a strategy for investigating the dynamics of electron de-excitations in zinc oxide (ZnO), a prototypical material exhibiting slow photoresponse, using photoluminescence (PL) spectroscopy. The peak intensities of PL spectra of ZnO thin film exhibited an exponential decrease while performing continuous PL measurements and is attributed to the prolonged lifetime of electrons in the conduction band. The time constant ((τ_{cap})) associated with the slow electron de-excitations to the trap states is estimated to be 1.95 minutes by performing a sequence of PL measurements with different time delays between the scans. The very slow electron relaxations to the trap states in ZnO after UV exposure is found to be affecting the Fermi level of ZnO thin film, reverse saturation current in ITO/ZnO/MoO_3/Ag heterojunction and photocurrent in ITO/ZnO/Ag device. We have successfully simulated these modest variations using the time constant τ_{cap} obtained from the PL spectra analysis. The proposed strategy can be adopted to quantitatively interpret the electron trapping dynamics in materials exhibiting slow photo response and can be used to tune their photoresponse.

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Embracing the Molecular Memristors with Binuclear Singlet Diradical Cobalt (III) Complex

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Abstract: Neuromorphic computing (NC) has attracted massive global attention due to its capability of in-memory data processing at an energy cost much lower than the conventional one.[1] Devices with neuromorphic characteristics have been reported using a variety of materials. Organic thin-film devices are showing potential to achieve the desired metrics for NC.[2] Here we report a ligand-centered redox-controlled strategy for the synthesis of cobalt coordinated complexes and their application towards molecular memory devices.[3] Spectroscopic analysis, DFT studies, and control experiments were performed to understand the electronic structures and the ligand-centered redox-controlled interconversion of the complexes. Among the complexes an unusual binuclear singlet-diradical cobalt (III) complex $[Co_2^{III}(L^{3-\cdot})_2]$ based thin film device gives better memristor performance. Redox controlled inter-conversion mechanism helps in the bipolar resistive switching of the fabricated memristors. The devices were giving current ON/OFF ratio as high as 10^6 with a very low voltage of 1V. An endurance of more than 150 cycles and retention of 10^3 s without any deviation in the ON and OFF conductance states makes the device a potential candidate for future RAM based applications.

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Photoluminescence Enhancement in $TaSe_2/MoSe_2$ van der Waals Heterostructure

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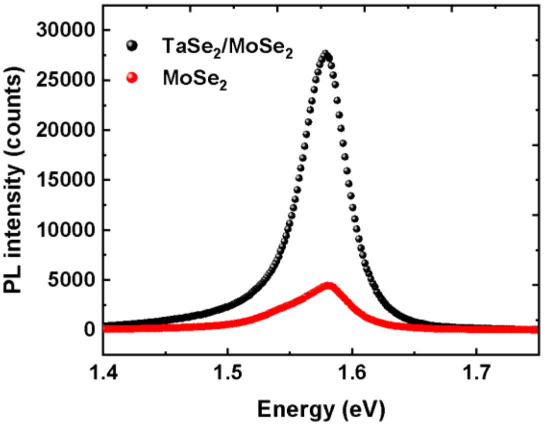
Abstract: Van der Waals heterostructures (vdWH) are the new playground of emergent physics, including proximity effects, high-temperature superconductivity and Bose-Einstein condensation. The lattice mismatch between the layers of two-dimensional materials in the vdWH holds great promise to study interfacial effects like orbital hybridization, charge density wave (CDW) proximity and magnetic interactions.[1] Here, we investigate the optical signatures of the interlayer coupling in the semiconducting 2H-$MoSe_2$ with the layered CDW material 2H-$TaSe_2$, which exhibits incommensurate CDW transition at 122 K and transition to Commensurate CDW at 90 K.[2] The Raman measurements on the individual layers and the heterostructure confirms strong coupling between the layers. Here we report the photoluminescence (PL) studies spectra of the heterostructure. The PL from the vdWH exhibits an enhancement of about six times higher and a blue shift compared to the monolayer $MoSe_2$ at room temperature. The temperature-dependent measurements and the band structure calculations can give more insights into the role of CDW transitions in the excitonic landscape of the heterostructure.



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Growth of Highly Crystalline Ultrathin Two-Dimensional Selenene

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Abstract: Elemental two-dimensional (2D) crystals have recently emerged as promising materials for advanced electronics and optoelectronics applications. However, achieving controllable growth of high-quality, ultra-thin flakes of elemental 2D materials remains challenging. Among them, the group VI 2D semiconductors, selenene and tellurene, have emerged as promising materials with potential applications in optoelectronic devices, owing to their simple composition and excellent electronic and optoelectronic properties. Here, demonstrate a seed-assisted chemical vapour transport growth of ultra-thin triangular flakes of highly crystalline trigonal selenium (t-Se) with lateral size >30 µm. Density functional theory calculations support the experimental findings in establishing the structure and stability of the as-grown selenene. We studied the optical response of a photodetector fabricated using a bilayer selenene. Our growth strategy can be extended to other elemental 2D materials to realize their full potential in applications ranging from optoelectronics and electronics to energy conversion.

Superconducting Reosonators for Spin-Photon Coupling

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Abstract: Superconducting resonators are microwave circuits which are currently used in state-of-the-art implementations of quantum computers, where they are used to couple with superconducting or semiconducting qubits to perform fast readout measurements or couple distant qubits without losing coherence. The high operating frequency of these superconducting circuits also allows for fast transport measurements in 2D layered systems and topological insulators whose quantum capacitance can be probed. The resonance frequency and Q-factor of the superconducting resonator depends on its physical properties such as the dielectric constant of the substrate, the shape and size of the resonator. Our work involves the design and fabrication of superconducting coplanar waveguide (CPW) resonators whose resonant frequency is set to around 3GHz. We performed electromagnetic field simulations of these circuits and obtained their S-parameters, particularly the S11 and compared them with the measured S11 of a fabricated resonator through a vector network analyser. The $\lambda/2$ CPW resonators were fabricated on sapphire whose resonant frequency was measured to be 3.6GHz, which approximately matches with the simulated resonant frequency of 3.25 GHz. Currently, the resonator cavity is defined using capacitors on both sides to couple to the transmission lines. We explore alternate methods of defining the cavity, such as by varying the centre conductor width periodically which causes an impedance mismatch and thereby creating standing waves within the cavity. Such a design can potentially remove the need for separate DC biasing lines which are needed for coupling to quantum dot-based qubits.

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Ultra-Sensitive Self-Powered Photodetector Using $CsPbBr_3$ Monocrystal

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Abstract: Halide perovskites are superior materials for optoelectronic applications. The present research is directed at developing electronic devices with the self-powered operation to save electrical power. Self-powered photodetector (PD) is one device in this category. There are plenty of reports on perovskite PDs. To our knowledge, type-II heterojunctions or asymmetric metal electrodes are used to achieve self-power nature in perovskite PDs. Here we report a simple and cost-effective method to fabricate monocrystalline perovskite PD devices that show self-powered operation. Monocrystalline $CsPbBr_3$ (MC CPB) is used as an active material. Perovskite PD (Device A) is fabricated by directly growing MC CPB on vacuum-evaporated Au electrodes by Antisolvent Vapour Assisted Crystallization (AVAC) technique. Because of direct growth on the electrodes, there is a homogeneous interface between Au and crystal. The device has the Metal-Semiconductor-Metal (MSM) architecture with back-to-back Schottky contacts. Self-powered Perovskite PD showed excellent white light photodetection (at 0V) with 10^5 orders of ON/OFF ratio, Responsivity of 23 mA/W and very high Specific Detectivity of the orders 10^{12} Jones at 1.14 mW/cm^2 white light intensity. The device showed response speed with rise time (τ_r) = 230 ms and decay time (τ_d) = 60 ms. The reproducibility of self-powered perovskite PD is also studied in this work. To explore the role of the electrode-material interface on the self-powered operation of MC CPB perovskite PD, we fabricated a device (Device B) with top electrode configuration. Device A showed stable self-power nature but not Device B. The Back-to-Back Schottky (BBS) diode model is utilized to understand the source of self-power operation in the case of Device A. At last, to examine the accuracy of the BBS model and also to realize the effect of Schottky barrier height on the self-powered operation of perovskite PD, one more device with MSM architecture is fabricated with Al as bottom electrodes (like Device A) and electrically characterized to confirm the ultra-sensitive performance of MC $CsPbBr_3$ PD.

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Inverse magnetocaloric effect in Field induced Random Field to Spin Glass crossover in $SmCaCoMnO_6{-}SmMnO_3$ composite

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Abstract: 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. 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 H_{thresh} vs T diagram, the displacement of T from 35 K to 15 K follows $H_{thresh} \sim a(T_0{-}T)^{\Phi_{co}/2}$ with the exponent, $\Phi_{co} \sim 1.5$ which is very close to the scaling behavior of RF system. 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 ($-\Delta S_M$) 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. So, the enhancement of inverse MCE due to such crossover may circumvent the dependence on conventional yet expensive low temperature liquid cryogens.

Keywords: Random Field, Spin-Glass, Crossover, Inverse magnetocaloric effect, Double perovskite.

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Iron Doped Nickel Diselenide as an Efficient Bifunctional Electrocatalyst for Anion Exchange Membrane Water Electrolyzer

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Abstract: Electrocatalytic water splitting is a very efficient technique with zero carbon emission for hydrogen production. Currently, platinum group metals (PGMs) and iridium/ruthenium oxides are the best catalysts for hydrogen evolution reaction (HER) and oxygen evolution reaction (OER), respectively. However, the high cost and scarcity of these materials make them challenging to commercialize. Therefore, it is pivotal to fabricate efficient, low-cost, earth-abundant catalysts for water splitting.[1] Nickel selenide is a class of transition metal dichalcogenide compounds, in which nickel has a unique electronic configuration ($3d^8$, $4s^2$), and selenium has high electrical conductivity and electronegativity, helps nickel selenide to form different crystal structures ($NiSe$, $NiSe_2$, Ni_3Se_2, Ni_3Se_4).[2] Herein, we demonstrated a simple and single-step electrodeposition method for iron doping on nickel diselenide over nickel foam (Fe-$NiSe_2$/NF) as an efficient bifunctional electrocatalyst for alkaline water splitting. The optimized Fe-NiSe2/NF showed excellent HER and OER activity compared to the reported nickel diselenide work.[3] Further, we fabricated an anion-exchange membrane (AEM) electrolyzer, showing a very high current density of ~2 A cm^{-2} at 1.9 V and long-term stability of 20 h in alkaline media.

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Flexible Thin-Film Photodetectors Based on Solution-Processed Molybdenum Disulphide Nanosheets

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Abstract: Implementing two-dimensional (2D) materials as an active layer in flexible photodetectors has gained interest due to their high mechanical flexibility and excellent optoelectronic properties. Here, we demonstrate a high-performance flexible photodetector based on liquid-phase exfoliated MoS2 nanosheets (NSs), exhibiting fast and stable performance under ambient conditions. The obtained NSs have a lateral size of hundreds of nanometres, an average thickness of ~3 nm, and high crystallinity in the semiconducting 2H phase. The devices show stable current-time (I-t) characteristics under pulsed illumination with the transient rise and decay time constant around 135 µs. The devices exhibit excellent omnidirectional light detection capabilities for wide incident angles ranging from 0° to 70°. It also shows a non-linear dependence on incident intensity with a power-law exponent of 0.75, indicating defect-assisted trapping of photo-generated charge carriers. Efficient photoresponse is observed in MoS_2 NSs-based flexible photodetectors with different radii and repeated bending.[1, 2]

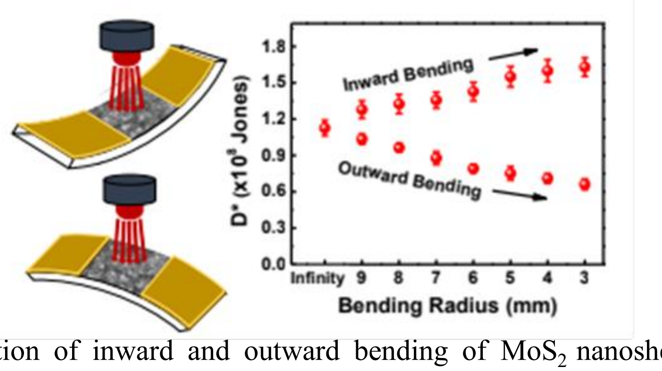

Figure 1. Representation of inward and outward bending of MoS_2 nanosheets-based flexible photodetectors with corresponding variation in specific detectivity while bending the detectors.

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Quantum phase transition between two-dimensional superconductor and quantum metal phases on ionic liquid gated MoS_2

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Abstract: Studies of superconductor insulator (S-I) transitions in two-dimensional (2D) superconductor with its characteristic short-range order and phase transitions involving quasi-long-range ordering exhibit a variety of phases due to the enhancement of quantum fluctuations. True two-dimensional superconductivity with bound vortex-antivortex pairs and condensed cooper pairs exists only at zero magnetic field[1,2]. Disorder or defects developing from material growth can pin vortices forming a vortex glass phase that can survive quantum fluctuations and a direct S-I transition can be induced by tuning the magnetic field or disorder strength. As a function of pinning strength, the system reveals various non-trivial quantum phases such as Bose metal, quantum Griffith state and Bose insulator. To observe these phenomena, one requires a clean disorder-free two-dimensional system with carrier concentrations beyond $10^{13}/cm^2$ which are not accessible by the conventional dielectric gating. Here we use an electric double layer gating technique to eclipse carrier concentrations in the range of 10^{14} to $10^{15}/ cm^2$ range and study 2D superconductivity, evolution of a quantum metal state and vortex dynamics on a few-layered MoS_2 device. We use DEME-TFSI as the ionic liquid. MoS_2 flakes were micro mechanically exfoliated and devices were fabricated using electron-beam lithography and Cr/Au metallization. Low-noise transport measurements are performed in a dilution refrigerator with a base temperature of 10 mK. We observe transition to a 2D superconducting state from a metallic state with Tc~ 2.8 K and BKT transition temperature of 1.5 K. Further, we also observe a transition to a quantum metal phase with the application of perpendicular magnetic fields. Study of the quantum phase transition between the 2D superconducting state and the quantum metal state reveals that our sample has ultra-low pinning strength and the vortex lattice is soft. Inherently 2D Superconducting circuit technology utilizes the van der Waals (vW) material systems. Vortex motion and dissipation will have profound effect on the design and performance of these devices.

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Pump-Probe studies on the phoniton structure

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Abstract: In a photon semiconductor microcavity structure, electron-photon interaction and coupling of a photon with exciton (polariton) led to a flurry of discoveries in fundamental physics and helped to make new devices with better quality, like new lasers and detectors[1]. Owing to the similarity in the wave equations describing photons and phonons, an idea analogous to polariton was conceived for the phonon interaction. In 2011, it was predicted that the interaction of phonons with a Two-Level System (TLS) in an acoustic cavity could lead to a new quantum quasiparticle called phoniton[2]. The Realisation of Phoniton will result in the development of a new technique for studying nanoscale mechanical systems and finding applications in quantum computers to store and process data, which can be used as tools for coupling quantum systems. To practically realize phoniton, GaAs/AlAs double quantum well (QW) with a tunable TLS having a very high-Q value ($Q \sim 10^4$) inside a cavity was designed[3]. The structure also contains a generator superlattice (GSL) to generate the required phonon frequency. The GaAs/AlAs double quantum well will act as a TLS whose energy splitting can be tuned by external bias until it matches with cavity phonon energy. Under resonance with cavity phonon, the electrons keep moving between the ground state of the two QWs with the absorption and emission of longitudinal acoustic phonons leading to vacuum Rabi Splitting of the cavity mode. From Photoluminescence measurements at 15 K, we identified the first electron to heavy hole (E1-HH1) transitions of mirror SL and GSL/Cavity QW at ~750 nm and ~762 nm. Two colour pump-probe studies were performed to study the phonon dynamics. A pump wavelength of 760 nm was chosen to excite the GSL. The probe wavelength was chosen such that the probe energy is either above (750 nm) or below (770nm) the GSL/Cavity QW E1-HH1 transition energy. The results of the 760 nm pump and 770 nm probe are shown in the figure. A beating pattern due to the GSL/cavity (~ 444 GHz) and 2k-probe (~401 & ~ 487 GHz) modes is seen in the initial ~100 ps. The GSL/Cavity mode is visible for several hundreds of ps, and its amplitude decreases exponentially. The oscillation amplitude shows a growth initially & reaches a maximum at ~ 230 ps, then decreases exponentially with a time constant of ~ 550 ps. Hence we obtained long-lived cavity phonons in the phoniton structure. Further pump-probe studies on biased phoniton structure would reveal the realization of the phoniton.

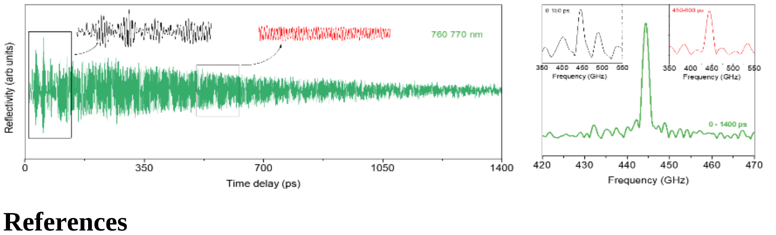

Figure 1 (a) Time domain signal of pump-probe studies on the phoniton structure. In inset 0-150 ps (black) and 450-600 ps (red) signal is enlarged. (b) Frequency domain signal obtained by FFT of signal in (a)

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Engineering omnidirectional, spectrally selective optical properties using epsilon-near-zero media

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Abstract: Recent advancements in nanoscience and nanotechnology have revolutionized applications of plasmonics and photonics. Direct optical excitation of surface plasmons on nanostructures and thin films with free carriers brings about unique ways to influence light-matter interactions. Novel optical materials have been utilized to develop innovative devices where degenerately doped, wide band gap metal oxides such as ITO, doped CdO, etc., [1] can replace metals as plasmonic materials. This is enabled by their controllable carrier density that allows tuning of their dielectric to metallic transition wavelength known as epsilon near zero (ENZ) wavelength (λ_{ENZ}) [2] where the real part of permittivity goes to zero. A niche application of ENZ materials and their plasmonic properties is evidenced in the development of spectrally selective coatings which have potential applications in areas such as solar energy conversion, thermal management, radiative cooling, smart windows, etc. [3] The challenges are the overall complexity and thickness of the coatings along with the angular dependence of their spectral selectivity.

Here we demonstrate how surface engineering can impart spectrally selective optical properties to a completely opaque as well as a transparent substrate from visible to near IR. The surface engineering has been executed by coating a tri-layer thin film each of optimal thicknesses on SS as well as NBK7 glass substrates with an elementary periodic grating of ITO nanostructures of optimized dimensions over the coated substrate. Investigated from 400 – 4000 nm wavelength range, the coated substrate (~200 nm in thickness) shows low average reflectivity (~10%) over the entire visible up to a particular wavelength λ_0 beyond which the reflectivity becomes ~ 80%. In other words, the reflection coefficient is like a "step function" at that particular wavelength λ_0 (here around ~1670 nm), which is an omnidirectional feature realized between 0° to 60°, as shown in Fig 1c. Importantly, λ_0 can be tuned using a proper selection of materials which has been showcased here through the utilization of an ENZ material i.e. ITO both in thin film and nanostructured form supported by the absorbing coating underneath. The selectable range can be expanded further by replacing ITO with doped CdO and intelligent choice of materials. We discuss the generic design principles of such thin film coatings and the role of the underlying light-matter interactions that manifests the effects and finally contributes to the technological solutions

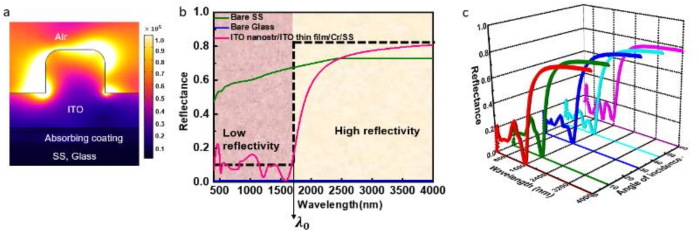

Fig. 1a. Magnitude of simulated electric field (in V/m) variation across the system, b. Simulated reflectance spectra depicting the evolution of the spectrally selective response from bare SS and glass, c. Reflectance plots from 0 to 60° angle of incidences

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Surface layer optical turbulence characteristics at a semi-arid region inferred from sonic anemometer-thermometer measurements

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Abstract : Atmospheric refractive index fluctuation, commonly represented using the term optical turbulence, is one of the main challenges that limit the accuracy of astronomical observations and the performance of satellite-to-Earth as well as terrestrial Free-Space Optical (FSO) communication systems. A priori knowledge of optical turbulence and its dependence to various meteorological phenomena will be helpful during the FSO link budget analysis and in the design and development of mitigation techniques (such as adaptive optics). Making use of two-year surface layer sonic anemometer-thermometer measurements at a semi-arid region in the Deccan Plateau, this study attempts to construct a time series of atmospheric refractive index structure parameter (C_n^2) typical to semi-arid environments and to understand the role of atmospheric stability in regulating its temporal evolution. The findings from this study will be helpful in the design and development of FSO communication links, laser guidance systems, and directed energy applications specific to semi-arid environments.

Keywords: Atmospheric turbulence, free-space optical communication, refractive index

Realizing Dielectric-Metal-Dielectric Quasi Optical Micro-cavity for Spectrally Selective Solar Photo-thermal Absorbers

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Abstract: Solar energy, being the most renewable form of energy, is converted to thermal energy by concentrated solar power plants which require spectrally selective solar absorber coatings to increase their photothermal efficiency. Microcavities have been known to dramatically enhance or suppress light absorption, emission in directional manner and used in nanophotonics, photodetectors, lasing etc.[1] Light-matter interactions happening at each boundary decide the total spectral selectivity of the absorber. Increasing the spectral selectivity by making a metal-dielectric multilayer [2] or cermet coatings [3] has widely studied by tuning the optical constants of each layer. Here we show that metal-dielectric multilayer thin films where an optical micro-cavity of tungsten has been created between two dielectric layers of transition metal oxide $CuCo_2O_4$ (CCO) layers. CCO-W-CCO thin film multilayers thus formed achieved a 90% absorption in all over the entire solar spectrum. Optimization of thicknesses showed a change in solar absorptance and thermal emittance from sample to sample. Besides, material characterizations revealed that the underlying spinel crystal structure and the nano-sized grain like morphology of CCO layers caused the enhanced visible absorption. Numerical simulations were done by making a model of the system in COMSOL Multiphysics, thereby reproducing the optical properties of each layers.

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AI Assisted Design And Fabrication Of Gas Sensor Array For VOCs Detection

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Abstract: Semiconducting Metal Oxides (SMO) are the most common materials used in gas sensor technology. The promising candidates include ZnO, CuO, TiO_2, NiO, V_2O_5, etc. It works on the variation of surface electrical conductance in a gaseous environment. Medium to wide-bandgap oxide semiconductors is an excellent choice for gas sensing material due to intrinsic donors/acceptors in the bandgap. It has been demonstrated that high-power consumption can be reduced by designing nanostructure-based chemical sensors with ultra-small device footprints to achieve room-temperature operations. By designing a sensor array, this study investigates the low selectivity of SMO by using multivariate data analysis tools. Here the pattern of each gas-sensitive oxide layer is recorded and analyzed using a statistical analysis method, for example, Principal Component Analysis (PCA) and Artificial Neural Network (ANN) algorithms. This can help to detect gases like volatile organic compounds (ethanol, acetone, hexane, Benzene, etc.), humidity, ammonia, NOx, etc. Even biomolecules such as glucose, lactose, and other metabolites can be detected and classified. Therefore, the same sensor array could be used to detect various gases for applications like monitoring body vitals, detecting air pollutants, processing control in industries and space, and defense-related applications.

Near Infrared Waveguide using multilayer ITO metamaterial

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Abstract: Optical waveguides of subwavelength dimensions, for enabling on-chip all optical or electro-optic modulation has remained a challenge in terms of efficient light coupling with low propagation losses. Epsilon near zero (ENZ) materials like indium tin oxide (ITO) offer multiple advantages for realizing such a on-chip device. Transparent in the visible ITO undergoes a dielectric to metal transition at the ENZ wavelength, at which the real part of its dielectric constant (Re()) becomes zero[1]. The near zero relative permittivity and refractive index below 1 nucleates interesting optical properties therein like perfect absorption (PA)[2], local electric field enhancement and high nonlinearities[3]. In parallel the conducting nature of the oxide allows for electro-optic modulation where the refractive index of the material may be modulated by an applied voltage. Here we propose a sandwich waveguide structure of stacked ITO multilayers on glass substrate, with a low electron density ITO (n=1e27 m^{-3}) having ENZ wavelength 2.22 µm of thickness 10 nm in between two higher electron density ITO (n=2e27 m^{-3}) having ENZ wavelength 1.52 µm of thickness 50 nm and 90 nm respectively. In the attenuated total internal reflection (ATR) configuration this stack allows for exciting modes in the middle ITO waveguide in wavelength regimes where the stack behaves as a metallic-dielectric-metallic metamaterial.

Finite element modelling simulations performed on the above structure shows feasibility of efficient light coupling into the waveguide in the spectral range 1.7 - 2.1 µm. Figure 1a shows the effective dielectric constant of the sandwich waveguide showing a protracted spectral region with Re() close to zero. Figure 1b plots the y-component of the Poynting vector quantifying the energy transport along the dielectric ITO channel in an analogous ITO waveguide where the third ITO layer is replaced by 40 nm of Au, for incident excitation of 1.88 µm. Figure 1c then shows the variation of the Poynting vector along the dashed line in figure 1b showing the energy localization within the 10 nm waveguide. Across the applicable spectral window our results show that approximately 1/3rd of the incident power is successfully coupled into the proposed waveguide using a simple stacked multilayer of ITO. We further discuss experimental realisation of the waveguide and electro-optic modulation of the same by application of bias across the ITO channel.

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Enhancement of Second-harmonics generation by pulse compression in a silica nanowire

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Abstract: Frequency combs in the deep-UV, visible and NIR has multiple applications. Certain applications like single photon spectroscopy in NIR (780 nm) [1] low-power combs are useful. In material like silica, the second – order nonlinearity is ideally absent due to its centrosymmetric nature. But material defects, and breaking of symmetry in the surface can induce second – order nonlinearity in silica [2].

There is demonstration of simultaneous generation of the THG, SHG, CSHG from silica nanowire[3]. The efficiency of the harmonic signal was low. Enhanced efficiency will be enabling in generating compact frequency comb generator which can perform photon-level spectroscopy and quantum optics. The Efficiency of the SHG is in proportional to peak power of the pump and it can be increase by compressing the pump pulse. Here we are analyzing three pulses having similar pulse energy with different pulse parameters and corresponding SHG.

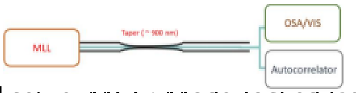

Fig 1: Schematic of the experimental setup. MLL: Mode-locked laser, OSA: Optical spectrum analyzer, VIS: visible spectrometer. (b) IR spectrum of input and output pulses having similar pulse energy but different pulse parameters

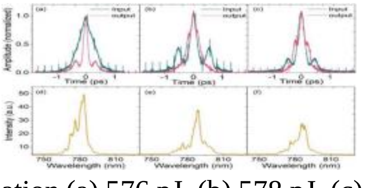

Fig 2: Input and output autocorrelation (a) 576 pJ, (b) 578 pJ, (c) 579 pJ pulse energies. (d-e) SHG spectra for 576 pJ, 578 pJ and 579 pJ respectively

Fig 2 (a-c) shows the input and output autocorrelations plotted one above the other and figure 2 (d f) showing the SHG respectively. In figure 2a, the output pulse is compressed by a factor ~ 3 and it leads to increase in the peak power in same factor. In figures 2(b &c), the output pulse is broadened or remain same. We also see that the ratio of the area under the curve for Fig. 2(d) to (e) is 1.35 and (d) to (f) is 1.7. This clearly shows that for the pulses of similar pulse energy, pulse parameters like chirp, pulse width and peak power plays a role in determining the behavior of the pulses inside the nanowire and so the SHG. Here we have demonstrated nearly two-fold enhancement in the efficiency of the SHG by controlling the pulse parameters for input pulse energy ~580 pJ

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Double magnetic transitions and field induced quantum spin liquid in the triangular lattice antiferromagnets Sr3Co(Nb,Ta)2O9

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Abstract: Widely accepted as a model system, frustrated spin-1/2 triangular lattice antiferromagnet is a recognized as an ideal cradle to host a quantum spin-liquid (QSL) state driven by its ground state degeneracy. In such an instance, two triangular lattice antiferromagnets $Sr_3Co(Nb,Ta)_2O_9$ with an effective $j_{eff} = 1/2$ of Co^{2+} are synthesized and their magnetic properties are investigated via magnetization and heat capacity measurements. The leading in-plane antiferromagnetic exchange coupling is estimated to be $J/k_B \approx 4.7$ K and 5.8 K, respectively. Both the compounds feature two-step magnetic transitions at low temperatures [($T_{N1} \approx 1.47$ K and $T_{N2} \approx 1.22$ K) and ($T_{N1} \approx 0.88$ K and $T_{N2} \approx 0.67$ K), respectively], driven by weak easy-axis anisotropy. Under magnetic field $Sr_3CoNb_2O_9$ evinces a plateau at 1/3 magnetization. Interestingly, the high field magnetization of $Sr_3CoTa_2O_9$ reveals an exotic regime (between H_{S1} and H_{S2}), below the fully polarized state in which the heat capacity at low temperatures is governed by a power law ($C_p \propto T^{\alpha}$) with a reduced exponent $\alpha \approx 1.5$. These results demonstrate an unusual field induced spin-liquid type state with gapless excitations in the strongly frustrated magnet $Sr_3CoTa_2O_9$. The complete *T-H* phase diagram is discussed for both the compounds.

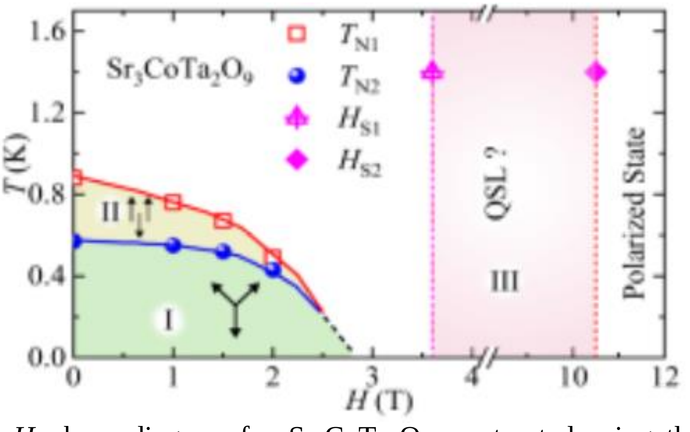

Figure 1: *T* vs. *H* phase diagram for $Sr_3CoTa_2O_9$ constructed using the heat capacity and magnetization data. The anticipated QSL regime (III) between H_{S1} and H_{S2} for $Sr_3CoTa_2O_9$ is highlighted in a different colour.

Deformed spin-1/2 square lattice in antiferromagnetic $NaZnVOPO_4(HPO_4)$

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Abstract: We report the structural and magnetic properties of a new spin-1/2 antiferromagnet $NaZnVOPO_4(HPO_4)$ studied via x-ray diffraction, magnetic susceptibility, high-field magnetization, specific heat, and ^{31}P nuclear magnetic resonance (NMR) measurements, as well as density-functional band-structure calculations [1]. This compound crystalizes in monoclinic structure with the space group $P2_1/c$. There are two nonequivalent phosphorus (P) sites in the crystal structure. In the crystal structure V^{4+} ions in the square-pyramidal coordination. They are joined into layers via P(1)O_4 tetrahedras and build a deformed square lattice [2]. While thermodynamic properties of this compound are well described by the J_1-J_2 square-lattice model, *ab initio* calculations suggest a significant deformation of the spin lattice. From fits to the magnetic susceptibility we determine the averaged nearest-neighbor and second-neighbor exchange couplings of $\bar{J}_1 \simeq -1.3$ K and $\bar{J}_2 \simeq 5.6$ K, respectively, resulting in the effective frustration ratio $\alpha = \bar{J}_2/\bar{J}_1 \simeq -4.3$ that implies columnar antiferromagnetic order as the ground state [3]. Experimental saturation field of 15.3 T is consistent with these estimates if 20% spatial anisotropy in J_1 is taken into account. Specific heat data signal the onset of a magnetic long-range order at $T_N \simeq 2.1$ K, which is further supported by a sharp peak in the NMR spin-lattice relaxation rate. The NMR spectra mark the superposition of two P lines due to two nonequivalent P sites where the broad line with the strong hyperfine coupling and short T_1 is identified as the P(1) site located within the magnetic planes, while the narrow line with the weak hyperfine coupling and long T_1 is designated as the P(2) site located between the planes.

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Experimental Realization of Metal-Insulator Composites

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Abstract: Metal insulator composites are of great interest for a wide range of applications across many industries such as EMI shielding, ESD, photovoltaic devices, flexible and transparent plastic electronics. The electrical conduction in these composite materials is mainly determined by percolation and tunneling mechanism. Percolation occurs at a fraction of metallic concentration at which the composite material transits from being metallic to be a dielectric. Initially, the composite electrical conductivity is owing to percolation via the network; however, once the stain is applied, conductivity is due to tunnelling. In this work, our motivation is to make a dynamically controllable electrical system to study the optoelectrical properties at the percolation threshold. Additionally, the formation of multiple tunnel junctions while stretching the polymer can enhance the signature from tunnel junctions, allowing us to analyze the optoelectronic coupling and optical frequency variations of the tunnel current.
In this work, we fabricated an interconnected random network of gold microchannels using solution-based crackle paint lithography, which is partially embedded in polydimethylsiloxane (PDMS) substrate. Since, PDMS is an elastomeric substrate, nanometric break junction will develop across the gold network when it is subjected to strain. Further stretching leads to the formation of multiple such junctions, and thereby a significant change in resistance can be observed. In order to measure Electrical Response while stretching and relaxing, the composite was attached to a screw gauge with silver paint contacts on two sides. We found that Current-Voltage (I-V) characteristics were linear for lower values of strain and non-linear for larger values of strain (1.2% strain). This non-linear I-V is attributed to the formation of multiple tunnel junctions. We also observed that the composite could return to its original low resistance state if the strain was progressively removed, allowing us to create a controllable electrical system. In order to understand the intrinsic plasmonic characteristics of Gold and optical frequency fluctuations of the tunnel current, we also intend to perform experiments to investigate the light-matter interaction in tunnel junctions.

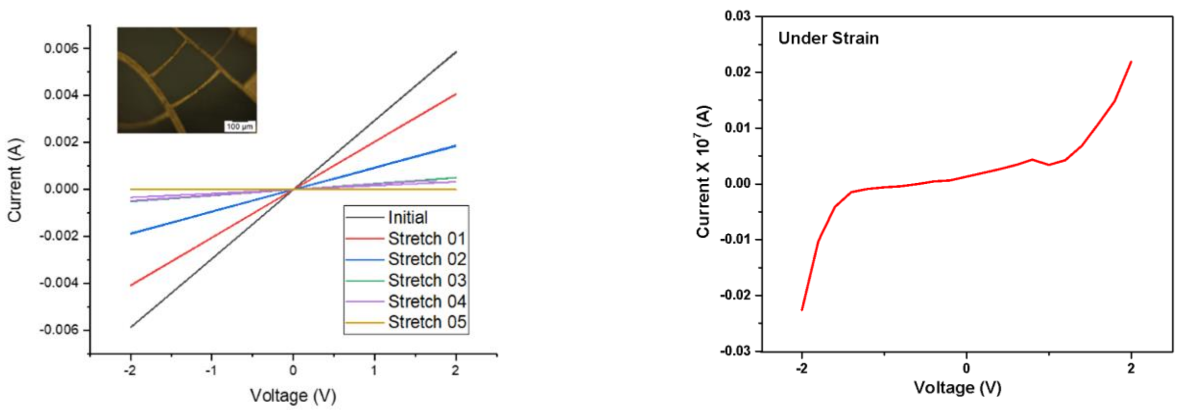

Figure 1: Change in Current-Voltage characteristics with the increasing strain (b) I-V under 1.2 % strain0

Vertical Shift of hysteresis loop in exchange coupled hard/soft ferromagnetic bilayers

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Abstract: Exchange bias (EB) is one of the most researched phenomena for memory device applications. Conventional EB is a shift of magnetic hysteresis loop (*M-H*) in the horizontal or field (*H*) axis due to the interfacial coupling at the ferromagnetic (FM)/antiferromagnetic (AFM) interface. A shift of the hysteresis loop in the vertical direction is also observed in some systems. The origin of this vertical shift (VS) is still not well studied and is often considered a consequence of EB. In this work, we observed an EB independent vertical shift in EB coupled $La_{0.67}Sr_{0.33}MnO_3/SrRuO_3$ and non-EB $Ni_{80}Fe_{20}/SrRuO_3$ bilayers prepared in 1:2 thickness ratio. We manually removed EB in both systems and even in the absence of EB, we observed VS. This proves that VS is not Directly Linked to EB shift. We further studied the field and temperature dependence of EB and VS. These studies provide a route to independently tune the EB and VS in the Hard/Soft Bilayer. We also performed OOMMF simulation for the study of the thickness and anisotropy dependence of the hard layer on the vertical shift of the bilayer. Observed vertical shifts from the simulations are in good correspondence with experimentally observed data. A generalised model is developed based on experimental and simulated data which could help to estimate VS in other materials systems

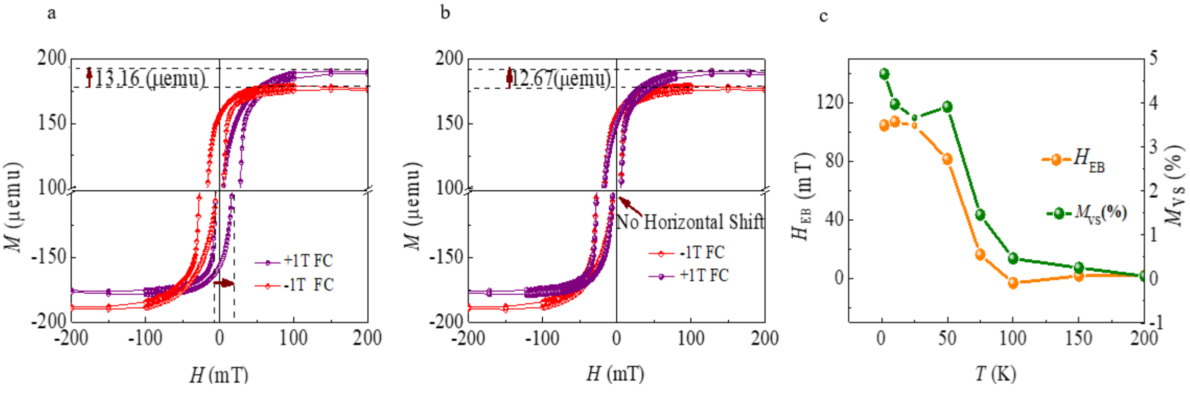

Figure: a. M-H loop of LSMO/SRO at temperature T=2K. b. EB removed M-H loop of LSMO/SRO at T=2K. The arrow represents the shift difference in the vertical and horizontal directions. c. EB and VS vs Temperature.

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Mechano-chemistry of the cell wall drives Bacterial Morphogenesis

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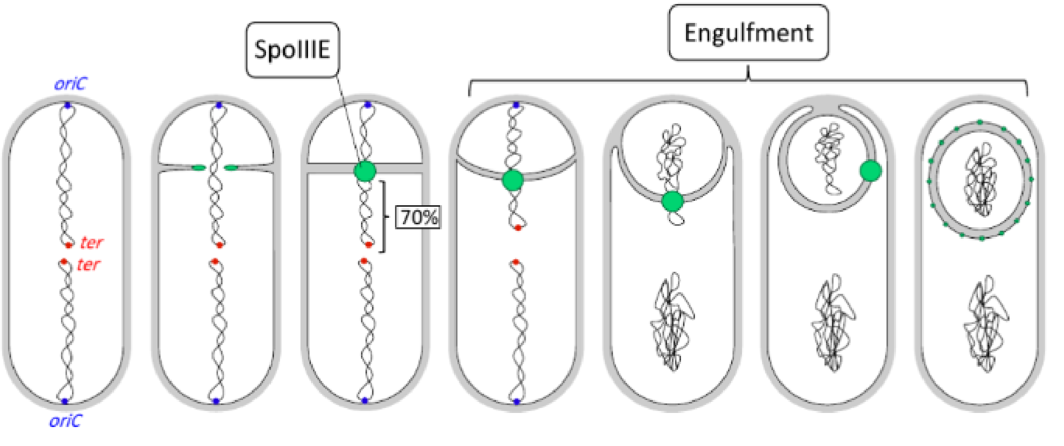
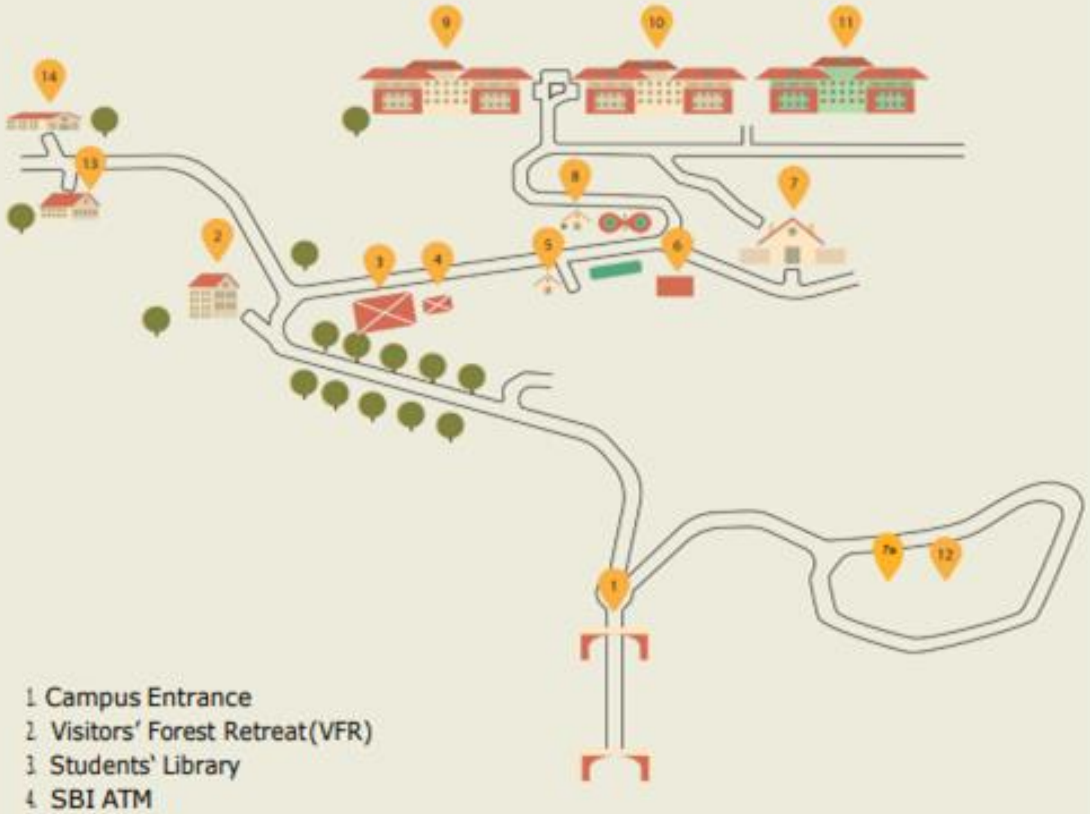
Abstract: Essential morphogenetic processes like cell growth, binary fission, sporulation in bacteria require remodelling of its cell wall. In this work, we have integrated molecular level mechanisms in the cell wall to evolve a mesoscopic description of the cell wall dynamics. We have focussed on formation of endospore in gram positive bacteria and shown how the order structure of the cell wall cracks systematically due to stress exerted by the synthesis of new material to produce a new wall for the endospore.



Source: Coordination between Chromosome Translocation and Peptidoglycan Remodeling during Spore Development by Ahmed Mostafa Taha Mohamed

In our phenomenological model, we have shown the crack propagation speed is determined by the shear modulus of Peptidoglycan(PG) lattice, strength of peptide bonds, wall geometry, PG synthesis rate and the change of mass and volume in the spore and the mother cell. We have also assumed that PG synthesis machinery moves in the circles along the cell wall in order to generate new glycan strands. Using these assumptions we have calculated the septum closure speed for bacterial organisms and compared it with experimental results.

Campus map



1. Campus Entrance
2. Visitors' Forest Retreat (VFR)
3. Students' Library
4. SBI ATM
5. Restaurant
6. Bus Stop
7. Central Dining Hall 1 (CDH1 and iCafe) & 7a. Central Dining Hall 2
8. Student Lounge and Cafe
9. Physical and Mathematical Sciences Block (PSB & Conference Venue - PSB 3201)
10. Chemical Sciences Block
11. Biological Sciences Block
12. Students' Hostel area (Anamudi - D & Anamudi - E blocks)
13. Medical Center
14. General Store

KSRTC BUS TIMINGS – THIRUVANANTHAPURAM BUS STAND TO VITHURA BUS STAND

From	Departure Time	To	Arrival Time
Thiruvananthapuram /Thampanoor	06:40	Vithura Bus Stand	08:00
Thiruvananthapuram /Thampanoor	07:30	Vithura Bus Stand	09:30
Thiruvananthapuram /Thampanoor	08:50	Vithura Bus Stand	10:50
Thiruvananthapuram /Thampanoor	09:10	Vithura Bus Stand	11:10
Thiruvananthapuram /Thampanoor	10:10	Vithura Bus Stand	12:10
Thiruvananthapuram /Thampanoor	10:20	Vithura Bus Stand	12:20
Thiruvananthapuram /Thampanoor	10:40	Vithura Bus Stand	12:40
Thiruvananthapuram /Thampanoor	10:45	Vithura Bus Stand	12:45
Thiruvananthapuram /Thampanoor	10:50	Vithura Bus Stand	12:50
Thiruvananthapuram /Thampanoor	11:00	Vithura Bus Stand	13:00
Thiruvananthapuram /Thampanoor	11:55	Vithura Bus Stand	13:55
Thiruvananthapuram /Thampanoor	12:05	Vithura Bus Stand	14:05
Thiruvananthapuram /Thampanoor	12:20	Vithura Bus Stand	14:20
Thiruvananthapuram /Thampanoor	13:10	Vithura Bus Stand	15:10
Thiruvananthapuram /Thampanoor	13:20	Vithura Bus Stand	15:20
Thiruvananthapuram /Thampanoor	13:40	Vithura Bus Stand	15:40
Thiruvananthapuram /Thampanoor	13:50	Vithura Bus Stand	15:55
Thiruvananthapuram /Thampanoor	14:35	Vithura Bus Stand	16:35
Thiruvananthapuram /Thampanoor	15:30	Vithura Bus Stand	17:30
Thiruvananthapuram /Thampanoor	16:10	Vithura Bus Stand	18:10
Thiruvananthapuram /Thampanoor	16:20	Vithura Bus Stand	18:20
Thiruvananthapuram /Thampanoor	16:30	Vithura Bus Stand	18:30
Thiruvananthapuram /Thampanoor	16:50	Vithura Bus Stand	18:50
Thiruvananthapuram /Thampanoor	17:00	Vithura Bus Stand	19:00
Thiruvananthapuram /Thampanoor	17:20	Vithura Bus Stand	19:20
Thiruvananthapuram /Thampanoor	17:30	Vithura Bus Stand	19:30
Thiruvananthapuram /Thampanoor	17:50	Vithura Bus Stand	19:50
Thiruvananthapuram /Thampanoor	18:00	Vithura Bus Stand	20:00
Thiruvananthapuram /Thampanoor	18:05	Vithura Bus Stand	20:05
Thiruvananthapuram /Thampanoor	18:10	Vithura Bus Stand	20:10
Thiruvananthapuram /Thampanoor	18:20	Vithura Bus Stand	20:20
Thiruvananthapuram /Thampanoor	18:30	Vithura Bus Stand	20:30
Thiruvananthapuram /Thampanoor	18:40	Vithura Bus Stand	20:40
Thiruvananthapuram /Thampanoor	18:50	Vithura Bus Stand	20:50
Thiruvananthapuram /Thampanoor	19:10	Vithura Bus Stand	21:10
Thiruvananthapuram /Thampanoor	20:10	Vithura Bus Stand	21:50
Thiruvananthapuram /Thampanoor	20:50	Vithura Bus Stand	22:50
Thiruvananthapuram /Thampanoor	21:50	Vithura Bus Stand	23:50

KSRTC BUS TIMINGS – THIRUVANATHAPURAM BUS STAND TO IISER CAMPUS			
From	Departure Time		Arrival Time
Thiruvananthapuram /Thampanoor	05:00	IISER Campus	07:00
Thiruvananthapuram /Thampanoor	06:40	IISER Campus	08:40
Thiruvananthapuram /Thampanoor	06:50	IISER Campus	08:50
Thiruvananthapuram /Thampanoor	08:30	IISER Campus	10:30
Thiruvananthapuram /Thampanoor	14:40	IISER Campus	16:40
Thiruvananthapuram /Thampanoor	15:15	IISER Campus	17:15

Internal Shuttle Service (Mini Bus) (Monday to Sunday)

Main Gate	BSB /CSB/ PSB	CDH1	Residence C3/B1	Anamudi Block Hostels	Residence C3/B1	Anamudi Block Hostels	CDH1	PSB/CSB/BSB	Main Gate
7.40am			7:50						
		7:55		8:00					
				8:00			8:05		
		8:05		8:10					
				8:10			8:15		
		8:15		8:20					
				8:20			8:25		
		8:25		8:30					
				8:30			8:35		
					8:40			8:45 (CSB)	
	8:45			8:50					
				8:50			8:55		
		8:55		9:00					
				9:00			9:05		
		9:05		9:10					
				9:10			9:15		
		9:15		9:20					
				9:20			9:25	9:30	
Monday to Saturday only	10.10		10.20		10.30			10.40	

Internal Shuttle Service (Mini Bus) (Monday to Sunday)

Main Gate	BSB /CSB/ PSB	CDH 1	Residence C3/B1	Anamudi Block Hostels	Residence C3/B1	Anamudi Block Hostels	CDH1	PSB/CSB/BSB	Main Gate
	12:30 pm			**12.40 (via CDH1)**					
				12:40			**12:45**		
		12:45		**12:50**					
				12:50			**12:55**	**1:00**	
Monday to Saturday only	**1:00**		**1:10**				**1:15**		
		1:15		**1:20**					
				1:20			**1:25**		
		1:25		**1:30**					
				1:30			**1:35**		
		1:35		**1:40**					
				1:40			**1:45**		
		1:45			**1:50**			**2:00**	
						2:15		**2:20**	
	04.30 pm		**04.40pm**		**4.50pm**				**5.00PM**
Monday to Saturday only	**05.30 pm**		**05.40pm**	**-**	**-**	**-**		**05.50pm**	
	06.00 pm		**-**	**06.10pm**	**-**	**06.15pm**		**06.25pm**	
		07:25 pm		**07:30 pm**		**07:35pm**	**07:40pm**		

In addition to the above, the schedule of 49-seater bus from Monday to Friday

From Monday to Friday (49 seater) (2 buses)	CSB	CDH1	Anamudi Block Hostels	Anamudi Block Hostels	CDH1	CSB
			9:05		9:15	
			9:15		9:25	
	12:35 pm		12:45		12:50	
	12:40		**12:50**		**12:55**	
		12:50	**1:00**		**1:05**	
		12:55	**1:05**		**1:10**	
		1:05	**1:15**		**1:20**	
		1:10	**1:20**		**1:25**	
		1:20		**1:30**		**1:40**
		1:25		**1:35**	**1:45**	
	1:40			**1:50**		**2:00**
		1:45		**1:55**		**2:05**

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