SATYENDRA NATH BOSE NATIONAL CENTRE FOR BASIC SCIENCES

Vol. 10, Issue 1

Editorial

We are very happy to publish this online issue of the Newsletter. It is great that we have manged to maintain our activities even under significant hardship due to the pandemic situation, which has been prevailing for the second year running. Indeed we are deeply appreciative of the sincere efforts by all the contributors for sending their interesting articles, which, we hope, would provide some delight, and solace, to the readers. This Newsletter issue covers the Centre's various activities during the second half of the previous year 2020. We hope we continue with our fruitful works also in the coming days. We wish you all the best! Stay safe and healthy.

News and Events (Academic)

COLLOQUIM / NAMED LECTURES

Bose Colloquium

1. Prof. Lorenzo Pavesi, Nanoscience Laboratory, Department of Physics, University of Trento Italy, delivered a lecture on 27th November, 2020. The title of the lecture was '*Quantum Silicon Photonics*'.

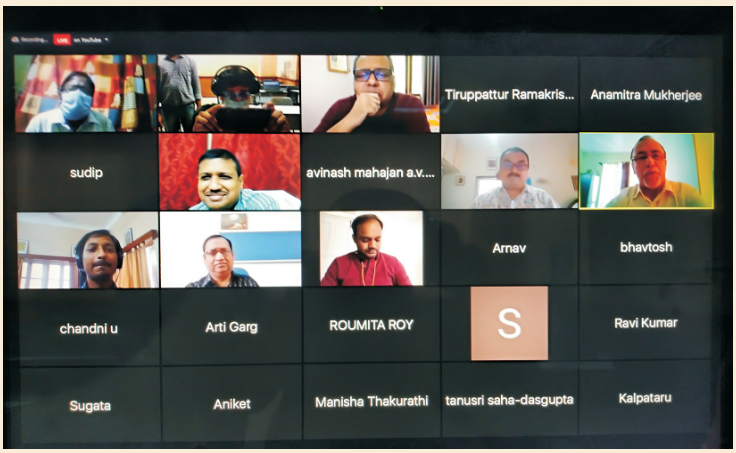
2. Prof. Pratap Raychaudhuri, Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental Research delivered a lecutre on 11th December 2020. Title of the lecuture was '*Observation of Hexatic vortex fluid in a superconducting thin film*'.

COLLOQUIM / NAMED LECTURES

Q-MAT 2020

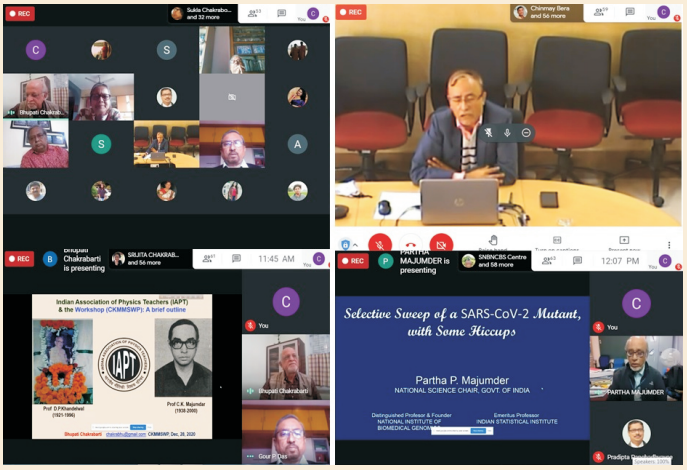
3rd Annual Conference of Quantum Condensed Matter (Q-MAT 2020) was held during 7-11 September, 2020 through virtual platform.

The third annual conference on Quantum Matter (Q-MAT) was held from 7th to 11th of September 2020, hosted by the S.N. Bose National Centre for Basic Sciences (SNBNCBS), Kolkata on a virtual platform due to the pandemic Covid-19. Since its inception in the year 2018 at IISER Mohali, followed by the second edition at IISC, Bangalore, Q-MAT has been a flagship conference on quantum matter bringing large fractions of Quantum condensed matter community together in a spirit of community meeting. This year the conference was a part of the Golden Jubilee Celebration of the Department of Science and Technology (DST). The third edition of QMAT has witnessed maximum participation amongst all the editions, with total 294 participants including 131 speakers and 163 other participants. In this conference, participants were from prestigious institutes of seven countries like United Kingdom, Canada, Israel, USA, Poland, etc. in addition to participants from reputed institutions of India. The conference covered many broad areas of the subject like nanotech, topological aspects of materials,



superconductivity, magnetism, quantum information etc. The organizing committee consists of members from SNBNCBS, Kolkata; IISER Mohali; TIFR, Mumbai; IACS, Kolkata; IISC, Bangalore; Bose Institute, Kolkata; SINP, Kolkata and IISER Kolkata. The conference was partially funded by IOP Publishing, UK and IISC, Bangalore. The next annual conference will be organized by the Tata Institute of Fundamental Research, Mumbai

C. K. Majumdar Memorial Workshop



C. K. Majumdar Memorial Workshop in Physics, 2020 held through virtual platform during 28 December 2020 to 04 January 2021. Convener: Dr. Sukla Chakraborty, Ananda Mohan College, Kolkata. Co-Convener: Prof. Kalyan Mandal.

SCIENTIFIC STORIES

Air-stable all Inorganic β-$CsPbI_3$ Perovskite Solar Cells a Low Cost Solution for Growing Energy Demand

Samit K. Ray (Director, SNBNCBS)

Global warming leading to climate change has now been accepted as a serious threat to the earth and the life of human being, originated from fossil fuels such as burning of coal, oil and gases etc. Scientists are exploring renewable energy sources to produce energy without producing CO_2. Among them, solar energy is extremely promising because it is practically inexhaustible. With about 300 sunny days in a year, the available solar energy from the Sun in India's land area per day exceeds the possible energy output of all of the fossil fuel energy reserves in India. Therefore solar photovoltaic (PV) industry in India has continued its rapid growth in recent years with country's solar installed capacity reaching to ~37.627 GW, as of 31 March 2020.

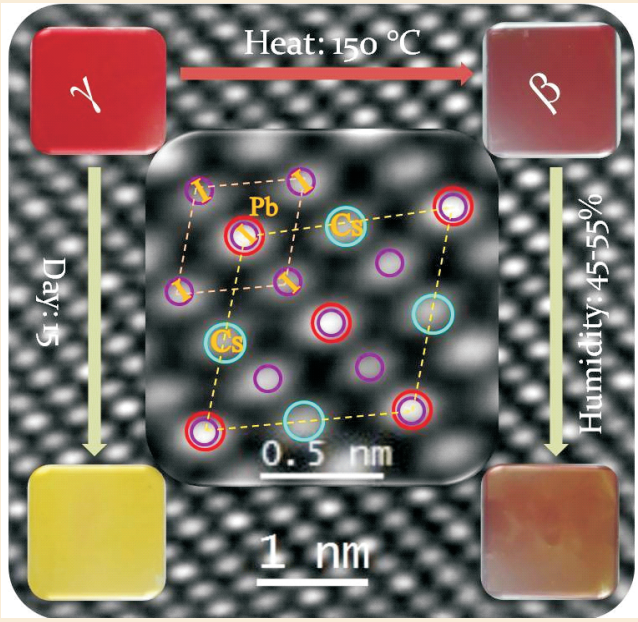
While silicon (Si) being the most dominated PV technology for the first and second-generation solar cells have done well in terms of efficiency and stability, they are based on ultra-high-pure Si in crystalline / polycrystalline forms, requiring relatively higher cost of materials and processing temperature, which have prevented them to be real alternatives to fossil-fuel-based energy sources. A lot of research and development has therefore been devoted to the search for cost effective alternatives, leading to the third-generation photovoltaic devices like organic solar cells and dye-sensitized solar cells (DSSCs), although their efficiency remained relatively low along with the long term stability issues, limiting their commercial use.

In recent years, there has been a rapid development of Perovskite Solar Cells (PSCs) making them the rising star of the PV technology The evolution of organic–inorganic lead halide perovskite solar cells with low-cost solution-based processes and high efficiency attest to the immense potential of PSCs to be a PV technology of the future. However, there have been serious bottlenecks about their poor thermal and environmental stability owing primarily to the organic cation part. In this regard, all inorganic pervoskite materials have emerged as suitable alternatives.

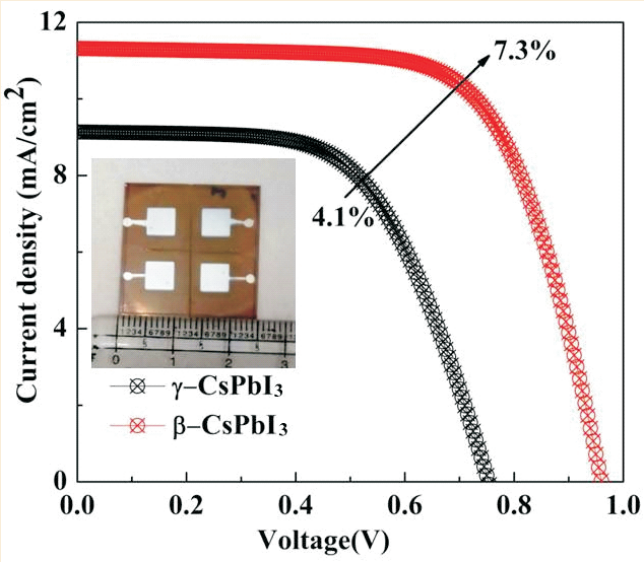
Prof. Samit K. Ray in collaboration with his research group at IIT Kharagpur invented a new phase of all inorganic β-$CsPbI_3$ perovskite in its one dimensional form, showing an excellent photo-stability under humid conditions. Theoretically it has been predicted that β-$CsPbI_3$ can be crystallized at a lower temperature with higher stability, as compared to α-$CsPbI_3$ but experimental realization has remained a challenge. Prof. Ray and his group have used a novel, low temperature (150°C), colloidal synthesis process for obtaining a high quality single-crystalline β -$CsPbI_3$ nano-rods. The photo-physical properties of β-phase has been found to be superior with an optical band gap value better matched to the peak of the solar radiation incident on the earth. The fabricated PV devices with inverted p-i-n configuration of ITO/PEDOT: PSS/CsPbI3/C60/BCP/Al structure show a significant enhancement in fill factor from 59.6% to 67.2% and 78% enhancement in efficiency for β-$CsPbI_3$, in comparison to conventional γ-$CsPbI_3$ phase.

The efficiency of the air-stable device employing β-CsPbI3 nano-rods of inverted perovskite solar cells is found to be moderately high ~ 7.3% without any use of glovebox or encapsulation, which could be improved significantly by surface passivation/encapsulation and the optimization of process parameters in future. The reported high-quality, single-crystalline β-CsPbI3 nano-rod films not only underscore the performance of PV devices with a moderately high efficiency but also provide highly stable, low cost colloidal synthesis route of perovskite layers

under 4555% humid condition for potential use of photovoltaic and optoelectronic devices in future.



(a)



(b)

Fig. (a) Schematic low temperature phase transition, air stability and atomic arrangements of crystalline β-CsPbI3 nano-rods and **(b)** I-V characteristics of the PV device with its photograph at the inset.

The paper has been published recently in Advanced Energy Materials, *Adv. Energy Mater*. 2020, 2001305 (DOI: 10.1002/aenm.202001305).

Eco-friendly and Energy-efficient Magnetic Refrigeration

Subrata Ghosh and **Kalyan Mandal**

Magnetic refrigeration (MR), one of an energy efficient and eco-friendly cooling technology based on magneto-caloric effect, has tremendous potential to replace the conventional gas refrigerators and is expected to be applicable in solid-state-based modern refrigeration devices

Conventional vapor compression refrigerators are used for cooling technology which are bulky, energy inefficient and contains hazardous and ozone layer depleting gases like CFC, HCFC as refrigerant materials. Though in recent time, the previous usage of hazardous gas is replaced by harmless HFC gas, the lower efficiency of conventional gas refrigeration and also the potential in global warming are still concerns. Magnetic refrigeration, one of such energy efficient and eco-friendly solid-state-based cooling technology, can replace the conventional gas refrigerators. The energy efficiency of a MR is predicted to be 30% higher than that of conventional gas refrigerator.

Depletion of natural energy resources and atmospheric pollution are two major concerns of the present day scientific society. Therefore, in the present scenario, it is important to conduct research on the renewable energy resources as well as on the technologies which can reduce energy consumption significantly compared to the existing one. A major portion of the electricity (~16.38 trillion kWh) used by the entire world population is consumed for cooling devices such as freezer to store food in a supermarket and home, air conditioning in private and public buildings, in industrial fields for liquefaction of different kind of gasses and also in certain medical fields. Conventional vapor compression refrigerators are used for the cooling technology which is energy inefficient and causes atmospheric pollution. On the other hand, MR is eco-friendly and energy efficient.

Magnetic refrigeration is based on the magneto-caloric effect (MCE). MCE is a magneto-thermodynamic phenomenon which refers to a magnetic material's thermal response when subjected to changes in magnetic field. The magneto-caloric material which exhibits temperature change under varying magnetic field is the most crucial requirement for a MR device. It is worth noting that MCE is an intrinsic property of any magnetic material. However, MR requires commercially cost-effective, earth abundant materials with large magneto-caloric properties around room-temperature as refrigerant. The use of MCE in a magnetic refrigeration cycle, similar to gas refrigeration cycle is presented

schematically in Fig. 1.

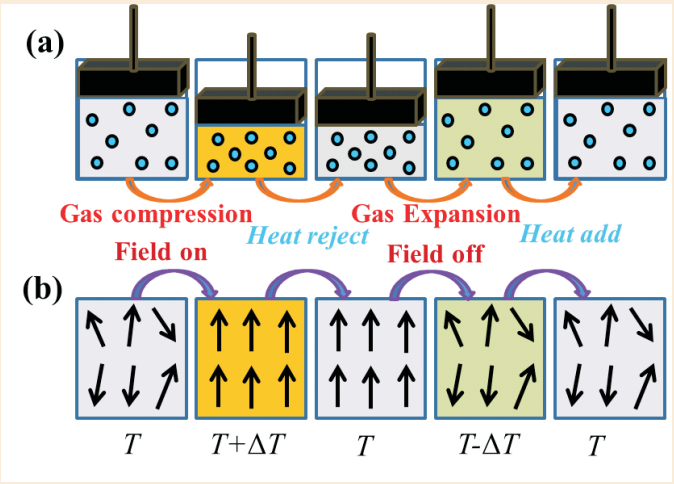


Fig. 1: A schematic representation of (a) gas refrigeration cycle (b) magnetic refrigeration cycle

The study of magnetic refrigeration based on MCE, was first initiated on 1881 by German physicist E. Warburg who observed the heat evolution in Fe under the application of magnetic field. In 1918, Weiss and Piccard measured experimentally a temperature change in Ni around its Curie temperature due to change in magnetic field. The discovery of giant MCE in $Gd_5(Si_2Ge_2)$ alloy by Pecharsky and Gschneidner, which initiated the path of room temperature MR with the materials with first order transition. After the discovery of giant MCE in $Gd_5(Si_2Ge_2)$ alloy, the MCE properties of various rare earth based materials are investigated to find suitable magnetic refrigerant. Though the rare earth elements associated with large saturation magnetization are found to exhibit excellent magneto-caloric properties, the high cost of the raw materials is the major limitation for the commercial applications. Subsequently in recent times, the research on magneto-caloric materials is shifted to the low-cost transition metal based alloys to find the promising magnetic refrigerant material with large magneto-caloric properties near room temperature to make the magnetic refrigeration cost-effective. In this regard, Ni-Mn-based Heusler alloys, Mn-Fe-based compounds, MnNiSi based intermetallic compounds can be very promising refrigerant material as they exhibits large magneto-caloric response associated with a first order magneto-structural transition around room temperature though they possesses thermal as well as magnetic hysteresis which is real obstacle for the commercialization of MR. Hence, the optimization of the magneto-caloric effect and the new magnetic materials showing a large MCE with narrow hysteresis around room temperature are the subject of recent research activity.

Magnetic refrigeration is a promising cooling technology which is energy efficient and eco-friendly. The energy efficiency of a MR can be 30% higher than that of a convention gas refrigerator. If the efficiency of energy conversion can be enhanced by a very small percentage in cooling technology, it will save a huge amount of energy globally. Moreover, MR is a solid state based technology which does not contain any hazardous fluid.

S. Ghosh, P. Sen, and K. Mandal, *Magnetostructural Transition and Large Magnetocaloric Effect in* $(Mn_{0.6}Fe_{0.4})NiSi_{1-x}Al_x$ *(x = 0.060.08) Alloys*, **J. Magn. Magn. Mater.** 500, 166345 (2020); S. Ghosh, A. Ghosh, P. Sen, and K. Mandal, *Giant Room-Temperature Magnetocaloric Effect Across the Magnetostructural Transition in* $(MnNiSi)_{1-x}(FeCoGa)_x$ *Alloys*, **Phys. Rev. Appl.** 14, 014016 (2020).

Geometry at Quantum Gravity scale: A Plausible Scenario

Biswajit Chakraborty

Algebra is the offer made by the devil to the mathematician. The devil says: "I will give you this powerful machine, it will answer any question you like. All you need to do is give me your soul: give up geometry and you will have this marvelous machine." - Michael Atiyah.

The geometry formulated by Euclid more than 2000 thousands years back served as an essential tool in the development of modern science and technology. In fact, the whole of modern civilization can be said to rest on this in the most crucial way. Of course, on the way it had to be generalized suitably in various manners to make it applicable to various contexts-arising primarily in different physical situations and engineering applications. The first generalization was the development of analytical geometry, where the notions of Cartesian coordinate was introduced, so that lines or curves could be described by algebraic equations and in the process subsumed the entire Euclidean geometry. Not only that it paved the way for its generalization to 3 or higher dimensional spaces, which describes, almost accurately, the space we are the inhabitants of. In fact the whole of Sir Isaac Newton's Principia makes extensive use of this and plays a vital role in the subsequent development of Calculus by him and Leibniz. As is well known that the industrial revolution, which primarily originated in Great Britain in later years owes its roots to these works of Newton and some of his well known predecessors and contemporaries. On the other hand, quite a few number of mathematicians, across several generations were busy in trying to prove or dis-prove the

logical independence of 5th postulate of Euclid in an essentially quest driven research. Eventually, this problem was sorted out independently and more or less simultaneously by Gauss and Lobachevski, where they could demonstrate that geometry of positively or negatively curved two dimensional surfaces can only be described by transcending the framework of Euclid and where the 5th postulate of Euclid is necessarily violated. This was generalized subsequently to arbitrary dimension by Riemann where he showed how to quantify the curvature of these spaces and formulated the complete Non-Euclidean geometry. It found its most profound application in Einstein's General Theory of Relativity-which is a classical theory of gravitation, as manifested through the curvature of space-time. Till this stage however, two of the basic concepts from Euclidean geometry, like point and straight line (or more generally geodesic) was retained. On the other hand, an even more radical generalization in the form of Noncommutative geometry was formulated by Alain Connes during the nineties of last century. Here, on the contrary, there are no a priory concepts like points and geodesics and has been christened as "point-less" geometry. Here Connes generalized the celebrated work due to Gelfund and Naimark, who showed that the space of complex-valued functions defined on any geometrical space itself carries all the topological information about this geometrical space. In this algebraic approach, the concept of a point is replaced by the evaluation maps of the functions at this point. To pin down the geometry, also, one further requires a suitable Dirac operator and whose spectrum provides, not only this geometrical information, but also the dynamics of the system inhabiting the space. This space of functions is, however, commutative in nature and Connes generalized it to spaces of matrices to render it noncommutative and could formulate a new framework of Standard model of particle physics. In this approach he could, for example, compute the Higgs mass, apart from other effects. This, in fact, also comes quite handy in describing the geometrical properties of certain toy models describing quantum space time, where there are no notions of points and/or geodesics, and are some of the possible candidates describing space time at quantum gravity scales and are postulated to serve as deterrents against possible gravitational collapse associated with the localization of an event at quantum gravity (Planck) length scale. Recently, we have studied the geometry of such spaces using this framework of Connes. It will be quite interesting to extend the formulation of the standard model of particle physics to this scale as well and come up with some suitable predictions, so that the same can be tested experimentally. And for that one needs to just start searching downwards from a few orders below the length scale required to detect gravitational wave to detect any footprint of quantum space-time.

Ref: A Chakraborty, B Chakraborty, *Spectral distance on Lorentzian Moyal Plane*, Int. J. Geom. Meth. Mod. Phys. 17 (2020) 06, 2050089.

Exploring the Thermodynamics of Strongly Correlated Quantum Wires with New Hybrid ED/DMRG Method

Manoranjan Kumar

Competing kinetic energy and repulsive electronic interactions in materials governs their electronic properties such as superconductivity, magnetism, dielectric properties, etc. Each electron in the system is interacting with all other electrons; therefore, this phenomenon gives rise to many body interactions in the system. In the low dimensional systems like one, quasi-one or two dimensional systems, many body interaction becomes dominant due to confinement of the electrons. Unfortunately, theoretical studies of the quantum many body systems are challenging because of the exponentially increasing degrees of freedom with system size. There is no general method to study the electronic properties at low temperature where both the quantum and thermal fluctuations are competing.

Manoranjan Kumar and his team (Sudip Kumar Saha and Dayasindhu Dey) in collaboration with Z. G. Soos from Princeton University, USA have developed a hybrid ED/DMRG method for low dimensional systems and they also applied it to one dimensional (1D) magnetic systems to study the magnetic properties at finite temperature.

Density matrix renormalization group (DMRG) method, invented by S. R. White, is a state of the art numerical technique to calculate the ground and low-lying excited states of the strongly correlated systems. However, study of the thermodynamic properties has always been challenging. Transfer matrix renormalization group and minimally entangled typical thermal state based DMRG methods are restricted to relatively high temperature calculations. However, other methods like Quantum Monte Carlo (QMC) methods suffer from sign problem in the case of frustrated magnets and fermionic systems away from half filling. The group has developed a hybrid approach that is better equipped to study the thermodynamics of low dimensional models and applied it to the 1D-spin systems. At high temperature, the correlation length of the system is small and exact diagonalization (ED) can be used to get the full spectrum of small systems to calculate the high temperature properties. Whereas at low temperature, correlation length increases and the DMRG is used to calculate the

low lying spectrum of larger systems, because only few low lying excitations are required to compute the partition function accurately.

They have successfully applied this hybrid method to the Heisenberg antiferromagnetic (HAF) spin chains and the frustrated J_1-J_2 model where antiferromagnetic next nearest neighbor exchange interaction J_2 is responsible for the frustration. The HAF, a non-frustrated model, provides convenient test of the hybrid ED/DMRG approach to spin chains. The Fig. 1 compares the susceptibility and the specific heat calculated using this method to results obtained by the well-established Quantum Monte Carlo (QMC) method shown with open symbols and exact T=0 results marked by the arrows. They also successfully modeled a very old puzzle of the spin-Peierls (SP) transition of organic crystal TTF-$CuS_4C_4(CF_3)_4$ and inorganic compound $CuGeO_3$.

Refs: S. K. Saha, D. Dey, M. Kumar, and Z. G. Soos, Phys. Rev. B 99, 195144 (2019) [DOI: https://doi.org/10.1103/PhysRevB.99.195144]; S. K. Saha, M. S. Roy, M. Kumar, Z. G. Soos, Phys. Rev. B 101 054411 (2020) DOI: https://doi.org/10.1103/ PhysRevB.101.054411

Computer Discovers Two Dimensional Magnets

Tanusri Saha-Dasgupta

We are all familiar with the electrons, as one of the basic components of atoms, that are the glue binding atoms together. Electron, in addition to its charge, contains spin, which crudely can be described as spinning-top rotating around its axis. Ferromagnetism is the phenomena in which electron spins line up parallel to each other forming long range ordered pattern. Most ferromagnetic materials we know of, exist in three dimension. It is of great interest to know what happens to ferromagnetic long range order when the dimensionality of the system is reduced from three to two by forming atomically thin layer, which recent experimental advances allow us to synthesis. Two-dimensional (2D) ferromagnetism, if can be stabilized, can bring in important advances both in scientific knowledge as well as technological development owing to its low-dimensionality. For example, one of the upcoming fields in technology is *spintronics*, in which devices such computers and memories can be built based on movement of electron spin rather the charge (known as electrical current). It would be huge advantage to have 2D magnets for the realization of such technology. However, finding 2D magnets is challenging. There exists a rigorous theorm (known as Mermin-Wagner theorem) that says that stabilization of two-dimensional ferromagnetism is impossible at any finite temperature. In other words, two-dimensional ferromagnetism can only occur at absolute zero temperature (0 Kelvin or -273 degree Celcius). Through our computational study, we predict existence of two dimensional systems which show long-range ferromagnetic ordering even at finite temperature, making an exception to the conventional wisdom, given by the Mermin-Wagner theorem. The key to this exceptional behavior turned out to be governed by a special property of these materials, namely the magnetic anisotropy. As opposed to magnetically isotropic materials for which there is no preferential direction for an object's spin, for magnetic systems with finite values of magnetic anisotropy, the spins prefer to point towards a specific direction. The studied two-dimensional systems comprised of a single layer of Cu spins connected to each other through halogen atoms, exhibit the anisotropy property so that the Cu spins prefer to orient in the out of plane direction as opposed to in-plane, which in turn help them to line up parallel to each other at a finite temperature. Discovery of these ultra-thin magnets provide an important step forward in realizing spintronics devices which can be integrated into the next generation spin-transfer torque magnetic random-access memory.

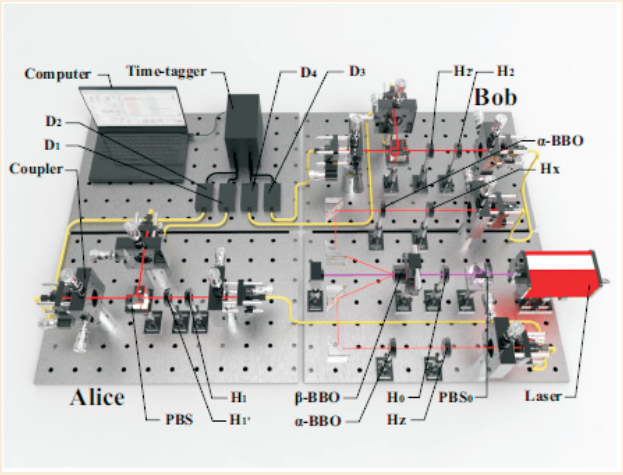
Ref: *2D ferromagnetism in layered inorganic-organic hybrid perovskites*, D. Nafday, D. Sen, N. Kaushal, A. Mukherjee, and T. Saha-Dasgupta, Phys. Rev. Research 1, 032034 (2019).

Certifying Quantum Entanglement: A step towards Quantum Security

Archan S. Majumdar

Nearly hundred years after its discovery, quantum mechanics has reached an important threshold. Today, the laws of quantum physics play an essential role in safeguarding our ability to communicate securely. All communication activities ranging from financial transactions, data exchange and online education to personal emails, all would be untrustworthy in the absence of guaranteed protection from hackers and fraudsters. During the last two decades, it has been realized that two inherent properties possessed by fundamental particles such as photons, can indeed guarantee the privacy of communication using such information carriers. The application of quantum principles in storage, transfer and manipulation of information using these two properties, *viz.*, superposition and entanglement, has opened up a whole new branch of physics called Quantum Information Science.

Quantum information theory predicts the possibility of certain tasks which cannot be realized using laws of classical physics. Primary among them are the processes of quantum teleportation, quantum computation and quantum cryptography. Some of these tasks can be accomplished through the creation of quantum entanglement between the states of two or more particles such as photons. Entanglement is a resource which enables many useful tasks of quantum information processing. However, entanglement is fragile, and is easily lost during the transit of photons through the environment. It is hence, extremely important to know whether a pair of photons is entangled, in order to use them as resource. Verification of entanglement requires the use of measurement devices, but such devices may be hacked or compromised by eavesdroppers. In order to overcome such a possibility, device independent entanglement verification, or device independent self-testing has been proposed recently.



Device-independent self-testing (DIST) enables the verification of entanglement in an unknown quantum state of two photons without having direct access to the state, or complete trust in the measurement devices. The theory relies on application of the quantum uncertainty principle. Implementing full device independence is a difficult task. In several practical situations, one of the parties may be fully trusted, whereas, the other is untrusted, for example, the server-client relationship in banking transactions. For such situations, quantum information theory enables one-sided DIST (1sDIST). See, the figure where Bob is the trusted party and Alice is untrusted, and we have to verify that the pair of photons they share is entangled.

In our work we have formulated the first protocol (both theory and experiment) for 1sDIST. The theoretical idea is based on applying the fine-grained uncertainty relation to perform quantum steering [Phys. Rev. A 98, 022311 (2018)]. This idea has been successfully implemented experimentally by us in collaboration with a group in Beijing Computational Science Research Centre, and Key Laboratory of Quantum Information, Hefei [Phys. Rev. A 101, 020301 (2020)]. The experiment uses an all optical set-up (see the figure), in which entangled pairs of photons are created by laser light on BBO crystals. In a single run of the experiment, one photon goes to Alice's lab (bottom left), and another to Bob's lab (top right). Next, several optical operations using beam-splitters, phase-shifters, and quantum gate operations are implemented before the photons are detected. Using the detection statistics, we are able to not only certify the presence of entanglement, but also determine the magnitude of entanglement in the photon pairs with minimum error. We can thus conclude that the entangled pairs of photons generated by the laser and BBO crystals can be reliably used to perform secure communication tasks.

Ref: https://doi.org/10.1103.PhysRevA.98.022311, https://doi.org/10.1103.PhysRevA.101.020301

Your Exhaled Breath May Reveal Gastric Disorders

Manik Pradhan

When we exhale, we breath out several thousands of molecules with a diverse range of concentrations. However, when we have any disease or metabolic disorder, or any kind of bacterial infection, the profile and excretion kinetics of these exhaled molecular constituents change. Their concentrations may also change from the normal levels. Some of these molecules or their specific isotopes may be associated with the pathogenesis of the disease and can be markers of the particular medical conditions. Consequently, when our health changes, breath analysis may provide an alternative, rapid and non-invasive diagnostic method.

Manik Pradhan and his research group have recently developed a new-generation non-invasive diagnostic strategy by means of human breath analysis that might help physicians for early and quick diagnosis of *Helicobacter pylori* bacterial infection residing in human stomach as well as

its related complicacies like ulcer disease and non-ulcerous dyspepsia, thus obviating the existing painful endoscopic and biopsy based tests.

Helicobacter pylori is a very common bacterial infection in human stomach and causes stomach inflammation (gastritis). This infection may lead to the development of peptic ulcer disease and certain types of cancer. Interestingly, this bacterial infection is often asymptomatic, indicating that most individuals have no noticeable signs or symptoms and thus their infection with the bacteria remain undiagnosed. Therefore, an early diagnosis is very essential to prevent complications.

Dr. Pradhan has established research collaborations with medical scientists to ensure the translation of the new breath analysis technology, so-called, "Pyro-Breath" to clinical testing. The medical challenges Dr. Pradhan's team has tackled include finding new "Breath-Prints" and estimating "Risk-Factors" of various gastric disorders for non-invasive diagnosis of these diseases with an accuracy better than 96% when compared with "gold-standard" endoscopic tests. This will make appealing case studies for communication of the impact of modern analytical science on health care to the general public and will certainly be a "game-changer" in non-invasive medical diagnosis. The "Pyro-Breath" technology exploits a simple residual gas analyzer (RGA) which scans specific "Breath-Print Masses (BPMs)" in real-time. These BPMs are strongly associated with the onset of *H. pylori* infection and various gastric disorders such as gastritis and ulcer. From the nature of the various exhaled molecules or their isotopic species (breath-prints), it is possible to noninvasively monitor whether a person has a specific type of gastric disorder or *H. pylori* bacterial infection or both. As this is a non-invasive and painless method, it would be an attractive and alternative diagnostics method for any persons including infants, children, pregnant woman and seniors. This breath test method may also help to follow-up the patients after standard therapies, thus avoiding further painful and invasive endoscopic method.

The idea of disease diagnosis based on human breath analysis was also presented to Dr. Harsh Vardhan, the Hon'ble Union Minister of Science and Technology, Govt. of India, when Dr. Vardhan visited Dr. Pradhan's lab at S. N. Bose Centre, Kolkata in 2015. Dr. Vardhan's great appreciation on breath analysis work and subsequent tweet played a pivotal role in Dr. Pradhan's group in transforming ideas into a product. The group has already filed a patent, dated on 21/01/2016 (File No: 201631002214) for this technological innovation.

However, few prototype "Pyro-Breath" analyzers have been developed in the last few years to establish the *proof-of-concepts* and subsequently for demonstration and technology showcase as picturised below. One prototype breath analyzer has currently been installed in a reputed hospital at Salt Lake, Kolkata for large-scale clinical trial. Breath tests are being performed on patients in regular basis for non-invasive diagnosis of *H. pylori* bacterial infection as well as gastric disorders. Three startup companies have already shown their interests to take up this technology for commercialization and the transfer of technology (TOT) is currently under process through NRDC, New Delhi.

Patent filed: *"A System and Kit For Non-invasive detection of Peptic Ulcer Diseases, Non-Ulcerous Dyspepsis And Helicobacter Pylori Infection"*, Indian Patent: File No: 201631002214 (dated: 21/01/2016); Inventors: M. Pradhan & A. Maity.

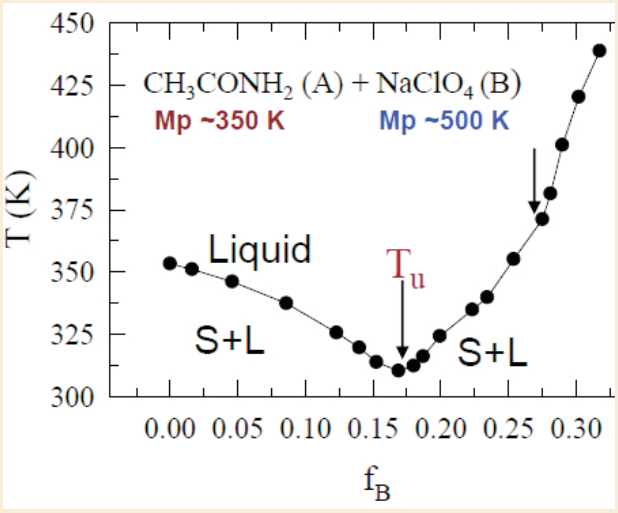
Sone pe Sohaaga – Icing on the Cake!

Ranjit Biswas

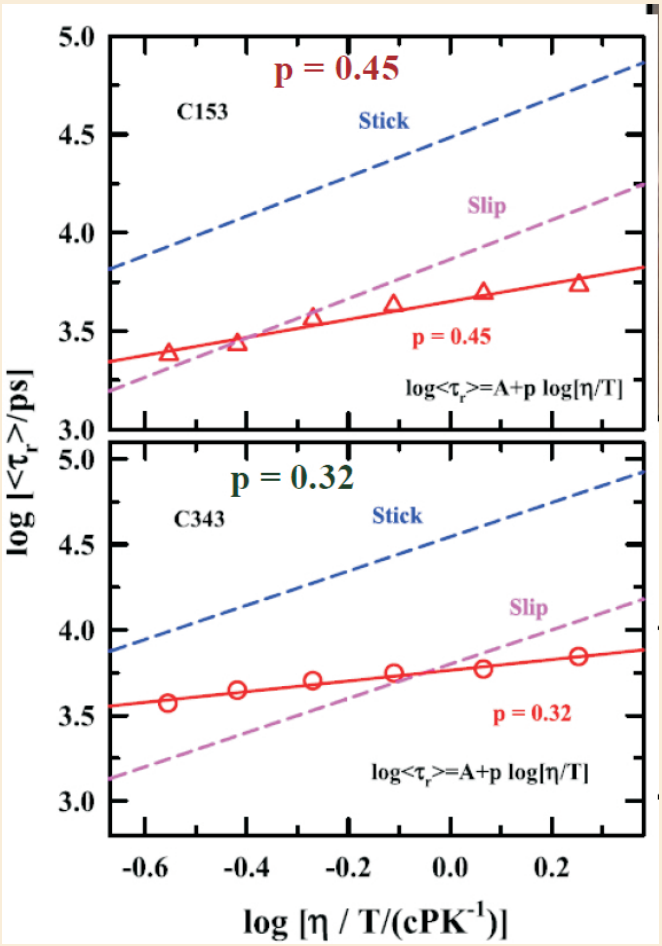
All of us are familiar with the proverb '*Sone pe Sohaaga*'- aren't we? What exactly does this mean? In English, the closest to this is '*Icing on the cake*' or '*Cherry on top*'. Broadly, this proverb means additional benefit to something that is already considered positive or beneficial. For food, this indicates addition of taste or aroma enhancer; insertion of an appropriate stone to a pendant could do the same to the beauty of an attractive necklace. But you wonder what this has to do with science? Yes, it has a lot to do with science! The action

hermitically expressed in this can indeed generate a huge interest among chemical engineers who look for accessing, through liquid solvent engineering, new environment friendly reaction media for large scale industrial applications as well as basic science researchers who searches for non-uniformity inside seemingly uniform distributions. Let us elaborate a bit with some examples.

Many of us have witnessed local goldsmiths, using a wax lamp and blow-pipe, trying to melt something by directing the lamp light on a target plate via controlled yet intense blowing. What was done there was simple melting of gold ornaments by mixing with a known amount of *sohaaga* or borax. The use of borax for melting gold is known for more than 100 years. Borax, whose chemical formula is $Na_2B_4O_7.10\ H_20$, melts at around 1000 K. Gold melts at around 1300 K. Interestingly, when gold is sprayed with the right proportion of borax and heated the mixture melts at around 850 K! Then this molten mixture was used to refine gold by following a process known them. Note here the mixture melts at a temperature much lower than the melting temperature of both gold and borax. This depression of melting point is a source for preparation of a new class of solvents known as deep eutectic solvents, and a manifest of colligative property often read in Physical Chemistry. The figure below explains this deep depression of melting or freezing point.



This figure shows that addition of an electrolyte, sodium perchlorate ($NaClO_4$) to an organic compound, acetamide (CH_3CONH_2) can bring down the melting temperature near to room temperature. The beauty of these 'deep eutectic solvents' is that they remain as a stable liquid at that eutectic temperature (T_u) even after removing the heat source. The number of such combinations are practically limitless as innumerable compounds are available that are capable of, on right combinations, producing deep eutectic solvents (DESs) with desired physicochemical properties. In addition, they are less hazardous to handle and transport because the parent components are solid. One may even find biodegradable components to produce room temperature DESs. Indeed we have produced two such DESs and studied the basic physical chemistry aspects. They are (i) glucose-urea-water DES[1] and (ii) betaine-urea-water DES.[2] In both these media we found, via time-resolved spectroscopic measurements, strong deviation from the simple inverse proportionality relationship between the diffusion process and viscosity of the medium. A representative figure depicting this for the glucose containing DES is shown below.



Refs: E. Tarif, J. Mondal and R. Biswas" by E. Tarif, J. Mondal, and R. Biswas, *Journal of Molecular Liquids*, 2020, 303, 112451(1-11).

Vanishing Resistance and "Giant" Mass Fluctuation in Self-Propelled Particles

Punyabrata Pradhan

Active matters are ubiquitous in nature. They can be found in living systems, such as fish schools, swarm of insects, flocking birds and bacterial colonies, and in non-living systems, such as chemically powered colloids and

thermos-phoretic particles. Active matters consist of interacting self-propelled "particles", or units, which convert internal or external chemical energy to mechanical one and traverse ballistically in a particular direction for some time (called persistence time), before changing their directions randomly. Due to continuous input of energy, such systems are driven far from equilibrium and exhibit, unlike in equilibrium, fascinating collective behaviours like clustering, "giant" mass fluctuations and anomalous transport. Particularly, their transport properties can be perplexing at times. Consider a cup of coffee, stirred with a spoon. If one stops stirring, the coffee will eventually come to rest, due to the internal viscous forces, which resist the fluid motion. On the other hand, imagine "stirring" a bacterial solution, which can exhibit perpetual or unceasing collective directed motion. Indeed, several experiments *[Phys. Rev. Lett. 115, 028301 (2015)]* demonstrated this intriguing phenomenon where the *viscous resistance*, under suitable conditions (bacterial concentration), vanishes in such "active" bacterial fluids. That is, the resistive forces in the bacterial solution can be much smaller than that in the solution without bacteria. There have been several phenomenological theories *[Phys. Rev. Lett. 92, 118101 (2004)]*, however understanding of the anomalous transport from microscopic dynamics have been lacking so far. To this end, we studied a toy model of an active fluid, consisting of interacting self-propelled particles. Here the ballistic motion of bacteria (like *Escherichia coli*) are mimicked through long-ranged particle hopping and the excluded-volume interactions among bacteria are incorporated through hard-core interactions among particles. Due to the simplicity of the model, we can analytically calculate the two transport coefficients, the bulk-diffusion coefficient and the conductivity, characterizing collective density relaxation and determining the mass fluctuations in the system. We show that, upon tuning concentration beyond a critical value, the conductivity, or the mobility, of the self-propelled particles diverges; in other words, *the resistance of the active fluid becomes zero*! Moreover, we demonstrated an intimate relationship between the zero resistance and the diverging mass fluctuations in the system, thus explaining the dynamical origin of the "giant'' mass fluctuations, observed in innumerable studies in the past. We believe our study would provide some useful insights into the emergent properties of active matters in general.

Ref: *Hydrodynamics, superfluidity, and giant number fluctuations in a model of self-propelled particles*, T. Chakraborty, S. Chakraborti, A. Das, and P. Pradhan, Phys. Rev. E 101, 052611 (2020).

Ph. D. Awarded / Submitted

Ph.D. degree awarded

1. **Supriyo Ghosh**, Thesis title: *Studies of Cool and Evolved Stars.* Supervisor: Soumen Mondal

2. **Anindita Mondal**, Thesis title: *Multi-wavelength Studies of Novae*. Supervisor: Ramkrishna Das and Soumen Mondal.

3. **Probir Kumar Sarkar**, Thesis title: Spectroscopic Studies on Molecules and Nanomaterials for Potential Applications in Medical Diagnosis and Environmental Pollution Monitoring. Supervisor: Samir Kumar Pal.

4. **Priya Singh**, Thesis title: *Spectroscopic Studies on Structure, Function and Dynamics of Biological Macromolecules in Physiologically Relevant and Engineered Environments.* Supervisor: Samir Kumar Pal.

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7. **Nafday Dhani Milind**, Thesis title: *Electronic Structure and Magnetic Properties of Graphene Derivatives and Graphene-based Composite Structures.* Supervisor: Tanusri Saha Dasgupta.

8. **Indranil Chakraborty**, Thesis title: *Magneto-Fluorescent Transition Metal Oxide Nanostructures for Biomedical Application*. Supervisor: Kalyan Mandal.

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11. **Sumanta Kundu**, Thesis title: *Some Studies of Percolation Phenomena in Disordered Systems.* Supervisor: Subhrangshu S Manna.

12. **Arpan Krishna Mitra**, Thesis title: *Canonical Formulation of Fluid Dynamics*. Supervisor: Rabin Banerjee.

Ph.D. thesis submitted

1. **Sandip Saha**, Thesis title: *Characterization of Periodic Orbits in Open Nonlinear dynamical Systems.* Supervisor: Gautam Gangopadhyay

2. **Sanchi Maithani**, Thesis title: *Evanescent wave and cavity enhanced absorption spectroscopy for trace molecule sensing using diode and quantum cascade lasers*. Supervisor: Manik Pradhan.

3. **Kajal Kumbhakar**, Thesis title*: Interactions and Dynamics of Cryoprotectants, Energy Materials and Other Complex Mixtures*. Supervisor: Ranjit Biswas.

4. **Tuhin Kumar Maji,** Thesis title: *Spectroscopic and Computational Studies on Functionalized Nanohybrids for Potential Manifold Applications*. Supervisor: Samir Kumar Pal.

5. **Suraka Bhattacherjee**, Thesis title: *Study of Generalized Spin and Charge Stiffness Constants of Doped Quantum Anti-Ferromagnets on Low Dimensional Lattices Based on T-J-Like Models*. Supervisor: Ranjan Chaudhury.

6. **Avinash Kumar Chaurasiya**, Thesis title: *Investigation and Control of Spin Waves in Ferromagnetic Thin Films, Interface and Nanostructures.* Supervisor: Anjan Barman.

7. **Santanu Pan**, Thesis title: *Experimental Study of Ultrafast Spin Dynamics in Ferromagnetic Thin Films and Multilayers*. Supervisor: Anjan Barman.

8. **Dipika Mandal**, Thesis title: *Magnetic, Dielectric and Microwave Absorption Properties of Transition Metal based Ferrite Nanostructures.* Supervisor: Kalyan Mandal.

9. **Subrata Ghosh**, Thesis title*: Large Magnetocaloric Effect in Low-Cost Transition Metal Based Alloys for Magnetic Refrigeration.* Supervisor: Kalyan Mandal

NEWS AND EVENTS (ADMINISTRATIVE)

Hindi Workshops at the Centre

1. Online Hindi Workshop held on 28.09.2020; Topic: "*Rajbhasha Hindi aur Uplabhdh Takniki Subhidhao ka Prayog*"; Speaker was Shri Dinesh Kumar Sharma, Hindi Officer, Indian Oil, Mumbai.

2. Online Hindi Workshop held on 10.12.2020; Topic: "*Karyalayen Hindi Ka Swarup*"; Speaker was Dr. Sanjay Kumar Jaiswal, Assistant Professor, Hindi Department, Vidyasagar University, Midnapore, West Bengal

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