Title & Abstracts

Part-I (5-7 June): Semi-pedagogical talks

Bimalendu Deb, IACS

EPR Paradox & Bell's Theorem

In a paper published in 1935 [A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. 47, 777 (1935)], Einstein, Podolsky and Rosen argued that certain types of quantum mechanical predictions are in conflict with the principle of "locality", and hence quantum mechanical description is not "complete". This is what is known as EPR paradox which had led to a long debate whether quantum mechanics required extra variables (known as "hidden variables") for its completeness. Thirty years later, John S. Bell [J. S. Bell, Physics (N.Y.), 1, 195 (1965)] gave the first quantitative criterion (now known as Bell's inequality) to test the validity of hidden variable theory. Bell's work had tremendous implications on the foundation of quantum physics, leading to several experimental attempts in 70s and 80s to prove or disprove whether or not hidden variables were required to explain certain quantum mechanical results. These attempts were culminated with the conclusive experimental proof given by Aspect, Grangier and Roger [Alain Aspect, Philippe Grangier, and Gerard Roger, Phys. Rev. Lett. 49, 91 (1982)] that hidden variable theory is not tenable. Thus EPR paradox is resolved and the triumph of quantum mechanics is firmly established.

In this semi-pedagogical talk, after a brief description of EPR "paradox" (though it is no more a paradox), a derivation of Bell's inequality will be given. The 1982 experiment will be discussed. Implications of all these progress on the emerging nonlocal quantum physics and its applications will be briefly outlined.

Debasis Sarkar, University of Calcutta

Quantum Correlations- Entanglement and beyond Entanglement

Entanglement is one of the most profound inventions of quantum information theory. It is effectively the quantum correlation that exists between different subsystems of a composite system. Apart from its peculiar characteristics, entanglement is considered as an important physical resource in various quantum information processing tasks. However, recent investigations show other non-classical correlations exist beyond entanglement; e.g., quantum discord that relates two different notions of mutual information as obtained from classical theory. It creates lot of interest now-a-days as it is observed that there is trait of non-classical correlation beyond entanglement. In light of various such measures quantifying quantum correlations in composite systems, it is natural to investigate various relations or hierarchies between them. In our lecture we will try to review some of the quantum correlations. As application, we will discuss the most fascinating discovery of quantum information theory, viz., quantum teleportation.

Bhupendra Nath Dev, IACS

Solid-State Quantum Structures in Quantum Information Processing and Quantum Technology

Information processing is entering from the classical regime to the quantum regime. After presenting a brief historical development and requirement for quantum information processing, some basic solid-state quantum structures will be discussed. This presentation will further explore how these quantum structures are being used for developing quantum computers and quantum technology.

Manas Mukherjee, CQT, NUS, Singapore

Quantum control of a few atoms, photons and phonons

A system of well controlled few atoms interacting with a single or a few photons, drives the fields of precision measurement, single ion clock, quantum information and computation, thermodynamics in quantum limit and much more. In these few lectures, we will build up the basics physics behind such a system namely ion trap, atom-light interaction, basic quantum logic operations and measurement procedures. We will conclude discussing some examples of the present state-of-the-art experiments in this field.

Arnab Das, IACS
Quantum Computation and it's Analog Version: A Basic Primer
The basic idea of quantum computation and some physically motivated realizations will be discussed.

Subhadeep De, NPL, New Delhi
Precise "time keeping" using atoms and lasers
Accurate timing system is the basis for many sophisticated technologies that are being used in our daily life. However most of the time we do not pay attention to it. As for example, high speed communication, positioning of satellites in their orbits, navigation, weather prediction, digital archiving, international trade, transportation, electronic transaction and many more rely on accurate time stamping as well as synchronization of it to a standard reference. In scientific researches measuring temporal constancy of fundamental constants, violation of Lorentz symmetry, radio astronomy, space research and so on depends on ultra-precise timing systems. Thus, due to vast requirements worldwide there is a continuous effort for upgradation of the atomic clocks since these are the backbone for generation and maintenance of accurate time and frequency. Presently "one second" is defined as the time required for 9 192 631 770 oscillations between doubly splitted hyperfine ground states of caesium-133 atoms, when they are cooled to 0 K. The state of the art laser cooled and trapped caesium fountain clocks has reached to an uncertainty of few parts in 10^{16} which is few second inaccuracy of time over the age of the Earth (4.543 billion years). The caesium based SI definition of second has served last five decades and it is expected that it will be redefined based on an optical transition in the coming years. Due to the fact that this unprecedented accuracy does not meet the requirement of many scientific experiments to unravel truths of nature. The optical clocks operate in few hundreds of THz associated to a highly forbidden electronic transition of the atomic systems and reaches to an accuracy of few parts in 10^{18}. In absolute time this can be compared to 1 s inaccuracy of the clock that is running since the big bang (that is age of universe 13.8 billion years). The optical clocks are realized using both neutral atoms and singly charged ions. The optical atomic clock use either neutral atoms localized in an optical lattice or a single atomic ion trapped in an electrodynamic trap. In both of these cases the trapped species are laser cooled to mK temperature, which are then used to probe the forbidden optical transitions in it. Applications of the precise timing systems together with the present scenario of the atomic clock technologies will be discussed in this meeting.

Saikat Ghosh, IIT-Kanpur
Cavity QED/Cavity Optomechanics

Part-II (8th June): Discussion Meeting

Prasanta Panigrahi
Cat and Kitten states : Their use is quantum metrology
Cat and Kitten states are superposition of classical coherent states, showing highly quantum behavior. Their physical properties will be studied in the phase space through the Wigner function. The effect of interference in phase space leads to sub-Planck structures, which can be used for sensitive quantum metrology. I will elaborate on the wek measurement and weak values, which appear in a domain where interference effects are minimal.

Bhupendra Nath Dev
Solid-State Quantum Structures

Krishnendu Sengupta
Entanglement generation and dynamical transition in a periodically driven integrable closed quantum system.

Subhadeep De
Atomic clock

Sonjoy Majumder
Interaction of trapped Rydberg atoms with optical vortex
Optical light with orbital angular moment (OAM) is popularly know as optical vortex. Recently we have shown the formalism of OAM transfer from light to ultra cold atoms and molecules. Here I will discuss the mechanism of OAM of light to trapped Rydberg state of atoms under paraxial approximation. We consider Laguerre-Gaussian (LG) beam as our input light source. Our derivation shows that optical OAM can be directly transferred or shared to the electronic state of Rydberg atom at the level of dipole transitions unlike trapped atoms in their ground state. The Gaussian part of the profile of the LG beam, which is generally neglected, is found to have an important effect on the OAM transfer to the Rydberg atoms. Our numerical calculations using Rydberg Rubidium atoms trapped in a axisymmetric harmonic potential show mixing of the final states of different parities. Interesting feature will be shown on controlling different electronic transitions by changing combinations of OAM and polarisation of light.

Subhadeep Dutta
Mesoscopic quantum dot physics and nanomagnetism

Dipankar Bhattacharya
Observation of EIT and EIA signal in Rb-D2 transition

Pradip Mandal
Exchange of angular momentum in interaction of optical vortex beams with molecules

Shyamal Kumar Bhadra
Negative resonant radiation in optical nonlinear medium
The massless Dirac equation predicts the existence of two conjugate solution e.g. particle and anti-particle. It is expected that Maxwell's electromagnetic equation can predict two eigen solutions one in the positive frequency domain and other in the negative frequency domain irrespective of the direction of propagation of EM wave. The study of Maxwell's wave equation incorporating laboratory frame negative frequencies gives interesting results which can be observed in nonlinear optical medium like in photonic crystal fiber. Intense pulse propagation in such nonlinear media provides an analogue system to study the physics of astrophysical event horizon. Incorporation of negative frequency domain in such study will be more interesting. Some of these aspects will be presented.

Somobrata Acharya
Nanomaterials Based Device Applications
Nanomaterials appeared as central building blocks for manifold device applications. These building blocks consist of quantum dots, nanorods, nanowires and nanosheets. Coupled quantum dots (CQDs) consist of two or more different semiconductor quantum dots (QDs) containing junctions at the interface of the constituent blocks [1, 2]. Unlike the band gap tuning by changing the sizes of mono-component QDs, CQDs rely on controlling the band gap by band-offset engineering at the interface. Such complex nanostructures allow spontaneous charge carrier separation or recombination across the interface to obtain tunable photovoltaics or electroluminescence properties respectively. We showed the possibility of fabrication of solar cell and light emitting devices using such junctioned materials. We developed a method to design two-dimensional (2D) nanocrystals with high performance dielectric properties. 2D structure was achieved through dimensional change from nanorods to nanowires, from nanowires to 2D

structure by using surface-pressure as direct driving force or by direct colloidal synthesis route [3, 4]. These novel processes led to the fabrication of well-controlled freestanding 2D nanocrystals suitable for miniaturized device fabrication. Incorporation of nanomaterials in garbage nylon enhances the surface roughness which could be used for enhancing the output power of Triboelectric generator. We described such possibility using nylon and PVDF combinations. Taking together, the prospects of nanomaterials in manifold device applications will be described.

References:

[1] S. Sengupta, N. Ganguly, I. Dasgupta, D. D. Sarma, S. Acharya *Adv. Mater.* **2011**, *23*, 1998–2003.

[2] S. A. Ivanov, A. Piryatinski, J. Nanda, S. Tretiak, K. R. Zavadil, W. O. Wallace, D. Werder, V. Klimov *J. Am. Chem. Soc.* **2007**, *129*, 11708–11719.

[3] S. Acharya and S. Efrima *J. Am. Chem. Soc.* 127, 3486- 3490 (2005)

[4] S. Acharya, B. Das, U. Thupakula, K. Ariga, D. D. Sarma, J. Israelachvili, and Y. Golan, *Nano Letts.* 13, 409-415 (2013)