International School and Conference on Quantum Information

ISCQI-2008

Institute of Physics, Bhubaneswar

Title and Abstract of Talks

Organisers

Arun K Pati
Pankaj Agrawal

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Anwar, S

Title: **Quantum Computing with Para-Hydrogen**

Bose, Saugata

Title: **Quantum Communication and Entanglement Distribution Through Spin Chains and Allied Systems.**

Abstract: I will start with a brief introduction to the use of a spin chains for quantum communications. Following this, I will describe some methods to perfect these communications using certain reasonbable strategies when one uses chains in their ferromagnetic ground state. I will then briefly point out the use of antiferromagnetic spin chains for the same purpose. Next, I will discuss the use of a bosons hopping freely in a one dimensional lattice to generate entanglement between its ends. I will also describe the generation of entanglement from the ground state of a chain of qudits coupled by purely exchange interactions.

Brukner, Caslav

Title: **Testing the (un)deciadablity of mathematical propositions in quantum experiments**

Abstract: Gels incompleteness theorem states that every consistent axiomatic system, capable of expressing elementary arithmetic, there are propositions which can neither be proven nor disproven within the system, i.e. they are ?undecidable?. It was argued that mathematical undecidability arises whenever a proposition to be proven and the axioms contain together more information than the set of axioms itself. I will show that quantum systems are capable of encoding mathematical axioms, and quantum measurements are capable of revealing whether a proposition is decidable or not. Quantum mechanics puts an upper limit on how much information can be encoded in a quantum state, thus limiting the information content of the set of axioms. I will show that if a mathematical proposition is undecidable within the system of axioms encoded in the state, then the measurement associated to the proposition gives random results. This allows for an experimental test of certain instances of mathematical undecidability and demonstrates a yet another application of quantum computer.

Cabello, Adan, University of Sevilla (Spain)

Title: **Bell's theorem with and without inequalities for graph states**

Abstract: Graph states play a fundamental role in quantum information theory as quantum error correcting codes and initial states for measurement-based quantum computation and quantum simulation. Consequently, considerable efforts are devoted to their investigation. Here we consider the following problems: (1) Given a multiqubit graph state, how many distant observers are needed for a Greenberger-Horne-Zelinger-like proof of Bell's theorem using only single-qubit measurements? We solve this problem and present the explicit solution for all graph states of up to 8 qubits. (2) Given a multiqubit graph state, which is the Bell inequality with the maximum resistance to noise involving only perfect correlations of the graph state? We solve this problem for all graph states of up to 6 qubits. We discuss the importance of these results to design a photonic loophole-free Bell experiment.

Chaturvedi, S.

Title :

Ghosh, Sibasish, IMSc (India)

Title: Classical simulation of two spin-s singlet correlations for spin measurements.

Abstract: In this work, we have given a classical protocol to simulate quantum correlations hª j~a: ~b: jª i corresponding to the spin-s singlet state jª¡s i of two spin-s particles, using the measurements of the spin observables ~a:~S , ~b:~S separately on the two spin-s systems. Here ~a, ~b are real three dimensional unit vectors and ~S = (Sx; Sy; Sz) is the vector of spin observables. In any local hidden variable theoretic model for quantum correlations, not only we reproduce (via simulation) the marginal probabilities of having the outcomes ~a:~S = j, ~b:~S = k (where j; k = ¡s;¡s + 1; : : : ; s¡1; s) for the shared state jª¡s i but we also reproduce the joint probability of having the joint outcome ~a:~S = j and ~b:~S = k for the same shared state (and thereby, we reproduce the correlation hª¡s j~a:~S ~b:~S jª¡s i). In the folklore of classical simulation of quantum correlations, we generally put forward the apparently weaker task of reproducing the marginal probabilities as well as the the above-mentioned correlation, not necessarily the above-mentioned joint probabilities. Even in this weaker setting, one would require, in general, to have classical communications (on the top of local hidden variable theory) to get the simulation done. When s = 2, it turns out that there is no di®erence between the stronger simulation scenario versus the weaker one so far as the required amount of classical communication is concerned. In the weaker version of simulation, we have shown that, in the worst case scenario, dlog2(s + 1)e bits of communication will do the simulation job where dxe is the least integer greater than or equal to x. The simulation scheme we followed here is based on the binary representation of the Hilbert space dimension 2s + 1 of individual systems. To check the optimality of this simulation scheme, we have compared this scheme with another simulation scheme where 2s+1 is equal to n-th power of an integer. Although in the ¯nite regime, these two schemes require, in general, di®erent amount of classical communications, in the asymptotic case (i.e., for large s limit), the don't di®er. We have also tried to focus on the stronger version of the simulation method.

Goswami, D

Title: **Probing coherence aspects of adiabatic quantum computation**

Goyal, S.

Title : **The Structure of State Space for Quantum Information**

Gruska, Jozef, Faculty of Informatics, Masaryk university,Czech republic

Title: QUANTUM CHALLENGES of QUANTUM CRYPTOGRAPHY (for quantum information processing and physics)

Abstract: Quantum cryptography has developed in a short time to be a very broad and very applied area of science in which laws, limitations, elements and processes of quantum world are used to bring new quality to the area of security that is of growing importance for society and that also brings new challenges for our understanding of quantum physics in general and of quantum information processing in particular. Similarly, as in the classical case, key concepts of quantum cryptography play the key role for quantum information processing and communication. The aim of the talk is at first to present, discuss and analyze main primitives and new challenges of broadly understood quantum cryptography, both from security points of view as well as from the related quantum (information processing) problems. Secondly some recent particular approaches and challenges will be discussed in details.

Ivan, Solomon

Title : **Non-Classicality and Entanglement**

Joag, Pramod S, University of Pune

Title: **An Experimentally Accessible Geometric Measure for Entanglement in 3-Qubit Pure States.**

Abstract: We present a new entanglement measure for three qubit pure states which is experimentally accessible.We prove various properties of this measure for N-qubit pure states except one which we prove only for 3-qubit pure states.We compute this measure for N-qubit GHZ and W states and give more examples.

Kar, Guruprasad, ISI, Kolkata

Title: **Causality, Bell's inequality and quantum mechanics**

Abstract: In a general probabilistic theory, violation of Bell's inequality (even by its algebraic maximum) may not imply violation of causality. But there is a limit (Tsirelson's bound) on the quantum violation of Bell's inequality. This limit is not just a consequence of Hilbert space formalism of quantum mechanics, but it has physical consequence. Violation of this limit by quantum mechanics would imply instantaneous signaling. This is shown by using the joint measurement formalism of quantum mechanics.

Kumar, Anil, IISC, Bangalore

Title: **Experimental Implementation of Adiabatic Quantum Algorithms by NMR**

Abstract: Quantum algorithms start from a well defined initial state and perform computation by a sequence of reversible logic gates. After computation the final state of the system contains the result of the computation. Quantum adiabatic algorithms provide an alternate method of computation. In this method the computation is performed by evolving the system under a time varying Hamiltonian for a given amount of time. Such algorithms start from a well defined ground state and by evolution under a slowly varying Hamiltonian reach the desired output state. The ground state of the final Hamiltonian encodes the solution of the problem, but is not easy to prepare directly. The ground state of the beginning Hamiltonian is however, easy to prepare. Quantum adiabatic algorithms have been efficiently applied to various optimization problems. In these cases the condition of adiabaticity is fulfilled "globally" by using only the minimum energy gap between the ground state and the first excited state for calculating the time of evolution. This method is not efficient for some algorithms such as Grover's search algorithm and the DeutschJosza algorithms. These can be made efficient by using "locally" adiabatic evolution, where the adiabatic condition is fulfilled at each instant of time. This technique has been adopted by Roland and Cerf (PRA 65, 042308, 2002) for adiabatic Grover's algorithm and by S. Das (PRA 65, 062310, 2002) for adiabatic DJ algorithm. In this talk, we will present NMR Implementation of these two algorithms. Sometimes the adiabatic algorithm takes long time for its implementation, times longer than the "Coherence time", which degrade the performance of the algorithm. We have used "Control Theory" to optimize the implementation of one of such algorithm by using "Strongly Modulated Radio frequency Pulses" (SMP). The use of SMP will be described to implement globally adiabatic 1SAT problem in a homonuclear three qubit system by NMR.

Majumdar, A. S., S. N. Bose National Centre for Basic Sciences (India)

Title: **Teleportation and Broadcasting of continuous variable entanglement**

Abstract: We present the first example for broadcasting of the entanglement of a two-mode squeezed state of the electromagnetic field shared by two distant parties into two nonlocal bipartite entangled states. Using the technique of covariance matrices we demonstrate the entanglement between the nonlocal output modes and the separability of the local output modes. We find the range of values for the squeezing parameter and the amplifier phase for which broadcasting of continuous variable entanglement can be implemented for physical states. We next present a scheme for teleporting two-mode entangled states of continuous variables from Alice to Bob. Our protocol is operationalized through the creation of a four-mode entangled state shared by Alice and Bob using linear amplifiers and beam splitters. Teleportation of the entangled state proceeds with local operations and the classical communication of four bits. We compute the fidelity of teleportation and find that it exhibits a trade-off with the magnitude of entanglement of the resultant teleported state.

Nair, R

Title:

Pal, Sudebkumar Prasant, Professor, Dept. of Computer Sc. and Engg., IIT Kharagpur 721302

Title: **Combinatorial methods for studying LOCC incomparability**

Abstract: We consider a set V of n sites and a set E of e arbitrary subsets of these n sites, where each subset S of V shares a CAT state amongst its own sites. Such a set E is called an entanglement configuration of e CAT states defined over n sites. Given two distinct entanglements configurations E1 and E2 over the same set V of n sites, we address the question of LOCC incomparability between E1 and E2. We demonstrate the limitations of partial entropic criteria in establishing LOCC incomparability forsome such pairs of configurations. We characterize certain classes of configurations where partial entropic criteria are applied judiciously using combinatorial approaches in order to establish non-trivial LOCC incomparability results. Finally, we address the issue of quantum distance between LOCC incomparable configurations.

Panigrahi, P. K., Indian Institute of Science Education and Research and Physical Research Laboratory (India)

Title: **Teleportation, Quantum Information Splitting and Dense Coding through Cluster and Brown States**

Abstract : Brown state is a five qubit entangled state which reveals robust multi-partite entanglement property, so far confirmed through numerical checks. We illustrate its utility by explicating its efficacy for teleporting two qubit states, as well as its use in quantum information splitting and dense coding. We then analyse the much studied and experimentally realized Cluster states for their use in quantum information splitting. A number of algorithms are exhibited for splitting of one and two qubit states, which can also be entangled. Plausible experimental schemes are also exhibited.

Patel, Apoorva, IISC Bangalore

Title: **Improving quantum random walk search on a hypercubic lattice**

Abstract: We present a quantum random walk algorithm, based on the Dirac operator and without a coin toss instruction, to search for a marked vertex on a hypercubic lattice in arbitrary dimensions. We demonstrate how inclusion of a mass term improves the search speed.

Pareek, T. P., HRI

Title: **Spin based quantum computing in solid state systems**

Abstract: In this talk we will review recent developments in spin-based solid state quantum computing. We will review some of the many theoretical proposals for solid state quantum computation based on controlling Heisenberg exchange interaction between two neighbouring spin quantum dots. In most of these proposals, control of Heisenberg exchange interaction is achieved by changing the gate voltage which controls the overlap of wavefunction between two electrons. In contrast to this we will discusses a proposal based on Rashba spin orbit interaction which can be tuned by an external gate voltage and does not require wavefunction overlap between two electrons which is difficult to control. We will discusses the spin coherent transport in presence of spin-orbit interaction and provide a generalized Landauer_B\"uttiker spin and charge transport theory. Our analysis shows that spin-orbit interaction in quantum dots leads to equilibrium and non-equilibrium spin currents in non-magnetic ideal leads. We point that equilibrium spin currents can be controlled by an external electrical filed and can be used to initializes the spin qubit states. Further it also provide possibility of implementing some of the quantum gates.

Qiu, Daowen

Title: **Bounds on minimum-error discrimination between mixed quantum states.**

Abstract: In this talk, we talk a general lower bound on the minimum-error probability for ambiguous discrimination between arbitrary m mixed quantum states with given prior probabilities. When m=2, this bound is precisely the well-known Helstrom limit. Also, we report a general lower bound on the minimum-error probability for discriminating quantum operations. Then we further analyze how this lower bound is attainable for ambiguous discrimination of mixed quantum states by presenting necessary and sufficient conditions related to it. Furthermore, with a restricted condition, we introduce a upper bound on the minimum-error probability for ambiguous discrimination of mixed quantum states. Therefore, some sufficient conditions are also presented for the minimum-error probability attaining this bound. Finally, under the condition of the minimum-error probability attaining this bound, we compare the minimum-error probability for ambiguously discriminating arbitrary m mixed quantum states with the optimal failure probability for unambiguously discriminating the same states. To conclude, we address some open problems for further consideration.

Rajagopal, K .

Title: **Distinctive Subdynamic Features of Bipartite Systems**

Abstract: There are several important bipartite systems of great interest in condensed matter physics (e.g., electron-phonon) and in quantum information science (e.g.,bipartite dbits). In condensed matter systems, the subsystems are examined traditionally by using the Green function and mean-field-like methods based on the Heisenberg representation. In quantum information science, the subsystems are handled by composite density matrix, its marginals describing the subsystems, and the Kraus representation to elucidate the subsystem properties. In this work, we first establish a relationship between the two techniques which appear to be distinct at first sight. We will illustrate this in detail by presenting the two methods in the case of the celebrated exactly soluable Jaynes – Cummings model (1963) of a two-state atom interacting with a one-mode quantized electromagnetic field. The dynamics of this system was treated in the Heisenberg representation by Ackerhalt and Rzazewski (1975) and the corresponding subdynamics using a modification of Kraus representation by the present authors (2007). In this work, we establish a relationship between the two and discuss the relative merits of the two techniques in elucidating the distinctive features of the subdynamics. The striking effects of interaction and entanglement are reflected in the dressing of the non-interacting number and spin representations displaying quasi-particle-like properties.

Sacchi, Massimiliano Federico, Pavia, Italy

Title: **Minimum-error-probability and minimax discrimination of quantum operations.**

Abstract: We address the problem of discriminating two given quantum operations both in the Bayesian approach (minimising the error probability) and in the minimax approach (maximising the smallest of the probabilities of correct identification). Unlike in the case of discrimination between unitary transformations, we show that the use of entanglement with an ancillary system can strictly improve the discrimination.

Sarkar, Debasis, University of Kolkata

Title: **On Local Distinguishability and Indistinguishability of Orthogonal Composite States**

Abstract: The problem of local distinguishability and indistinguishability of orthogonal quantum states shared between distant parties is one of the most important issues in quantum information processing. Since the states are orthogonal, therefore globally they are distinguishable. But the situation is dramatically peculiar if we restrict ourselves with only local operations alongwith classical communications (in short, LOCC). The results are just counterintuitive. There exists set of locally indistinguishable completeorthonormal product basis (the feature is known as non-locality with entanglement); in contrast, there are many sets of locally distinguishable orthogonal entangled states. It is quite interesting to study the behaviour of canonical set of maximally entangled states in any dxd system. The complete set of d^2 orthonormal basis is locally distinguishable with certainty, if two copies

of each state is supplied. However, for single copy case, any set of more than d maximally entangled states is not locally distinguishable with certainty. For d or less than d number of states, the result is not complete yet. In my lecture, I would like to address the basic issues of local distinguishability or indistinguishability in general. In particular, my aim is to provide some evidences to resolve the problem of local distinguishability of maximally entangled states in canonical form for set consisting of d or less than d number of states.

Schuch, Norbert

Title: **Simulating quantum many-body systems using string-bond states**

Abstract: We introduce string-bond states, a class of states obtained by placing strings of operators on a lattice, which encompasses the relevant states in Quantum Information. We show that for string-bond states, expectation values of local observables can be computed efficiently using Monte Carlo sampling, making them suitable for a variational abgorithm which extends DMRG to higher dimensional, frustrated, and irregular systems. We relate string bond-states to Matrix Product States (MPS) and Projected Entangled Pair States (PEPS), and show how Monte Carlo sampling can be used to speed up general MPS and PEPS-based algorithms as well.

Simon, R.

Title: **Entanglement and Gaussian States**

Sirsi, S

Title:

Srikanth, R.

Title: **The squeezed generalized amplitude damping channel**

Abstract: We consider the possibility of deriving the no-signaling theorem on basis of the assumption that, as seen from a computation theoretic perspective, the universe is a polynomial place. A fact that disallows such a derivation is the existence of operations, which we call {\em polynomial superluminal} gates, that permit superluminal signaling but cannot be harnessed to solve hard problems efficiently. Therefore, if we regard the polynomiality of the universe as a basic principle, then either additional assumptions are required to prohibit all such operations, or, where such a prohibition cannot be physically justified, no-signaling is not an exact law. Here we propose a quantum optical experiment involving position-momentum entangled photons, well within the reach of current technology, that seems to testably realize a polynomial superluminal gate. In fact, the operation is possibly already implicit in an experiment performed a decade ago.

Unnikrishnan, C. S., Gravitation Group, TIFR (India)

Title: **Quantum Correlations from Classical Insights: Implications to understanding entanglement and nonlocality**

Abstract: I will show that quantum correlations arise as a reflection of the validity of the classical conservation laws on the average in quantum ensembles. This has the implication that theories with even a slightly different correlation function are incompatible with conservation laws and symmetries, and hence physically irrelevant. The local hidden variable theories considered by Bell and others fall in this category. While discussing this result and its implications, I will trace the real source of the violation of Bell's inequalities in experiments and argue that the experimental results do not imply the violation of Einstein locality. The insights gained from this analysis help us in understanding quantum entanglement and the apparent nonlocality better. I will end with a few remarks on quantum entropy, in the context of these results.

Ushadevi, A. R., Department of Physics, Bangalore University (India)

Title: **Generalized measurements to distinguish classical and quantum correlations**

Abstract: We address the fundamental question of distinguishing classical and quantum correlations in bipartite states based on generalized quantum measurements performed on only one part of the system. A quantum correlated state is sensitive to such local measurements. An optimal measurement is one that disturbes the state minimally. On the other hand, there always exists an optimal measurement scheme under which a classically correlated state remains insensitive. Quantum discord, a measure proposed by Ollivier and Zurek [1] to extract genuine quantum correlations and another such quantification put forth independently by Henderson and Vedral [2], aim towards quantifying the minimum disturbance upon an optimized partial measurement (Ollivier and Zurek restrict themselves to orthogonal projective measurements; Henderson-Vedral consider optimization using POVMs) . Using these quantifications, it has been realized that only a subset of bipartite separable states show insensitivity to partial measurements performed on one of the subsystems. An alternative measure, quantum deficit- proposed by Rajagopal and Rendell [3] - which is the distance between the bipartite state with its decohered classical counterpart, is non-zero for a widerange of separable states implying that there exist residual quantumness in these states. These investigations suggest that the concept of quantum correlations goes beyond entanglement, as separable states too exhibit non-classical features. This naturally questions the traditionally accepted notion that separability and classicality of correlations are synonymous. We approach this issue by considering optimization over generalized measurements in a larger Hilbert space than that associated with the bipartite states and propose a new measure, quantumness [4]. We find that quantunmess vanishes for all separable states i.e., there always exists a generalized optimal measurement on separable states which leaves them unperturbed. We further show that that our measurement-based quantification gets related to the relative entropy of entanglement - a well-known measure of quantum entanglement. This provides the much needed connection between the concepts of quantum entanglement with those based on quantum measurement theroy. Such a connection leads to conflict free merging of quantumness of correlations with quantum entanglement itself. Issues like separating total correlations,quantified through mutual information entropy, into classical and quantum parts will also be elucidated.

Virmani, Shashank S., Imperial college, London

Title: **Many Body Physics and the capacity of Quantum Channels with Memory**

Abstract: I discuss a connection between lattice systems in many body physics, and the issue of quantum channel capacities in the presence of correlated error. A number of interesting models of correlated error can be viewed in this light, and one can observe "phase transition" like behaviour in the capacity of related quantum channels. We hope that such connections may give more general insights into non-analytic behaviour of the capacity of correlated quantum channels.

Zyczkowski, Karol, Jagiellonian University, Cracow and Centre for Theoretical Physics, Warsaw, Poland

Title: **Dark spaces, error correction codes, and decoherence free spaces** (analysed with help of higher rank numerical range)

Abstract: The notions of quantum dark spaces, quantum error correction codes and decoherence free spaces are reviewed. We show that the problem of finding these spaces is equivalent to an algebraic task of solving a set of coupled algebraic compression problems. This can be accomplished through finding the higher-rank numerical range of operators determined by a given quantum channel. A general solution of the quantum error correction problem is presented for the case of bi-unitary channels acting on a multiqunit system.

Adhikari, Satyabrata

Title: **Testing of the class of W-states as a channel for entanglement swapping**

Abstract: There are two important types of tripartite entangled state viz. GHZ-type state and W-type state. Like GHZ-type state, there are many important applications of W-type state in quantum information theory. We study here among one of them. Recently, Agarwal and Pati defined a new class of W-type state and showed that they can be used as a quantum channel for teleportation and superdense coding. In this work, we identify those three-qubit states from the set of new class of W-states which are most efficient. Further we show that with some probability $W_{1}=\frac{1}{2}(|100\rangle+|010\rangle+\sqrt{2}|001\rangle)$ is best suited for entanglement swapping channel in the sense that it does not depend on the input state.

POSTER PRESENTATION

Gandhi, Manjula S. and Prabhakar, R.

Title: **Quantum Query Complexity to determine Radius of a Graph**

Abstract: Algorithms are the key concepts of computer science. Classical computer science provides a vast body of concepts and techniques which may be reused to great effect in quantum computing. Many of the triumphs of quantum computing have come by combining existing ideas from computer science with the ideas from quantum mechanics. The question of which classical algorithms can be sped by quantum computing is of course a very interesting one. At present there are only few general techniques known in the field of quantum computing and finding new problems that are amenable to quantum speed ups is a high priority. Classically, one area of mathematics that is full of interesting algorithms is graph theory. It is therefore natural to ask whether any of the classical graph theory algorithms can take advantage of quantum computing. The problem of determining quantum query complexity for determining the Radius of a graph is considered. Quantum query complexity of a problem is the minimum number of queries required to the graph for solving the problem.

Gupta, Manu and Srikanth, R., Poornaprajna Institute of Scientific Research, Bangalore(India)

Title: General Circuits for Indirection and Distributing Measurement in Quantum Computation

Abstract: A problem of theoretical and practical interest is to measure a qubit observable indirectly by means of an ancilla that interacts with the qudit and is then measured in the computational basis. A related problem is to distinguish between various mutually orthogonal, entangled states of spatially separated qudits by means of such indirect implementations of incomplete measurements. We provide general circuits that can be used to implement such measurements and present their relevance to quantum error correction.

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