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WORKSHOP ON
THEORY AND TECHNOLOGY
in

QUANTUM INFORMATION, COMMUNICATION,
COMPUTATION AND CRYPTOGRAPHY

ICTP, Trieste, Italy
(19 - 23 June 2006)

LIST OF SPEAKERS' TALKS

(TITLES AND ABSTRACTS)

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01. G. ADESSO
Centre for Quantum Computation, DAMPT, Univ. Cambridge,
Cambridge, U.K.

TITLE: Entanglement in Gaussian matrix product states

ABSTRACT:
Gaussian matrix product states are obtained as the outputs of projection operations from an ancillary space of M infinitely entangled bonds connecting neighboring sites, applied at each of N sites of a harmonic chain. Here we show how the matrix product formalism, inherited from discrete-variable systems, proves effective in investigating the structure and the distribution of continuous-variable entanglement in N mode Gaussian states. Replacing the projections by associated Gaussian states, the'building blocks', we demonstrate that the entanglement range in translationally-invariant Gaussian matrix product states depends on how entangled the building blocks are. In particular, infinite entanglement in the building blocks produces fully symmetric Gaussian states with maximum entanglement range. From their peculiar properties of entanglement sharing, a basic difference with spin chains is revealed: Gaussian matrix product states can possess unlimited, long range entanglement even with minimum number of ancillary bonds (M=1). Finally we show how these states can be experimentally engineered from N copies of a three-mode building block and N two-mode finitely squeezed states.

02. K. AUDENAERT
Imperial College Department of Physics Blackett
Laboratory London

TITLE: Entanglement on mixed stabiliser states

ABSTRACT:
The stabiliser formalism allows the efficient description of asizeable class of pure as well as mixed quantum states of n-qubit systems. In this talk, I consider efficient reduction procedures to obtain various useful normal forms for stabiliser states. I explicitly prove that these procedures will always converge to the correct result and that these procedures are efficient in that they only require a polynomial number of operations on the generators of the stabilisers.

On one hand, I obtain two single-party normal forms. The first, the row-reduced echelon form, is obtained using only permutations and multiplications of generators. This form is useful to calculate partial traces of stabiliser states. The second is the fully reduced form, where
the reduction procedure invokes single-qubit operations and CNOT operations as well. This normal form allows for the efficient calculation of the overlap between two stabiliser states. As a by product I prove that the Uhlmann fidelity between two mixed stabiliser states is just the square root of their overlap, so that their Bures distance can also be calculated easily.

On the other hand, I also find a reduction procedure of bipartite stabiliser states, where the operations involved are restricted to be local ones. The two-party normal form thus obtained lies bare a very simple bipartite entanglement structure of stabiliser states. To wit, I prove that every bipartite mixed stabiliser state is locally equivalent to a direct product of a number of maximally entangled states and, potentially, a separable state. As a consequence, using this normal form I can efficiently calculate every reasonable bipartite entanglement measure of mixed stabiliser states.

03. H. BRIEGEL
University of Innsbruck Institut für Theoretische Physik

TITLE: Universal resources for measurement-based quantum computation

ABSTRACT:
We investigate which entanglement resources allow universal measurement-based quantum computation via single-qubit operations. We find that any entanglement feature exhibited by the 2D cluster state must also be present in any other universal resource. We obtain a powerful criterion to assess universality of graph states, by introducing an entanglement measure which necessarily grows unboundedly with the system size for all universal resource states. Furthermore, we prove that graph states associated with 2D lattices such as the hexagonal and triangular lattice are universal, and obtain the first example of a universal non-graph state.

Authors: Maarten van den Nest, Akimasa Miyake, Wolfgang D¸r, and Hans J.
Briegel

Preprint: quant-ph/0604010

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04. S. BOSE
Centre for Quantum Computation Clarendon Laboratory Oxford

TITLE: Spin Chains in Quantum Information Processing

ABSTRACT:
I will discuss how quantum many body systems such as spin chains, where the constituents are permanently coupled to each other, can be exploited for useful tasks in quantum information processing. I will describe, for example, how they might be used as quantum wires to connect quantum registers. Many recent developments in this area, which include the openness of such wires, encoding and decoding of quantum information on them, and generation of entanglement in such wires will be reported. Using spin chains for running specific quantum algorithms with minimal control will be discussed. I will also discuss how certain exchange coupled N dimensional systems in their ground state can be used to distribute arbitrary amount of entanglement between separated sites.

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05. M. D'ARIANO
Istituto Nazionale di Fisica della Materia, Unita' di
Pavia, Dipartimento di Fisica "A. Volta", Universita' di Pavia

TITLE: Hilbert-Space Formulation of Quantum Mechanics From Purely Operational Axioms

ABSTRACT:
I show how it is possible to derive the Hilbert space formulation of Quantum Mechanics from a comprehensive definition of "physical experiment" and assuming "experimental accessibility and simplicity" as specified by five simple Postulates. Pivotal roles are played by the "local observability principle", which reconciles the holism of nonlocality with the reductionism of local observation, and by the postulated existence of "informationally complete observables" and of a "symmetric faithful state". This last notion allows one to introduce an operational definition for the real version of the "adjoint"-- i.e. the transposition--from which one can derive a real Hilbert-space structure via either the Mackey-Kakutani or the Gelfand-Naimark-Segal constructions. I will analyze in detail the Gelfand-Naimark-Segal construction, which leads to a real Hilbert space structure analogous to that of (classes of generally unbounded) self adjoint operators in Quantum Mechanics. For finite dimensions, general dimensionality theorems that can be derived from a local observability principle, allow us to represent the elements of the real Hilbert space as operators over an underlying complex Hilbert space. The route for the present operational axiomatization was suggested by novel ideas originated from Quantum Tomography.

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06. N. DATTA
Statistical Laboratory, Centre for Mathematical Sciences,
Cambridge, U.K.

TITLE: Classical capacity of arbitrary Quantum channels

ABSTRACT:
The classical capacity of a memory-less quantum channel, for product state inputs, is given by the Holevo capacity. This was proved by Holevo, and independently by Schumacher and Westmoreland, and is the statement of the celebrated Holevo--Schumacher--Westmoreland (HSW) Theorem.

We study an extension of this channel coding theorem to arbitrary channels under arbitrary inputs using two different approaches. Firstly, we use the information spectrum method to evaluate the classical capacity of an arbitrary quantum channel. Secondly, we take the particular example of a quantum channel with classical memory, and consider the scenario in which Alice sends messages emitted by a classical ergodic source to Bob, via this channel. In this second case, we prove a direct channel coding theorem by using a quantum version of Feinstein's Lemma.

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07. J. EISERT
Institut für Physik University of Potsdam

TITLE: Entanglement, area, and the problem of finding ground states of many-body systems

ABSTRACT:
This talk is concerned with the question of finding ground states of local quantum many-body systems. The first part is concerned with the quantum part of the problem: when can one expect a provable entanglement-area-relationship to hold, and what implications does this have to the possibility of approximating ground states with matrix-product states (MPS).

The second part deals with the classical complexity of the problem: Crucially, even if one knows that MPS would in principle faithfully represent the true ground state, one still has to find the optimal one. Known variational methods in DMRG make use of local variations, with the expectation that one should reach the globally optimal state in a convergence. Here, we rigorously show that surprisingly, the global variational variant of DMRG to find ground states is NP-hard, by polynomially relating it to exact Boolean satisfiability.

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08. A.M. ERICSSON
Stockholm University, Physics Dept., Stockholm, Sweden

TITLE: The search for Mutually Unbiased Bases

ABSTRACT:
A complete set of mutually unbiased bases, for any finite dimensional quantum system, is a generalization of the spin states in the x-, y- and z-directions for a spin1/2-particle. Such sets have been found for systems with a prime power dimension. But for all other dimensions the question of their existence is still open.

After introducing the problem and the connection to complex Hadamard matrices, I will discuss the lowest dimensional case not yet solved: What can be said about mutually unbiased bases in six dimensions?

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09. R. FAZIO
SISSA/ISAS Trieste, Italy

TITLE: Decoherence by controlled quantum baths

ABSTRACT:
Understanding decoherence is central to the description of the crossover between quantum and classical behaviour and it is a crucial issue for the successful implementation of quantum information processing. Loss of phase coherence arises because the quantum system gets entangled with its environment. Although desirable, it is not always possible to fully characterize the bath and therefore it is necessary to resort to ingenious modelizations. Paradigmatic models represent the environment as a set of harmonic oscillators or spin-1/2 particles. In order to grasp all the subtleties of the entanglement between the system and its environment it would be of great importance to study engineered bath (and system-bath interaction) that can realized experimentally and whose properties are amenable of an exact solution. Here we discuss an entire new class of spin baths. We show how to realize them by means of optical lattices and we find the exact solution for the decoherence.

Authors: D. Rossini, T. Calarco, V. Giovannetti and S. Montangero

10. G. FLORIO
Dipt. di Fisica, Universita' degli Studi di Bari, Bari, Italy

TITLE: Robustness of optimal working points for non-adiabatic holonomic quantum computation

ABSTRACT:
Geometric phases are an interesting resource for quantum computation. In this case, the transformations needed to implement the quantum gates are realized by making the Hamiltonian of the quantum computer dependent on a set of controlling parameters which describe suitable closed loops in an associated parameter space. In the adiabatic limit the dynamical contribution to the evolution can be factorized and the quantum gate only depends on the topological structure of the manifold.

Recently [Phys. Rev. A 73, 022327 (2006)] we studied a class of one-qubit gates, focusing on non-adiabatic effects and bringing to light the presence of fidelity revivals, namely an infinite number of (optimal) times at which the fidelity reaches unity.

Here we study in detail the effects of the environment on this class of transformations. In particular we shall investigate the behaviour of the fidelity at the first of these optimal working points and study its robustness against noise effects. The deviations from the ideal (noiseless) case will be numerically analyzed as a function of the strength of the noise (the coupling of the system with its environment) and a heuristic definition on robustness will be introduced.

Ref: 1) Phys. Rev. A 73, 022327 (2006)
2) quant-ph / 0604180

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11. E. F. GALVAO
Universidad Federal Fluminense, Instituto de Fisica,
Rio de Janeiro, Brazil

TITLE: Classicality in discrete Wigner functions

ABSTRACT:
Gibbons et al. [Phys. Rev. A 70, 062101(2004)] have recently defined discrete Wigner functions W to represent quantum states in a Hilbert space with finite dimension. We show that such a class of Wigner functions W can be defined so that the only pure states having non-negative W for all such functions are stabilizer states, as conjectured by one of us [Phys. Rev. A 71, 042302 (2005)]. We also show that the unitaries preserving non-negativity of W for all definitions of W in the class form a subgroup of the Clifford group. This means pure states with non-negative W and their associated unitary dynamics are classical in the sense of admitting an efficient classical simulation scheme using the stabilizer formalism. This talk is based on joint work with Cecilia Cormick, Daniel Gottesman, Juan Pablo Paz and Arthur Pittenger.

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12. M. GENOVESE
IEN Galileo Ferraris (INRIM), Torino, Italy

TITLE: Review on recent studies at INRIM on polarisation entanglement transmission

ABSTRACT:
In this talk I will describe some recent researches performed at INRIM on polarisation entanglement transmission. A first part will concern our recent researches on fibre propagation of polarisation entangled photons. In particular, I will present an experiment that pointed out for the first time two-photon interference in the shape of the second-order intensity correlation function for spontaneous PDC. Experimental results with different fibre lengths will be presented. Implications for quantum communication will be discussed. Then, I will consider the possibility of introducing a controlled decoherence in this channel and I will hint at the possibility of characterizing it as a CP map. Finally, I will report on some our recent study to careful consider atmospheric effects on propagation of polarisation qubits with the purpose of precisely characterizing an Earth-space quantum communication channel. Preliminary studies on these effects on such quantum communication channel in various realistic atmospheric situations will be presented and discussed with the purpose of drawing some first conclusions on the feasibility and properties of such a channel in some specific scenarios.

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13. M. HORODECKI
Institute of Theoretical Physics and Astrophysics
University of Gdansk

TITLE: Quantum key distributions beyond entanglement distillation

ABSTRACT:
For a long time, quantum key distribution was strictly connected with distillation of pure entanglement. In 2003 it was discovered that one can obtain secret key from states that are bound entangled i.e. no pure entanglement can be distilled from them. The discovery allowed to create a general theory of key distillation. I report here recent development of the theory, including the construction of four qubit bound entangled states with quite high distillable key as well as the proof of unconditional security of key distribution by use of channel which have zero capacity to convey quantum information.

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14. F. ILLUMINATI
Dipt. di Fisica "E. R. Caianiello", Università degli Studi di Salerno
Baronissi, Salerno, Italy

TITLE: Qualifying and quantifying entanglement in continuous variable systems.

ABSTRACT: Quantum information science may lead to real-world applications for communication and computation unavailable without the exploitation of quantum properties such as nonorthogonality or entanglement. Interest has been growing in the last years on quantum information protocols based on nonclassical states of continuous variable systems, especially with respect to quantum optical implementations in terms of the quadrature amplitudes of the electromagnetic field.

In this talk I will review the characterization of entanglement in nonclassical Gaussian states of continuous variable systems, such as squeezed states or squeezed thermal states. I will first discuss the problem of qualifying the entanglement of quantum states defined on infinite-dimensional Hilbert spaces, and I will review the most important classe of inseparability criteria that have been introduced. For two-mode Gaussian states, I will discuss how their bipartite entanglement can be accurately quantified in terms of the global and local amounts of mixedness, and efficiently estimated by direct measurements of the associated purities. For multimode Gaussian states endowed with local symmetry with respect to a given bipartition, I will show how the multimode block entanglement can be completely and reversibly localized onto a single pair of modes by local, unitary operations. I will then analyze the distribution of entanglement among multiple parties in multimode Gaussian states, and I will introduce the continuous-variable tangle to quantify entanglement sharing in Gaussian states, showing that it satisfies the Coffman-Kundu-Wootters monogamy inequality.

Pure, symmetric three-mode Gaussian states, at variance with their discrete-variable counterparts, allow a promiscuous sharing of quantum correlations, exhibiting both maximum tripartite residual entanglement and maximum couplewise entanglement between any pair of modes. I will investigate the connection between multipartite entanglement and the optimal fidelity in a continuous-variable quantum teleportation network. I will show how the fidelity can be maximized in terms of the best preparation of the shared entangled resources and, viceversa, that this optimal fidelity provides a clearcut operational interpretation of several measures of bipartite and multipartite entanglement, including the entanglement of formation, the localizable entanglement, and the continuous-variable tangle. Finally, I will briefly touch upon the problem of qualifying and quantifying entanglement of non Gaussian quantum states of light, a research subject that is still in its infancy, but promises to be of great importance for a deeper understanding of the nature of quantum correlations.

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15. A. JAMIOLKOWSKI
Faculty of Physics, Astronomy
and Informatics NCU, Torun, Poland

TITLE: Comparison of some methods of quantum state tomography

ABSTRACT:
Determining the state of a quantum system and measuring properties of its evolution are two of themost important tasks of quantum information science. For the first purpose one can use state tomography, a method that after subjecting the system to a number of experiments and finding mean values of some observables, determines all independent elements of the density operator. For the second task, one uses a set of techniques to determine an explicit form of the generator of the time-evolution (e.g. the Linfblad-Gorini-Kossakowski-Sudarshan operator) or an explicit form of the Kraus representation of a quantum operation. The main aim of this talk is to discuss a combined method of state reconstruction, the so-called stroboscopic quantum tomography (SQT), where we assume a model of time-evolution and we use the mean values of a small number of observables (measured at different moments of observations) to determine the actual state of the system. The problem of minimal number of observables for reconstructibility of states (for a given generator of the time-evolution) and minimal number of moments of observations are addressed.

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16. P. JORRAND
Leibniz Laboratory Institut d'Informatique et de
Mathematiques Appliquees de Grenoble, France

TITLE: Classically-controlled Quantum Computation

ABSTRACT:
Known quantum algorithms, quantum teleportation and quantum cryptographic protocols all take place under the control of the classical world. This is also clearly the case for measurement-based quantum computations. It is reasonable to assume this situation holds for most quantum information processing tasks. This standard, dominating situation deserves the elaboration of specific, adequate formal models, or abstract machines, in order to identify the resources that are needed, to serve as a model for evaluating the complexity of quantum information processing tasks, and for comparing this form of quantum computation with other forms. The original Quantum Turing Machine by David Deutsch is obviously not adequate for this purpose. A formal model will be introduced, in the form of a Classically-controlled Quantum Turing Machine (CQTM), which is a Turing Machine with a quantum tape for acting on quantum data, and a classical transition function for a formalized classical control. All quantum operations in a CQTM take the form of so-called admissible transformations, of which unitary transformations and measurements are special cases. It will be shown that any classical Turing Machine is simulated by a CQTM without loss of efficiency. Furthermore, any k-tape CQTM is simulated by a 2-tape CQTM with a quadratic loss of efficiency. CQTMs will be compared to existing models of quantum computation. For example, any uniform family of quantum circuits is efficiently approximated by a CQTM. Moreover, any measurement calculus pattern (V. Danos, E. Kashefi, P. Panangaden, quant-ph/0412135) can be efficiently simulated by a CQTM. A Measurement-based Quantum Turing Machine (MQTM) will also be defined, which is a restriction of CQTMs where admissible transformations are restricted to projective measurements only. Any CQTM can be efficiently simulated by a MQTM. Some examples of CQTMs will be given.

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17. C. KING
Northeastern University, Department of Mathematics, Boston, U.S.A.

TITLE: Review of multiplicativity results for product maps.

ABSTRACT:
Recent work on the additivity problem in quantum information theory has focused on proving multiplicativity of maximal p-norms for products of completely positive maps. Techniques involve matrix inequalities and results from operator algebras. The most complete results to date have been obtained for products where one of the factors is a qubit map. This talk will describe some of the recent progress in this area, and indicate possible directions for further progress.

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18. T. KRUEGER
Institut für Mathematik, Technische Universität, Berlin, Germany

Title: Typical subspaces for quantum sources and applications

Abstract:

Typical subspaces are a major theoretical tool in classical and quantum information theory. Many fundamental results are based on the proper use and characterization of them. Main applications in information theory are related to data compression and complexity.

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19. L.C. KWEK
Physics Department, Faculty of Science,
National University of Singapore, Singapore

TITLE: Hybrid Quantum Computing

ABSTRACT:
In this talk, we focus on a hybrid quantum computing architecture using stationary qubits inside an optical cavity and flying qubits (photons). It has been shown that direct qubit-qubit interactions for two-qubit gate implementations can be replaced by the experimentally less demnding generation of single photons on demand and linear optics photon pair measurements. The outcomes of these measurements indicate either the completion of the gate or the presence of the original qubits such that the operation can be repeated until success.

Authors: S.D. Barret, A. Beige, P. Kok, L.C. Kwek, Y.L. Lims

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20. D. LIDAR
Dept. of Chemistry and Electrical Engineering,
University of Southern California Los Angeles, U.S.A.

TITLE: Adiabaticity in open quantum systems: theory and applications to adiabatic quantum computation and geometric phases

ABSTRACT:

The adiabatic approximation is an 80+ year old pillar of quantum mechanics, which has found rich applications in a variety of physics and chemistry problems. However, in its original formulation the adiabatic theorem was derived in the context of closed quantum systems, described by unitary dynamics. We have recently introduced a generalization of the adiabatic theorem to open quantum systems described by convolutionless master equations [1]. This version of the adiabatic theorem is naturally suited to problems in quantum information theory, and we describe applications to the adiabatic quantum computing paradigm [2], and to the problem of geometric phases (both Abelian and non-Abelian) in open quantum systems undergoing cyclic adiabatic evolution [3]. One of our main findings is that, in general, adiabaticity in an open quantum system depends on two competing timescales: the speed of the driving field and the decoherence due to the interaction with the environment. These timescales generically determine a finite interval for adiabaticity. This has implications for both adiabatic quantum computing and the robustness of geometric phases to decoherence.

Joint work with Dr. Marcelo Sarandy.

References:
[1] Adiabatic Approximation in Open Quantum Systems, M.S. Sarandy and D.A. Lidar, Phys. Rev. A 71, 012331 (2005).
[2] Adiabatic Quantum Computation in Open Systems, M.S. Sarandy and D.A. Lidar, Phys. Rev. Lett. 95, 250503 (2005).
[3] Abelian and Non-Abelian Geometric Phases in Adiabatic Open Quantum Systems, M.S. Sarandy and D.A. Lidar, quant-ph/0507012.

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21. H. MAASSEN
Institute of Mathematics, Radboud University, Nijmegen, Netherlands

TITLE: Purification of quantum trajectories and dark subspaces

ABSTRACT:
We prove that the quantum trajectory of repeated perfect measurement on a finite quantum system either asymptotically purifies, or hits upon a family of `dark' subspaces, where the time evolution is unitary.

22. C. MACCHIAVELLO
Dipartimento di Fisica "A. Volta", Pavia, Italy

TITLE: Ideal broadcasting, purification and time-reversal for mixed states

ABSTRACT:
"Broadcasting", namely distributing information to many users, suffers in-principle limitations when the information is quantum. For pure states ideal broadcasting coincides with "quantum cloning". This is forbidden by the no-cloning theorem for pure states drawn from a non orthogonal set. For mixed states the no broadcasting theorem says that perfect broadcasting from an input state drawn from a set of two non commuting density operators to two output states cannot be achieved. We prove that this theorem cannot be generalised to more than a single input copy. Moreover, we present the phenomenon of superbroadcasting, where it is possible to purify the input states while broadcasting. We also discuss the relations between optimal broadcasting and other tasks of interest in quantum information, such as estimation procedures and time-reversal operations.

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23. L. MASANES
Department of Mathematics, University of Bristol
Bristol, U.K.

TITLE: Entanglement is equivalent to non-simulability by classical correlations

ABSTRACT:
In this talk, a series of properties which are equivalent to the property of being entangled are presented. It is shown that a state is non-simulable by classical correlations if, and only if, it is entangled. It is also presented a scheme for extracting useful entanglement from all non-separable states, including bound entangled states. This answers the long-standing question whether bound entangled states are useful for quantum information processing, with an affirmative answer.

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24. S. MICHALAKIS
Department of Mathematics, University of California at Davis
Davis, U.S.A.

Title: Entanglement in Finitely Correlated States

Abstract: "We derive bounds for the entanglement of a spin with an (adjacent and non-adjacent) interval of spins in an arbitrary pure finitely correlated state (FCS) on a chain of spins of any magnitude. Finitely correlated states are otherwise known as matrix product states or generalized valence-bond states. The bounds become exact in the limit of the entanglement of a single spin and the half- infinite chain to the right (or the left) of it. Our bounds provide a proof of the recent conjecture by Benatti, Hiesmayr, and Narnhofer that their necessary condition for non-vanishing entanglement in terms of a single spin and the "memory" of the FCS, is also sufficient . Our result also generalizes the study of entanglement in the ground state of the AKLT model by Fan, Korepin, and Roychowdhury. Our result permits one to calculate more efficiently, numerically and in some cases even analytically, the entanglement of arbitrary finitely correlated quantum spin chains."

25. M. MOSCA
Department of C&O, University of Waterloo, Canada

TITLE: Self-Testing of Quantum Circuits

ABSTRACT:
We prove that a quantum circuit together with measurement apparatuses and EPR sources can be "self-tested", i.e. fully verified without any reference to some trusted set of quantum devices.To achieve our goal we define the notions of simulation and equivalence. Using these two concepts, we construct sets of simulation conditions which imply that the physical device of interest is equivalent to the one it is supposed to implement. Another benefit of our formalism is that our statements can be proved to be robust. Finally, we design a test for quantum circuits whose complexity is polynomial in the number of gates and qubits, and the required precision.

Authors: Frederic Magniez, Dominic Mayers, and Harold Ollivier.

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26. H. NARNHOFER
Institut fuer Theoretische Physik, University of Vienna, Austria

TITLE: Passage between finite dimensional classical and quantum phase spaces

ABSTRACT:
Based on Weyl operators we construct a classical algebra with phase space structure as subalgebra of the tensor product of two matrix algebras, reflecting maximal entanglement between these two matrix algebras. The partial transposition maps the abelian algebra into a new matrix algebra of the same dimension provided it is odd. This allows to find relations between concepts of entanglement and phase space structure in finite dimensional quantum mechanics. E.g. ppt states correspond to states with positive Wigner function. Appropriate separable states belonging to density matrices of the abelian algebra correspond to a complete set of mutually unbiased bases if d is prime. The relation of tangent functionals on the set of separable states over the tensor product and positive maps over one algebra as given by Horodeckis is sufficiently explicit to find tangent functionals numerically for small dimensions, using symmetry relations offered by the phase space structure.

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27. M. PALMA
Istituto di Fisica, Universita' degli Studi di Palermo,
Palermo, Italy

TITLE: Entanglement controlled electron transport

ABSTRACT:
We consider a system consisting of single electrons moving along a 1D wire in the presence of two magnetic impurities. Such system shows strong analogies with a Fabry - Perot interferometer in which the impurities play the role of two mirrors with a quantum degree of freedom: the spin. We discuss how the electron transmittivity of the wire is affected by the presence of entanglement between the impurity spins. In particular we will show that for suitable values of the electron momentum, there are two maximally entangled state of the impurity spins the first of which makes the wire transparent whatever the electron spin state while the other strongly inhibits the electron transmittivity.

28. M.G.A. PARIS
Universita' degli Studi di Milano, Dipt. di Fisica, Milano, Italy

TITLE: Cloning: states, observables and noise

ABSTRACT:
We address the distribution of quantum information to two or more users in the presence of noise both in the transmission and in the detection stages. Two issues are analyzed in details: on one hand we consider how to optimally send to m receivers the information encoded into an unknown coherent state, and show that for a wide range of noise parameters telecloning based on nonlocal quantum correlations is more effective than local cloning followed by direct transmission. On the other hand, we analyze linear cloning schemes for generic Gaussian states taking into account the effect of non-unit quantum efficiency and unbalanced mode-mixing, and evaluate cloning fidelity for classes of Gaussian states with fluctuating covariance matrix. Finally, for qubit systems, we introduce the concept of cloning for classes of observables and classify cloning machines for qubit systems according to the number of parameters needed to describe the class under investigation. A no-cloning theorem for observables is derived and the connections between cloning of observables and joint measurements of noncommuting observables are elucidated. Relationships with cloning of states and non-demolition measurements are also analyzed.

References:

Stefano Olivares, Matteo G. A. Paris, Ulrik L. Andersen
Cloning of Gaussian states by linear optics
quant-ph/0601164

Alessandro Ferraro, Matteo Galbiati, Matteo G. A. Paris
Cloning of Observables
J. Phys. A 39, L219-L228 (2006).

Alessandro Ferraro and Matteo G. A. Paris
Local vs Nonlocal cloning in a noisy environment
J. Opt. B 7, 532, (2005).

Alessandro Ferraro and Matteo G. A. Paris
Multimode entanglement and telecloning in a noisy environment
Phys. Rev A 72, 032312

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29. S. PASCAZIO
Dipartimento di Fisica, Universita' degli Studi di Bari
Bari, Italy

TITLE: A characterization of multipartite entanglement

ABSTRACT:
Entanglement is one of the most intriguing features of quantum mechanics. Although it is widely used in quantum communication and information processing and plays a key role in quantum computation, it is not fully understood. It is deeply rooted into the linearity of quantum theory and in the superposition principle and basically consists (for pure states) in the impossibility of factorizing the state of the total system in terms of the states of its constituents.

The quantification of entanglement is an open and challenging problem. It is possible to give a good definition of bipartite entanglement in terms of the von Neumann entropy and the entanglement of formation. The problem of defining multipartite entanglement is more difficult and no unique definition exists.

A method is proposed to characterize and quantify multipartite entanglement for pure states. The method hinges upon the study of the probability density function of bipartite entanglement and is tested on an ensemble of qubits in a variety of situations.

The entanglement features of a class of random states is also analyzed. These states turn out to be very entangled and their entanglement is multipartite, in a sense that can be precisely defined. We analitically determine the thermodynamical limit of the purity of such states.

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30. F. PETRUCCIONE
School of Pure and Applied Physics, University of KZN
Durban, South Africa

TITLE: Dynamics of qubit systems in a spin star environment

ABSTRACT:
The exact dynamics of a central two qubit system in a spin star configuration is investigated. Initially pure states of the central system evolve into mixed ones. Decoherence-free states of the model are determined. The long time behaviour of the system shows partial decoherence.

31. D. PETZ
Alfred Renyi Institute of Mathematics
Hungarian Academy of Sciences Budapest,
Budapest, Hungary

TITLE: State tomography for qubits

ABSTRACT:
The state determination is studied for a single qubit and for a composite system of two qubits. Different kind of measurement strategies and estimation schemes are discussed and compared.

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32. M. PLENIO
Institute for Mathematical Science and Quantum Optics
and Laser Science Group, Blackett Lab., Imperial College London, U.K.

TITLE: Generic Entanglement is Physical

ABSTRACT:
While a great deal of insight into the structure of two-particle entanglement has been gained, it has become equally clear that the complexity and diversity of multi-particle entanglement grows exponentially with the number of particles. On the other hand it may be expected that a much simplified theory exists for the properties of generic quantum states if, in some appropriate sense, most states behave similarly. This intuition gives hope that significant progress can be made by restricting attention to classes that are typical (generic) relative to the uniform (Haar) measure. In fact, it was demonstrated that relative to the Haar measure, practically all pure states of large numbers of spins exhibit maximal bi-partite as well as multi-partite entanglement. This suggests that the exploration of the entanglement properties of generic states is a promising approach. But a big question mark exists as to whether statements about generic states relative to the Haar measure are physical for the following reason. If we want to achieve the uniform distribution to a fixed accuracy, the number of applications of random 2-qubit unitaries necessary grows exponentially with the size of the system, and quickly becomes unphysical. It may therefore turn out that there is no efficient procedure for the generation of generic quantum states leaving their properties mathematically sound and interesting but physically irrelevant. On the other hand entanglement properties represent a restricted class of physical properties of a quantum state. It may therefore be that the faithful reproduction of generic entanglement properties may be possible with far fewer physical resources than those required for the precise generation of the expectation value for an arbitrary observable.

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33. T. PROSEN
Department of Physics, Faculty of Mathematics and Physics,
University of Ljubljana, Slovenia

TITLE: Order to chaos transition in quantum spin chains

ABSTRACT:
Several models of non-integrable kicked quantum spin chains will be discussed, exhibiting phase transition from non-ergodic to ergodic behaviour in thermodynamic limit. Several different numerical methods are employed to attack the problem. Suitable order parameters are proposed, showing an abrupt transition to ergodic behaviour, typically for a non-vanishing critical value of the integrability breaking parameter.

34. M.B. RUSKAI
Tufts University, 503 Boston Avenue, Medford, MA 02155, U.S.A.

TITLE: Pauli diagonal channels constant on axes

ABSTRACT:

Pauli diagonal channels are a special type of Weyl-Heisenberg channel, which can be defined using mutually unbiased bases. Each basis corresponds to an "axis" and acts like a depolarizing channel for inputs on that axis; but different axes can have different levels of depolarization. This talk will focus on recent progress on the additivity and multiplicativity conjectures for this class of channels.

35. A. SANPERA
Grup de Física Teòrica & IFAE, Universitat Autònoma de Barcelona, Barcelona, Spain

TITLE: Spinor ultracold gases: atom-photon interfaces and entanglement properties

ABSTRACT:
We investigate properties of spinor ultracold gases in optical lattices which can reproduce diverse magnetic models associated to large spin chains. We discuss a feasible model to detect different magnetic phases of such models via single-atom single-photon interfaces and discuss their distinc properties by analysing entanglement.

Authors: O. Romero-Isart, K. Eckert, M. Lewenstein, E. Polzik, and A. Sanpera

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36. Wonmin SON
University of Leeds, U.K.

TITLE: Untangled entanglement in solid state

ABSTRACT:
Entanglement is a fundamental feature of quantum mechanics and is regarded as one of the most important resources in quantum information theory. It provides the key ingredient for teleportation schemes, one-way quantum computing and many quantum cryptography protocols. A challenging problem experimentalists face is how to verify the existence of entanglement in the system under observation and entanglement witness (EWs) are designed to detect only one property of the system - its entanglement - without any need to know other details of the state. A central question is thus to identify EWs that are convenient to measure in practice. In this talk, we will present some examples of EWs in various cases for example, solid state model, and will discuss the nature of entanglement such as whether it is possible for a single particle to be entangled. We will then show a quantum field treatment of entanglement and examine to what extent the standard thermodynamical quantities provide natural and easily measurable EWs. These entanglement witnesses will then be applied to typical condensed matter and high energy systems to identify the precise relationship between entanglement and phase transitions.

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37. Y. SUHOV
Statistical Laboratory, Centre for Mathematical Sciences,
Cambridge, U.K.

TITLE: On some geometric/topological aspects of additivity and multiplicativity of quantum channels

ABSTRACT:
I'll attempt to review recent results in additivity and multiplicativity for quantum channels and to provide a link with geometric and topological aspects of variational calculus on matrix algebras.

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38. I. TSOHANTJISA
Institute of Matter Structure & Laser Physics,
Dept. of Science, Technical University of Crete,
Crete, Greece

TITLE: Quantum operations induced by Classical Randomness

ABSTRACT:

Classical variables determining the manifold of qubit states are left to perform a classical random walk formulated algebraically by means of Hopf algebras. It is shown that this may induces quantum operations on qubit states such as known CPTP maps and unitary transformations.

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39. F. VERSTRAETE
Control & Dynamical Systems, California Institute of Technology, Pasadena, CA, U.S.A.

TITLE: Lieb-Robinson bounds and the generation of correlations and topological quantum order

ABSTRACT:
The Lieb-Robinson bound states that local Hamiltonian evolution in nonrelativistic quantum mechanical theories gives rise to the notion of an effective light-cone with exponentially decaying tails. We discuss several consequences of this result in the context of quantum information theory.

First, we show that the information that leaks out to space-like separated regions is negligable, and that there is a finite speed at which correlations and entanglement can be distributed.

Second, we discuss how these ideas can be used to prove lower bounds on the time it takes to convert states without topological quantum order to states with that property. Finally, we show that the rate at which entropy can be created in a block of spins scales like the boundary of that block.

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40. L. VIOLA
Department of Physics and Astronomy, Dartmouth College,
Hanover, New Hampshire, U.S.A.

TITLE: Generalized Entanglement as a Framework for Exploring Complex Systems

ABSTRACT:
Characterizing and quantifying quantum correlations in complex systems is critical for a variety of applications ranging from quantum information science to condensed-matter theory. In this talk, I will describe how a recently introduced notion of generalized entanglement provides useful diagnostic tools for investigating the properties and evolution of entanglement in settings involving both distinguishable and indistinguishable quantum subsystems, as well as indecomposable quantum systems. In particular, I will focus on the problem of constructing entanglement measures capable to serve as reliable dynamic indicators in two paradigmatic instances of complex behavior: systems undergoing a quantum phase transition; and systems undergoing a dynamical crossover from integrability to quantum chaos.

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41. D. VITALI
Dipartimento di Fisica, Universita' degli Studi di Camerino
Camerino (Macerata), Italy

TITLE: Optomechanical networks for continuous variable quantum information processing

ABSTRACT:
We study how optomechanical systems can be used for manipulating continuous variable entanglement. Quantum state transfer among optical and vibrational modes is possible by exploiting the correlations established by radiation pressure. We shall consider various applications, teleportation of optical states onto a vibrational mode, continuous variable telecloning, and also entanglement swapping. In this latter case, the generated optomechanical entanglement is used to entangle two micromechanical mirrors, thanks to the homodyne measurement performed on the optical modes.

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42. C. VIVIESCAS
Max-Planck Institute for Physics of Complex Systems,
Dresden, Germany

TITLE: Unraveling Entanglement

ABSTRACT:
Quantum information processing requires the ability to produce entangled states and coherently perform operations on them. Under realistic laboratory conditions, however, entanglement is degraded through uncontrolled coupling to the environment. It is of crucial practical importance to quantify this degradation process. So far, a complete understanding of entanglement decay has been hampered by the intricate mathematical notions upon which our understanding of entanglement relies. Up to now, no general observable is known which would complement such essentially formal concepts with a specific experimental measurement setup. Here we come up with a radically different dynamical characterization of entanglement, through the continuous observation of a quantum system which evolves under incoherent coupling to an environment. We show that the entanglement of the time evolved, mixed system state is given by the average entanglement over different realizations of a suitably chosen measurement strategy - which filters out the minimal amount of non-classical correlations required to describe the time-evolved state. Thus, a quantum trajectory unraveling of the open system dynamics based on appropriate observables allows to continously monitor entanglement dynamics.

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43. Reinhard WERNER
Institut für Mathematische Physik, TU Braunschweig. Germany

Title: "The really mean king uses biased bases"

Abstract:
In this talk the retrodiction problem, known as the mean king's problem is extended beyond its most widespread context, the theory of "mutually unbiased bases" (MUBs). In the problem, Alice has to hand the mean king some d- dimensional quantum system, on which the king's men perform a von Neumann measurement in some basis chosen from an agreed set of k bases. Alice is allowed to make a final measurement on the system, also involving some entangled records of the preparation she has kept. After that she is told which basis the king's men used and her task is to retrodict with certainty the result they must have found.

When the bases are mutually unbiased, a strategy for Alice is known, but it is highly unclear how many such bases can be found, unless d is not a power of a prime number. Here we present a general theory for the existence of a strategy for Alice, which, perhaps surprisingly, amounts to the problem of finding a joint probability distribution for the overlap probabilities between the bases. In the simplest case, d=2, the existence of a strategy is decided by Bell's 1963 inequality.

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44. Michael WOLF
Max-Planck-Institut für Quantenoptik,
Garching bei Munchen, Germany

Title: Special properties of special quantum channels

Abstract:

The talk will present new results on contractivity of quantum channels and the additivity of the quantum channel capacity.

45. K. ZYCZKOWSKI
Instytut Fizyki Wydziat Fizyki, Astronomii i Informatyki Stosowanej, Krakow, Poland

TITLE: Quantum Error Correction and Compression Problems

ABSTRACT:
Conditions for designing classical and quantum error correction codes are compared. A general solution of the quantum error correction problem is presented for the case of bi-unitary channels acting on two-qubit Hilbert space. We construct qubit codes for such channels on arbitrary dimension Hilbert space, and identify correctable codes for Pauli-error models not detected by the stabiliser formalism. This is accomplished through solving of certain algebraic compression problems and finding the `higher-rank numerical range'' of the error matrix. We describe basic properties of the generalised numerical range and discuss possible further applications.