Q 50: Quantum Effects: Entanglement and Decoherence

Time: Thursday 10:30–13:00 Location: SCH A01

Q 50.1 Thu 10:30 SCH A01

Treatment of genuine quantum effects in the initial energy excitation propagation in light harvesting complexes — •Markus Tiersch[1,2], Hans J. Briegel[1,2], and Sandu Popescu[3,4] — [1]Institut für Theoretische Physik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenhschaften, Innsbruck, Austria — [3]H. H. Wills Physics Laboratory, University of Bristol, U.K. — [4]Hewlett-Packard Laboratories, Bristol, U.K.

The studies of the initial energy excitation propagation in light-harvesting proteins, in particular in the Fenna-Matthews-Olson protein complex, have recently been enriched with the discussion of quantum-coherent excitation transfer and genuine quantum effects such as entanglement. The presence of quantum-coherent energy transfer and quantum entanglement during excitation transfer have been linked to an improved energy transport efficiency in light harvesting complexes.

In this presentation, we investigate the theoretical modeling that underlies the excitation transfer dynamics in light harvesting complexes, and we elucidate its impact on genuine quantum effects such as entanglement.

Q 50.2 Thu 10:45 SCH A01

Long-distance entanglement between two harmonic oscillators via a quantum reservoir — •Endre Kajari[1,2], Alexander Wolf[2], Gabriele De Chiara[3,5], Eric Lutz[4], and Giovanna Morigi[1,5] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarberücken, Germany — [2]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [3]Grup de Física Teorica, Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain — [4]Department of Physics, University of Augsburg, D-86135 Augsburg, Germany — [5]Grup d'Òptica, Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain

We discuss the creation of entanglement between two harmonic oscillators that interact via a common reservoir consisting of a chain of harmonic oscillators with nearest-neighbor coupling. The oscillators are initially prepared in squeezed states with squeezing parameter r, whereas the chain starts from a thermal state at temperature T. The entanglement between the oscillators is studied as a function of r and T using the logarithmic negativity. We first identify a parameter regime in which the chain acts as an Ohmic environment and recover a long time behavior of the entanglement that is qualitatively in agreement with the predictions of [1]. When the oscillators couple to two separate sites of the chain, decoherence free subspaces support quasi-stationary quantum correlations between the oscillators for certain frequency ranges. The requirements for long-distance entanglement are identified and possible experimental realizations are envisaged.

[1] J. P. Paz, A. J. Roncaglia, Phys. Rev. Lett. **100**, 220401 (2008).

Q 50.3 Thu 11:00 SCH A01

Effects of retardation on sudden death and revival of entanglement — •Qurrat Ul-ain[1], Zbigniew Ficek[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]The National Centre for Mathematics and Physics, King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia

In the standard setup of atoms coupled to a cavity, a finite time is required by light to travel between the atoms and the cavity boundaries. In suitable parameter regimes, these retardation effects can affect the time evolution of the combined system of atoms and cavity field to a large degree [1].

Here, we study the effects of retardation on the entanglement dynamics of a system of two two-level atoms placed inside a one-dimensional ring cavity. For this, we calculate the time evolution of the concurrence [2], which quantifies the entanglement between the two atoms. We indentify suitable parameter ranges for the study of retardation effects, analyze sudden death and revival of entanglement [3] in the presence of retardation, and interpret the obtained results in terms of the traveling time of light between the atoms and the cavity mirrors.

[1] E. V. Goldstein and P. Meystre, Phys. Rev. A **56**, 5135 (1997).
[2] W. K. Wootters, Phys. Rev. Lett. **80**, 2245 (1998).
[3] T. Yu and J. H. Eberly, Phys. Rev. Lett. **93**, 140404 (2004).

Q 50.4 Thu 11:15 SCH A01

Unconditional Preparation of Bound Entanglement — •Aiko Samblowski[1], James DiGuglielmo[1], Boris Hage[1], Carlos Pineda[2,3], Jens Eisert[3,4], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck Institut für Gravitationsphysik (Albert-Einstein-Institut), 30167 Hannover, Germany — [2]Instituto de Física, Universidad Nacional Autónoma de México, México — [3]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [4]Institute for Advanced Study Berlin, 14193 Berlin, Germany

Among the possibly most fascinating aspects of quantum entanglement is that it comes in "free" and "bound" instances. In contrast to free entanglement it is not possible to distill bound entangled states.Their existence hence certifies an intrinsic irreversibility of entanglement in nature and suggests a connection with thermodynamics.

A first experimental unconditional preparation and detection of a bound entangled state of light [1] will be presented in this talk. The focus will be set on the realization and results of our experiment that continuously produced a continuous-variable (CV) bound entangled state with an extraordinary significance of more than ten standard deviations away from both separability and distillability. This platform allows the efficient preparation of multi-mode entangled states of light with various applications in quantum information, quantum state engineering and metrology.

[1] J. DiGuglielmo, A. Samblowski, B. Hage, C. Pineda, J. Eisert and R. Schnabel, arXiv:1006.4651 (2010)

Q 50.5 Thu 11:30 SCH A01

Task-dependent control of open quantum systems — •Jens Clausen — Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

We consider the evolution of an open quantum system to second order in its coupling to a bath and describe the effect of a controlled time-dependence of the system Hamiltonian on a chosen function of the system state at a fixed time. This function defines a task quantity to be optimized such as fidelity, purity, or entanglement. If the time-dependence of the system Hamiltonian is fast enough to be comparable or shorter than the response-time of the bath, then the resulting non-Markovian dynamics allows to optimize the chosen task quantity. This implies on the one hand protecting a desired unitary system evolution from bath-induced decoherence but on the other hand also allows to use the system-bath coupling to realize a desired non-unitary effect on the system. Joint work with G. Bensky and G. Kurizki.

Q 50.6 Thu 11:45 SCH A01

Entanglement Control with Measures Optimized on the Fly — •Mark Girard and Florian Mintert — Freiburg Institute of Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg

We develop optimal time-dependent control fields that drive many-body quantum systems into states that maximize genuine multipartite entanglement. We build on techniques [1] to derive such control fields that have recently been derived to optimize entanglement as characterized by an approximate entanglement measure. This quantity, however, cannot accurately recognize genuine multipartite entanglement. To overcome this, we employ a recently derived criterion [2] to identify genuine many-body entanglement. Similar to typical entanglement measures, its evaluation requires an optimization. Thus we have two optimizations to solve, one for the control fields and one for the separability criterion. We investigate how both of these can be addressed simultaneously with the same techniques.

[1]Felix Platzer, Florian Mintert and Andreas Buchleitner, Phys. Rev. Lett., **105**, 020501 (2010)
[2]Marcus Huber, Florian Mintert, and Andreas Gabriel, Beatrix Hiesmayr, Phys. Rev. Lett., **104**, 210501 (2010)

Q 50.7 Thu 12:00 SCH A01

Environment-assisted entanglement in a Penning trap — •Michael Genkin and Alexander Eisfeld — MPIPKS, Dresden, Germany

Penning traps are known as an excellent tool for high precision measurements on charged particles since decades. More recently, however, also their potential in quantum information related applications was pointed out. Motivated by the recent proposals to store quantum information in the spatial degrees of freedom, we study theoretically the possibility of environment-assisted entanglement of the axial and cyclotron motion of a single charged particle in an ideal Penning trap, as the separability of the modes which is normally assumed for an ideal trap cannot be taken for granted in the presence of an environment. The dynamics is treated in the framework of a master equation with linear coupling to the environment, while the emergence of entanglement is monitored by means of the positive partial transpose criterion. Our results strongly suggest that weak environmental coupling of the axial and cyclotron degrees of freedom does not lead to entanglement at experimentally realistic temperatures, since detrimental thermalization appears to be dominant in this regime. The conclusion is supported by observation of entanglement at unrealisticly low temperatures; In this context, we also briefly address the interplay with decoherence which is known to grow with increasing temperature.

Q 50.8 Thu 12:15 SCH A01

Collisional decoherence in the non-Markovian regime — •Federico Levi[1,2] and Bassano Vacchini[1] — [1]Università degli Studi di Milano, Dipartimento di Fisica, Via Celoria 16, 20133 Milano, Italy. — [2]Freiburg Institute for Advanced Studies (FRIAS), Albert-Ludwigs-Universität Freiburg, Albertstr. 19, 79104 Freiburg

The issue of collisional decoherence is addressed theoretically in the framework of the theory of open quantum systems. With reference to the well-known experiments involving mesoscopic particles flying through a two slit interferometer in controlled pressure conditions [1], a test particle drifting through a gas can be described by means of the quantum linear Boltzmann equation [2]. If dissipative effects are neglected in order to focus on the suppression of the contrast of interference fringes generated by the action of decoherence, and if the Markovian approximation is performed, the dynamics can be described as a sequence of scattering events given by random momentum kicks. We show how these dynamics are immediately characterized by means of classical stochastic counting processes, and how a distribution of the scatterings in time following a so-called renewal processes generate strong non-Markovian dynamics. The non-Markovian dynamics thus obtained are analyzed in the strong and weak decoherence regimes and are compared with the Markovian case.

[1] K.Hornberger *et al.*, Phys. Rev. Lett. **90**, 160401 (2003).
[2] B. Vacchini and K. Hornberger, Phys. Rep. **478**, 71-120 (2009).

Q 50.9 Thu 12:30 SCH A01

Noise assisted long time entanglement for non-Markovian interactions — •Ines de Vega and Susana Huelga — Insitute of Theoretical Physics, University of Ulm

Noise is an ubiquitous phenomena in physical systems, and it is normally associated with a loss of quantum coherence, and hence entanglement, in the system. This picture was modified some years ago, when it was discovered that under particular conditions, a certain quantity of Markovian noise in the system can actually build entanglement in the long time limit. In this presentation, we extend this analysis to non-Markovian environments, and observe how the building of entanglement is strongly modified by the bath memory effects. Our analysis is based on the so-called stochastic Schrödinger equations, which allow the generation of a complete positive density matrix of the system, as it is required in order to measure properties such as entanglement.

Q 50.10 Thu 12:45 SCH A01

Spontaneous decay into a BEC near a surface — •Carsten Henkel and Jürgen Schiefele — Universität Potsdam

The spontaneous emission rate of an excited two-level atom placed in a Bose-Einstein condensate of ground-state atoms is enhanced by bosonic stimulation. The magnitude of the effect depends on the overlap between the atomic wave functions and the wavevector of the photon involved in the decay. We present calculations based on a quantum field theory of the atom-photon interaction that illustrate the importance of two- and four-point correlation functions of the ground-state field for the Bose enhancement [1].

For an excited atom prepared in a wavepacket, the transition rate to the ground state can be increased under optimum conditions by a factor $N/10$ where N is the atom number in the BEC. The effect can be used to amplify the small distance-dependent oscillations of the decay rate of an excited atom near an interface.

[1] PLA, 2010 (in press), `doi:10.1016/j.physleta.2010.11.058`.