Q 33: Quantum Effects: Entanglement and Decoherence I

Time: Wednesday 11:00–13:00 Location: f442

Q 33.1 Wed 11:00 f442

Ancilla-assisted preparation of steady-state entanglement — •Joachim Fischbach and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

The dissipative creation of entanglement is a promising field of research, that has seen many theoretical advances as well as experimental verifications in the last years. Dissipatively preparing an entangled state is not only an every day task for protocols in quantum information theory, but also bears interesting fundamental questions about how decoherence can counter-intuitively lead to entanglement. In our work [1], we show how the bipartite entanglement in a system of two two-level systems can be enhanced by coupling it with a dissipative ancilla. The steady-state is furthermore analyzed in terms of the eigenstates of the Hamiltonian, describing system and ancilla without environment. In this picture we are able to give an explanation for the enhancement effect. This could not only be used for practical purposes, like preparing entangled states, but also for further research of how engineered environments can be used for dissipative state preparation.

[1] J. Fischbach, M. Freyberger, *Phys. Rev. A* **92**, 052327 (2015)

Q 33.2 Wed 11:15 f442

Entanglement through complex photonic environments — •Sven Moritz Hein[1,2], Camille Aron[2,3,4], Hakan E. Türeci[2], Andreas Knorr[1], and Alexander Carmele[1] — [1]Institut für theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Deutschland — [2]Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA — [3]Laboratoire de Physique Théorique, École Normale Supérieure, CNRS, 24 rue Lhomond, 75005 Paris, France — [4]Instituut voor Theoretische Fysica, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

Creating, controlling and stabilizing nonclassical entangled states is one of the main challenges in current quantum optics. A promising approach is to couple the quantum-optical system to a non-Markovian reservoir to induce frequency-dependent dissipative dynamics. We present two approaches that utilize non-Markovian reservoirs to create and stabilize qubit entanglement. One is based upon time-delayed quantum-coherent feedback [1], which acts upon single qubits in a quantum network [2]. The second one uses resonant Raman scattering to counteract dephasing in qubits coupled to cavity modes, based upon a recent proposal of Aron *et al.* [3].

[1] Pyragas, K., Phys. Lett. A **6**, 421–428 (1992)
[2] Hein, S., *et al.*, Phys. Rev. A **91**, 052321 (2015)
[3] Aron, C. *et al.*, Phys. Rev. A **90**, 062305 (2014)

Q 33.3 Wed 11:30 f442

Effects of Local Measurements on Quantum Statistical Ensembles — •Walter Hahn[1] and Boris Fine[1,2] — [1]Institute for Theoretical Physics, University Heidelberg, Germany — [2]Skolkovo Institute of Science and Technology, Moscow, Russia

We investigate the effect of local measurements on quantum statistical ensembles for macroscopic systems. The system chosen is a lattice of spins 1/2 subject to projective measurements of individual spins. We find that the effect of measurements depends on system's Hamiltonian and on the initial statistical ensemble. The above findings justify prescriptions for protecting unconventional statistical ensembles.

Q 33.4 Wed 11:45 f442

Controlled generation of multipartite quantum correlations in a large spin ensemble — •Johannes Greiner, Durga Dasari, and Jörg Wrachtrup — 3. Phys. Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

The complex behavior of many body dynamics offers new insights into the emergence of correlated clusters, spread of entanglement and in general to non-equilibrium phenomena of quantum systems. We show how color centers in diamond can be used as a testbed to study these phenomena in a well-controlled fashion. Within the central spin model comprised of the spin states of a Nitrogen-Vacancy center in diamond coupled to a spin-ensemble, we show how correlated states can be generated and analyse them using entanglement witnesses. For finite ensemble sizes these states can also be used for quantum error correction and state transport.

Q 33.5 Wed 12:00 f442

Detection of Bell correlations in a spin-squeezed Bose-Einstein condensate — •Matteo Fadel[1], Roman Schmied[1], Jean-Daniel Bancal[1], Baptiste Allard[1], Valerio Scarani[2], Philipp Treutlein[1], and Nicolas Sangouard[1] — [1]University of Basel, Switzerland — [2]National University of Singapore, Singapore

The results of measurements by different observers can show correlations that are stronger than any classical theory allows. These Bell correlations can be confirmed by violating a Bell inequality, for which quantum entanglement is not sufficient.

A family of Bell inequalities has recently been proposed that requires only single- and two-particle measurements even for many-body systems [1]. Based on this work, we present the first experimental observation of Bell correlations in squeezed states of a two-mode Bose-Einstein condensate (BEC).

The system consists of a two-component 87Rb BEC of a few hundred atoms created on an atom-chip [2]. A state-selective potential gives rise to nonlinear one-axis twisting dynamics, which we use to prepare spin-squeezed states of the condensate, with up to 7dB of squeezing according to the Wineland criterion.

We measure the first and second moments of the collective spin operator along several axes. These measurement results demonstrate the presence of Bell correlations in our system by more than three standard deviations [3].

[1]J. Tura, et. al. Science 344, 1256 (2014) [2]M.F. Riedel, et. al. Nature 464, 1170 (2010) [3]R. Schmied, et. al. submitted (2015)

Q 33.6 Wed 12:15 f442

Simulating spin-boson models with trapped ions — •Andreas Lemmer[1], Cecilia Cormick[2], Susana Huelga[1], Tobias Schaetz[3], and Martin Bodo Plenio[1] — [1]Institut für Theoretische Physik, Universität Ulm, Germany — [2]FaMAF, National University of Cordoba, Argentina — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany

The spin-boson model is a paradigmatic model for the emergence of dissipation and decoherence in quantum mechanics and has motivated a lot of research in the past and present [1]. Still, no closed analytic solution of the model*s Hamiltonian is known. On the other hand, it is known that the dynamics of the model is fully determined by the so-called spectral density of the environment [1]. Here, we propose a method to simulate environments with continuous spectral densities in the setup of trapped ions using mixed species crystals and a small set of damped modes. In comparison with previous proposals [2] this has the advantage of reducing the experimental complexity and therefore moves the study of the statistical mechanics of the spin-boson model firmly into the realm of current ion trap technology.

[1] U. Weiss, Quantum Dissipative Systems (World Scientific, Singapore, 2008) Third Edition
[2] D. Porras et al., Phys. Rev. A 78, 010101(R) (2008)

Q 33.7 Wed 12:30 f442

Multi-qubit Zeno subspaces through repetitive projections — •Norbert Kalb[1], Julia Cramer[1], Daniel Twitchen[2], Matthew Markham[2], Ronald Hanson[1], and Tim Taminiau[1] — [1]QuTech and Kavli Institute of Nanoscience, Delft, The Netherlands — [2]Element Six Innovation, Oxford, United Kingdom

Quantum superposition states are susceptible to decoherence due to interactions with the environment. Generally, these interactions are uncontrolled and undesired: they cause a rapid loss of the phase of the quantum state and the associated information. Here we experimentally demonstrate that adding a strong channel of decoherence in the form of repeated projections of multi-qubit operators can actually protect complex quantum states from environmental decoherence.

We create quantum states of up to three ^{13}C nuclear spins in diamond [1] using a nitrogen vacancy center and repetitively project a joint observable of the nuclear spins. This projection freezes the unwanted evolution due to the environment through the Quantum Zeno effect, while leaving the remaining degrees of freedom available to encode multiple protected logical quantum bits, including entangled states. We quantify the suppression of dephasing through the derivation and experimental verification of a number-independent scaling law. This result enables the exploration of quantum computations with multiple logical quantum bits and studying complex spin dynamics under engineered decoherence.

[1] T.H. Taminiau et al., Nature Nanotech. 9, 171, 2014

Q 33.8 Wed 12:45 f442

Testing No-signalling principle in an optical parity-time symmetric system — •Lida Zhang and Jörg Evers — Max Planck Institute for Nuclear Physics, 69117 Heidelberg

As compared to traditional Hermitian dynamics, recently, a new class of Hamiltonians respecting parity-time (PT) reflection symmetry have revealed a great variety of fascinating phenomenon in optical system, i.e., nonreciprocal propagation, negative refrective index, etc.. We propose a novel scheme to test no-signalling principle in an atomic system where an optical PT-symmetric Hamiltonian is formed. We first create a vector laser beam pair having inseparable structures with respect to the different degrees of freedom, i.e., space distribution and polarization, which serves as a classical analogy of quantum-entangled state. The beam pair then passes through two different paths, where the laser beam experiences PT-symmetric evolution at one path and Hermitian evolution at the other. Finally, the beam pair is detected at two stations called "PT" and "Hermitian", which are remote from each other. It is found that the single probability detected at the "Hermitian" station is not equal to the summation of joint probabilities over the "PT" station, thus violating the no-signalling principle. Since the detection is independent from the evolution process, we thus find that the no-signalling violation originates from the non-Hermiticity of the optical PT-symmetric Hamiltonian. Furthermore, based on the analytical findings, we show that there is linear orrelation between the parameter characterizing no-signalling violation and the order parameter defining the PT-symmetry transition.