Q 22: Quantum Effects: Entanglement and Decoherence II

Time: Wednesday 10:30–12:15 Location: A 310

Q 22.1 We 10:30 A 310

Dynamic entanglement in oscillating molecules and potential biological implications — •Gian Giacomo Guerreschi[1,2], Jianming Cai[1,2], Sandu Popescu[3,4], and Hans J. Briegel[1,2] — [1]Institut für Theoretische Physik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der ÖAW, Innsbruck, Austria — [3]H.H. Wills Physics Laboratory, University of Bristol, U.K. — [4]Hewlett-Packard Laboratories, Stoke Gifford, U.K.

The fragility of entanglement under noise and decoherence is often used as an argument to dismiss the possibility of entanglement in biological systems. Here, we however demonstrate that entanglement can persistently recur in an oscillating two-spin molecule coupled to a hot and noisy environment, in which no static entanglement can survive. The system, driven through the oscillatory motions, represents a non-equilibrium quantum system. As a building block, the present simple mechanism supports the perspective that entanglement can exist also in systems which are exposed to a hot environment and to high levels of decoherence, which we expect e.g. for biological systems. Experimental simulation of our model with trapped ions is within reach of the current state-of-the-art quantum technologies.

Q 22.2 We 10:45 A 310

Bell*s inequalities can be violated due to a trivial experimental loophole. Nonlocality is still unproven — •Karl Otto Greulich — Fritz Lipmann Institut Jena

Usually, optical experiments on the violation of Bell*s inequalities are theoretically explained with an atom as light source which emits two entangled photons. The experimental verification is, however, completely different. In essentially all real experiments, a down-converting birefringent crystal, pumped by a laser, is used. Thereby it is assumed that one can work, by sharp attenuation and spatial selection, in the *single photon* limit. This approach is risky, since there is growing evidence that it is extremely difficult, if not impossible, to safely achieve such a single photon limit from a multi atom light source. If in this respect a minimal error occurs, Bell*s inequalities can be violated in a very trivial way. Since this loophole so far never has been considered, a safe proof of nonlocality is still elusive.

Q 22.3 We 11:00 A 310

Environment-induced bound entanglement — •Julio T. Barreiro[1], Philipp Schindler[1], Otfried Gühne[2,3], Thomas Monz[1], Michael Chwalla[1], Volckmar Nebendahl[2], Markus Hennrich[1], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Entanglement, the most powerful physical resource for quantum information, has been conjectured to decay, under the influence of decoherence, into a seemingly unprofitable form, known as bound entanglement. Bound entangled states have several applications, but most importantly, they underpin our understanding of multiparticle entanglement and its dynamics under decohering environments.

Here, we discuss our experiments with trapped calcium ions showing the existence of bound entanglement in nature. By embedding an entangled and distillable quantum state of four qubits in a dephasing environment (via spontaneous decay), we explore the rich dynamics of multiparticle entanglement. Upon the action of the environment, we observe the transition from multiparticle entanglement, via bound entanglement, to a fully separable state. The environment possibly even leads to a novel kind of bound entangled state, separable in all bipartitions, but not fully separable. To our knowledge, our work is the first to experimentally explore such multiparticle entanglement dynamics.

Q 22.4 We 11:15 A 310

Scattering laser light on cold atoms: multiple scattering signals from single-atom responses — •Tobias Geiger[1], Thomas Wellens[1], Vyacheslav Shatokhin[1,2], and Andreas Buchleitner[1] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Stepanov Institute of Physics, National Academy of Sciences, Nezavisimosti Ave 68, 220072 Minsk, Belarus

We present a new approach to calculate the spectrum of a strong laser field multiply and inelastically scattered between cold atoms. A detailed diagrammatic ansatz is used to reduce the known master equation results derived in the complete composite Hilbert space of a few atoms to optical Bloch equations for *single atoms*, which can be linked to each other in a self consistent way. Equivalence between the exact solution and our new approach is derived in the case of large distances between the atoms. Putting our new approach to work, the treatment of mutiple scattering of intense laser light by a dilute cloud of many atoms comes into reach.

Q 22.5 We 11:30 A 310

Quantum non-linear optics with ultra-cold atoms in an optical lattice — •Hessam Habibian[1,2], Stefano Zippilli[2], Stefan Rist[1,2], and Giovanna Morigi[2] — [1]Grup d'Óptica, Departament de Física, Universitat Autònoma de Barcelona, E-08193 Barcelona, Spain — [2]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

In this work, it is shown that an array of atoms inside an optical cavity can act as a controllable quantum non-linear optical medium. Here, the quantum properties of the generated light can be tuned by changing the interparticle distance with respect to cavity mode wavelength.

We characterize the quantum nature of the emitted light by the lattice as a function of the interparticle distance and the coupling amplitude between the lattice and the electromagnetic field and we discuss in which regime for the parameters the system can act as a single photon source.

Q 22.6 We 11:45 A 310

Detection of avoided crossings by fidelity — •Patrick Plötz[1,2], Michael Lubasch[1,2,3], and Sandro Wimberger[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, 69120 Heidelberg — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The overlap of eigenstates of two slightly different Hamiltonians—the fidelity—is proposed as an easy-to-use detector of avoided crossings in the energy spectrum [1]. It has been used to detect quantum phase transitions in the ground state of many-body quantum systems, and we lift its application to the complete energy spectrum. The value of this new Hilbert space measure for characterising complex quantum spectra is underlined by spectral analysis of many-body Bose–Hubbard systems.

[1] P. Plötz, M. Lubasch, and S. Wimberger, *Detection of avoided crossings by fidelity*, arXiv:0909.4333v1 [quant-ph].

Q 22.7 We 12:00 A 310

Complete suppression of atomic spontaneous emission and exited level shift with a half cavity — •Hétet Gabriel, Slodicka Lukas, Hennrich Markus, and Blatt Rainer — Institut für Experimentalphysik Innsbruck University, Austria

In this presentation we investigate the emission properties of a single atom in front of a spherical mirror covering half of the emission solid angle. We show that in this configuration it is possible to completely suppress the spontaneous emission of the atom and the level shift of its excited electronic state.

First, we explain the underlying physical process on a simplied one dimensional model. We then present a three dimensional theory that demonstrates that the density of modes around a linearly polarized atomic dipole can reach zero within a small volume around the atom.

We discuss the implications of such a finding for quantum information processing and QED effects in free space, and present the ongoing experimental efforts towards observing large effects using single trapped ions in front of high numerical aperture optical elements.