# Q 8: Quantum Effects: Interference and Correlations II / Entanglement and Decoherence I

Time: Monday 16:30–19:00 Location: A 310

**Group Report** Q 8.1 Mo 16:30 A 310

**Quantum optics with single molecules: photon-photon interactions** — •Stephan Goetzinger, Jaesuk Hwang, Robert Lettow, Martin Pototschnig, Alois Renn, Yves Rezus, Gert Zumofen, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zurich, CH-8093 Zurich, Switzerland

In this talk we shall review our quantum optical experiments with single molecules at cryogenic temperatures with emphasis on interacting photons. In the first experiment, we show that photons can be efficiently coupled to a single emitter without the need for a microresonator [1], resulting in a strong extinction of a weak laser beam. We achieved stimulated emission from a single molecule and demonstrated that it can act as an optical transistor [2]. In a further experiment we exploited the fact that single molecules serve as independent frequency-tunable single photon sources with a flux of more than one million photons per second [3]. By tuning the frequencies and spectral widths of two individual remote molecules, we explored various aspects of two-photon interference [4].

[1] G. Wrigge et. al., Nature Physics 4, 60 (2008). [2] J. Hwang et al., Nature 460, 76 (2009). [3] R. Lettow et al., Optics Express 15, 15842 (2007). [4] R. Lettow et al., arXiv:0911.3031v1 [quant-ph], (2009).

Q 8.2 Mo 17:00 A 310

**Superradiance from Nuclear Spins in Single Quantum Dots and NV-Centers** — Eric Kessler[1], J. Ignacio Cirac[1], Susanne Yelin[2], Mikhail D. Lukin[3], and •Geza Giedke[1] — [1]Max-Planck Institut für Quantenoptik, 85748 Garching, Deutschland — [2]University of Connecticut, Storrs, CT 06269, USA — [3]Harvard University, Cambridge, MA 02138, USA

We show that superradiant optical emission can be observed from the polarized nuclear spin ensemble of a single quantum dot or NV center. The superradiant light is emitted under optical pumping conditions and would be observable in quantum dots at nuclear polarizations already demonstrated in the lab.

Q 8.3 Mo 17:15 A 310

**Absorption of single photons by a single ion** — •Lukas Slodicka[1], Gabriel Hetet[1], Sebastian Gerber[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

A single trapped ion is an ideal system to investigate the most essential physical processes in atom-photon interfaces.

Here, we report on absorption spectroscopy experiments with a single trapped $^{138}Ba^{+}$ ion. We focus a weak and narrowband Gaussian light beam onto an optically cooled ion using a high numerical aperture lens. Single ion absorption was observed and peak absorption of up to 3% was measured, close to the limit set by the size of solid angle covered by the input lens. Furthermore, we observe electromagnetically induced transparency by tuning a dressing beam over a two photon resonance in a three level lambda system. A 50% inhibition of the absorption due to population trapping was measured.

Our results are first important steps towards realizing an efficient quantum network using single atoms and single photons in free space.

Q 8.4 Mo 17:30 A 310

**Using coherently backscattered light from two atoms to measure the photon statistics of dipole-dipole interactions** — •Vyacheslav Shatokhin[1,2], Sergei Kilin[2], and Andreas Buchleitner[1] — [1]Albert Ludwigs University of Freiburg, Freiburg, Germany — [2]B.I.Stepanov Institute of Physics, Minsk, Belarus

We discuss properties of the second-order temporal intensity correlation function of laser light coherently backscattered from two isotropic atoms in the helicity preserving polarization channel. We show that this function exhibits photon antibunching, and hence, it can be used as a measure of the photon statistics of resonant dipole-dipole interactions.

Q 8.5 Mo 17:45 A 310

**Ramsey Interferometry of Ion Coulomb Crystals in Spin-Dependent Potentials** — •Jens Domagoj Baltrusch[1,2], Gabriele De Chiara[2], Tommaso Calarco[3], Shmuel Fishman[4], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, Germany — [2]Grup d'Òptica, Universitat Autònoma de Barcelona, Spain — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [4]Department of Physics, Technion, Haifa, Israel

Ions confined in a harmonic, but highly anisotropic potential crystallize in a linear chain at sufficient low temperatures. By lowering the ratio between the radial and axial trapping frequency below a critical value, the system passes through a second order phase transition from a linear to a zig-zag configuration. By coupling the internal and the motional degrees of freedom, it is possible to measure the statistical properties of the crystal via a Ramsey type of experiment. One example is given by the autocorrelation function of the crystal which is connected to the visibility of the Ramsey signal [G. De Chiara et al. PRA 78, 043414 (2008)]. We present prospects to extend this model for ion crystals subjected to spin-dependent potentials.

Q 8.6 Mo 18:00 A 310

**Quantum entanglement in dense multiparticle samples** — •Mihai Macovei, Joerg Evers, and Christoph H. Keitel — Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

The existence of entanglement in multi-particle samples is an important fundamental problem. Here, we discuss the pairwise entanglement of atoms randomly extracted from a laser-driven dense multi-particle sample [1]. Our model includes a control laser field as well as quantum dissipation due to spontaneous emission. We find that the dipole-dipole interaction between the particles shifts the laser-qubit resonance frequency and consequently modifies the quantum entanglement. By means of an appropriate tuning of the laser frequency, one can optimize the entanglement in this system. For large ensembles, the maximum entanglement occurs near the laser parameters where the steady-state sample exhibits phase transition phenomena.

[1] M. Macovei, J. Evers, C. H. Keitel, arXiv:0911.1223v1 [quant-ph].

Q 8.7 Mo 18:15 A 310

**Single spontaneous emission inducing motional coherence of atoms** — •Jiri Tomkovic[1], Michael Schreiber[1], Joachim Welte[1], Jörg Schmiedmayer[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, Heidelberg — [2]Atominstitut der österreichischen Universitäten, Stadionallee 2, 1020 Wien

Spontaneous emission of a photon leads to a momentum transfer to the emitting atom resulting in an incoherent momentum distribution of an atomic ensemble. In case the atoms are close to a mirror, the situation can drastically change since directly emitted and reflected light can principally not be distinguished in certain directions. Thus at distances of few micrometers the spontaneous emission of a single photon leads to a coherent superposition of two momentum states of the atom. We will present our experimental results revealing the expected coherence.

Q 8.8 Mo 18:30 A 310

**Towards electron-electron entanglement in Penning traps** — •Lucas Lamata[1], Diego Porras[1], Juan Ignacio Cirac[1], Joshua Goldman[2], and Gerald Gabrielse[2] — [1]Max-Planck-Institut fuer Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Entanglement of isolated elementary particles other than photons has not yet been achieved. We show how building blocks demonstrated with one trapped electron might be used to make a model system and method for entangling two electrons. Applications are then considered, including two-qubit gates and more precise quantum metrology protocols.

Q 8.9 Mo 18:45 A 310

**Two interacting atoms in a cavity: Entanglement vs decoherence** — •Emerson Sadurní[1,2], Thomas Seligman[2,3], and Mauricio Torres[2] — [1]Institut fuer Quantenphysik, Ulm Universitaet —

[2]Instituto de Ciencias Físicas, UNAM. México — [3]Centro Internacional de Ciencias, UNAM, México

We address the problem of two interacting atoms of different species inside a cavity and find the explicit solutions of the corresponding eigenvalue problem. Closed expressions for concurrence and purity as a function of time when the cavity is prepared in a number state are found. The behavior in the concurrence-purity plane is discussed.