Q 23: Quantum gases: Interaction effects II

Time: Tuesday 11:00–12:30 Location: E 001

Group Report Q 23.1 Tue 11:00 E 001

Cavity Quantum Electrodynamics with utracold atoms — •Hessam Habibian[1,2,3], Stefano Zippilli[4], André Winter[1], Simone Paganelli[2], Fabrizio Illuminati[4], Heiko Rieger[1], and Giovanna Morigi[1] — [1]Universität des Saarlandes, Germany — [2]Universitat Autonoma de Barcelona — [3]ICFO-The Institute of Photonic Sciences, Spain — [4]Universita degli Studi di Salerno, Italy

Bragg scattering by atoms in optical lattices has been demonstrated in several experiments. When the atoms are confined in an array inside a resonator, they can elastically scatter photons into the cavity. In this work we assume that the periodicity of the lattice is such that there is no elastic scattering into the cavity mode. In this limit, when the atoms are deep in the Mott-insulator phase, the light at the cavity output can be squeezed or anti-bunched, depending on the amplitude of the laser intensity. We also show that the stationary entanglement between light and spin-wave modes of the array can be generated. While for point-like atoms photon scattering into the cavity is suppressed, for sufficiently strong lasers quantum fluctuations can support the build-up of an intracavity field. Numerical simulations show that for large parameter regions cavity backaction forces the atoms into clusters with a local checkerboard density distribution. The clusters are phase locked one with another so to maximize the number of intracavity photons. This state can be revealed in a non-destructive way by measuring the light at the cavity output. We argue that this system constitutes a novel setting where quantum fluctuations give rise to effects usually associated with disorder.

Q 23.2 Tue 11:30 E 001

Spin and Photon Glasses in Open Quantum Systems — •Michael Buchhold[1], Philipp Strack[2], and Sebastian Diehl[1,3] — [1]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]Department of Physics, Harvard University, Cambridge MA 02138 — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

Recent studies of strongly interacting atoms and photons in optical cavities have triggered the interest in open system realizations of the Dicke model of atomic qubits coupled to discrete photon cavity modes. In the framework of a non-equilibrium Keldysh path integral approach tailored to study open quantum systems with disorder, we analyze the open multi-mode Dicke model with variable atom-photon couplings and cavity photon loss. In spite of the dissipative nature of this model, we identify a spin glass phase as a possible steady state of the system. The glassy system shows low frequency thermalization and unusual spectral behavior of the atoms as well as a strong competition between relaxational and reversible dynamics close to the glass transition. As a main feature, the physical properties of the spin glass are completely mapped onto the photonic degrees of freedom, which, as we demonstrate, makes spin glass physics directly observable in cavity QED experiments.

Q 23.3 Tue 11:45 E 001

Intrinsic optical bistability in a cooperative Rydberg ensemble — •Christopher Carr, Ralf Ritter, Kevin Weatherill, and Charles Adams — Joint Quantum Centre (JQC), Durham University, Durham, England

We demonstrate a non-equilibrium phase transition in a cooperative Rydberg ensemble. A thermal Rydberg ensemble provides an ideal environment for studying cooperative effects which dominate when the number of atoms per cubic wavelength is large [1,2]. We perform a three-photon excitation scheme to Rydberg states in Caesium which allows us to obtain high Rydberg densities [3] and large transition wavelengths to nearby states.

The first-order non-equilibrium phase transition in the atom-light interaction occurs due to competition between a single-body response and a cooperative many-body response. Long-range correlations between Rydberg atoms arise due to virtual photon exchange in the dipole-dipole interaction. In the frequency domain, we observe a cooperative mean-field shift resulting in intrinsic optical bistability [4]. In the time domain, we observe a superradiant Rydberg cascade [5] due to cooperative emission.

[1] J. Keaveney et al., Phys. Rev. Lett. **108** 173601 (2012)
[2] J. Pritchard et al., Phys. Rev. Lett. **105** 193603 (2010)
[3] C. Carr et al., Opt. Lett. **37** 3858 (2012)
[4] M. Hehlen et al., Phys. Rev. Lett. **73** 1103 (1994)
[5] F. Gounand et al., J. Phys. B **12** 547 (1979)

Q 23.4 Tue 12:00 E 001

Bistability in Bose-Einstein condensates with attractive two-body and repulsive three-body contact interaction — Hamid Al-Jibbouri[1], •Antun Balaž[2], and Axel Pelster[3] — [1]Fachbereich Physik, Freie Universität Berlin, Germany — [2]SCL, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Fachbereich Physik, Technische Universität Kaiserslautern, Germany

The effects of three-body contact interactions on the properties of harmonically trapped Bose-Einstein condensates are usually quite small. Only in exceptional circumstances, e.g. in the presence of geometric resonances [1], such effects can reach the level of a few percent of two-body effects, and thus become experimentally observable. However, in the case of an attractive Bose-Einstein condensate, the repulsive three-body interaction can stabilize the system against collapse by increasing the critical number of atoms. Furthermore, motivated by Ref. [2], we show that the system parameters can be tuned in such a way that two stable equilibria coexist. Following Ref. [3] we use a variational approach and perform a detailed numerical analysis of the underlying cubic-quintic Gross-Pitaevskii equation to study the occurrence of a possible bistability.

[1] H. Al-Jibbouri, *et al.*, eprint `arXiv:1208.0991`
[2] A. Montina and F. T. Arecchi, Phys. Rev. A **66**, 013605 (2002)
[3] I. Vidanović, *et al.*, Phys. Rev. A **84**, 013618 (2011)

Q 23.5 Tue 12:15 E 001

Ionizing collisions of metastable neon in different spin states — •Jan Schütz, Alexander Martin, Sanah Altenburg, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Metastable rare-gas atoms (Rg^*) prepared by laser cooling techniques present a unique class of atoms for the investigation of cold and ultracold collisions. The extremely low kinetic energy ($\approx 10^{-10}$ eV) of the laser-cooled atoms stands in strong contrast to the high internal energy (≈ 15 eV) of the metastable state which enables Penning and associative ionizing collisions. For unpolarized Rg^* samples, these collisions lead to two-body loss rate coefficients up to 10^{-9} cm^3/s. Spin polarizing the atoms to a spin-stretched state suppresses the ionizing collisions. The amount of suppression, however, depends crucially on the details of the interaction.

We perform detailed investigations on the collisions of Ne*. To gain closer insight into the details of the suppression mechanisms, we investigate ionizing collisions for Ne* prepared in the individual $m_j = +2, +1$, and 0 sublevels of the metastable $^3P_2$ state and controllable mixtures of all five m_j-states. We apply two techniques, one based on RF induced Rabi oscillations and one based on STIRAP, to prepare the states. We present the resulting rate coefficients for the two bosonic isotopes ^{20}Ne and ^{22}Ne.