Q 25: Quantum Effects: Cavity QED II

Time: Tuesday 14:30–16:15 Location: P 4

Q 25.1 Tue 14:30 P 4

Distinguishing models of surface response through the self-energy of an electron — •Robert Bennett[1], Stefan Yoshi Buhmann[1], and Claudia Eberlein[2] — [1]Albert-Ludwigs-Universität Freiburg, D-79104 Freiburg i. Br., Germany — [2]University of Sussex, Falmer, Brighton BN1 9QH, UK

We consider the self-energy of an electron confined between parallel plates, representing a simple model of a cavity. The formalism of macroscopic quantum electrodynamics is used to describe the boundary-dependent fluctuating quantised vacuum field to which the electron is coupled, thereby endowing it with a surface-dependent self-energy [1,2]. After introducing the formalism we will outline the derivation of a general formula for this energy shift and demonstrate that its sign is different for two commonly-used models of surface response, namely the plasma model and the Drude model. Following this we propose a cyclotron-based experiment which could in principle detect this difference in sign, shedding light on continuing disagreements about the correct prescription for the interaction of low-frequency vacuum photons with media.

[1] R. Bennett, S.Y. Buhmann and C. Eberlein: arXiv:1610.01416 [quant-ph]

[2] R. Bennett, C. Eberlein - Physical Review A 86 (6) 062505, 2012

Q 25.2 Tue 14:45 P 4

Propagation of field-matter excitations in a microcavity: an application to photon Bose-Einstein condensation — •Yaroslav Gorbachev, Robert Bennett, and Stefan Yoshi Buhmann — Institute of Physics Albert-Ludwigs University of Freiburg Hermann-Herder-Str. 3 D-79104 Freiburg Germany

The progress of the last few years in photonics has led to new challenges in quantum optics. Especially interesting is a new class of systems which are called quantum fluids of light [1]. In these systems light and matter can be combined to create new types of quasiparticles. These particles differ from vacuum photons and are characterized by effective masses and mutual interactions. We are interested in developing a description of the underlying phenomena in a photon BEC. There, photons thermalize through emission and absorption in a dye medium inside a cavity. We use the language of quantum electrodynamics to describe the propagation of composite field-matter excitations in a dye filled optical microcavity. We will present some preliminary results which are related to this problem.

1: J.Klaers, J.Schmidt, F.Vewinger and M.Weitz. Bose-Einstein condensation of photons in an optical microcavity. Nature, 468(7323): 545-548, 2010

Q 25.3 Tue 15:00 P 4

Cavity-QED beyond model systems — •Christian Schaefer[1], Johannes Flick[1], Heiko Appel[1], Camilla Pellegrini[2], and Angel Rubio[1,2] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [2]Nano-bio Spectroscopy Group and ETSF, Departamento de Fisica de Materiales, Universidad del Pais Vasco UPV/EHU, San Sebastian, Spain

The optimized effective potential (OEP) is a natural connection between local density-functional theory and Many-body perturbation theory. In principle, this variationally best local potential reduces the problem to solving a system of one-particle Kohn-Sham equations combined with the solution of the OEP integral equation. The Krieger-Li-Iafrate (KLI) approximation reduces the integral equation to an analytically solvable one via a dominant orbital approximation.

In the present work, we extend the OEP [1] and KLI approaches to the case of electron-photon interactions in cavity quantum electrodynamics. Here an effective electronic interaction is transmitted via transversal photons. We present first results for KLI and OEP derived from an effectively reformulated Sternheimer response equation [2].

With these approaches, we are able to determine the influence of the quantized electromagnetic field on the electronic configuration of realistic molecules described fully real-space resolved [2,3].

[1] C. Pellegrini et al., Phys. Rev. Lett. **115**, 093001 (2015).

[2] J. Flick, C. Schaefer, H. Appel, C. Pellegrini, and A. Rubio, in preparation

[3] C. Schaefer, J. Flick, H. Appel, and A. Rubio, in preparation

Q 25.4 Tue 15:15 P 4

Microcanonical description of an extended Dicke model — •Miguel A. Bastarrachea-Magnani[1], Sergio Lerma-Hernández[2], and Jorge G. Hirsch[3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany. — [2]Facultad de Física, Universidad Veracruzana, México. — [3]Instituto de Ciencias Nucleares, México.

A paradigmatic model in quantum optics, the Dicke Hamiltonian, describes a system of N two-level atoms interacting with a single monochromatic electromagnetic radiation mode within a cavity. Its algebraic simplicity makes it suitable to describe qubit systems interacting with a bosonic field within the quantum information framework. The model is known because it exhibits a quantum phase transition, both in the ground state and in the excitation spectrum, which can be related to the underlying, classically chaotic spin dynamics, and implies certain entanglement properties. A general question is how the spectral properties of a quantum system are reflected in its thermodynamical phase diagram. In this work it is employed a semi-classical approximation to calculate the thermodynamics of an extended Dicke model in the microcanonical ensemble. The results are compared to calculations for the canonical ensemble. A straightforward thermodynamical manifestation of the critical phenomena on the spectral level is derived.

Q 25.5 Tue 15:30 P 4

Dissipation-Assisted Prethermalization in Long-Range Interacting Atomic Ensembles — Stefan Schütz[1,2], •Simon B. Jäger[1], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]icFRC, IPCMS (UMR 7504), ISIS (UMR 7006), Université de Strasbourg and CNRS, 67000 Strasbourg, France

We theoretically characterize the semiclassical dynamics of an ensemble of atoms after a sudden quench across a driven-dissipative second-order phase transition. The atoms are driven by a laser and interact via conservative and dissipative long-range forces mediated by the photons of a single-mode cavity. These forces can cool the motion and, above a threshold value of the laser intensity, induce spatial ordering. We show that the relaxation dynamics following the quench exhibits a long prethermalizing behavior which is first dominated by coherent long-range forces and then by their interplay with dissipation. Remarkably, dissipation-assisted prethermalization is orders of magnitude longer than prethermalization due to the coherent dynamics. We show that it is associated with the creation of momentum-position correlations, which remain nonzero for even longer times than mean-field predicts. This implies that cavity cooling of an atomic ensemble into the self-organized phase can require longer time scales than the typical experimental duration. In general, these results demonstrate that noise and dissipation can substantially slow down the onset of thermalization in long-range interacting many-body systems.

Q 25.6 Tue 15:45 P 4

Atomic self-organization in multi-mode cavities — •Tim Keller[1], Simon B. Jäger[1], Stefan Schütz[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]icFRC, IPCMS (UMR 7504) and ISIS (UMR 7006), University of Strasbourg and CNRS, 67000 Strasbourg, France

We derive a semiclassical model for the out-of-equilibrium dynamics of laser driven atoms, which also interact with two high-Q crossed cavities as in [1]. In the semiclassical limit the dynamics of the atoms is governed by a Fokker-Planck equation (FPE) for the atomic Wigner function, which generalizes the FPE of [2]. We identify the conditions under which the stationary state of the system can exhibit (i) a paramagnetic phase, where there is no stationary intracavity field, (ii) a nematic phase where the intracavity field is of solely one of the two resonators, and (iii) a ferromagnetic phase where both cavities are populated. Each phase of the cavity field is accompanied by different atomic density distributions. We show that this system can be mapped to the Generalized Hamiltonian Mean Field model [3] and determine the phase diagram as a function of the laser parameters. We furthermore analyse the dynamics following sudden quenches across the various phases.

[1] J. Léonard et al., arXiv preprint arXiv:1609.09053 (2016).
[2] S. Schütz, H. Habibian, and G. Morigi, PRA 88, 033427 (2013).
[3] A. Pikovsky et al., Phys. Rev. E 90, 062141 (2014).

Q 25.7 Tue 16:00 P 4

Localization transition in presence of cavity backaction — Katharina Rojan[1,2,3], •Rebecca Kraus[1], Thomás Fogarty[1,4], Hessam Habibian[1], Anna Minguzzi[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Université Grenoble-Alpes, LPMMC, BP166, F-38042 Grenoble, France — [3]CNRS, LPMMC, BP166, F-38042 Grenoble, France — [4]Quantum Systems Unit, OIST, Okinawa 904-0495, Japan

We study the localization transition of an atom confined by an external optical lattice in a high-finesse cavity. The atom-cavity coupling yields an effective secondary lattice potential, whose wavelength is incommensurate with the periodicity of the optical lattice. The cavity lattice can induce localization of the atomic wave function analogously to the Aubry-André localization transition. Starting from the master equation for the cavity and the atom we perform a mapping of the system dynamics to a Hubbard Hamiltonian, which can be reduced to the Harper's Hamiltonian in appropriate limits. We evaluate the phase diagram for the atom's ground state and show that the transition between extended and localized wave function is controlled by the strength of the cavity nonlinearity, which determines the size of the localized region and the behavior of the Lyapunov exponent. The Lyapunov exponent, in particular, exhibits resonancelike behavior in correspondence with the optomechanical resonances. We then analyse localization when this setup confines a gas of identical bosonic atoms, which solely interact via the cavity-mediated long-range forces.