Q 37: Quantum Gases (Bosons) IV

Time: Tuesday 14:00–16:00 Location: K 2.020

Q 37.1 Tue 14:00 K 2.020

Fluctuation-dissipation relations and finite compressibility of a grand canonical Bose-Einstein condensate — •Fahri Emre Ozturk[1], Tobias Damm[1], David Dung[1], Christian Kurtscheid[1], Erik Busley[1], Frank Vewinger[1], Julian Schmitt[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [2]Present address: Cavendish Laboratory, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom

We measure the density fluctuations and the isothermal compressibility of a two-dimensional photon Bose-Einstein condensate confined in a dye microcavity. The photon gas is coupled to a reservoir of molecular excitations, which serves both as a heat bath and a particle reservoir [1]. This leads to grand canonical statistical behavior with photon number fluctuations which can be as large as the average condensate photon number [2]. In thermal equilibrium, such fluctuations are related to the isothermal compressibility and the thermal energy k_BT. We report on the progress of an ongoing experiment investigating this relation, expressed by the fluctuation-dissipation theorem, for the condensed photon gas.

[1] Klaers et al., *Nature* **468**, 545 (2010)
[2] Schmitt et. al., *Phys. Rev. Lett.* **112**, 030401 (2014)

Q 37.2 Tue 14:15 K 2.020

Modeling Dye-Mediated Photon-Photon Interaction in Condensates of Light — •Milan Radonjić[1], Wassilij Kopylov[2], Antun Balaž[1], and Axel Pelster[3] — [1]Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Department of Physics, Technische Universität Berlin, Germany — [3]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

Based entirely on the Lindblad master equation approach we obtain a microscopic description of photons in a dye-filled cavity, which features condensation of light [1,2]. To this end we generalize the nonequilibrium approach of Ref. [3] such that the dye-mediated contribution to the photon-photon interaction in the light condensate is accessible. We describe the dynamics of the system by analyzing the resulting equations of motion. In particular, we discuss the existence of two limiting cases for steady states: photon BEC and laser-like. In the former case, we determine the corresponding dimensionless interaction strength relying on realistic experimental data and find a good agreement with the previous theoretical estimate [4]. Furthermore, we investigate how the dimensionless interaction strength depends on the respective system parameters such as the effective temperature of the dye and the number of the dye molecules.

[1] J. Klaers et al., Nature **468**, 545 (2010)
[2] R. A. Nyman and M. H. Szymanska, Phys. Rev. A **89**, 033844 (2014)
[3] P. Kirton and J. Keeling, Phys. Rev. Lett. **111**, 100404 (2013)
[4] E. C. I. van der Wurff et al., Phys. Rev. Lett. **113**, 135301 (2014)

Q 37.3 Tue 14:30 K 2.020

Photon Condensates in Microstructured Trapping Potentials — •Christian Kurtscheid[1], David Dung[1], Erik Busley[1], Julian Schmitt[2], Tobias Damm[1], Frank Vewinger[1], Jan Klärs[3], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn — [2]present address: Department of Physics, University of Cambridge, JJ Thomson Avenue, Cambridge, United Kingdom — [3]present address: Faculty of Science and Technology, University of Twente, Horst- Meander 123, Enschede, The Netherlands

In earlier work, Bose-Einstein condensation of photons has been re- alized in a dye- lled optical microcavity at room temperature. The short mirror spacing of the curved mirror microcavity introduces a low- frequency cuto , and thermal contact to the dye solution is achieved by subsequent absorption and re-emission processes. In the present work, we present recent results on a thermo-optic technique to generate variable potentials for light within a supermirror optical microcavity. The long photon lifetime allows for the thermalization of photons and the demonstration of a microscopic photon condensate with a critical photon number of 68. We observe e ective photon interactions as well as the tunnel coupling between microsites. We also report on a delamination technique realising static potentials in the dye microcavity environment.

Q 37.4 Tue 14:45 K 2.020

QED treatment of the photon BEC in arbitrary geometries: Coupled dissipative dynamics of dye molecules — •Yaroslav Gorbachev[1], Robert Bennett[1], and Stefan Yoshi Buhmann[1,2] — [1]Institute of Physics, University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), University of Freiburg, Germany

Progress in photonics over the last few years has led to a new challenge in quantum optics: the photon BEC. This has been experimentally observed in a small microcavity filled with a dye medium [1]. Confinement of laser light within such an optical microcavity creates conditions for light to equilibrate as a gas of conserved particles. We use the language of macroscopic quantum electrodynamics [2] together with theory of open quantum systems [3] to describe this phenomenon. We are interested in realistic description of the cavity geometry, whose frequency dependent reflection and absorption are fully encoded in the classical Green's function for the electromagnetic Helmholtz equation. This extension of the standard Jaynes-Cummings model to absorbing cavities with realistic geometries opens the door to studying the effects of discrete mode coupling in a resonant geometry to the strong body-assisted electromagnetic field of the cavity.

[1] J.Klaers, J.Schmitt, F. Vewinger, and M. Weitz, Nature (London) 468, 545 (2010)
[2] S.Y.Buhmann, Dispersion Forces I, Springer, Berlin Heidelberg, 2012
[3] P. Kirton, J.Keeling, Phys.Rev. A 91, 033826 (2015)

Q 37.5 Tue 15:00 K 2.020

Mode selection in a system of photons in a dye-filled microcavity — •Martina Vlaho, Daniel Vorberg, Alexander Leymann, and André Eckardt — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We investigate the non-equilibrium steady state of a gas of photons in a dye-filled microcavity as it has been realized by the Weitz group. We consider the regime where the system is pumped away from the cavity center so that the pump spot predominantly overlaps spatially with excited transverse photon modes. We observe that when increasing the pump rate above a threshold, such an excited mode acquires a macroscopic occupation, i.e., becomes selected. Ramping up the pump rate further, we find that the ground mode can become selected for a given range of system parameters, resulting from an increased density of excited state molecules in the cavity center, once the excited mode gets selected. We also consider the case of a homogeneously pumped system where we observe a cascade of transitions between the selected modes. We find that a blocking mechanism between modes with a large spatial overlap effects which modes are selected before saturation takes place.

Q 37.6 Tue 15:15 K 2.020

Towards photon Bose-Einstein condensation in a quantum dot microcavity — •Thilo vom Hövel, Christian Kurtscheid, David Dung, Erik Busley, Tobias Damm, Hadiseh Alaeian, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn

Bose-Einstein condensation has been achieved with cold atoms, exciton-polaritons, and more recently with photons in a dye-filled optical microcavity. In the latter work, thermalization of the photon gas is achieved by subsequent absorption and re-emission cycles of photons in the dye molecules. A non-trivial energy ground state is created by the long-wavelength cutoff introduced by the short mirror separation of the used cavity.

In the present work, semi-conductor quantum dots are investigated as a potential alternative to organic dyes as thermalization mediator. For this, the applicability of the Kennard-Stepanov theory to quantum dot absorption and emission spectra has been investigated. We are currently working on the observation of thermalization and Bose-Einstein condensation of photons in a quantum dot-filled optical microcavity. The current status of the experiment will be presented.

Q 37.7 Tue 15:30 K 2.020

Collective Frequencies of Trapped Photon Bose-Einstein Condensate — •Enrico Stein and Axel Pelster — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

In a photon Bose-Einstein condensate the main contribution to the effective photon-photon interaction is due to a thermooptic effect [1]. In order to describe this effect at a mean-field level, we use an open-dissipative Schrödinger equation coupled to a diffusion equation for the temperature of the dye solution [2]. With this we calculate analytically the lowest-lying collective frequencies and damping rates via a linear stability analysis for a harmonically trapped photon BEC. Since it is not possible to investigate its dynamical properties within a variational approach by using an action, we work out an approximation which is based on determining the equations of motion for the lower moments for Gaussian shaped condensate wave function and temperature distribution. As a result of the photon-temperature coupling the collective frequencies and damping rates turn out to depend on the diffusive properties of the dye solution. In particular, we examine whether the Kohn theorem is valid, i.e. whether the dipole-mode frequency is the same as the trap frequency [3,4].

[1] J. Klaers et al., Appl. Phys. B **105**, 17 (2011)
[2] D. Dung et al., Nature Photonics **11**, 565 (2017)
[3] A. L. Fetter and D. Rokhsar, Phys. Rev. A **57**, 1191 (1998)
[4] H. Al-Jibbouri and A. Pelster, Phys. Rev. A **88**, 033621 (2013)

Q 37.8 Tue 15:45 K 2.020

Towards a Photon Bose-Einstein Condensate in the Vacuum-Ultraviolet Spectral Regime — •Christian Wahl, Marvin Hoffmann, Frank Vewinger, and Martin Weitz — IAP, Universität Bonn

We propose an experimental approach for photon Bose-Einstein condensation in the vacuum-ultraviolet spectral regime, based on the thermalisation of photons in a noble gas filled optical microcavity. Our current experiments realizing photon Bose-Einstein condensates operate in the visible spectral regime with organic dyes as a thermalisation medium [1]. To reach the vacuum-ultraviolet spectral regime, we plan to replace the dye medium by high pressure xenon or krypton gas with absorption re-emission cycles on the transition from the ground to the lowest electronically excited state of the noble gases for thermalisation. In order to achieve sufficient spectral overlap between the atomic absorption and the di-atomic excimer emission, noble gas pressures of up to 180 bar will be created inside the cavity. For the case of the heavier noble gases xenon and krypton, emission wavelengths in the 120-160 nm regime seem feasible. The current status of experimental work will be reported.

References

[1] J. Klaers et al. Nature 468, 545-548 (2010)