Q 46: Quantum Gases (Bosons) IV

Time: Thursday 10:30–12:15 Location: S HS 037 Informatik

Invited Talk Q 46.1 Thu 10:30 S HS 037 Informatik

Controlling the flow of two-dimensional photon gases — •Jan Klaers[1,2], Mario Vretenar[1], Klaas-Jan Gorter[1], David Dung[2], Christian Kurtscheid[2], Tobias Damm[2], Julian Schmitt[2], Frank Vewinger[2], and Martin Weitz[2] — [1]Complex Photonic Systems (COPS), MESA+ Institute of Nanotechnology, University of Twente, Enschede, Netherlands — [2]Institute for Applied Physics, University of Bonn, Bonn, Germany

Controlling the flow of light is a fundamental requirement for quantum simulations with light. We have recently introduced a novel microstructuring technique that allows to control the transverse flow of light in a high-finesse optical microresonator [1]. This technique is based on the direct laser writing of a thermo-sensitive polymer enclosed in an optical microresonator, which effectively introduces a fully tunable trapping potential for two-dimensional photon gases. In particular, it is possible to capture photons onto periodic lattices sites with controllable tunnel couplings between nearest neighbors. A unique feature of this technique is the fact that it is fully reversible. The latter allows us to realize an arbitrary number of different geometries and tunnel coupling configurations in the same system, which would not be possible with standard semiconductor microstructuring techniques. This provides an ideal platform for photonic simulations of condensed matter physics.

[1] D. Dung, C. Kurtscheid, T. Damm, J. Schmitt, F. Vewinger, M. Weitz, and J. Klaers, Variable potentials for thermalized light and coupled condensates, *Nature Photonics* **11**, 565 (2017).

Q 46.2 Thu 11:00 S HS 037 Informatik

Phase Space Compression of Light by Thermalization of a 2D Photon Gas — •Erik Busley[1], Christian Kurtscheid[1], Fahri Öztürk[1], Julian Schmitt[1,2], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn — [2]Present address: Cavendish Laboratory, University of Cambridge, United Kingdom

A two-dimensional photon gas confined in an optical microcavity can exhibit both thermalization and – above a critical particle number – Bose-Einstein condensation, as shown in earlier work of our group [1, 2]. The used short spacing of the two curved mirrors of the microcavity makes the system equivalent to a two-dimensional, harmonically trapped one of massive bosons, where thermalization of the photon gas is achieved by subsequent absorption and emission cycles on the dye molecules.

Notably, photon thermalization in the trapping potential can besides a spectral also lead to a spatial redistribution of photons. Here we investigate an expected phase space compression of photons below the threshold to Bose-Einstein condensation from the thermalization, which results in an effective cooling of the photon cloud in the trapping potential. The variation of the final phase space density is studied versus the thermalization time. The current status of the experiment will be reported.

[1] J. Klärs et al., *Nature* **468**, 545 (2010)
[2] J. Klärs et al., *Nat. Phys.* **6**, 512 (2010)

Q 46.3 Thu 11:15 S HS 037 Informatik

Lasing assisted photon Bose-Einstein condensation in variable traps — •Martina Vlaho[1], Alex Leymann[2], Daniel Vorberg[1], and André Eckardt[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Istituto Nazionale di Ottica, Trento, Italy

We investigate the non-equilibrium steady state of a gas of photons in a dye-filled microcavity as it has been realized by the groups of Martin Weitz and Rob Nyman. By varying the photon cavity lifetime and the spatial distribution of the pump power, we show a transition from a quasi-equilibrium photon Bose-Einstein condensate (BEC) to an increasingly non-equilibrium situation in which a transition to a macroscopically occupied ground mode is triggered by a lasing transition in an excited mode of the system. The parameter regime for this form of lasing-assisted BEC can be extended by introducing a tilted double well potential, as it was recently introduced in the Weitz group. When the upper well is pumped, above a threshold the lasing mode "transports" excited dye molecules into the region of the lower well, the thermalization of which eventually, for sufficiently strong pumping, causes ground-state condensation.

Q 46.4 Thu 11:30 S HS 037 Informatik

Semiclassical Mean-Field Equations for Photon Bose-Einstein Condensates — •Enrico Stein and Axel Pelster — Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

In recent years the phenomenon of non-equilibrium Bose-Einstein condensation (BEC) has been studied extensively also within the realm of a Bose-Einstein condensate of photons. At its core this system consists of a dye solution filling the microcavity in which the photons are harmonically trapped. Due to cyclic absorption and reemission processes of photons the dye leads to a thermalisation of the photon gas at room temperature and finally to its Bose-Einstein condensation. Because of a non-ideal quantum efficiency, those cycles yield in addition a heating of the dye solution, which results in an effective photon-photon interaction. This talk focuses on the influences of the matter degrees of freedom on both the homogeneous photon BEC and the lowest-lying collective frequencies of the harmonically trapped photon BEC. In order to treat the matter, a modified semiclassical laser model is used. Following this track, the photon BEC is then described by an open-dissipative Gross-Pitaevskii equation, with a temporally retarded photon-photon interaction. The differences to the results of the corresponding analysis of a standard Gross-Pitaevskii equation are worked out within a linear stability analysis. In the trapped case the analysis refers, in particular, to the violation of the Kohn theorem, which arises from the temporal non-locality of the thermo-optic interaction.

Q 46.5 Thu 11:45 S HS 037 Informatik

Left- and right-handed photonic Bose–Einstein condensates — •Stefan Yoshi Buhmann[1,2], Yaroslaw Gorbachev[1], and Robert Bennett[1,2] — [1]University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Germany

Photonic Bose–Einstein condensation arises when a laser-driven ensemble of dye molecules thermalises with light inside a cavity, resulting in a macroscopic occupation of the lowest cavity mode [1]. Typically, modes of different polarisation are degenerate, leading to a condensate which is either unpolarised or whose polarisation follows that of the driving laser in a straightforward way [2].

Here, we explore means of breaking the polarisation symmetry by introducing chiral or birefringent media. In this way, differently polarised cavity modes acquire distinct energies and the photons condense into a state of well-defined polarisation. We explore the dependence of left- vs right-handed (or vertical vs. horizontal) polarisation on the chiral cross-susceptibility (or anisotropy) of the medium and the strength of the pump laser, both numerically and by means of a simple analytical formula.

[1] J. Klaers, J. Schmitt, F. Vewinger and M. Weitz, Nature **468**, 545 (2010).

[2] R. I. Moodie, P. Kirton and J. Keeling, Phys. Rev. A **96**, 043844 (2017).

Q 46.6 Thu 12:00 S HS 037 Informatik

Photon Condensates in Microstructured Trapping Potentials — •Christian Kurtscheid[1], David Dung[1], Erik Busley[1], Julian Schmitt[1,2], Frank Vewinger[1], 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, Cambridge, United Kingdom

In earlier work, Bose-Einstein condensation of photons has been realized in a dye-filled optical microcavity at room temperature. The short mirror spacing of the curved mirror microcavity introduces a low-frequency cutoff, and thermal contact to the dye solution is achieved by subsequent absorption and re-emission processes on the dye. In the present work, we present recent results on a delamination based technique realising static potentials for light within a supermirror optical microcavity, allowing for the creation of taylored potential landscapes for the optical quantum gas. We report on thermalization and condensation of photons in a created non-trivial potential consisting of a double well superimposed by a harmonic trapping potential, where the macroscopically occupied ground state of the system is a coherent symmetric superposition of states induced by the tunnel coupling between the double well sites.