Bose-Einstein Condensate of Photons Coupled to a Reservoir: From a Non-Hermitian Phase Transition to Collective Excitations

M Weitz[1], A Erglis[2], A Sazhin[1], F Vewinger[1], S Buhmann[3], and J Schmitt[1,4]

[1] *Institute of Applied Physics, University of Bonn, Bonn, Germany*
[2] *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany*
[3] *University of Kassel, Kassel, Germany*
[4] *University of Heidelberg, Heidelberg, Germany*
Contact Email: martin.weitz@uni-bonn.de

In optical quantum gases, near-equilibrium physics can be studied in the presence of a controllable dissipation. Here we report experiments studying the interplay of open system dynamics and grand canonical system properties in a Bose-Einstein condensate of photons, as realized in a dye-solution filled optical microresonator.

Thermalization of the two-dimensional photon gas occurs by absorption and re-emission processes on the dye molecules, the latter providing both an energy and an effective particle reservoir due to the possible interconversion of cavity photons and dye electronic excitations. This allows to observe a non-Hermitian phase transition between two different condensate phases due to an exceptional point in the condensate that is associated with the (small) system losses [1]. While usually Bose-Einstein condensation is separated by a smooth crossover to lasing, the presence of this phase transition reveals a state of the light field characterized by a bi-exponential second order coherence that is separated by a phase transition from lasing. In more recent work, we have studied time-periodic driving of the dye-microcavity condensate [2]. We find that as the photon number increases, the response of the coupled condensate-bath system transitions from overdamped to resonant behavior, indicating a transition from closed to open system dynamics. In particular, we can identify the characteristic spectrum of collective excitations, determined by the remaining openness of the photon condensate coupled to the reservoir of molecular excitations.

References

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