Chilling Photons in Variable Potentials: From a Two-State System of Light to Quantum Rings

M Weitz[1]

[1] *Institute of Applied Physics, University of Bonn, Wegelerstr. 8, 53115, Bonn, Germany.*
Contact Phone: +49228734837
Contact Email: martin.weitz@uni-bonn.de

Photons in optical microcavities radiatively coupled to a room temperature bath, such as dye molecules or more recently also semiconductor materials, can operate as collective quantum systems of light at near thermal equilibrium conditions, enabling e.g. the observation of photon Bose-Einstein condensates. In my Bonn group, we have recently thermalized photons in a two-mode dye microcavity system at conditions of tuneable chemical potential, demonstrating the elementary statistical mechanical problem of N bosons in a two-level system. To begin with, in a preparatory experiment carried out at pulsed pump conditions, Josephson oscillations between the two quantum states are observed, which verifies the possibility for coherent manipulation. Next, at stationary conditions thermalization of the two-mode system is investigated, arising from the radiative coupling of photons to the dye. Despite that the energetic splitting between the eigenstates is two orders of magnitude below the thermal energy such that at low occupations an almost equal distribution of the modes occupation is observed as expected from Boltzmann statistics, we observe efficient population of the ground state population and saturation of the upper level at high filling [1]. The experiment holds promise for state preparation in quantum technologies as well as for quantum thermodynamics studies. In other work with the dye microcavity system, we have demonstrated the realization a Bose-Einstein condensate of photons in a four-site quantum ring [2]. Photons here macroscopically populate the linear combination of site eigenstates with no phase winding, which is the ground state of the ring lattice.

References

[1] C Kurtscheid, A Redmann, F Vewinger, J Schmitt and M Weitz, arXiv:2411.14838 (2024)

[2] A Redmann, C Kurtscheid, N Wolf, F Vewinger, J Schmitt and M Weitz, Phys. Rev. Lett. **133**, 093602 (2024)