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Calorimetry and Coherence of a photon Bose-Einstein condensate in a dye microcavity

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Bose-Einstein condensation has been studied in different systems over the last years. One of them are photons trapped in a high-finesse microcavity, where thermalization is achieved by thermal contact to a dye medium [1]. Here, the dye molecules serve both as a heat bath and a particle reservoir, and grand-canonical statistical conditions can be realized experimentally in this system. Owing to the effective particle exchange with the reservoir, statistical physics predicts unusually large number fluctuations of the condensate, which for the first time can be unveiled in our experiments [2].

As the photons are close to a non-interacting quantum gas, our system can serve as a model for the ideal, trapped Bose gas in two dimensions. We have measured the thermodynamic properties, and found the characteristic cusp singularity for the specific heat at criticality (Figure 1), which strikingly resembles the well-known λ-transition in superfluid liquid helium [3]. Our measurements follow nicely the theory, and can serve as a textbook example for the ideal Bose gas.

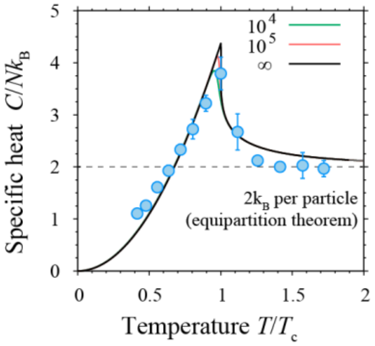

Figure 1. Specific heat of the photons as a function of the reduced temperature T/T_c. At the critical temperature, a cusp singularity indicates the phase transition from a classical gas at high temperatures ($T > T_c$) to a Bose-Einstein condensate of "cold" photons ($T < T_c$).

Following this, we have studied the temporal interference of a Bose-Einstein condensate of photons in a dye microcavity with a phase stable optical reference source, observing the phase evolution and the emergence of temporal coherence of the photon condensate [4]. In a Hanbury Brown-Twiss experiment, we identify a regime with large statistical intensity fluctuations, which are a consequence of grand-canonical ensemble conditions [2]. For small condensate sizes, we observe phase jumps of the condensate following statistical condensate fluctuations to small photon numbers. Subsequently, upon reemergence of the condensate a new and random macroscopic phase develops, demonstrating spontaneous symmetry breaking at the phase transition. For large composite condensate-reservoir-systems, our experimental data shows phase coherence even in the presence of statistical number fluctuations [4].

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[4] J. Schmitt, T. Damm, D. Dung, C. Wahl, F. Vewinger, J. Klaers, M. Weitz, Phys. Rev. Lett. 116, 033604 (2016)

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