Observation of quantum depletion in a nonequilibrium exciton-polariton condensate

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Exciton-polariton condensates in semiconductor microcavities form a nonequilibrium bosonic quantum system with a spontaneously appearing macroscopic coherence. The quantum nature of exciton-polariton interactions has been shown recently on a single particle level [1]. In the many-body case, when ground state is macroscopically occupied and the condensate is formed, a fundamental consequence of quantum fluctuations and polariton-polariton interactions is the appearance of the ghost excitation branch with negative energies with respect to the condensate. It is occupied by particle-particle scattering, reducing the population of the condensate in the process of so-called quantum depletion [2]. In the case of polariton condensates, this effect is strongly suppressed due to the nonequilibrium processes [3].

In this contribution, we present experimental evidence of quantum depletion in a nonequilibrium, optically trapped exciton-polariton condensate created in a ultrahigh quality GaAs-based microcavity sample. We create a high density of polaritons reaching the interaction-dominated Thomas-Fermi regime [4] and record the photoluminescence signal from both normal (NB) and ghost (GB) excitation branches. This was possible utilising a filtering technique with blocking the strong photoluminescence from the condensate to gain access to very weak signal of the branches. Analysis of the occupation in the momentum space reveal the populating mechanisms of the NB and GB, where the GB is populated solely due to quantum depletion. This is manifested in specific power-law decays of the occupation in momentum space [2]. Furthermore, we observe deviations from the equilibrium theory in both branches at high condensate densities, especially pronounced for negative exciton-photon detunings. We analyse and discuss the observed phenomena pointing out the importance of the nonequilibrium nature of polariton condensation process, distinguishing exciton-polariton condensates from Bose-Einstein condensates in thermal equilibrium.

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