Non-equilibrium physics of Bose-Einstein condensates of microcavity polaritons

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For the theoretical modeling of a polariton condensate, it is important to take into account that it has the crucial novelty of being an intrinsically non-equilibrium system: because of the finite lifetime of polaritons, the condensate has to be continuously replenished from the relaxation of optically injected high energy excitations (e.g. free carriers or hot polaritons), and its steady state results from a dynamical balance of pumping and losses. From this point of view, the polariton condensate shares some similarities with a spatially extended laser, but a direct analogy is made impossible by the strong nonlinearity due to polariton-polariton collisions.

We have proposed a generalization of the Gross-Pitaevskii equation that takes into account the pumping and dissipation of polaritons [1]. Within this model, the elementary excitation spectrum of the polaritons is dramatically changed at long wave lengths: the Goldstone mode acquires a diffusive instead of the sound character of equilibrium BECs.

Due to the non-equilibrium character of the polariton condensates, new phenomena arise: in the disordered potential landscape of the semiconductor microcavities, vortices may spontaneously form in the polariton condensate without setting the system into rotation. Such vortices have been observed in recent experiments and theoretically modeled with the generalized Gross-Pitaevskii equation [2].

At thermodynamical equilibrium, the chemical potential sets a single condensate frequency for the whole system. In the non-equilibrium case on the other hand, the condensate frequency may vary spatially, depending on the potential landscape. Recent experiments have shown that indeed, either a single frequency condensate or a fragmented state with different frequencies may form [3]. Our mean field model provides insight in the conditions under which a single or multiple frequency condensate appears [4].

Fluctuations can be included in the classical field model through the formalism of quasi-probability distributions from quantum optics. Within the resulting stochastic classical field model, we have studied the built up of spatial correlations across the condensation transition.

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