Virtual Many-particle Excitations in a Polariton Condensate under Nonresonant Pumping

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Exciton-polaritons, composite bosonic quasiparticles arising from exciton-photon strong coupling in a semiconductor microcavity system, form a novel type of dissipative quantum condensates. A spectacular consequence of the parametric scattering in polariton fluids is appearance of non-parabolic scattering bands, including normal branches (NB) and ghost branches (GBs), the latter ones populated by the virtual off-branch exciton-polaritons. The GB has been evidenced in a resonant excitation scheme in a complex geometry of four-wave-mixing [1], where GB states laying below the energy of the condensate were detected. However, since the work of Utsunomiya et al. [2], where the Bogoliubov-like dispersion of excitations in polariton condensates was detected in the absence of signal from the GB in a photoluminescence (PL) experiment, there has been a debate if the ghost branch can be observed at all in a nonresonant excitation scheme.

In this work we present the first observation of a PL signal of a spontaneously formed GB in a polariton condensate [4]. We investigate the luminescence of a polariton gas excited nonresonantly with a pulsed laser focused to a diffraction limited spot. The studied sample is a GaAs-based microcavity containing high indium content quantum wells $In_{0.3}Ga_{0.7}As$. Our excitation scheme provided a potential landscape, forming a ballistic flow of polaritonic wave packets propagating outside the pump spot. Under a sufficient pump fluence we observe a distinct renormalization of a polariton wave-vector dispersion and record strong signal of virtual off-branch states, comparable to the signal intensity originating from the thermally populated NB. This observation is verified in polarization-resolved measurements, were we explore the peculiar polarization nature of the two coupled branches, according to exact polarization selection rules in polariton-polariton scattering processes [3]. Further insight is given in time-resolved measurements of full dispersion evolution after a pump pulse, where we resolve signal from the NB and GB. Discussion on observed features is given in terms of spontaneous multiple scattering processes of polaritonic waves on intrinsic disorder potential of the sample.

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