Instability effects in cw FWM of cavity polaritons in planar microcavities

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Since the pioneering work by Weisbuch *et al* a lot of exciting physics has been established in a system of quasi 2D excitonic polaritons in a semiconductor microcavity (MC) [1]. The physics is connected to a bosonic nature of polaritons and their unique dispersion with an extremely small effective mass at the bottom and an inflection point at small wavevectors. One of the most striking features, a giant parametric polariton scattering has been found under the excitation close to the inflection point of the lower polariton (LP) branch [2]. That was explained theoretically [3] as a MC polariton parametric amplifier, with threshold dependence of the coherent gain due to renormalized polariton four-wave-mixing (FWM). Further studies have shown that the stimulated parametric polariton scattering does not follow the key prediction of a standard FWM theory, namely, the shift of the excitation energy $h\omega_{exc}$ and wavevector k_{exc} from the inflection point does not lead to shift of the signal along the LP dispersion curve predicted by the energy and momentum conservation laws. Instead, the signal appears always at k=0, the idler shifts to $k=2k_{exc}$, and the conservation laws are fulfilled due to the shift of the idler out of the LP dispersion curve to the point $E(k=2\ k_{exc})= h\omega_{exc}(k=2\ k_{exc})$ - $E_S(k=0)$ [4]. Such a behavior was suggested to occur due to a competition between two instabilities in the polariton-polariton scattering, namely, stimulated polariton-polariton scattering and bistability of the pumped polariton mode response.[5,6]

In the present contribution we report and discuss two new surprising properties of stimulated parametric scattering of cavity polaritons in GaAs based MCs. First, the expected increase in the threshold power for the stimulated scattering P_{thr} with increasing temperature T appears only in MCs with shallow LP branch. With deepening of the LP branch the dependence of $P_{thr}(T)$ changes unexpectedly to opposite one. In particular, the ratio $P_{thr}(18\ K)/P_{thr}(5\ K)$ changes from 0.3 to 3 with an increase of the LP branch depth from 2.4 to 4.6 meV. Second, P_{thr} displays a drastic decrease already at very weak additional excitation of MC above GaAs band gap generating exciton density an order of magnitude smaller than the resonant excitation near the LP inflection point.

Finally, we discuss the behavior of the FWM signal under the cw excitation with two lasers, A resonant with the LP inflection point and B exciting out of the inflection point. These measurements of the FWM response I_{FWM} at $k=2k_A-k_B$ were carried out to made certain of the fact that the unusual behavior of parametric scattering in the MCs is connected to the bistability of the pumped polariton mode response. Experiments have shown that the dependence of I_{FWM} on P_A differs in kind from a square one and displays a threshold-like increase in the intensity at some critical excitation power $P_{A,cr}$ which value is slightly smaller than P_{thr} for an appearance of the stimulated parametric polariton scattering of the laser A at $\mathbf{k}$~0.

The nontrivial nonlinear behavior of the scattered polariton signal in case of two pumped polariton modes is modeled numerically via a solution of coupled Maxwell's and nonlinear

Schrödinger's equations. This method was introduced in [5,6] but for a single externally pumped exciton mode. The Maxwell's equation, written in a resonant scalar approximation, couples the electric field in MC and the exciton polarization with the external electromagnetic field far from the MC. The latter is treated as a bi-chromatic electromagnetic wave with two different frequencies and two different angles of incidence. The inhomogeneous nonlinear Schrödinger equation couples the exciton polarization with electric field inside MC and has additionally a stochastic Langevin-noise source allowing us to model the quantum fluctuations of the scattered signals using the quasiclassical equations. The solutions of these equations demonstrate an extraordinary rich behavior of different transitions in cavity polariton system under two simultaneous excitations. The calculated behavior is directly connected to a bosonic nature of polaritons and their specific energy dispersion. The comparison of calculations with experimental data shows that they are in a qualitative agreement with each other.

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