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Multiple polariton scattering in semiconductor microcavities

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In semiconductor microcavities (MCs) with embedded quantum wells a strong two-dimensional (2D) confinement of light makes accessible very high densities of photonic field which may result in the realization of a new type of nonlinear effects. Another intriguing property is connected to the boson nature of the mixed exciton–photon states in MCs, 2D polaritons. Due to a very small in-plane mass the density of polariton states is strongly reduced relative to that of excitons. This makes it possible to achieve high filling factors of the polariton states, which in turn may lead to the stimulation of scattering processes. Indeed, recent studies demonstrated that scattering involving two polaritons photocreated with particular momentum k to final states with $2k$ and $k = 0$ is stimulated above a particular threshold density by a high population of the $k = 0$ polaritons [1]. Theory predicts that as a result of polariton–polariton interaction the low polariton (LP) dispersion curve shifts to higher energy [2]. Both the magnitude of such shift and the threshold density for occurrence of polariton–polariton scattering is proportional to LP homogeneous linewidth γ.

Here we present the detailed investigations of the LP properties in the regime of polariton–polariton scattering in a wide range of temperature 2 K $< T <$ 30 K. Firstly, it was observed that both the amplitude of renormalisation of polariton energy and threshold density increase with growing temperature, which is accompanied by increasing of γ. The changes of γ is assumed to be connected to free excitons the density of which increases with T. Such growth of high k exciton population should lead to a significant polariton–exciton interaction and, consequently, larger γ.

Most surprisingly in addition to previous observations of strong nonlinearities in polariton emission at $k = 0$ (energy E_S) and $2k$ (E_I) at resonant excitation at k (E_L) we have also observed a novel feature in the emission pattern at $3k$. The linewidth (0.1 meV) and polarization degree (> 0.95) of the new peak is very similar to those of the peaks at $k = 0$ and $2k$. The energy of this line (E_M) with very high accuracy satisfies the condition for higher order polariton scattering process (in which k-vector is also conserved), namely, $3E_L = 2E_S + E_M$. Also it satisfies the condition $2E_I = E_L + E_M$. We thus clearly demonstrate that the higher order multiple polariton scattering processes should be taken into account for full description of the observed nonlinearities.

References

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