Polariton dynamics in double coupled microcavities

Krzysztof Sawicki[1], Thomas J. Sturges[2], Magdalena Stobińska[2], Maciej Ściesiek[1], Marcin Muszyński[1], Wojciech Pacuski[2], Tomasz Kazimierczuk[1], and Jan Suffczyński[1]

[1]*Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland*
[2]*Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland*

Exciton-polaritons are half-light, half-matter quasiparticles arising from the strong coupling between excitons and photons. Thanks to their matter component, polaritons mutually interact, which leads to energy relaxation, thermalization and nonlinear effects such as optical parametric scattering and oscillation. The bosonic nature of polaritons enables their Bose-Einstein condensation, which is associated with a massive occupation of the bottom of the lowest polariton branch. In the present work we switch from a widely studied case of two-level polariton system of a semiconductor microcavity embedding a quantum well to a four-level polariton system formed in double coupled microcavities, each embedding quantum wells. A high degree of tunability gives us a possibility to study the complex dynamics of polariton relaxation and condensation as well as inter-branch polariton scattering.

The strong coupling regime between optical modes of the double (Cd,Zn,Mg)Te microcavities and excitons confined in embedded (Cd,Zn)Te quantum wells is confirmed by the observation of four polariton branches in photon momentum resolved μ-photoluminescence (μ-PL) and reflectivity spectra of the investigated sample. The polariton condensation under non-resonant, pulsed optical excitation at normal incidence is proven in power dependent μ-PL by a threshold behavior of a non-linear increase of the emission intensity, narrowing and blueshift of the emission. Time-resolved measurements uncover a complex dynamics of polariton relaxation, condensation and radiative decay: in the initial stage following the excitation pulse, when the polariton density is the highest, the emission from the lowest polariton branch dominates. When the polariton density decreases below some threshold value, emission from this branch quenches completely and emission from the upper branch emerges. A rate equation model is derived to describe the observed emission dynamics. The modelling indicates that the observed effects can be explained by a competition between relaxation from the reservoir to the two different lower polariton branches.

Furthermore, the angle-resolved experiment provides evidence for polariton parametric scattering in the investigated system. The emergence of the condensate at the bottom of the upper polariton branch gives rise to inter-branch polariton scattering. During the scattering, a polariton pair from the condensate in the upper branch turns to a pair of polaritons with $+k_{\|}$ and opposing $-k_{\|}$ in-plane momentum at the lowest polariton branch. Time-resolved experiment shows that the lifetimes of polariton states involved in the scattering are comparable. This indicates that the rate of energy exchange between these states is faster than their lifetime and suggests that scattering has, at least in part, an oscillatory character.