mgr inż. Maciej Pieczarka

Doctoral dissertation abstract

„Investigations on the exciton-polariton condensates in semiconductor optical microcavities with built-in disorder"

Optical investigations on exciton-polaritons in optical microcavities are presented in the following doctoral dissertation. Exciton-polaritons are quasi-particles being a natural excitations of a system of strongly coupled photons and excitons inside a planar microcavity. These quasi-particles are composite bosons, thus their condensation can be achieved, having many analogical properties to the Bose-Einstein condensates. For instance, polaritons can coherently propagate with absence of scattering on small defects, which is a consequence of a superfluidity of the system.

Within the doctoral thesis, investigations on the exciton-polariton condensate created in a microcavity structure based on GaAs substrate were performed. The investigated structure consist of two distributed Bragg reflectors made of alternating GaAs/AlGaAs layers. The active region is placed inside the microcavity and was made of InGaAs/GaAs quantum wells with high molar content of InAs (above 27%). High impact of disorder and localization level of exciton-polaritons within natural defects was determined in the optical characterization studies (reflectivity measurements and local scanning of emission with micrometer spatial resolution). The polariton condensate was created in the experimental configuration employing a nonresonant pulsed laser having much higher energy than the bandgap of the quantum well material. Under this kind of excitation, laser generated a localized incoherent excitonic reservoir, which was a source of bosonic stimulation to the polariton condensate mode. Additionally, the reservoir causes the ballistic propagation of polaritonic waves outside of the pumps spot. This caused radial propagation of polaritons, which were scattered on the strong potential defects. This subsequently generated interactions between polaritons, due to overlapping of scattered waves. Hence, this led to occupation of quasi-linear Bogoliubov excitation branches, especially the relative negative energy branch. These observations have been confirmed in polarization-resolved measurements, where orthogonal linear polarization of photons from two branches were detected. This was the basis of the interpretation of the origin of the negative branch occupation in a multi-particle scattering processes. The measurements were supported by time-resolved studies, where complicated polariton dynamics in real and momentum space were registered. Additionally, real space propagation of the polariton condensate was modelled within the phenomenological mean-field theory approach, using the generalized Gross-Pitaevskii equation. Qualitative agreement between the simulation and the experiment was achieved.

Scientific results presented in the dissertation are worldwidely unique and show first observation of spontaneously generated occupation of both excitation branches of a polariton condensate, which was detected directly in a nonrensonantly excited photoluminescence measurement. They make an important contribution to the understanding of physics of polariton condensates generated in microcavities with a significant contribution of defect potential.