Abstract

This dissertation presents an experimental study of optical nonlinear effects in exciton-polariton microcavities based on II-VI semiconductors, with cadmium telluride (CdTe) as the main material platform. The work focuses on phenomena such as optical bistability, exciton-polariton condensation, and controlled interactions between polariton condensates. It also develops experimental tools that advance reciprocal- and real-space resolved studies for precise imaging and efficient excitation of microstructures.

First, transmissive CdTe microcavities in the strong coupling regime fabricated by a lift-off process are introduced. The input-output characteristics revealed optical bistability with two distinct types of hysteresis loops, depending on laser detuning: one with the conventional shape and direction reported for other types of microcavities, and a new one, exhibiting a triangular shape and an opposite direction of formation. Angle-resolved measurements demonstrated that the switching mechanism is linked to a thermally induced transition between strong and weak coupling regimes. A theoretical model including thermal redshifts and coupling reduction reproduced the observed bistabilities. The system also provided access to natural exceptional points in the polariton spectrum. Encircling experiments were performed by simultaneously tuning the excitation power, which effectively modulated the coupling strength, and by tracing the in-plane wavevector. Together, these parameters allowed the exploration of the exceptional point topology.

Then, ballistic coupling of condensates in semimagnetic CdTe microcavities is investigated. In this system, the giant Zeeman effect under an external magnetic field modifies exciton-photon detuning and polariton effective masses. Experiments showed that the magnetic field switches the parity of the condensate dyads between in-phase and anti-phase states. The effect was observed in real- and momentum-space interference patterns and was explained using analytical model and spinor Gross-Pitaevskii simulations.

Finally, polymer microlenses fabricated directly on the surface of microcavities using two-photon polymerization are presented. Ray-tracing simulations guided the microlens design. Experiments confirmed that the microlenses extend the accessible in-plane wavevector range, allow parallel measurements in reciprocal space from multiple spots on the sample with microlens arrays, and reduce the laser pulse energy required to achieve condensation threshold by locally concentrating excitation. Their functionality was demonstrated in both dielectric and semiconductor microcavities under cryogenic conditions.

Altogether, the dissertation reports the realization of transmissive CdTe microcavities with novel bistability mechanisms, the appearance and encirclement of natural exceptional points, the magnetic-field induced parity switching of condensate supermodes, and the development of microlenses as tools for single and multiplexed reciprocal space studies. Together, these results document new nonlinear effects in II-VI microcavities and establish novel methods for their systematic investigation.