Occupancy-driven Zeeman suppression and inversion in trapped polariton condensates

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Polariton spin is a degree of freedom that can be used to manipulate the emission properties of polariton condensates. The study addresses spin-related phenomena, which are difficult to observe due to the relatively weak Zeeman effect of exciton-polaritons in GaAs-based structures. Here, we overcome this limitation by generating optically trapped exciton-polariton condensates, which are known to possess extremely high condensate coherence time and, thus, ultra-narrow spectral linewidths (see Figure 1(a)). This makes it possible to resolve magnetically induced $\sim$ μeV fine-energy shifts in the condensate, and identify unusual dynamical regions in its parameter space [1]. The continuous control over the polariton confinement allows exploration of two regimes of operation depending on the strength of the polariton-polariton interaction: (1) the full parametric screening of the Zeeman splitting, known as the spin-Meissner effect (see Figure 1(b)) and (2) Zeeman inversion regime, where, upon reaching the critical excitation pump power, the Zeeman splitting reverses (see Figure 1(c)). In the experiment, the transition from one range to the other occurs by adjusting the size of the optical trap, which controls the strength of the polariton-polariton and polariton-exciton reservoir interactions. Both of the above-mentioned effects have not been reported so far for optically trapped exciton-polariton condensates. We develop a mean field model based on a zero-dimensional generalized Gross-Pitaevskii equation coupled to a rate equation for the exciton reservoir, which qualitatively captures the observed effects.

Optical trapping of polariton condensate offers a powerful tool for magneto-optical studies of microcavities, which has not been explored so far. These observations bring new fundamental insights into the magnetic properties of the optically trapped exciton-polaritons. The magnetic control of the emission properties, tunability and reconfigurability, apart from their importance for the fundamental physics of polaritons, paves the way to the potential practical application of magnetically controlled polariton systems.

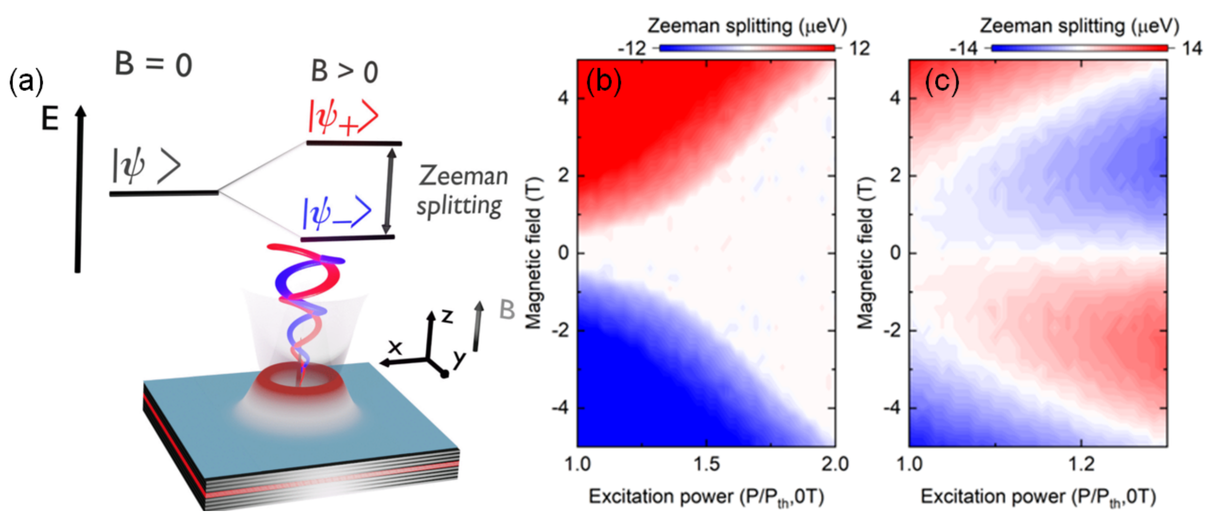

Fig. 1. (a) Schematic illustration of the investigated sample. The linearly polarized, non-resonant continuous wave laser was used to create equal populations of the $|\psi_\pm\rangle$ polaritons. The $\sigma_\pm$ emission (blue and red spirals) is detected simultaneously. The magnetic field applied parallel to the sample growth axis lifts the degeneracy of the polariton spins, manifesting in a detectable energy difference between the emitted circularly polarized photons. (b) Power-induced suppression of the Zeeman splitting. The splitting vanishes at certain critical boundaries in the B-P plane (white region), becoming parametrically screened by the condensate interactions (c) Power-induced inversion of the Zeeman splitting. The splitting sign is reversed after exceeding the critical value of the excitation power.

References

[1] K. Sawicki et al. Phys. Rev. B **109**, 125307 (2024).