Optically Trapped Exciton-Polariton Condensates in a Perovskite Microcavity

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We present the demonstration of optical trapping of exciton-polariton condensates in monocrystalline $CsPbBr_3$ perovskite microcavities at room temperature. By utilizing an annular nonresonant excitation profile, we achieve all-optically reconfigurable quantum state selection leveraging the strong polariton nonlinearities and ultrafast response times characteristic of perovskite systems. This study explores the influence of optical trap dimensions and excitation power on the behavior of polariton condensates, leading to the formation of high-order angular harmonics and enabling the manipulation of quantum state numbers.

Our novel microcavity design employs high-quality $CsPbBr_3$ perovskite monocrystals encapsulated using a low-temperature plasma-enhanced chemical vapor deposition (PECVD) technique, ensuring microcavity confinement with a photon stopband centered at 535 nm. The fabrication process involves dripping the prepared perovskite solution into a polydimethylsiloxane (PDMS) template placed on a substrate of 6.5 pairs of SiO distributed Bragg reflectors (DBRs), followed by microfluidic-assisted crystallization to form monocrystalline $CsPbBr_3$ microwires [1]. Finally, the structure is encapsulated with 10.5 pairs of SiO_2/TiO_2 DBRs, achieving a high Q-factor cavity with precisely defined geometry.

Using an annular nonresonant excitation profile focused onto the perovskite microcavity, we induce a polariton potential barrier at the maxima of the focused field. This effective potential, created by a background of incoherent excitons, drives polaritons towards the ring center, facilitating their stimulated scattering and condensation [2]. The observed condensate states include high-order angular harmonics reminiscent of whispering gallery modes and ripple states, demonstrating the tunability of polariton quantum states. Notably, for low excitation powers, condensation occurs in extremely high-order angular harmonics with orbital angular quantum numbers up to $l = 19$, while at higher powers, the condensate collapses to successively lower order modes due to enhanced stimulated scattering and phonon-mediated energy relaxation.

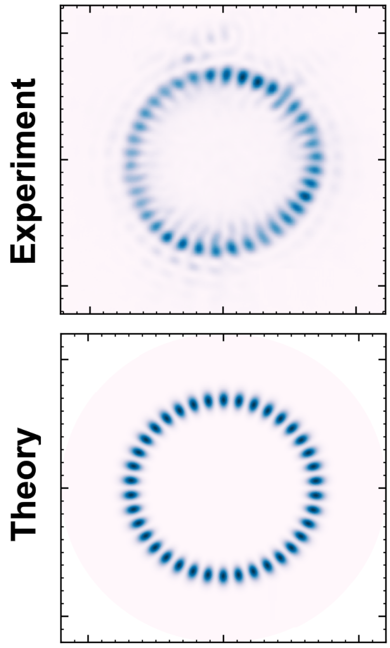

Figure 1: Polariton condensation in angular harmonics with orbital angular quantum number $l = 19$. Comparison of experiment results with theory model.

Acknowledgments

M.Z. and B.P. acknowledge the European Union EIC Pathfinder Open project “Polariton Neuromorphic Accelerator” (PolArt, Id: 101130304). M.K., R.M., W.P. acknowledge the National Science Center, Poland, project No. 2022/47/B/ST3/02411. L.S., K.P., K.K. and A.S. acknowledge the support by the statutory funds of the Łukasiewicz Research Network – Institute of Microelectronics and Photonics. H.S. acknowledges the Icelandic Research Fund (Rannís), grant No. 239552-051. M.Z. and H.S. acknowledge the project No. 2022/45/P/ST3/00467 co-funded by the Polish National Science Center and the European Union Framework Programme for Research and Innovation Horizon 2020 under the Marie Skłodowska-Curie grant agreement No. 945339. A. O. acknowledges the National Science Center, Poland, project No. 2024/52/C/ST3/00324.

References

[1] M. Kędziora et al., *Journal of Applied Physics* **135**, 2024.
[2] S. Askitopoulos et al., *Physical Review B* **88**, 041308 (2013).
[3] A. Opala et al., *Optica* **10**, 1123 (2023).

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