Experimental investigation of optically trapped polariton condensation phase diagram

A. Bieganowska[1, *], **A. Svetlichnyi**[2,3], **M. Betke**[1], **C. Schneider**[4], **S. Höfling**[5], **S. Klembt**[5], **P. Comaron**[2,6], **M. Szymańska**[2], **M. Pieczarka**[1]

[1]Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
[2]Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom
[3]School of Physics, University of Bristol, Beacon House, Queens Rd, Bristol BS8 1QU, United Kingdom
[4]Carl von Ossietzky Universität Oldenburg, Fakultät V, Institute für Physik, Oldenburg 26129, Germany
[5]Julius-Maximilians-Universität Würzburg, Physikalisches Insitut and Würzburg-Dresden Cluster of Excellence ct.qmat, Lehrstuhl für Technische Physik, Am Hubland, 97074 Würzburg, Germany
[6]CNR NANOTEC - Institute of nanotechnology, Via Monteroni, 73100 Lecce, Italy

Strong coupling between cavity photons and quantum well excitons results in the emergence of new quasiparticles - exciton polaritons. After reaching a critical particle density, they form a condensed state. However, the spatial overlap of the high-energy reservoir and the condensate influences the coherence of a polariton condensate. This challenge has been tackled with the idea of optical trapping, a method of separating the excitonic reservoir and the condensed polaritons [1]. Shaping the excitation laser beam into a ring creates a circular potential trap because of repulsive interactions between polaritons and excitons. This approach, distinct from previous studies that used a Gaussian-shaped laser beam for sample excitation, is yet to be fully understood in terms of the condensation phase diagram of optically trapped polaritons.

In this contribution, we comprehensively investigate the polariton condensation inside an optical trap using a GaAs-based microcavity sample. The structure was nonresonantly excited with a pulsed laser shaped into a ring on the sample surface to obtain an effective circular potential. Our extensive power-dependent investigation of polariton condensation at various photon-exciton detunings in three different trap diameters revealed significant findings. We discovered the most favorable trap size that allows for ground state condensation in a wide range of detunings, including strongly photonic polaritons, which has not been observed in previous studies with homogenous excitation. Moreover, the dependency on detuning on the condensation threshold power showed different trends compared to those known from the single-spot excitation phase diagram [2–5]. Interestingly, it is quite difficult to capture the observed behaviour and trends using regular mean-field theories. These results are a major advancement in our understanding of polariton condensation in optical traps and have the potential to optimize the operation of coherent polaritonic devices in the trapped geometry.

Acknowledgments

This work was supported by National Science Center Poland within the Grants No. 2018/30/E/ST700648 and No. 2023/51/ST3/02741.

References

[1] A. Askitopoulos et al. *Phys. Rev. B* **88**, 041308 (2013)
[2] J. Kasprzak et al. *Phys. Rev. Lett.* **101**, 146404 (2008)
[3] J. Levrat et al. *Phys. Rev. B* **81**, 125305 (2010)
[4] J. Schmutzler et al. *Appl. Phys. Lett.* **102**, 081115 (2013)
[5] O. Jamadi et al. *Phys. Rev. B* **93**, 115205 (2016)

*E-mail: antonina.bieganowska@pwr.edu.pl