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Talbot interference of exciton-polaritons in structured microcavities

T. Gao[1], E. Estrecho[1] , G. Li[1] , O. A. Egorov[2] , X. Ma[3] , K. Winkler[4] , M. Kamp[4] , C. Schneider[4], S. Höfling[4, 5], A. G. Truscott[1], and E. A. Ostrovskaya[1]

[1]*Research School of Physics and Engineering, The Australian National University, Canberra ACT 2601, Australia*
[2]*Institute of Condensed Matter Theory and Solid State Optics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany*
[3]*Department of Physics, Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Warburger Strasse 100, 33098 Paderborn, Germany.*
[4]*Technische Physik, Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany*
[5]*SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews KY16 9SS, United Kingdom*

The optical Talbot effect is the near-field diffraction pattern of a coherent plane wave on a periodic grating. It was discovered two centuries ago [1] and observed for waves of various physical nature and spatial scales such as optical waves, atoms, electrons, X-rays, single photons, and surface plasmon polaritons [2]. Applications of Talbot effect in imaging, metrology, atomic lithography, and optical manipulation have been suggested.

In this work, we employ an incoherently pumped exciton-polariton condensate in a one-dimensional array of microstructured traps to observe the Talbot interference patterns for coherent quantum light-matter waves [3]. The array of mesa traps is created in the plane of the quantum well imbedded in a semiconductor microcavity by etch-and-overgrowth technique. Incoherent optical pumping enables condensations of exciton-polaritons in a higher-order energy state of the band-gap structure imposed by the periodic potential. This higher-order mode is characterized by the periodic pattern of large polariton densities located on the barriers between mesa traps and acts as a periodic array of sources of polariton waves. The polariton density distribution outside the mesa array displays the Talbot effect (Figure 1).

Numerical calculations exploiting a mean-field nonlinear model of polariton condensation, as well as a simple linear mean-field theory in combination with the Huygens-Fresnel principle, allow us to reproduce the spatial distribution and spectral signatures of the Talbot effect [3]. Our results represent the first, to the best of our knowledge, observation of the Talbot effect with quantum coherent light-matter waves. This research opens the avenue for using the current advanced nanofabrication techniques to engineer patterns of exciton-polaritons in the plane of the quantum wells embedded in the microcavity. In particular, lensing, beam splitting, and phase-dependent shaping of polariton waves enabled by the Talbot effect could be realized. The resulting control over in-plane polariton propagation could aid the development of integrated polaritonic devices.

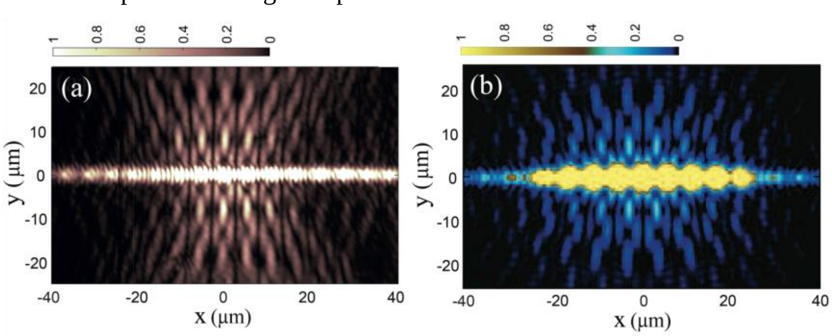

Figure 1. (a) Experimentally observed and (b) numerically calculated distribution of polariton density in the Talbot pattern

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[3] T. Gao, et al. "Talbot effect for exciton-polaritons", arXiv:1603.05056 (2016).

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