Polaritonic lenses for manipulation of exciton-polariton condensates

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Abstract

We present experimental and theoretical results on controlled manipulation of exciton-polariton condensates. Optically-induced ”soft” potentials and *polaritonic lenses* with engineered symmetry breaking are used to create directed currents and selected angular momentum states.

Recent advances in optical excitation and manipulation of exciton-polaritons in semiconductor microcavities lead to creation and trapping of the polariton Bose-Einstein condensate [1] in optically induced potentials [2]. These potential are created by incoherent optical sources of exciton-polaritons due to self-trapping mechanisms [3] that are similar to those at play in optical systems with gain and loss [4]. The advantage of the ”soft” induced potentials over those ”hard-wired” in the microcavity, e.g., by etching process, is the ability to reconfigure their spatial and energy landscape by structuring the optical pump. Our work is focused on efficient engineering of the collective states of exciton-polaritons with prescribed properties by means of the ”soft” potentials.

One example is a long-standing problem of orbital angular momentum transfer from the optical pump to the spontaneously condensed exciton-polaritons. The effective potentials created by an incoherent, off-resonant optical pump via reservoir of ”hot” excitons depend only on pump intensity, and all of the phase information is scrambled in the process of energy relaxation. This is in stark contrast to a condensate of ultracold atoms that admits direct imprinting of quantum state of photons, and to coherently driven polaritons in the resonant excitation schemes. The solution of this problem would enable controlled creation quantised angular momentum states, which could potentially be employed in sensing and information encoding devices, as well as in the fundamental studies of vortices. In the absence of total angular momentum in the system, vortices can form only spontaneously as vortex-antivortex pairs [5].

In this work we show that optical potentials with broken symmetries – *chiral polaritonic lenses* – induced by a spatially structured optical pump, enable reliable creation of orbital angular momentum states of polariton condensates, as shown in Fig. 1. The role of the broken symmetry is twofold: first, it triggers nonlinear instabilities leading to formation of vortices and anti-vortices, and secondly, the distinct handedness of the system leads to isolated persistent

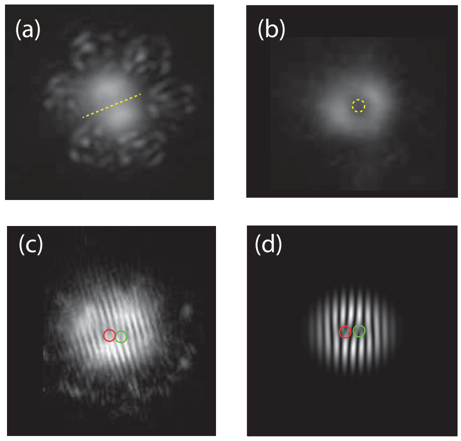

Figure 1: (a,b) Experimental real space image of cavity emission intensity ($\sim 30\ \mu m$ spot size) showing (a) dipole and (b) charge one vortex formed in the non-chiral and chiral polaritonic lens, respectively. (c) Experimental and (d) theoretical interference patterns of retro reflected far-field photoluminescence from the charge one vortex in (b). Counter-facing ”forks” in the interference pattern indicate presence of a single isolated vortex in the condensate. Lines and circles are guides to the eye.

currents and overall non-zero angular momentum. Our results contribute towards construction of all-optical elements for shaping and directing the polariton flow.

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