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Polaritonic two-dimensional nonlinear crystals

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Exciton-polaritons are bosonic quasiparticles resulting from the strong coupling of light and matter (excitons) in a semiconductor microcavity. Polaritons may form metastable macroscopic coherent phases (MCP) with properties such as Bose-like condensation and superfluidity. Also, the excitonic dipole provides strong nonlinearity through repulsive particle-particle interactions. The periodic modulation of such a nonlinear system may thus give rise to interesting phenomena, such as spatial wave localization. In particular, states localized within the gap of the band structure induced by the periodic modulation, termed gap solitons, have been the subject of widespread attention and were demonstrated in atomic and photonic systems. The study of solitonic phenomena in polaritons has been limited to homogeneous media and one dimensional periodic potentials.

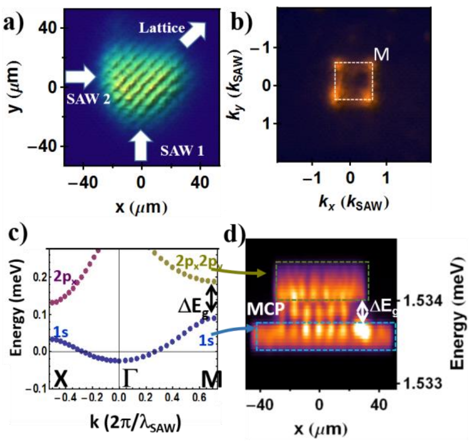

Figure 1. a) Real space image of the polariton MCP under the 2D SAW potential. b) k-space map of the emission of the polariton MCP, showing the preferential emission at the M points of the Brillouin Zone (white lines). c) Calculated 2D lattice band structurec) d) Spatially resolved spectra of the MCP where the low and high energy emission regions (boxes) show that the MCP is located within the gap ΔEg between the s- and p-states of the lattice (the region in the rectangles has been amplified by 100).

In this work, we show nonlinear polariton MCP features consistent with gap-solitonic behavior [1] in a two dimensional (2D) polaritonic crystal. The MCP is resonantly pumped in an (Al,Ga)As microcavity under a 2D periodic potential created by surface acoustic waves (SAWs) (Fig. 1a). The lattice introduces a band structure with energy band gaps ΔEg at the edges of the Brillouin Zone (BZ) (Fig. 1c). [2] Under the lattice, the MCP forms at the negative effective-mass M-points of the BZ at $\mathbf{k}=(\pm k_{SAW},\pm k_{SAW})/2$ (Fig. 1b), and within the gap ΔEg between the low density s- and p-like dispersion branches (Fig. 1d). The threshold for formation of the MCP in the 2D crystal is lower than for an unmodulatedMCP, which we attribute to the efficient accumulation of particles at the anomalous dispersion M-points. Also, the reduction of the MCP coherence length with the potential amplitude shows that the state is localized in space. These features are consistent with a model predicting the formation of a soliton within the band gap ΔEg. This work opens the possibility for the study of complex solitonic phenomena in polaritons as well the possibility for implementation for modulable robust polaritonic components for optical information processing.

[1] E. A. Ostrosvskaya and Yuri S. Kivshar, Phys. Rev Lett. 90, 160407 (2003)
[2] E. Cerda-Méndez et al., Phys. Rev. B., 86, 100301(R) (2012)