Emerging supersolidity in photonic-crystal polariton condensates

D. Trypogeorgos [1,*], A. Gianfrate [1], M. Landini[2], D. Nigro[3], D. Gerace[3], I. Carusotto[4], F. Riminucci[5], K. W. Baldwin[6], L. N. Pfeiffer[6], G. I. Martone[1], M. De Giorgi[1], D. Ballarini[1], D. Sanvitto[1],

[1]CNR Nanotec, Institute of Nanotechnology, via Monteroni, 73100, Lecce, Italy
[2]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria
[3]Dipartimento di Fisica, Unversità degli Studi di Pavia, via Bassi 6, 27100 Pavia, Italy
[4]Pitaevskii BEC Center, CNR-INO and Dipartimento di Fisica, Università di Trento, I-38123 Trento, Italy
[5]Molecular Foundry, Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, California, 94720, USA
[6]PRISM, Princeton Institute for the Science and Technology of Materials, Princeton University, Princeton, New Jersey 08540, USA

A supersolid is a counter-intuitive phase of matter where its constituent particles are arranged into a crystalline structure, yet they are free to flow without friction. This requires the particles to share a global macroscopic phase while being able to reduce their total energy by spontaneous, spatial self-organisation. The existence of the supersolid phase of matter was speculated more than 50 years ago however only recently there have been convincing experimental evidence, mainly using ultracold atomic Bose-Einstein condensates (BECs) coupled to electromagnetic fields. There, various guises of the supersolid were created using atoms coupled to high-finesse cavities, with large magnetic dipole moments, and spin-orbit-coupled, two-component systems showing stripe phases. Here we provide experimental evidence of a novel implementation of the supersolid phase in a driven-dissipative, non-equilibrium context based on exciton-polaritons condensed in a topologically non-trivial, bound-in-the-continuum (BiC) state with exceptionally low losses, realised in a photonic crystal waveguide [1, 2]. We measure the density modulation of the polaritonic state indicating the breaking of translational symmetry with a remarkable precision of a few parts in a thousand. Direct access to the phase of the wavefunction allows us to additionally measure the local coherence of the supersolid. We demonstrate that our synthetic photonic material can host phonon dynamics and a multimode excitation spectrum.

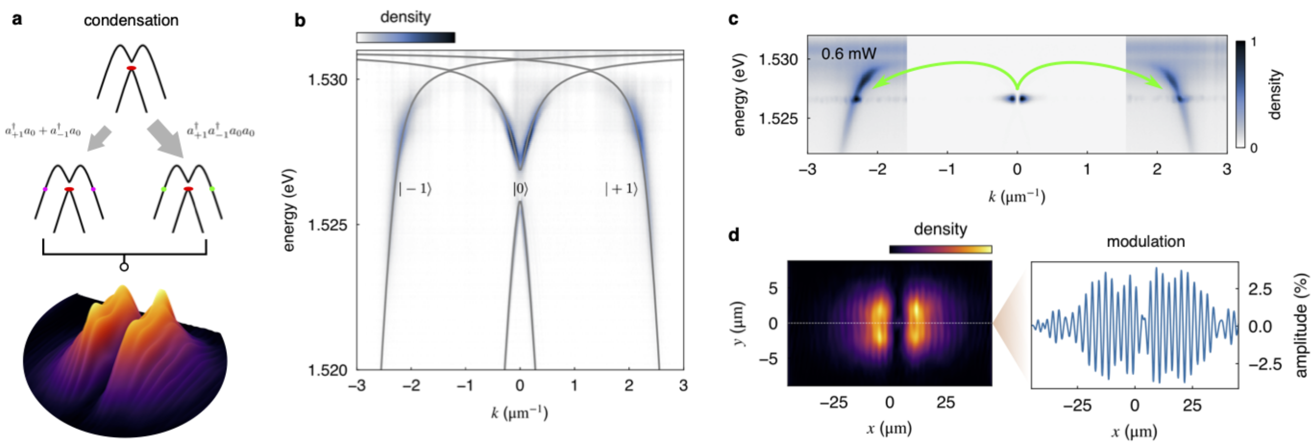

Figure 1: **a.** The mechanism that leads to the formation of the supersolid. Linear and nonlinear scattering processes combine and give rise to a density modulation in coordinate space. **b.** The dispersion comprises of four fundamental propagating modes. The measured dispersion closely matches the numerical dispersion obtained from diagonalising an effective 8×8 Hamiltonian. **c.** The BiC state $|0\rangle$ at $k = 0$ parametrically scatters to the modes $\pm k_r$, denoted as $|\pm 1\rangle$. At powers above threshold, the BEC needs to be masked in order for the $|\pm 1\rangle$ population to be measured. The parametric scattering generates photon pairs that populate the $|\pm 1\rangle$ states as indicated by the arrows. **d.** The density of the supersolid wavefunction $\psi(x, y)$ shows a characteristic fast modulation due to the spontaneous breaking of translational symmetry. The amplitude of the modulation along the $y = 0$ line is ~2.6%.

References

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*E-mail: dimitrios.trypogeorgos@cnr.it