

ABSTRACT

A semiconductor photonic-crystal device is disclosed that sustains a self-organised exciton–polariton supersolid at room temperature and provides native on-chip interfaces to its acoustic-like collective modes. A two-dimensional lattice of sub-wavelength apertures etched into a III–V (or other direct-gap) slab supports a symmetry-protected bound state in the continuum (BiC) whose ultra-high-Q optical field is strongly coupled to embedded quantum-well excitons. Continuous, non-resonant optical or electrical pumping above a first threshold produces a spatially uniform polariton condensate; above a second threshold intrinsic χ^3 interactions scatter polaritons into $\pm k$ side modes that phase-lock to the $k \approx 0$ component, spontaneously generating a periodic density grating while preserving global phase coherence—thereby realising a supersolid phase without any externally imposed potential. Lithographically defined line-defect or ring-defect phononic waveguides fabricated adjacent to the photonic crystal couple evanescently or piezo-electrically to the condensate’s low-energy Goldstone (phonon-like) branch, enabling chip-scale delay lines, filters, oscillators and quantum-simulation lattices. The architecture is compatible with wafer-level vacuum capping and heterogeneous integration of LiNbO₃, SiN or AlN control layers, permitting mass production on 200- to 300-mm foundry lines. Advantages include room-temperature operation, footprint and cost reductions relative to MEMS-SAW or cryogenic quantum hardware, and a platform for programmable photonic-phononic processors and ambient-temperature quantum simulators.