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Emergent co-crystallization of atoms and light in multimode cavities

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The self-organization of a Bose-Einstein condensate in a transversely pumped optical cavity is a process akin to crystallization: when pumped by a laser of sufficient intensity, the coupled matter and light fields evolve, spontaneously, into a spatially modulated pattern (i.e., crystal). In cavities having multiple degenerate modes, the quasi-continuum of possible crystalline arrangements, and the continuous symmetry breaking associated with the adoption of a particular one, give rise to phenomena such as phonons, defects, and frustration. A nonequilibrium field-theoretic approach enables the exploration of the self-organization of a Bose-Einstein condensate in a pumped, lossy optical cavity. At nonzero temperatures, this organization occurs via a fluctuation-driven first-order phase transition of the Brazovskii class; the transition persists to zero temperature and crosses over into a quantum phase transition. The field- theoretic approach also enables the investigation of the role of nonequilibrium fluctuations in the self-organization transition, as well as the nucleation of ordered-phase droplets, the nature and energetics of topological defects, supersolidity in the ordered phase, and the possibility of frustration effects controlled by the cavity geometry.

Work done in collaboration with Sarang Gopalakrishnan and Benjamin L. Lev.