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Non-zero momentum Bose-Einstein condensation of orbital atoms[1]

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Bose-Einstein condensation (BEC) is often associated with zero momentum to which a macroscopic fraction of bosons condense. Here we propose a new class of meta-stable quantum states where bosons condense at non-zero momenta, defying the paradigm. This becomes possible when bosonic atoms are confined in the p-orbital Bloch bands of an optical lattice rather than the usual s-orbital. A recent experiment at Mainz confirmed the discovery of such an exotic BEC with alkali-metal atoms in a 3D cubic lattice with anisotropic optical potentials. Non-zero momentum suggests crystalline order. Our theoretical studies further found that such non-zero momentum BECs are also naturally orbital ordered superfluids due to the fascinating, less studied center-of-mass p-wave symmetry (e.g., a vortex-like $p_x + ip_y$ condensate). Varying with the geometry from standard optical lattices to double-well lattices, the interesting orderings include staggered orbital currents, stripes of angular momenta, and modulated super-current density wave. Different than a phase of coexisting orders such as supersolidity, this new class of states is characterized by a single order parameter. Work done in collaboration with J. Moore, S. Das Sarma, V. M. Stojanovic, C. Wu, and E. Zhao.

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