Quantum Phases of Two-Component Interacting Bosons in Optical Lattices and in the Presence of Spin-Orbit and Rabi Couplings

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Theoretical work describing the quantum phases of two-component bosons with local interactions loaded into optical lattices is presented. The new twist in this work is the inclusion of artificial spin-orbit and Rabi couplings [1], which now can be created in the laboratory via spin-dependent momentum transfer techniques. In the regime of weak local interactions, the detuning versus Rabi coupling phase diagram resembles that of the continuum case when the spin-orbit coupling is fixed, and only superfluid phases are accessible. These superfluid phases have uniform, single-momentum, or multiple-momenta condensates. However, the phase diagram of spin-orbit versus Rabi coupling exhibits a series of non-uniform superfluid phases which are commensurate with the spin-orbit parameter (momentum transfer) and resemble a Devil’s staircase. In the strong coupling regime, the phase diagram becomes very different from that of the continuum limit, and insulating phases emerge directly from superfluid phases with uniform, single-momentum or multiple-momenta condensates for fixed spin-orbit, but varying Rabi coupling. A Ginzburg-Landau theory is also developed to understand the nature and type of the system’s phase transitions, and the momentum distribution is calculated to characterize the different superfluid and insulating phases which can be measured in upcoming experiments.

References