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Superfluid Breakdown and Multiple Roton Gaps in Spin-Orbit Coupled Bose-Einstein Condensates on an Optical Lattice DANIELE TONIOLO, JACOB LINDER, NTNU — Based on the results of Phys. Rev. A 89, 061605(R) (2014) I discuss the superfluid phases of a Rashba spin-orbit coupled Bose-Einstein condensate residing on a two dimensional square optical lattice in the presence of an effective Zeeman field Ω. At a critical value $\Omega = \Omega_c$, the single-particle spectrum $E_{\mathbf{k}}$ changes from having a set of four degenerate minima to a single minimum at $\mathbf{k} = 0$, corresponding to condensation at finite or zero momentum, respectively. I describe this quantum phase transition and the symmetry breaking of the condensate phases. The superfluid phase is discussed using the Bogoliubov theory, I present the phase diagram, the excitation spectrum and the sound velocity of the phonon excitations. A novel dynamically unstable superfluid regime occurring when Ω is close to Ω_c is analytically identified and the behavior of the condensate quantum depletion is discussed. Moreover, I show that there are two types of roton excitations occurring in the $\Omega < \Omega_c$ regime and obtain explicit values for the corresponding energy gaps.

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