Superfluid Breakdown and Multiple Roton Gaps in Spin-Orbit Coupled Bose-Einstein Condensates on an Optical Lattice

DANIELE TONILO, 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 $\Omega$. At a critical value $\Omega = \Omega_c$, the single-particle spectrum $E_k$ changes from having a set of four degenerate minima to a single minimum at $k = 0$, 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 $\Omega$ is close to $\Omega_c$ 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.