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Supersolid Phase in Multi-Band Bose-Hubbard Model with Long-Range Interactions

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Ultracold bosons in optical lattices provide a fertile platform for studying strongly-correlated many-body systems in a highly controllable manner. Bose-Hubbard (BH) models well describe bosons in optical lattices and have been widely investigated theoretically and experimentally. The conventional BH model consists of the nearest neighbor hopping and on-site interaction between bosons confined in the lowest-Bloch band and exhibits the quantum phase transition between the superfluid and the Mott-insulator, which has been witnessed experimentally with ultracold atoms. Theoretical works have also examined generalizations of the standard BH model, leading to enriched many-body physics. A paradigmatic example concerns long-range interactions —these lead to novel phases, such as the Haldane insulator in 1-dimension, density waves, and the most intriguing supersolid phase. While the experimental realization of long-range interacting Bose Hubbard models has been challenging, recent progress has been made with both cold atomic systems and excitons in semiconductor devices. Interestingly, in the last year, a multi-band extended Bose Hubbard model was realized in a GaAs double well device describing strongly interacting indirect (dipolar) excitons forming a density wave state in a two-dimensional square lattice. Motivated by these experimental breakthroughs, we theoretically investigate two-band physics with on-site and nearest-neighbor interactions in an extended one-dimensional BH model. In particular, we focus on “proximity” effects due to the interplay of the two bands. With this aim, we consider the case where the intraband parameters of the two bands considered independently support different phases and study the effects of inter-band interactions. We find that coupling a density wave state in one band to a superfluid state in the other can lead to lattice supersolids. Depending on the filling of the bands and the interband interaction strength, the supersolid phase competes with phase separation, superfluid order, or insulating density-wave orders. Interestingly, our results point to a novel possibility of stabilizing a supersolid phase by thermally exciting one of the two bands, which counterintuitively gives rise to a supersolid obtained from heating.

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