# Bosons on a Two Dimensional Optical Lattice: Effect of Correlations

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1. Introduction – Recent developments in experimental techniques have allowed precise control over the properties of ultracold atomic gases in traps and optical lattices, turning them into a simulation tool for quantum many body systems and allowing experimental investigation of static and dynamic behaviour of clean and low dimensional systems. Loading of a Bose Einstein Condensate onto an optical lattice leads to new kinds of physical phenomena. Such systems can be considered as experimantal realizations of Hubbard-type models and can be brought to a strongly correlated regime. It was predicted by M. Fisher et. al. that the homogeneous Bose-Hubbard model (BH) exhibits the Superfluid-Mott insulator (SF-MI) quantum phase transition [1]. This phase transition was observed experimentally by M. Greiner et.al. [2]. Later studies of BH models with interactions extended to nearest neighbors had pointed out that novel quantum phases, like supersolid (SS) and checkerboard phases (CB) are expected [9, 10, 11, 12].

2. Theory - We consider a system of bosons on a 2D optical lattice. Such a system can be described by the well known Bose-Hubbard Hamiltonian We study the problem in the mean-field regime, with an approach based on the Gutzwiller ansatz. This corresponds to writing the wave function as a product over different lattice sites of single-site wave functions. |ψ⟩=∏ i ∑ n fn i|n⟩i Even though this wave function does not directly include the effects correlations. We account for the correlations in an indirect way by using an effective correlation potential acting between the nearest neighboring sites resulting in a total Hamiltonian

3. Results and Discussion – We present our results for various interaction strengths and various effective correlation potentials. Our results are in good agreement with the experimental results for sufficiently strong effective correlation potentials.

4. References

[1] M. P.A. Fisher, P. B. Weichman, G. Grinstein, D. S. Fisher, Boson localization and the superfluidinsulator transition. Physical Review B, 40, 1,1989. [2] M. Greiner, O. Mandel, T. Esslinger, T. W. Hänsch, and I. Bloch, Quantum phase transition from a superfluid to a Mott insulator in a gas of ultracold atoms. Nature 415, 39-44 (2002). [3] K. Góral, L. Santos, and M. Lewenstein, Quantum Phases of Dipolar Bosons in Optical Lattices. Physical Review Letters, 88, 170406 (2002). [4] D. L. Kovrizhin, G. V. Pai, and S. Sinha, Density wave and supersolid phases of correlated bosons in an optical lattice. Europhysics Letters, 72, 162-168 (2005). [5] P. Sengupta, L. P. Pryadko, F. Alet, M. Troyer, and G. Schmid, Supersolids versus Phase Separation in Two-Dimensional Lattice Bosons. Physical Review Letters 94, 207202 (2005).