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Ultracold Bosonic Atoms in Optical Lattices

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This thesis covers most of my work in the field of ultracold atoms loaded in optical lattices. It makes a route through the physics of cold atoms in periodic potentials starting from the simple noninteracting system and going into the many-body physics that describes the strongly correlated Mott insulator regime. Even though this thesis is a theoretical work all the chapters are linked either with experiments already done or with ongoing experimental efforts. In the first part I investigate the validity of mean field approximations based on the Discrete Nonlinear Schrödinger equation and quadratic approximations of the Hamiltonian to describe the approach of the system from the superfluid to the Mott insulator regime. In the second part I adopt the closed time path (CTP) and two particle irreducible (2PI) effective action formalism to study the non-equilibrium dynamics of a condensate loaded every third lattice site of an optical lattice. I show this formalism to be a powerful tool to describe far-from-equilibrium situations, particularly through its ability to incorporate the non-local and non-Markovian aspects characteristic of the quantum dynamics. In the last part I investigate the properties of the system deep in the Mott insulator regime. By using perturbation theory I study the Mott insulator ground state and its excitation spectrum, the response of the system to Bragg spectroscopy, and propose a mechanism to correct for the residual number fluctuations inherent to the Mott insulator ground state.