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Abstract

Strongly correlated electron systems is an exciting and diverse field in condensed matter physics. In these systems, the competition between the kinetic energy and the Coulomb energies gives rise to many interesting phases like superconductivity, magnetism, electron localization, spin liquid and other exotic phases. In this thesis, we have explored the intricate physics of the simple and the extended Hubbard model, shedding light on the interplay between local (U) and non-local (V) Coulomb interactions. Theoretical modeling and computer simulations were used to investigate the phenomena such as the Mott metal-insulator transition, the formation of charge and spin density wave order, the charge-ordered insulators, the spin gap antiferromagnets as well as the pairing correlations leading to superconductivity. The present thesis comprises of eight chapters. Here is a brief overview of each chapter.

Chapter-1 presents the research context and theoretical framework for investigating strongly correlated electron systems.

Chapter-2 introduces the simple and the extended Hubbard model along with the exact diagonalization technique used in the present study.

Chapter-3 presents the results for the ground state properties and the energy level statistics of the simple Hubbard (t−U) model and the extended Hubbard (t−U −V) model on two-dimensional 3×3 square lattice with open boundary conditions.

Chapter-4 extends the investigation of ground state properties to 3×4 lattice of simple and extended Hubbard model for half-filled ($N_h = 0$), two-hole-doped ($N_h = 2$) and four-hole-doped ($N_h = 4$) systems within the spin subspace S = 0.

Chapter-5 presents the study of the ground state properties of 2×4, 3×4 and 4×4 lattice of simple and extended Hubbard model at quarter-filling.

Chapter-6 investigates the phase diagram of the extended Hubbard model, comparing the exact diagonalization results with the mean-field approximation.

Chapter-7 presents the study of conventional and unconventional superconductivity by investigating the possibility of binding of holes in the vicinity of phase separation.

Finally, chapter 8 review the main points of research reported in the present thesis, discuss their consequences, and lay out the road map for future studies that could lead to further advances in strongly correlated electron systems.