INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

In this thesis, we study the equilibrium, non-equilibrium and topological properties of interacting bosons in periodic potentials. In this context, we systematically address the physics of interacting bosons in various scenarios using numerical methods such as the cluster mean-field theory approach, exact diagonalization and density matrix renormalization group method.

We first explore the possible quantum phase transitions in a multi-body interacting Bose-Hubbard model in two dimensions. By keeping up to four-body onsite interactions we predict the existence of two-body repulsive bound bosonic pairs in the presence of attractive three-body and repulsive four-body interactions. We also explore the physics of two- and three-body hardcore constrained dipolar bosons in the non-locally coupled one-dimensional lattices and obtain the physics arising from the competing long-range interaction as well as local constraints.

We further explore the dynamical properties of interacting bosons in the context of the quantum walk. In our studies, we analyze the quantum walk of Mott insulator defects (particle and/or hole) in a one-dimensional lattice in the presence of onsite two and three-body interactions. Our analysis predicts an interesting phenomenon of quantum walk reversal of a pair of repulsive bosons as a function of attractive three-body interaction. We extend our analysis for two nearest-neighbor defects in the presence of nearest-neighbor interaction and show the property of antibunching in two-particle correlation function in vanishing interaction limit whereas for large interaction they form nearest-neighbor pair.

The last part of the thesis focuses on the topological phase transitions of interacting bosons in the Su-Schrieffer-Heeger (SSH) model which is one of the simplest one-dimensional models exhibiting the topological phase transitions. In this context, we first explore the bulk properties of the three-body constrained bosons in an SSH model predicting the groundstate phase diagram in the limit of repulsive and attractive two-body interactions using the DMRG method. The phase diagram is shown to exhibit various gapped dimer phases at densities 1/2, 1 and 3/2. Interestingly on the attractive side, we find a phase transition to a dimer phase of bound bosonic pairs

at unit filling. After analyzing the bulk properties of three-body constrained bosons, we study the topological phase transition of these bound bosonic pairs at unit filling. In our analysis, we show that these bound bosonic pairs undergo a trivial to topological phase transitions exhibiting non-trivial edge states. We concretely establish this fact by exploring various topological properties such as edge polarization, winding number and Thouless charge pumping. In the end, we predict the phenomenon of topological inheritance in the case of a half-SSH-Hubbard model. This system represents a model of two components hardcore bosons where one of the components experiences a dimerized hopping similar to the SSH model and the other component resides in a homogeneous lattice. The Hubbard interaction is inter-species interaction. We show that by tuning the inter-species interaction it is possible to induce the topological properties of one component on the other which originally does not possess any topological order. We show that the threshold for full inheritance occurs at weak interactions, for which the components are not yet paired. We illustrate this inheritance by discussing both bulk and edge properties, as well as dynamical observables such as mean chiral displacement and charge pumping.