INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : Sayan Lahiri

Roll Number : 166121102

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Name of Thesis Supervisor(s) : Dr. Tapan Mishra

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SHORT ABSTRACT

Study of quantum phase transitions in artificial systems has attracted enormous attention in recent years. In this thesis, we study the quantum phase transitions in systems of constrained bosons in low dimensional lattices. We consider two different scenarios within this framework, (i) in the case of ultracold atoms in optical lattices and (ii) in the context of microwave photons in superconducting circuits. We have analyzed the ground state properties of such systems by using numerical methods such as the cluster mean-field theory (CMFT) approach and the density matrix renormalization group (DMRG) method. We first explore the ground-state properties of a system of nonlocally coupled dipolar bosons in a bilayer optical superlattice by considering bosons in one layer to be of softcore in nature and separately allowing two- and three-body hard-core constraints on the other layer. We show how the presence of different constraints on bosons in one layer influences the overall phase diagram exhibiting various Mott insulator phases at incommensurate densities due to the presence of the superlattice potential apart from the usual Mott insulators at commensurate densities. Then we investigate the quantum phase transitions of constrained bosons in a two-leg Bose-Hubbard ladder. We consider hardcore bosons in one leg and three- body constrained bosons in the other leg in the limit of two body attractive interaction. Here we find that depending on the ratio between the rung and leg hoppings of the bosons, rung insulator phases are stabilized at unit filling. Moreover, at incommensurate fillings we obtain signatures of the pair superfluid phase. We extend this work to the case where both the legs of the ladder have three-body constrained bosons with onsite two-body attractive interaction. We obtain the signatures of the dimer rung insulator phase apart from the pair superfluid phases. In the last part of the thesis, we propose a method to achieve photon pair propagation in an array of three-level superconducting circuits. Assuming experimentally accessible three-level artificial atoms with strong anharmonicity coupled via microwave transmission lines in both one and two dimensions, we analyze the circuit quantum electrodynamics (QED) of the system. We explicitly show that, for a suitable choice of the coupling ratio between different levels, the single-photon propagation is suppressed, and the propagation of photon pairs emerges.