



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: **Anderson-like localization in weakly interacting Bose-Einstein condensate: Localization-delocalization transitions and non-equilibrium dynamics**

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SHORT ABSTRACT

Anderson localization (AL), first proposed by P. W. Anderson in 1958, describes the suppression of wave diffusion in disordered media due to quantum interference effects. Originally introduced in the context of electron transport in solids, AL has since been observed in a wide range of classical and quantum systems. Among these, ultracold atomic Bose-Einstein condensates (BECs) provide a uniquely controllable platform to study localization phenomena, owing to their tunable interactions, coherence, and engineered disorder. However, understanding localization in the presence of interactions remains a significant challenge.

This thesis investigates Anderson-like localization in weakly interacting BECs, focusing on localization-delocalization transitions and non-equilibrium dynamics. First, we study scalar BECs in one-dimensional quasiperiodic and random disordered potentials, analyzing how increasing interaction strength influences the ground-state localization. We propose a novel dynamical formalism to identify the transition from localized to delocalized phases of the condensate. We demonstrate that the non-equilibrium dynamics are periodic or quasiperiodic in the localized regime, and become chaotic in the delocalized regime, an identification that remains valid irrespective of the type of disordered potential.

Next, we explore pseudospin-1/2 spinor BECs with spin-orbit (SO) and Rabi couplings in disordered environments. Our analysis reveals rich localization phenomena, including reentrant localization transitions and spin-dependent Anderson-like phases. A combination of numerical

simulations and the Gaussian variational approach is employed to characterize both ground-state properties and dynamical behavior under various coupling conditions.

Finally, we examine a spin-asymmetric Rabi-coupled BEC, where only one spin component is subjected to a quasiperiodic potential. We show that Rabi coupling induces localization by enabling population transfer between components, even in the absence of interactions. Furthermore, we demonstrate that periodic modulation of the Rabi frequency leads to frequency-dependent dynamical delocalization that persists in the interacting regime.

