Open quantum systems in the strongly interacting regime

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General context

Recent experimental advances in diverse areas, ranging from cold atomic gases over photonic cavity arrays, have triggered the need for new theoretical developments since they are at the interface of quantum optics, many-body physics and statistical mechanics, and they share in common to be out of equilibrium. We will focus on open quantum systems composed of interacting bosons on a lattice, subjected to pump and loss in a driven-dissipative setup. While the weakly interacting regime has been the focus of several works, very little is known beyond. This issue, which this thesis addresses, will contribute to the benchmark and deployment of quantum computers.

Objectives of the thesis

We will consider models of interacting bosons under driven-dissipative conditions, such as the stochastic Gross-Pitaevskii equation generalized to account for pump and loss, or the Bose-Hubbard model on a lattice [1,2]. These models apply to describe coupled photonic cavity arrays and exciton-polaritons in semiconductor microcavity pillars. The main goal of the thesis is the characterization of the intermediate to strongly interacting regimes of this model. For this aim, we will use a combination of analytical and numerical methods, including field theory and renormalization group methods, exact diagonalization and quantum computations based on the machines of the Hybrid Quantum Initiative (HQI) consortium.

Requirements

The candidate is expected to have a very strong background in theoretical physics, in particular in field-theoretical methods including the renormalisation group, and a solid knowledge in numerical methods.

Bibliography :

[1] M. Zuendel, L. Mazza, L. Canet, A. Minguzzi, *Space-time first-order correlations of an open Bose-Hubbard model with incoherent pump and loss*, SciPost Physics (2025)

[2] L. M. Sieberer, M. Buchhold, S. Diehl, *Keldysh Field Theory for Driven Open Quantum Systems*, Rep. Prog. Phys. **79** 096001 (2016)