

Quantum information and non-equilibrium condensed matter physics with cold atoms

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We discuss scenarios of preparing entangled states of (i) cold atoms in optical lattices via driven dissipative processes^{1,2}, and (ii) in a hybrid system atomic / solid-state systems, which is of interest in both quantum information and condensed matter physics³.

ad (i): Quantum optics typically considers driven open quantum system, where a system of interest is driven by an external field and coupled to an environment inducing non-equilibrium dynamics, with time evolution described by a master equation. For long times, such a system will approach a dynamical steady state, which in general will be a mixed state. However, this steady state can also be a pure state: this is achieved by an appropriate design of the system-reservoir couplings, as reflected in the “quantum jump operators” (or Lindblad operators) in the dissipative terms of a master equation, in combination with a proper system Hamiltonian. Here we are interested in extending driven dissipative state preparation of quantum states to the case of many body systems. This is of interest both as a novel way of preparing entangled states in quantum information, and suggests a new form of non-equilibrium condensed matter physics. In this talk we will focus on the latter part, including topics like (i) physical realization of reservoir engineering with cold atoms, (ii) a characterization of non-equilibrium condensed matter phases of driven dissipative systems, including phase transitions, and (iii) questions related to the dynamics of approaching the steady state.

ad (ii) We suggest to interface nanomechanical systems via an optical quantum bus to atomic ensembles, for which means of high precision state preparation, manipulation and measurement are available. This allows for a Quantum Non-Demolition Bell measurement, projecting the coupled system atomic ensemble - nanomechanical resonator into an entangled state. The entanglement is observable even for nanoresonators initially well above their ground states and can be utilized for teleportation of states from an atomic ensemble to the mechanical system. Because of the rich toolbox readily available for both of these systems, we expect the interface to give rise to a variety of new quantum protocols.

¹B. Kraus, H. P. Büchler, S. Diehl, A. Kantian, A. Micheli, P. Zoller, Preparation of Entangled States by Quantum Markov Processes, arXiv:0803.1463

²S. Diehl, A. Micheli, A. Kantian, B. Kraus, H.P. Buchler, P. Zoller, Quantum States and Phases in Driven Open Quantum Systems with Cold Atoms, arXiv:0803.1482

³K. Hammerer, M. Aspelmeyer, E.S. Polzik, P. Zoller, Quantum Interface for Nanomechanics and Atomic Ensembles, arXiv:0804.3005