ICFO

PhD Thesis Defense CHRISTOS CHARALAMBOUS 'Quantum Brownian Motion in Bose-Einstein Condensates'

CHRISTOS CHARALAMBOUS

January 31, 2020

15:00

Blue Lecture Room

Friday, January 31, 2020, 15:00. ICFO's Blue Lecture Room

CHRISTOS CHARALAMBOUS

Quantum Optics Theory

ICFO-The Institute of Photonic Sciences

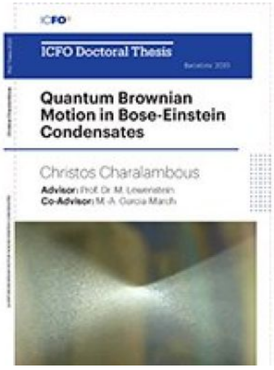
Quantum Brownian motion is one of the most prominent examples of an open quantum system, a system which cannot be treated in isolation from its environment. The simplest method to study the dynamics of a system undergoing such a type of motion, that satisfies Heisenberg Uncertainty principle is the approach of Quantum Generalized Langevin Equations (QGLE), which was used throughout this thesis. A Quantum Brownian motion approach is used in this work to study the Bose polaron problem. In this case, one transforms

the original problem into one where the impurities are treated as quantum Brownian particles interacting with a bath composed of the Bogoliubov modes of the condensate. Then by deriving the relevant QGLE, it was shown that the dynamics of the Bose polaron exhibit memory effects. This was studied for both a free Bose-Einstein condensate (BEC) and a harmonically trapped one, in both cases for experimentally relevant parameters. Taking advantage of this recent theoretical development, we study a number of phenomena that can be examined under this prism and show how various microdevices can be constructed and controlled. In the first project, we study the creation of entanglement and squeezing of two uncoupled impurities that are immersed in a single common (BEC) bath. We treat these impurities as two quantum Brownian particles. We study two scenarios:(i) In the absence of an external potential, we observe sudden death of entanglement;(ii) In the presence of an external harmonic potential, where entanglement survives even at the asymptotic time limit. In our second work, we studied the diffusive behavior of a Bose Polaron immersed in a coherently coupled two-component BEC. The particle superdiffuses if it couples in the same manner to both components, i.e. if it couples either attractively or repulsively to both of them. This is the same behavior of an impurity immersed in a single BEC. Conversely, we find that it exhibits a transient nontrivial subdiffusive behavior if it couples attractively to one of the components and repulsively with the other. We show how the magnitude of the anomalous exponent reached and the duration of the subdiffusive interval can be controlled with the Rabi frequency of the coherent coupling between the two components and the coupling strength of the impurity to the BEC. Then we proceeded with the construction of two microdevices, a quantum sub-nk thermometer and a heat diode. In the first project, we introduced a novel minimally disturbing method for sub-nK thermometry in a BEC. In this case, the impurity acted as a thermometer, where one detects temperature fluctuations from measurements of the position and momentum of the impurity. Crucially, these cause minimal backaction on the BEC and hence, realize a nondemolition temperature measurement. Following the paradigm of the emerging field of quantum thermometry, we combine tools from quantum parameter estimation and the theory of open quantum systems to solve the problem in full generality. We thus avoid any simplification, such as demanding thermalization of the impurity atoms. In our final work, we investigated the heat transport and the control of heat current among two spatially separated trapped BECs, each of them at a different temperature. To allow for heat transport among the two independent BECs we consider a link made of two dipole-dipole interacting harmonically trapped impurities, each of them interacting with one of the BECs. We address the dependence of heat current and current-current correlations on the physical parameters of the system. Interestingly, we show that heat rectification, can occur in our system, when a periodic driving on the trapping frequencies of the impurities is considered. Therefore, our system is a possible setup for the implementation of a phononic circuit, and hence contributes in the general framework of using BECs as platforms for quantum information processing.

Friday, January 31, 2020, 15:00. ICFO's Blue Lecture Room

Thesis Advisor: Prof Dr Maciej Lewenstein

Thesis Co-advisor: Dr Miguel A. Garcia-March



Christos Charalambous' Thesi Cover