Use of a non-equilibrium environment for controlling open quantum systems

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Control of atomic and molecular scale quantum systems attracts interest due to various existing and prospective applications for quantum technologies including laser-assisted control of chemical reactions, quantum cryptography, quantum information, quantum metrology, quantum optics, etc. Often quantum systems subject to control interact with their environment, i.e., they are open quantum systems. This circumstance requires the analysis of abilities to control open quantum systems. We will discuss ab initio description of dynamical equations for open quantum systems interacting with their environment, including ab initio derivation of non-Markovian master equation for quantum systems weakly interacting with reservoir. Then we will discuss use of the environment for preparation of arbitrary density matrices of finite-level quantum systems, as well as for manipulation of quantum systems with infinite number of states. In this approach the system dynamics is adjusted by using (a) suitably tailored generally non-equilibrium state (i.e., spectral distribution function) of incoherent environment surrounding the systems and (b) coherent laser pulse with tailored time dependent profile. Such combination allows for approximate generation of arbitrary mixed density matrices of a wide class of quantum systems. Thus it allows to achieve the strongest degree of state control for quantum systems, namely, controlled transfer of arbitrary initial state into arbitrary predefined target state. This strongest degree of controllability might be used for quantum information and computing with mixed states and non-unitary quantum gates.