

Quantum thermodynamics, Quantum control, Quantum gates for open systems

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Any quantum system is inherently open, continuously interacting with its environment. Therefore, effective manipulation of quantum devices must account for this reality. Control of open quantum systems is vital for advancing modern quantum science and technology. We demonstrate such control using a thermodynamically consistent framework, where the drive dynamically influences the systems interaction with the environment. This effect is embedded in the dynamical equation, leading to control-dependent dissipative fundamental component of open-system control.

We address two types of destructive noise: noise from the pulse generator and thermal noise from the environment. A Markovian model describes phase and amplitude noise from the external controller, and we investigate its impact on quantum gate execution, highlighting the degradation of gate fidelity. We show that optimal control techniques can mitigate fidelity loss. For this task we employ a highly accurate numerical solver and the Krotov algorithm to solve the optimal control equations in Liouville space.

To handle thermal noise, we construct the dissipative dynamical equations by evaluating a complete set of time-dependent invariants governed by the control field. The Lindblad jump operators emerge as eigen-operators of the commutator of a pair of invariants, satisfying thermodynamic consistency. We achieve the challenging task of controlling quantum gates for non-unitary reset maps with complete memory loss. Additionally, we identify a novel mechanism for controlling unitary gates by actively removing entropy from the system to the environment. This is a generalization of cooling to the quantum channel level.

This study is a joint effort of Aviv Aroch, Roie Dann, Shimshon Kallush.