THE IMPLEMENTATION OF A QUANTUM ABSORPTION REFRIGERATOR WITH TRAPPED IONS

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Thermodynamics is one of the oldest and well-established branches of physics that started as studies on macroscopic systems. Recently, remarkable progress has been made in the miniaturization of thermal machines such as heat engines all the way to the single Brownian particle as well as to a single atom. Despite several theoretical proposals, the implementation of heat machines in the fully quantum regime remains a challenge. In this work [1], we first report an experimental realization of a quantum absorption refrigerator [2] in a system of three trapped ions, with three of its normal modes of motion coupled by a trilinear Hamiltonian such that heat transfer between two modes refrigerates the third. Cooling below both the steady-state energy and the benchmark predicted by the classical thermodynamics treatment has been demonstrated.
We also investigate theoretically the dynamics and steady-state properties of this system and compare its cooling capability under various situations. Cooling or heating of the cold mode is found consistent with the recently developed virtual qubit model [3], even though the resulting steady state statistics is not thermal. By studying incoherent energy exchange among the modes, we elucidate that enhanced single-shot cooling in the transient regime is related to the coherence developed due to the interaction Hamiltonian [4,5]. However, we show that the effect also appears in an entirely classical framework. This system is further found to exhibit features of quantum equilibration, see for example [6], where the expectation values of observables quickly reach and stay close to the infinite-time average values for subsequent dynamics.

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