
A Spin Chain Quantum Refrigerator

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Abstract

Entropy reduction is a desired task in many physical processes of interest, ranging from pure state preparation in quantum information processing to heat transfer from a hot system to a colder one. A simple method of implementing such a protocol is to have at our disposal a supply of ancillary systems in pure states, and then to perform a swap operation between these and the system of interest. If we are only given one ancillary system, however, there will be a limit on the amount of entropy that can be reduced. To this end we propose a model where the system whose entropy we wish to reduce is a collection of identically prepared qubits in thermal equilibrium, and the ancillary system is a spin chain, of length N and with nearest neighbour Heisenberg interactions, prepared in the pure state $|0\rangle^{\otimes N}$. The protocol for entropy reduction would then consist of performing a swap operation between a thermal qubit and the first spin of the chain, and then to let the chain evolve for some time, and repeat the process. We devise strategies for optimising the time allowed for the spin chain to evolve before implementing the successive swap operations, and the dependence of entropy reduction on the length of the chain. We also investigate the effect of including a sink on spin N of the chain, as well as local dephasing on the spins. Our proposed scheme could be used as a fine probe to locally reduce entropy in a complex quantum device.

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