Quantum consensus dynamics by entangling Maxwell demon

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We propose a new type of Maxwell demon that is capable of generating many-body entanglement in the working substance [1]. The entangling demon randomly selects a qubit pair among many and performs a quantum feedback control, in continuous repetitions. Such protocol realizes the quantum steady-state engineering [2] as studied in quantum information and optics. Previous studies have identified possible types of entangled states which are stabilizable [2]. However, the quantum dynamics, i.e. how entanglement, coherence, and von Neumann entropy evolve in time, still lacks understanding. The mechanism behind the quantum dynamics is nontrivial due to two simultaneous tasks, the random selection and the continuous quantum measurement.

We study the quantum dynamics and the second law of thermodynamics under the action of such entangling Maxwell demon. We first propose a quantum version of the voter model, an entangling Maxwell demon adopting a protocol inspired by the noisy voter model, motivated by the fact that the classical model generates classical correlation of human opinions among agents. Our first main finding is that Greenberger-Horne-Zeilinger (GHZ) entanglement is generated among the working substance and stabilized against the bit-flip noises. During the entanglement generation, the purity and the entropy of the working substance change non-monotonically in time, which turns out to be due to the competition between the quantum-classical mutual information gain [3] and the absolute irreversibility [4] of the feedback control. Then, as our second main finding, we reformulate the second law of thermodynamics under the action of a generic class of entangling Maxwell demons. The upper bounds for the entropy reduction and the work extraction are determined by the competition between the information gain and the absolute irreversibility. This suggests that a general condition for the operation of a successful entangling demon, one for which many-body entanglement stabilization and work extraction are possible, is that the information gain is larger than the absolute irreversibility. We expect that our findings will be useful for stabilizing many-body entanglement and exploring quantum thermal machines with many-body entangled working substance.

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