Quantum thermodynamic and quantum heat engines

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ABSTRACT

We study a quantum Otto engine operating on the basis of a helical spin-1/2 multiferroic chain with strongly coupled magnetic and ferroelectric order parameters. The presence of a finite spin chirality in the working substance enables steering of the cycle by an external electric field that couples to the electric polarization. We observe a direct connection between the chirality, the entanglement and the efficiency of the engine. An electric-field dependent threshold temperature is identified, above which the pair correlations in the system, as quantified by the thermal entanglement, diminish. In contrast to the pair correlations, the collective many-body thermal entanglement is less sensitive to the electric field, and in the high temperature limit converges to a constant value. We also discuss the correlations between the threshold temperature of the pair entanglement, the spin chirality and the minimum of the fidelities in relation to the electric and magnetic fields. The efficiency of the quantum Otto cycle shows a saturation plateau with increasing electric field amplitude. Shortcuts to adiabaticity are employed to achieve an efficient, finite time quantum thermodynamic cycle which is found to depend on the spin ordering. We observe that the work mean square fluctuations are increased with the duration of the adiabatic strokes while the irreversible work and the output power of the cycle show a non-monotonic behavior. In particular the irreversible work vanishes at the end of the quantum adiabatic strokes. This fact confirms that the cycle is reversible. Our theoretical findings evidence the existence of a system inherent maximal output power. By implementing a Lindblad master equation we quantify the role of thermal relaxations on the cycle efficiency

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