PERFORMANCE ANALYSIS OF A BOSONIC QUANTUM OTTO REFRIGERATOR IN A THREE-DIMENSIONAL CUBIC POTENTIAL

UNDERGRADUATE THESIS

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ABSTRACT

This thesis studies a finite-time quantum Otto refrigerator with an ideal Bose gas confined in a three-dimensional cubic trap. Finite thermal contact times with the hot and cold reservoirs lead to partial thermalization during the isovolume processes, causing deviations from the quasistatic regime. The effects of trap volume ratio κ and thermalization time on the system performance are analyzed.

The results show that the coefficient of performance (COP) decreases monotonically with increasing κ, due to enhanced work input associated with spectral deformation during the isentropic processes, while heat extraction from the cold reservoir remains limited. A clear trade-off between the cooling rate and COP is observed, where higher efficiency is achieved at the expense of cooling power. Entropy production analysis indicates that near-reversible operation occurs when the heating and cooling durations are comparable, whereas prolonged heating increases irreversibility and degrades performance.

These findings highlight the important role of trap geometry and partial thermalization in determining the performance of finite-time quantum refrigeration systems.

Keywords: quantum Otto refrigerator, finite-time thermodynamics, partial thermalization, coefficient of performance, cooling rate, entropy production