Combining energy efficiency and quantum advantage in cyclic machines

Eric Lutz, Institute for Theoretical Physics I, University of Stuttgart, D-70550, Stuttgart, Germany

Abstract

Energy efficiency and quantum advantage are two important features of quantum devices. We report an experimental realization that combines both features in a quantum engine coupled to a quantum battery that stores the produced work, using a single ion in a linear Paul trap. We begin by establishing the quantum nature of the device by observing nonclassical work oscillations with the number of cycles as verified by energy measurements of the battery. We moreover apply shortcut-to-adiabaticity techniques to suppress quantum friction and improve work production. While the average energy cost of the shortcut protocol is only about 3%, the work output is enhanced by up to approximately 33%, making the machine significantly more energy efficient. We additionally show that the quantum engine consistently outperforms its classical counterpart in this regime. These results pave the way for energy efficient machines with quantum-enhanced performance.

Reference

Hou, W., Yao, W., Zhao, X. *et al*. Combining energy efficiency and quantum advantage in cyclic machines, Nature Communications **16**, 5127 (2025).