Quantum rotor engines and absorption fridges

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In this talk, I will present the recent work of our group on quantum models of thermal machines and the impact of quantum features on their performance. I will present our bottom-up approach to realistic autonomous heat engines using a rotor degree of freedom as the system ‘clock’ and drawing inspiration from actual piston engines. Then I will discuss a recent experiment realizing an absorption refrigerator with three harmonic modes of trapped ions.

The triumph of heat engines is their ability to convert the disordered energy of thermal sources into useful mechanical motion. In recent years, much effort has been devoted to generalizing thermodynamic notions to the quantum regime, partly motivated by the promise of surpassing classical heat engines. For a fair quantum-classical comparison and as a testbed for quantum effects, we introduce an autonomous rotor heat engine model. It consists of a rotor playing the role of the piston, a harmonic working mode driving the piston, and piston-synchronized coupling to two thermal reservoirs. Our model can be studied in both a quantum and classical framework and is built from standard closed-system Hamiltonians and weak bath coupling terms. I will present a thermodynamic analysis of the engine’s behaviour for several parameter regimes, using the classical model as a benchmark. An implementation of the engine model is not restricted to mechanical rotors, but can also be envisaged in the form of Josephson phase variables in superconducting circuits.

Another system for quantum-classical benchmarking is the absorption refrigerator model based on the resonant exchange coupling between three harmonic modes [1]. I will present a recent experiment with trapped ions implementing this model. In particular, I will discuss the experimental results on quantum coherence-assisted single-shot cooling below the steady state, as recently predicted by Mitchison et al [2].

[1] A. Levy and R. Kosloff, Phys. Rev. Lett. 108, 070604 (2012)

[2] M.T. Mitchison, M.P. Woods, J. Prior, and M. Huber, New J. Phys. 17, 115013 (2015)