Work extraction from quantum coherence

I. Maillette de Buy Wenniger[1], S. E. Thomas[1], M. Maffei[2], M. Pont[1], S. C. Wein[2,3], A. Harouri[1], A. Lemaitre[1], I. Sagnes[1], N. Somaschi[4], A. Auffeves[2], and P. Senellart[1]

[1] *Centre for Nanosciences and Nanotechnology, CNRS, Universite Paris-Saclay, UMR 9001, 10 Boulevard Thomas Gobert, 91120, Palaiseau, France*
[2] *Universite Grenoble Alpes, CNRS, Grenoble INP, Institut Neel, 38000 Grenoble, France*
[3] *Institute for Quantum Science and Technology and Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada T2N 1N4*
[4] *Quandela SAS, 10 Boulevard Thomas Gobert, 91120, Palaiseau, France*

Classical thermodynamics is considered one of the pillars of macroscopic physics dealing with notions such as heat and work and their transfer. These notions of work and heat, however, should be revisited when entering the quantum regime. Many theoretical papers have addressed the issue of reaching a general theory of quantum thermodynamics with unambiguous definitions for heat and work, and thermodynamic laws. Within these theoretical explorations, special emphasis is given to the role of quantum coherence when extracting work from quantum systems which allows for strikingly different thermodynamic features [1]. Despite a growing number of papers investigating the theory of thermodynamics in the quantum realm, there have been few experimental studies thus far.

Here we demonstrate the ability to experimentally extract work from coherence in a quantum engine and add the work to a (classical) battery. Our quantum engine, a two level system (InGaAs quantum dot in a GaAs/AlGaAs micropillar cavity), is fueled by a classical laser drive. We show that by driving the engine with pulses up to full population inversion, we can extract work depending on the amount of quantum coherence induced in the two level system. We further show that the amount of extractable work depends on the purity in frequency domain and in photon number basis. Finally, we load this work to a battery (laser field) using homodyne-type measurements and determine the amount of work extracted from the quantum engine.

The present study highlights the key role of quantum coherence in the laws of quantum thermodynamics, and demonstrates unambiguously the ability to add work from a quantum engine to a battery.

[1] Monsel, J. et al., "The energetic cost of work extraction", PRL, 124, 130601 (2020)