Reversible work extraction in a hybrid opto-mechanical system

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With the progress of nano-technology, thermodynamics also has to be scaled down, calling for specific protocols to extract and measure work. Usually, such protocols involve the action of an external, classical field (the battery) of infinite energy, that controls the energy levels of a small quantum system (the calorific fluid). Here we suggest a realistic device to reversibly extract work in a battery of finite energy : a hybrid optomechanical system (Fig.1). Such devices consist of an optically active two-level quantum system interacting strongly with a nano-mechanical oscillator that provides and stores mechanical work, playing the role of the battery. We identify protocols where the battery exchanges large, measurable amounts of work with the quantum emitter without getting entangled with it. When the quantum emitter is coupled to a thermal bath, we show that thermodynamic reversibility is attainable with state-of-the-art devices, paving the road towards the realization of a full cycle of information-to- energy conversion at the single bit level [1]. Applications of opto-mechanical systems as quantum heat engines will also be considered [2].

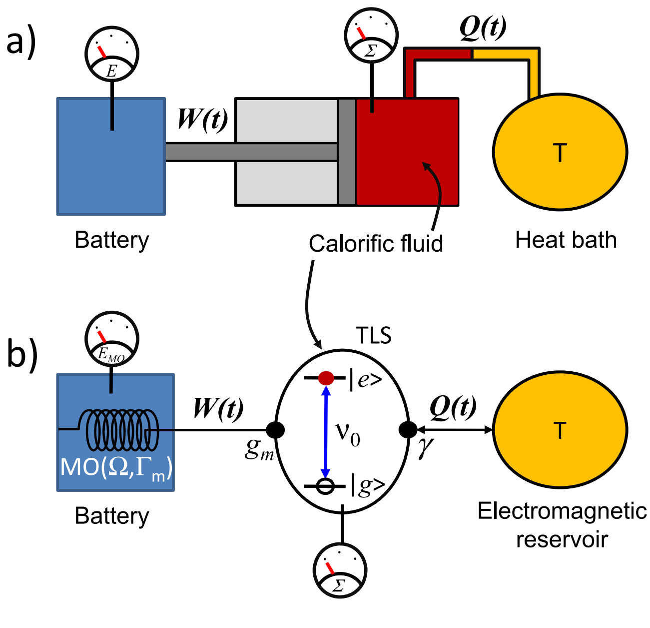

Figure 1. (a) A typical experimental setup in thermodynamics. A system (the calorific fluid) exchanges heat Q with a bath, and work W with a battery. In the framework of information thermodynamics, the system has two micro-states allowing to encode one bit of information. Mean work exchanges are usually studied by recording and processing the mean trajectory $\Sigma(t)$ of the system all along the transformation. In our protocol, work exchanges are inferred from the readout of the battery states at the initial time t_i and final time t_f. (b) A hybrid opto-mechanical system : an optically active two-level system (TLS) of transition frequency ν_0 is coupled to a mechanical oscillator (MO) of frequency Ω with a strength g_m. The TLS interacts with a reservoir of electromagnetic modes, its spontaneous emission rate being denoted γ. In the protocol that we suggest, information is encoded on the TLS, while the MO (resp. the electromagnetic reservoir) plays the role of the battery (resp. of the bath).

[1] C. Elouard, M. Richard, A. Auffèves, *Reversible work extraction in a hybrid optomechanical system*, New Journal of Physics **17**, 055018 (2015) (Special focus on Quantum Thermodynamics).

[2] M. Richard, A. Auffèves, *Optical driving of macroscopics mechanical motion by a single two-level system*, Physical Review A **90**, 023818 (2014).