

# Coherence-powered energy exchanges between a solid-state qubit and light fields.

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## Abstract

Quantum coherence has recently emerged as a key concept to describe the law of quantum thermodynamics, supporting the definition of work and governing the laws of energy exchange. More specifically, recent theory predicts quantum coherence to play a crucial role in the energy transfer from a quantum substance to a quantum battery [1–4]. The coupling of a two-level system to a single mode harmonic oscillator has been proposed as a toy model to explore these energy transfers [2, 3]. Such system can be mapped to a two level-system (qubit) coupled to a single mode of the electromagnetic field (battery), with light emission taking place either in the spontaneous (empty battery) or stimulated regime (loaded battery) [2, 3]. In the spontaneous emission regime, it was recently predicted that the maximum amount of work extracted from the working substance to the quantum battery is limited to the coherent part of the energy carried by the initial qubit. We experimentally study the role of coherence in the process of energy transfer both in the charging and discharging of a quantum battery. We investigate the energy transfer from a qubit (a two-level system of a quantum dot) into an initially empty quantum battery (a mode of the electromagnetic field). We observe that the amount of work charged into the quantum battery through spontaneous emission is proportional to the quantum coherence initially carried by the qubit and is altered by temperature. We then discharge the quantum battery into a classical coherent field, which acts as a work receiver using a homodyne-type measurement. The amount of energy transferred to the work receiver is controlled by the relative fields classical optical phase, the overall quantum purity of the charged battery field as well as long term fluctuations in the qubit energy. Our study lays the groundwork for the energetics of quantum light generation and optical quantum interferences - two key processes that are at the core of most light-based quantum technologies.

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