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

Ilse Maillette de Buy Wenniger[1], Sarah E. Thomas[1], Maria Maffei[2], Stephen C. Wein[2,3], Mathias Pont[1], Abdelmounaim Harouri[1], Aristide Lemaitre[1], Isabelle Sagnes[1], Niccolo Somaschi[4], Alexia Auffèves[2], and Pascale Senellart[1]

[1] *C2N, CNRS, 10 Boulevard Thomas Gobert, 92110 Palaiseau, France*
[2] *Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 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*

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 show that we can transfer the work from the battery into a classical coherent field using homodyne-type measurements, thereby discharging the battery. The amount of energy transferred to the classical field 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.

[1] G. Francica, F. C. Binder, G. Guarnieri, M. T. Mitchison, J. Goold, and F. Plastina, Phys. Rev. Lett. 125, 180603 (2020)

[2] J. Monsel, M. Fellous-Asiani, B. Huard, and A. Auffèves, Phys. Rev. Lett. 124, 1 (2020)

[3] M. Maffei, P. A. Camati, and A. Auffèves, Phys. Rev. Research 3, L032073 (2021)

[4] F. Caravelli, B. Yan, L. P. García-Pintos, and A. Hamma, Quantum 5, 505 (2021)