Time-resolved energetic exchanges during a Ramsey sequence

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Understanding the energetic exchanges between individual quantum systems is an active field of quantum thermodynamics, crucial to analyse the energetic footprint of the developing applications in quantum information processing [1].

In this work, we study the work and heat exchanges between a quantum emitter (an artificial atom constituted by a semiconductor quantum dot) and the electromagnetic field. The quantum emitter is driven resonantly via the Ramsey sequence (two resonant, delayed pulses with $\pi/2$ driving areas), see Fig. 1. Within this excitation sequence, the quantum emitter exchanges work and heat with the vacuum of the electromagnetic field through spontaneous emission. Theoretically, it has been predicted that the work transferred corresponds to the unitary part of the interaction [2].

We propose an experimental protocol to time-resolve emitted work and heat along the spontaneous emission. Our experimental time-resolved approach exploits quantum interference on a beam-splitter in a homodyne configuration [3]. The work emitted by the atom is shown to be independent of the Ramsey phase. Conversely, depending on the Ramsey phase, one can reduce or enhance the heat transferred - a signature of increased emitter-light entanglement during the sequence.

References

[1] A. Auffèves, *Quantum Technologies Need a Quantum Energy Initiative*, PRX Quantum **3**, 020101 (2022).

[2] M. Maffei, P. A. Camati, and A. Auffèves, *Probing Nonclassical Light Fields with Energetic Witnesses in Waveguide Quantum Electrodynamics*, Phys. Rev. Research **3**, L032073 (2021).

[3] I. M. de B. Wenniger et al., *Coherence-Powered Work Exchanges between a Solid-State Qubit and Light Fields*, arXiv:2202.01109.

Figures

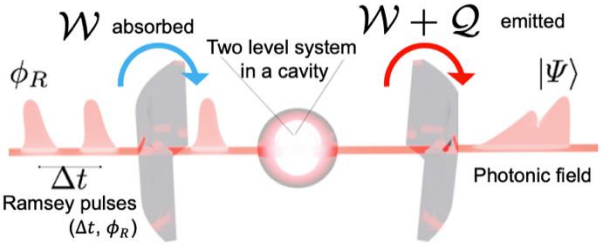

Figure 1: Sketch of the system: the classical drive provides work to the atom via the Ramsey sequence, and it emits heat and work into the photon field.

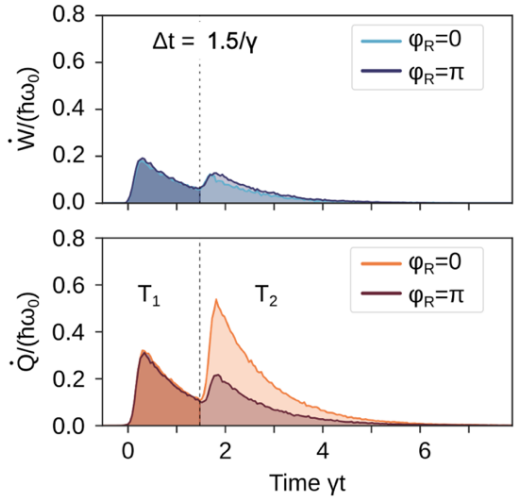

Figure 2: Variation of work (top) and heat (bottom) as a function of time (in units of γ=1/(190 ps)) for a 1.5/γ delay between Ramsey pulses and two different Ramsey phases φ_R=0 (light colors) and π (dark colors). T_1 [T_2] is the time bin between pulses [after the second pulse].