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Cyclic solid-state quantum battery: Thermodynamic characterization and quantum hardware simulation

In this work [1], we explore the concept of a cyclic quantum battery, an idea to harness quantum mechanics to improve energy storage in miniaturized devices. Conventional batteries rely on electrochemical processes, while a quantum battery uses the properties of quantum systems to store and release energy more efficiently. Our goal is to theoretically investigate a feasible model for such a battery, which could pave the way for future experimental realizations.

Our model is based on an interacting bipartite system, weakly coupled to a thermal bath, focusing on the case of two interacting qubits. The working cycle of the battery consists of four strokes: thermalization, where the system absorbs energy from a thermal bath; disconnection, which decouples the qubits; ergotropy extraction, where useful energy is extracted; and reconnection, preparing the system for the next cycle. The thermal bath acts as a charger in the thermalization stroke, while ergotropy extraction is possible because the ensuing thermal state is no longer passive after the disconnection stroke. The key point of our model is the exploitation of coherences and correlations between qubits to improve the overall efficiency of the cyclic quantum battery, we show that they can be exploited to reach working regimes with efficiency higher than 50% while providing finite ergotropy.

We validated our theoretical model discussing a simple feasible superconducting circuit and realizing simulations on superconducting quantum computers provided by IBM. Our results show that our scheme for cyclic quantum batteries can be successfully implemented in a superconducting quantum hardware.

[1] Luca Razzoli et al. 2025 Quantum Sci. Technol. 10 015064

Theme

Theme 3. Theoretical and experimental methods for quantum effects in energy processes

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