Harnessing electronic transport to enhance quantum battery charging

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Quantum batteries are energy-storing devices designed to supply power to another quantum system. Charging a quantum battery and maintaining the charged state over long times is generally challenging due to the needed control overhead and unavoidable dissipation. Autonomous setups, where the battery is charged by evolving into a non-equilibrium steady state, have attracted considerable interest as they completely circumvent both challenges. Here, we consider an experimentally feasible nanoelectromechanical model of a quantum harmonic oscillator battery coupled to a quantum dot acting as a charger. The resource used to charge the battery is the steady state electronic particle current that runs across the dot, which is generated by its coupling to two reservoirs with a chemical-potential imbalance. In this way, we establish a concrete pathway for recycling energy that would otherwise be discarded from a primary quantum transport process, enabling a self-sustaining operation of auxiliary quantum components. Our setup features two key novelties: first, strong battery–charger coupling enabling highly ergotropic charged states; second, full autonomy—the battery remains strongly coupled to the charger at all times, even during charge extraction. We quantify the amount of extractable energy stored in the battery by *local* ergotropy. We show that, while optimal charging always requires a strong current, it is not achieved at maximal current when the coupling is strong, meaning that strong coupling is beneficial for charging efficiency. Furthermore, we demonstrate that the extraction from the battery can be enhanced by introducing feedback from measuring the dot. This generalizes the notion of daemonic ergotropy to the strong coupling regime, and allows us to harness the battery–charger correlations created by the strong coupling. These results highlight the operational advantages of exploiting electron transport as a resource for efficient quantum-battery charging.