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Fast Charging of Quantum Batteries via Dephasing and Their Asymptotic Freedom

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Quantum batteries—energy storage devices based on quantum systems—have recently attracted significant attention as promising candidates for achieving fast and efficient charging by exploiting quantum effects. In this talk, we present our recent theoretical results showing that controlled decoherence, typically considered detrimental to quantum devices, can instead be harnessed as a universal resource for enhancing the charging performance of quantum batteries [1]. Specifically, we analyze a star-configuration model in which an ensemble of N qubits (the battery) is charged by a driven qubit (the charger) subject to pure dephasing noise. By carefully tuning the dephasing rate, one can balance coherent oscillatory energy exchange with quantum Zeno suppression, thereby realizing an optimal regime of fast and robust energy transfer. This mechanism is universal, applying to batteries modeled by either two-level systems or harmonic oscillators, and remains resilient against detuning of system frequencies.
Furthermore, we uncover an "asymptotic freedom"-like behavior: in the large-N limit, the ratio of extractable work (ergotropy) to stored energy approaches unity as 1-O(1/N), even though the steady state of the battery remains mixed [2]. This remarkable feature originates from the emergence of approximate ground-state degeneracy in the collective battery system. Finally, we discuss the scaling behavior of the charging time with N and the experimental feasibility of implementing our proposal with existing quantum platforms such as superconducting qubits and NMR systems.
[1] R. Shastri, C. Jiang, G.-H. Xu, B. P. Venkatesh, and G. Watanabe, npj Quantum Inf. 11, 9 (2025).
[2] C. Purkait, B. P. Venkatesh, and G. Watanabe, arXiv:2508.13497 [quant-ph] (2025).

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