Quantum speed-up predicted for charging quantum batteries

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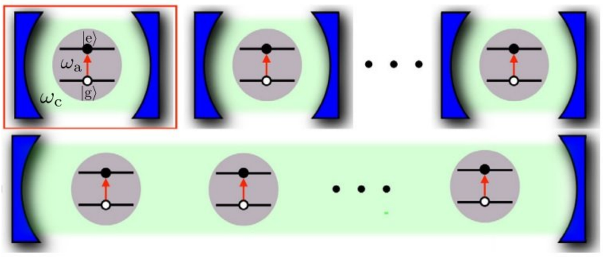

(Top) Quantum batteries operating in parallel and (bottom) the entangled building blocks of a quantum battery operating collectively. Credit: Ferraro et al. ©2018 American Physical Society

While batteries have been improving in recent times, at their core today's batteries still operate on the same basic electrochemical principles developed in the 18th and 19th centuries. Some physicists are now wondering whether quantum phenomena may revolutionize conventional battery chemistry and lead to the development of an entirely new class of potentially more powerful batteries.

In a new study published in *Physical Review Letters*, physicists Dario Ferraro and coauthors at the Italian Institute of Technology in Genova, Italy, have theoretically demonstrated a quantum speed-up for the charging time of quantum batteries, in analogy to the quantum speed-up that has been previously demonstrated for information processing in quantum computing.

"We have shown that, even in a simple but realistic model, the charging power can be considerably enhanced by properly exploiting the rules of quantum mechanics," Ferraro told *Phys.org*. "Quantum batteries, once experimentally realized, could be used in contexts where the rapidity of charging/discharging process is crucial. As a possible application, one can imagine the realization of nanoscale power supplies to provide energy to miniaturized devices directly on-site."

In their work, the physicists showed that entangling the units of a quantum battery, and then coupling all of the units to the same quantum energy source, results in a quantum collective enhancement in charging power compared to the case where the units are charged individually, in parallel. The enhancement increases as the number of units increases (specifically, when a quantum battery consists of *N* units, the quantum advantage scales as the square root of *N*).

The researchers attribute the faster charging time to the quantum entanglement among the units. They explain that the units are all coupled to a common quantized electromagnetic mode, and photons from the energy source mediate a long-range interaction between units, generating entanglement among them.

The work builds on previous abstract ideas about speeding up the charging time of quantum batteries through collective charging, making these concepts more concrete and putting them on experimentally feasible grounds. The researchers expect that the proposed system may be experimentally realized with current state-of-the-art technology, such as superconducting qubits, quantum dots, or photonic crystals, among other possibilities.

"Our work aims at creating a bridge between abstract mathematical physics theorems and actual experimental implementation of quantum batteries," Ferraro said.

In future work, the researchers also plan to investigate another interesting outcome of the new study, which is the existence of a tradeoff between the quantum battery's charging power and its energy storage capacity.

More information: Dario Ferraro et al. "High-Power Collective Charging of a Solid-State Quantum Battery." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.120.117702
Also at: arXiv:1707.04930 [cond-mat.mes-hall]