Quantum effects lead to more powerful battery charging

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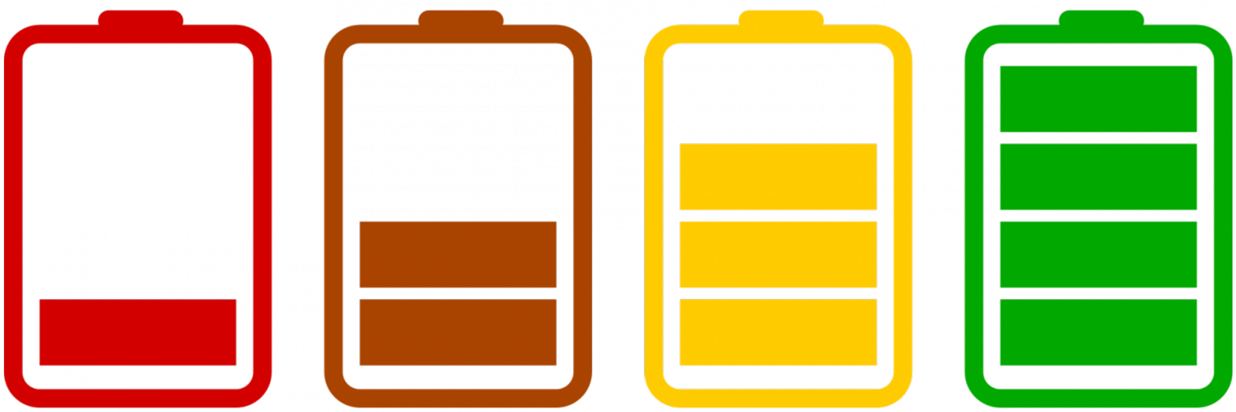

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(Phys.org)—Physicists have theoretically shown that, when multiple nanoscale batteries are coupled together, they can be charged faster than if each battery was charged individually. The improvement arises from collective quantum phenomena and is rooted in the emerging field of quantum thermodynamics—the study of how quantum effects influence the traditional laws governing energy and work.

The researchers, Francesco Campaioli et al., have published a paper on the fast charging of nanoscale batteries in a recent issue of *Physical Review Letters*.

Although a great deal of research has shown that quantum phenomena provide advantages in information processing applications, such as computing and secure communication, there have been very few demonstrations of quantum advantages in thermodynamics. In one recent study in this area, researchers showed that quantum entanglement can allow more work to be extracted from a nanoscale energy-storage device, or "quantum battery," than would be possible without entanglement.

In the new study, the researchers build on this result to show that quantum phenomena can also enhance the charging power of quantum batteries. They also found that the process does not necessarily require entanglement, although it does require operations that have the potential to generate entangled states.

"Our work shows how entangling operations—that is, interactions between two or more bodies—are necessary to obtain a quantum advantage for the charging power of many-body batteries, whereas entanglement itself does not constitute a resource," Campaioli, at Monash University in Australia, told *Phys.org*. "Additionally, we show that for locally coupled batteries the quantum advantage scales with the number of interacting batteries."

The quantum advantage is not without its limits, however, and the physicists derive the upper bound on how much faster a collection of batteries can be charged with the help of quantum phenomena. They show that for locally coupled batteries the quantum advantage grows with the number of interacting batteries. These bounds for the quantum advantage are based on quantum speed limits, which are used, for example, to estimate the maximum speed of quantum processes, such as calculations on a quantum computer. Here, the limit is for thermodynamic processes.

Overall, the results may lead to methods of improving future nanoscale energy-charging processes, as well as to a better understanding of how quantum theory and thermodynamics are related.

"Our result could be used to provide optimal charging for nanodevices that rely on batteries that consist of few quantum systems, such as charge qubits, ions or atoms," Campaioli said. "Our plan for future research in this field is to provide a tight upper bound to the advantage that can be obtained by means of interactions between a finite number of bodies. Furthermore, we would like to obtain an experimental realization of the above-mentioned quantum advantage."

More information: Francesco Campaioli et al. "Enhancing the Charging Power of Quantum Batteries." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.118.150601