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Remote Entanglement and Quantum Networks with Trapped Atomic Ions[1]

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The recent developments of quantum information science and its potential applications have brought many of the fundamental questions of quantum physics to the mainstream of not only theoretical but also experimental physics. I discuss a system at the heart of these questions – quantum entanglement of the spin states of two individual massive particles at a distance, as originally envisioned in Bohm's version of the Einstein-Podolsky-Rosen paradox. I present the theory and the experimental realization of the entanglement of two trapped atomic ions separated by 1 meter. Trapped ions are among the most attractive systems for scalable quantum information because they can be well isolated from the environment and manipulated easily with lasers. In particular, I discuss our results including the first explicit demonstration of both quantum entanglement between a single trapped ion and its single emitted photon, as well as entanglement between two macroscopically separated trapped ion quantum memories. The entanglement protocols used in these experiments, together with the recent developments of local entanglement between nearby ions based on their Coulomb interaction, can be used to create a platform for a scalable quantum information network or a distributed quantum computer, and perhaps confront some of the strangest features of quantum mechanics.

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