

Quantum Information Processing with Ions and Photons

Steven Olmschenk

FOCUS Center and Department of Physics, University of Michigan, Ann Arbor

Current work on the trapped ion quantum information processor is centered on scaling to larger systems. We report two approaches toward this end. One approach to scale up this system is to construct complex trap arrays where ions are shuttled between storage and entanglement areas, with nearby ions entangled via their Coulomb-coupled motion. Pursuing this course, we demonstrate the operation of ion traps fabricated using semiconductor MEMS technology; shuttle, separate, and swap ions in a two-dimensional T-trap array; and characterize the motional decoherence that plagues ion traps using a novel trap design with variable electrode spacing. Another approach to scalable quantum computation is to use a photon-mediated entanglement scheme to realize large networks of trapped ions. In this method, entanglement of two ions can be achieved by each emitting a single photon, and detecting these photons following interference at a beamsplitter. We demonstrate the quantum interference of two independent photons, and, subsequently, the entanglement of two ions separated by about one meter. Ultrafast pulses are used to simultaneously excite two individual ytterbium ions confined in separate vacuum chambers, and the resulting single photons emitted by the ions are coupled into optical fibers and combined on a beamsplitter. Due to the quantum interference of photon pairs, a coincident detection of the photons heralds the entanglement of the two trapped ions. While this linking is probabilistic in nature, it is still possible to efficiently implement long-distance quantum communication protocols and generate scalable cluster states for quantum computing applications.

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