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A two-node trapped-ion quantum network with photonics interconnects

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Trapped ions are a leading platform for quantum computing due to the long coherence time, high-level of control of internal and external degrees of freedom, and the natural full connectivity between qubits. Single and multi-qubit operations have been performed with high fidelity (>99.9%), which has enabled the demonstration of small universal quantum computers (~10 atoms). However, scaling up to bigger sizes remains a challenge. In our experiment we aim to demonstrate the first operational and fully controllable two-node quantum computer, where each node is small scale quantum processors (~5 ions) connected via photonic entanglement. We use two ion traps systems separated by ~2 m, where we confine mixed chains of Strontium and Calcium ions. Calcium-43 has excellent qubit coherence properties, while Strontium-88 has convenient internal structure for generating photonic entanglement. Single 422 nm photons emitted by the Strontium ion are used to generate remote entanglement. We recently have achieved a remote Strontium-Strontium entanglement fidelity of 96.0(2)% at a rate of 100 entangled events/s, and a average CHSH violation of 2.65..In this talk I will present our current work on the implementation of high-fidelity local Calcium-Strontium entangling gates, to swap the remote Strontium-Strontium entanglement into Calcium-Calcium remote entanglement. Thereafter, creating a second pair of remotely entangled ions will allow us to perform entanglement distillation to create high-fidelity remote entanglement, at the same fidelity of local entangling operations (>99%), which together with a a universal set of local gates will be use to demonstrate the first two-node quantum computer. Furthermore, I will present our preliminary results on the demonstration of secure quantum communications between the nodes of our network certified by continuous violation of the CHSH inequality.

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