Ion-Photon Entanglement in Strontium for City-Scale Quantum Networks

N M Linke[1,2]

[1]*Physics, University of Maryland, Stadium Drive, College Park MD, USA*
[2]*Duke University, 701 W. Main St., Durham NC, USA*
Contact Email: norbert.linke@duke.edu

Quantum computers have been realized in several physical platforms but they are not large or powerful enough to challenge classical computing methods. Trapped-ions are one of the most advanced modalities for creating quantum computers. Much like classical computing devices, in order to scale up quantum systems they need to be connected together in a network. For this purpose, quantum signals have to be exchanged between them in a coherent fashion. Achieving this over larger physical distances is challenging since photons emitted by atoms or ions are typically in the visible or UV range, far from the low-loss regions of optical fiber transmission.

We present a quantum network node based on Strontium ions that emit photons at 1092 nm with a polarization state that is entangled with a meta-stable D-level qubit in the emitting ion, resulting in the state: $|\psi\rangle = \frac{\sqrt{3}}{2}|\sigma^+\rangle|0\rangle + \frac{1}{2}|\sigma^-\rangle|1\rangle$. The wavelength transmits through optical fiber with moderate loss allowing for quantum network links of a few kilometers for a city-scale quantum network.

We present the first set of results from this experiment, establishing a new type of trapped-ion qubit with state-preparation, single-qubit rotations, and high-fidelity readout. We stimulate the emission of infrared photons, capture them with a high-NA objective and analyze their polarization state with a pair of SNSPDs. We use state-tomography to show that we generate the ion-photon entangled state with $> 95\%$ fidelity.

We transmit the photons over commercial optical fiber, 2.8 km in length, deployed in the field, stretching between two buildings in the downtown area of the city of Durham, North Carolina and show that entanglement persists, meaning the system is capable of establishing a municipal quantum network across multiple locations. We present a detailed analysis of the noise and error mechanisms affecting the measurement and discuss prospects for using this new trapped-ion quantum network node for the testing of quantum applications on a quantum computer network.