A network of trapped-ion quantum computers

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Trapped ions are a leading platform for quantum computing due to their long coherence time, high level of control over 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%), enabling the demonstration of small universal quantum computers (approx. 10 atoms). However, scaling up to larger sizes remains a challenge. In our experiment, we aim to demonstrate the first operational and fully controllable two-node quantum computer, where each node consists of small-scale quantum processors connected via photonic entanglement. We use two ion trap systems to confine mixed chains of Strontium and Calcium ions. 43Ca+ has excellent qubit coherence properties, while 88Sr+ has a convenient internal structure for generating photonic entanglement. Single 422 nm photons emitted by the Strontium ion are used to generate remote entanglement. We recently achieved a remote Strontium-Strontium entanglement fidelity of 96.0(2) % at a rate of 100 entangled events/s, along with an average CHSH violation of 2.65.
In this talk, I will present our latest results using this elementary quantum networks, including the implementation of a long-lived (>10s) memory qubit into our mixed-species trapped-ion quantum network nodes [1]; and how to use one of these nodes to implement simple instances of Blind Quantum Computing [2].
Furthermore, I will present the demonstration of secure quantum communications between the nodes of our network, certified by continuous violation of the CHSH inequality (DIQKD), and the demonstration of the first quantum network of entangled optical atomic clocks

References

[1] Phys. Rev. Lett. 130, 090803 (2023)
[2] arXiv:2305.02936 [2023]
[3] Nature 609, 689–694 (2022)
[4] Nature 607, 682–686 (2022)