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Ion-cavity node engineering for scalable networked quantum computing

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Networked architectures provide a route to freely-scalable quantum computation with trapped ions, with entanglement between ions in remote nodes mediated by the coherent production, interference and projective measurement of single photons. Two-node networks have provided proof-of-principle demonstrations but have been limited in the rate of entanglement achieved, and many further hurdles remain on the route to large-scale networked quantum computation.

To approach equivalency with local, phonon-mediated entangling operations, network photons must be generated near-deterministically and at high rate, most readily achieved via integration of a high-finesse optical cavity. The use of microcavities to enhance photon production has long been recognised as essential to success of scalable quantum networks, but the development of systems of sufficiently high performance and reliability remains a considerable challenge.

In Oxford, we are tackling this problem from multiple angles. To commission and operate a multi-node computational architecture will require ion trap system of vastly greater simplicity and reliability than currently available, enabling nodes capable of long-term autonomous operation. We are therefore working to improve the manufacturing precision and operational reliability of our traps, cavities and other subsystems. In parallel we aim to improve the intrinsic robustness of the photon production and entanglement schemes utilised, to minimise the detrimental impact of residual imperfections in system manufacture and environmental control.

I will present technical progress towards creating a multi-node quantum network, providing illustrative examples of the engineering efforts underway across our group. Here, I will focus on a selection of methods for complex 3D trap microfabrication, optical cavity integration, microlens arrays for laser delivery and fluorescence collection and high-efficiency compact atomic sources.

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