Challenges and Opportunities in Quantum Communication

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Quantum technologies have the potential to benefit society in exciting and diverse ways. Future quantum technologies are likely to be based on a quantum network where computational modules, with the power to revolutionise high-performance computing, will be connected to each other and to the users of the network via quantum communication links that have unbreakable security. Quantum communication focuses on the secure transfer of quantum information across a quantum network using photons. Whilst there are many protocols under consideration, one of the leading schemes relies on users having a shared entangled state which enables them to share quantum information. The fundamental resource in quantum communication is therefore a source of entangled photon pairs. I will outline the leading platforms, as well as their associated challenges, for generating entangled photon pairs.

A second challenge in quantum communication is the distribution of these entangled states over large distances. As the size of the quantum network increases, the amount of loss in the quantum communication links increases and it becomes impossible to share entangled photonic states. A solution to this problem is to use a quantum repeater protocol: entanglement is shared over a short distance, and then gradually distributed to larger distances using entanglement swapping operations. A key resource for quantum repeaters is a quantum memory: a device that can store photons while the probabilistic entanglement swapping operations take place. Quantum memories are critical for increasing the scalability of quantum networks. I will outline the leading platforms and protocols for building quantum memories. Finally I will discuss the challenges and progress in interfacing these two key technologies: sources of entangled photon pairs and quantum memories, which are typically based on different physical platforms.