Multi-node quantum network

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The development of a worldwide quantum internet requires the realization of an extended network of quantum registers that can store quantum states and that are linked by entanglement over large distances. In such a quantum internet, quantum information is transmitted via teleportation.

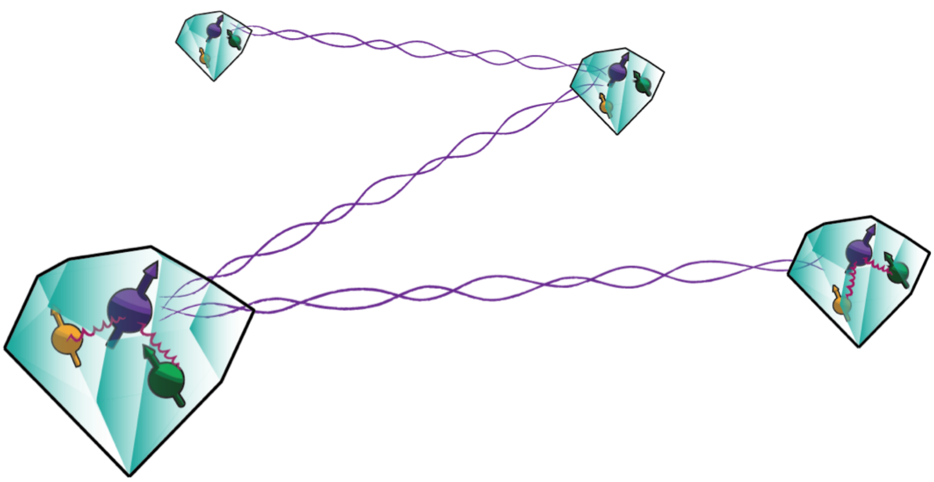
On the one hand a multi-node quantum network would allow the use of nonlocal correlations for intrinsically secure communication across the globe. On the other hand, it could provide a simulation platform to explore the nature of quantum phenomena.

Until now it has not been possible to spread entanglement between many and distant nodes due to the exponential decrease in entangling rate with distance combined with the difficulty to store a quantum state for a long period. An essential feature to overcome these problems is represented by quantum repeaters, it would allow to entangle its two neighbouring nodes via a protocol know as entanglement swapping.

In order to realize such a network architecture, included the quantum repeater, it is necessary to combine the key strengths of different types of quantum particles. The robustness of nuclear spins in solids can be used for storage of quantum states that can be initialized and read-out thanks to the optical interface of electron spins. Moreover, the mobility and coherence of photons is required to cover large distances and connect distant nodes; thus each node has to possess an efficient interface to light.

One of the most promising candidates for a node in such a quantum network architecture is the nitrogen-vacancy (NV) centre in diamond. The NV defect is a colour-centre in diamond consisting of a substitutional nitrogen atom and a neighbouring lattice vacancy. It is a well-isolated system that can be controlled with high precision. The NV defect centre results in an electronic spin that can be initialized and read out optically, and manipulated with standard magnetic resonance techniques. The hyperfine interactions between the NV electronic spin and nearby nuclei (in particular the host nitrogen ^{14}N and ^{13}C isotopic impurities) allow to store the electronic spin state on individual nuclear spins that can be used as quantum register thanks to their extremely long coherence times. Furthermore, at cryogenic temperatures, the spin-dependent optical transitions of a NV centre provide a mechanism for entangling its electronic spin with an outgoing photon, enabling the connection of such registers to macroscopic networks.

In the last years has been shown that is possible to entangle electron spins in different diamond chips over a distance >1km [1] and also to achieve a full control over some nuclear spins near one such electron spin [2]. These preliminary results suggest a possible strategy to build a quantum network from several multi-particle nodes.



[1] Hensen B. et al. . Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres. Nature 526, 682-686 (2015)

[2] Reiserer A. A. et al. . Robust quantum-network memory using decoherence-protected subspaces of nuclear spins. Phys. Rev. X 6, 021040 (2016).