Optical Networks of Coherent Qubits provide a flexible route towards scalable communication and processing of quantum information. Indium-gallium-arsenide quantum dots (QDs) can function as high-bandwidth network nodes in the solid state, with the creation of confined excitons providing an ultrafast interface between a single spin and well-defined optical modes.

A defining feature of a quantum network is the ability to distribute entanglement between its constituent nodes. We demonstrate this capability by generating highly entangled states of electron spins confined to distant QDs [1] through which-path erasure and projective measurement of a single spin-flip Raman photon [2]. The phase of the entangled state is then determined by the relative phase of excitation and detection of the two QDs, requiring both optical indistinguishability and phase-coherent interaction with the two emitters, which we achieve with a stabilised Mach–Zehnder interferometer incorporating both systems [Fig. 1a]. In Fig. 1b we present the results of spin-spin correlation measurements in both the population basis and a rotated basis for the $\psi^+$ Bell state. Our results confirm entangled state creation with a Bell-state fidelity $61.6 \pm 2.3\%$, violating the classical limit by over 5 standard deviations of the mean. The strong, coherent light-matter coupling of these QDs enables operation at a state generation rate of 7.3 kHz, the highest frequency entanglement distribution between distant nodes yet reported.

A key limit to the fidelity of the spin-photon interface in these systems is the interaction between the confined electron and the nuclei that form the QD. Through optical feedback under coherent population trapping we show that we can generate correlated states of the nuclear ensemble and extend the inhomogeneous dephasing time of the central spin by an order of magnitude [3]. Using the coherence of the electron as a probe we monitor the emergence and decay of correlations within the ensemble. This process can be directly included in network protocols, increasing the fidelity and rate of entanglement generation.

Figure 1a A Mach-Zehnder interferometer incorporating two electron spins as the ground states of optically-addressable lambda-schemes. Phase stability via $\Delta\phi(t)$ permits controlled entangled state creation by single photon detection at $D_1$. b Population (upper) and rotated basis (lower) measurements of two-electron spin correlations following entangled state generation. Spin correlations in the rotated basis evidence a coherent entangled state.

References