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Quantum entanglement between diamond spin qubits separated by 3 meters

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Entanglement of spatially separated objects is one of the most intriguing phenomena that can occur in physics. This can lead “spooky action at a distance” where measurement of one object instantaneously affects the state of the other object. Besides being of fundamental interest, entanglement is also a valuable resource in quantum information technology enabling secure quantum communication networks and distributed quantum computing. Here we present our most recent results towards the realization of scalable quantum networks with solid-state qubits. We have entangled two spin qubits in diamond, each associated with a nitrogen vacancy center in diamond [1]. The two diamonds reside in separate setups three meters apart from each other. With no direct interaction between the two spins to mediate the entanglement, we make use of a scheme based on quantum measurements: we perform a joint measurement on photons emitted by the NV centers that are entangled with the electron spins. The detection of the photons projects the spins into an entangled state. We verify the generated entanglement by single-shot readout of the spin qubits in different bases and correlating the results. These results open the door to a range of exciting opportunities. For instance, the remote entanglement can be extended to nuclear spins near the NV center. Our recent experiments demonstrate robust methods for initializing, controlling and entangling nuclear spins by using the electron spin as an ancilla [2,3]. Entanglement of remote quantum registers will enable deterministic quantum teleportation, distributed quantum computing tasks and the implementation of an elementary quantum repeater.

[1] H. Bernien et al., in preparation.
[2] T. van der Sar et al., Nature 484, 82 (2012).
[3] W. Pfaff et al., Nature Physics (2012); doi:10.1038/nphys2444.