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# A photonic link for donor spin qubits in silicon

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The electronic and nuclear spins of shallow donor impurities in silicon have many highly attractive properties as qubits for a semiconductor-based quantum information technology. In addition to being compatible with standard CMOS processing, these qubits are atomically identical, have demonstrated incredibly long relaxation times, T1, and coherence times, T2, and a single-spin technology has shown qubit initialization, manipulation and readout fidelities compatible with the requirements for successful quantum error correction.

The missing element for a donor spin qubit technology in Si is a method of coupling spatially-separated qubits. To scale up such systems it would be advantageous to connect silicon donor spin qubits in a cavity-quantum electrodynamics (c-QED) architecture. Many proposals in this direction introduce strong electric dipole interactions to the otherwise largely isolated spin qubit ground state in order to couple to superconducting cavities. Here we present an alternative approach, which uses the built-in strong electric dipole (optical) transitions of singly-ionized double donors in silicon. These donors, such as chalcogen donors S+, Se+ and Te+, have the same ground-state spin Hamiltonians as shallow donors yet offer mid-gap binding energies and mid-IR optical access to excited orbital states. The deep chalcogen double donors in Si can therefore combine all of the attractive properties of shallow donor spin qubits with the possibility of a strong photonic coupling.

This photonic link is spin-selective which could be harnessed to measure and couple donor qubits using photonic cavity-QED. This approach should be robust to device environments with variable strains and electric fields, and will allow for CMOS-compatible, bulk-like, spatially separated donor qubit placement, optical parity measurements, and 4.2K operation. We will present preliminary data in support of this approach, including 4.2K optical readout in Earth's magnetic field, where long T1/T2 times have been measured. Based on these results, a number of photonic readout and coupling schemes become possible for chalcogen donor spin qubits in Si, providing a new way forward for Si-based quantum information technology.

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