Donor quantum-dot coupled qubits

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There are numerous efforts to develop quantum bits (qubits) for quantum computing. Silicon is recognized as an appealing material system because, for example, it offers a low decoherence environment for spin qubits combined with its historical foundation in device and computer chip fabrication. Donors in silicon have been proposed as qubits and the combination of the electron and nucleus introduce a rich variety of qubit device architectural ideas as indicated in the literature. Donor qubits also promise very high fidelity operation, uniformity (i.e., every donor is the same) and extraordinarily well protected idle/memory (i.e., nuclear spins). However, placement, read-out and coherent control of single donors has been notoriously challenging. To date, it has been demonstrated in only two groups in the world, one of which is the Sandia National Lab quantum information, science and technology (QIST) group. At this time a central question is how to couple donor-based-qubits.

In this talk I will discuss the first experimental demonstration of coherent singlet-triplet (S-T) rotations in a MOS quantum dot and a single donor system. This represents both a new qubit configuration as well as a central demonstration of coherently coupling a buried donor spin with the oxide-silicon interface. This is a key step towards the realization of a long sought general goal of many donor device architectures, to mediate entanglement between two donors using the interface. Using a donor as one of the wells of the canonical double quantum dot S-T qubit configuration furthermore introduces an efficient, potentially very fast and potentially much higher fidelity gradient-field through the contact hyperfine interaction of the single 31P nucleus. That is, this resolves a challenge for S-T implementations in enriched silicon that otherwise need to introduce an external gradient field (e.g., micro-magnets) or add further complexity to achieve all-electrical control through addition of a third quantum dot. Instead this approach reduces lay-out complexity because it relies on only a single MOS quantum dot, instead of two, and provides a reliably repeatable gradient field specific to the donor species without the need for continuous pumping and monitoring of the background nuclear spin bath as is done in GaAs.