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Single-shot readout and microwave control of an electron spin in silicon

ANDREA MORELLO, Centre for Quantum Computation and Communication Technology, University of New South Wales

The electron spin of a donor in silicon is an excellent candidate for a solid-state qubit. It is known to have very long coherence and relaxation times in bulk [1], and several architectures have been proposed to integrate donor spin qubits with classical silicon microelectronics [2]. Here we show the first experimental proof of single-shot readout of an electron spin in silicon. The device consists of implanted phosphorus donors, tunnel-coupled to a silicon Single-Electron Transistor (SET), where the SET island is used as a reservoir for spin-to-charge conversion [3]. The large charge transfer signals allow readout fidelity $> 90\%$ with 3 μs response time. By measuring the occurrence of excited spin states as a function of wait time, we find spin lifetimes (T_1) up to ~ 6 s at $B = 1.5$ T, and a magnetic-field dependence $T_1^{-1} \propto B^5$ consistent with that of phosphorus donors in silicon [4]. In a subsequent experiment we have integrated the single-shot spin readout device with an on-chip microwave transmission line for coherent control of the electron spin. We have detected the spin resonance of a single electron, and observed two hyperfine-split resonance lines, consistent with Stark-shifted coupling to the ^{31}P nuclear spin. Further experiments are underway to demonstrate coherent spin control and observe Rabi oscillations. This demonstrates the microwave control of a single spin, combined – for the first time in the same experiment – with electrically detected single-shot spin readout.

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