High-fidelity readout and control of a nuclear spin qubit in silicon

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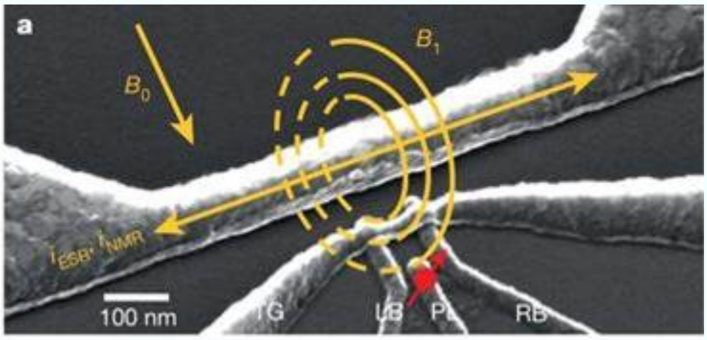

Scanning electron micrograph of the active area of the qubit device, showing an implanted donor (donor as red arrow).

Detection of nuclear spin precession is critical for a wide range of scientific techniques that have applications in diverse fields including analytical chemistry, materials science, medicine and biology. Fundamentally, it is possible because of the extreme isolation of nuclear spins from their environment. This isolation also makes single nuclear spins desirable for quantum-information processing, as shown by pioneering studies on nitrogen-vacancy centres in diamond. The nuclear spin of a P donor in silicon is very promising as a quantum bit: bulk measurements indicate that it has excellent coherence times and silicon is the dominant material in the microelectronics industry. Here we demonstrate electrical detection and coherent manipulation of a single P nuclear spin qubit with sufficiently high fidelities for fault-tolerant quantum computing. By integrating single-shot readout of the electron spin with on-chip electron spin resonance, we demonstrate quantum non-demolition and electrical single-shot readout of the nuclear spin with a readout fidelity higher than 99.8 per cent—the highest so far reported for any solid-state qubit. The single nuclear spin is then operated as a qubit by applying coherent radio-frequency pulses. For an ionized P donor, we find a nuclear spin coherence time of 60 milliseconds and a one-qubit gate control fidelity exceeding 98 per cent. These results demonstrate that the dominant technology of modern electronics can be adapted to host a complete electrical measurement and control platform for nuclear-spin-based quantum-information processing

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