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Quantum Computation and Simulation - Spins Inside

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Abstract

Quantum computation has captivated the minds of many for almost two decades. For much of that time, it was seen mostly as an extremely interesting scientific problem. In the last few years, we have entered a new phase as the belief has grown that a large-scale quantum computer can actually be built. Quantum bits encoded in the spin state of individual electrons in silicon quantum dot arrays, have emerged as a highly promising direction [1]. In this talk, I will present our vision of a large-scale spin-based quantum processor, and ongoing work to realize this vision.

First, we created local registers of spin qubits with sufficient control that we can program arbitrary sequences of operations, implement simple quantum algorithms [2], and achieve two-qubit gate fidelities of more than 99.5% [3]. In linear quantum dot arrays, we now achieve universal control of up to six qubits [4].

Second, we have explored coherent coupling of spin qubits at a distance via two routes. In the first approach, the electron spins remain in place and our coupled via a microwave photon in a superconducting on-chip resonator. After reaching the strong coupling regime of a single spin and a single photon [5], we have recently observed coherent spin-spin interaction at a distance, mediated by off-resonant photons [6]. In the second approach, spins are shuttled along a quantum dot array, preserving both the spin projection [7] and spin phase [8].

Third, in close collaboration with Intel, we have fabricated and measured quantum dots using all-optical lithography on 300 mm wafer, using industry-standard processing [9], demonstrating excellent qubit performance. We expect that this industrial approach to nanofabrication will be critical for achieving the extremely high yield necessary for devices containing thousands of qubits.

When combined, the progress along these various fronts can lead the way to scalable networks of high-fidelity spin qubit registers for computation and simulation.

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