Quantum computation and simulation – Spins Inside

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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 progress in our group along three fronts. First, we created and operated a programmable two-qubit device based on silicon spin qubits [2]. Through universal all-electrical control of two spin qubits in a double quantum dot combined with individual single-shot read-out of each qubit, we have successfully programmed the four instances of the Deutsch-Jozsa and the Grover algorithms on two qubits, and created high-fidelity entangled states. This work builds on our earlier work on all-electrical single-spin manipulation [3]. 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 an intermediary degree of freedom [4]. In the second approach, spins are shuttled along a quantum dot array, preserving both the spin projection [5] and spin phase [6]. Third, we have developed new concepts and techniques that make quantum dot arrays a credible platform for quantum simulation of the Mott-Hubbard model. As a first demonstration, we map out the transition from Coulomb blockade to collective Coulomb blockade, the finite-size analogue of the Mott insulator transition [7]. 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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