Stuttgarter Physikalisches Kolloquium

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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, in close collaboration with Intel. First, we demonstrate the creation of entanglement between two spin qubits in tunnel coupled quantum dots with fidelities of 85-90%, and we implement simple quantum algorithms on two qubits [2]. Second, we explore coherent coupling between spin qubits separated by microns to hundreds of microns on the chip. In a first approach, the electron spins remain in place and are coupled via microwave photon. As a major stepping stone, we show strong coupling of a single spin to a single microwave photon stored on the chip [3]. In a second approach, spins are shuttled along a quantum dot array, preserving spin coherence [4]. Third, we develop new concepts and techniques that make quantum dot arrays a credible platform for analog quantum simulation. As a first demonstration, we study the finite-size analogue of the metal to Mott insulator transition [5], and report the signatures of Nagaoka ferromagnetism in a plaquette of four quantum dots [unpublished]. 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.

[1]. L.M.K. Vandersypen, et al., Interfacing spin qubits in quantum dots and donors hot, dense and coherent, npj Quantum Information 3, 34 (2017).

[2]. T. F. Watson, et al., A programmable two-qubit quantum processor in silicon, Nature 555, 633 (2018).

[3]. N. Samkharadze, G. Zheng, et al., Strong spin-photon coupling in silicon, Science 359, 1123 (2018)

[4]. T. Fujita, et al., Coherent shuttle of electron-spin states, npj Quantum Information 3, 22 (2017)

[5]. T. Hensgens, et al., Quantum simulation of a Fermi-Hubbard model using a semiconductor quantum dot array, Nature, 548, 70 (2017)