Operating semiconductor quantum processors with hopping spins

Chien-An Wang[1]
Valentin John[1], Hanifa Tidjani[1], Cécile X. Yu[1], Alexander Ivlev[1], Corentin Déprez[1], Floor van Riggelen-Doelman[1], Benjamin D. Woods[2], Nico W. Hendrickx[1], Will I. L. Lawrie[1], Lucas E. A. Stehouwer[1], Stefan Oosterhout[3], Amir Sammak[3], Mark Friesen[2], Giordano Scappucci[1], Sander L. de Snoo[1], Maximilian Rimbach-Russ[1], Francesco Borsoi[1+], and Menno Veldhorst[1+]

[1]*QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft, The Netherlands*
[2]*Department of Physics, University of Wisconsin-Madison, Madison, USA*
[3]*QuTech and Netherlands Organisation for Applied Scientific Research (TNO), Delft, The Netherlands*

m.veldhorst@tudelft.nl

Qubits that can be efficiently controlled are pivotal in the development of scalable quantum hardware. Resonant control is commonly embraced to execute high-fidelity quantum gates but demands integration of high-frequency oscillating signals and results in qubit crosstalk and heating. Establishing quantum control based on discrete signals could therefore result in a paradigm shift. This may be accomplished with single-spin semiconductor qubits, if one can engineer hopping spins between quantum dots with site-dependent spin quantization axis. Here, we introduce hopping-based universal quantum logic and obtain single-qubit gate fidelities of 99.97%, coherent shuttling fidelities of 99.992%, and two-qubit gates fidelities of 99.3%, corresponding to error rates that have been predicted to allow for quantum error correction. We demonstrate that hopping spins also constitute an elegant tuning method by statistically mapping the coherence of a 10-quantum dot system. These results motivate dense quantum dot arrays with sparse occupation for efficient and high-connectivity qubit registers.

Figures

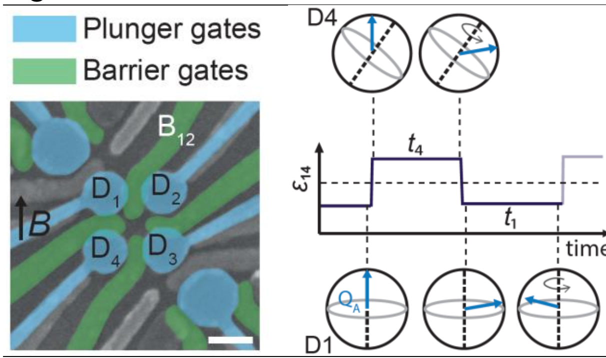

Figure 1: (left) SEM image of the germanium quantum dot array device. (right) Schematic illustration of the coherent quantum control by hopping a single spin.

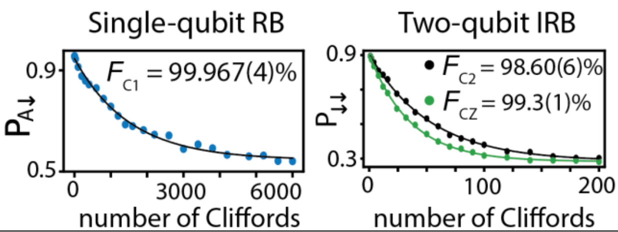

Figure 2: Randomized benchmarking of (left) hopping-based single-qubit gate, and (right) two-qubit adiabatic CZ gate.

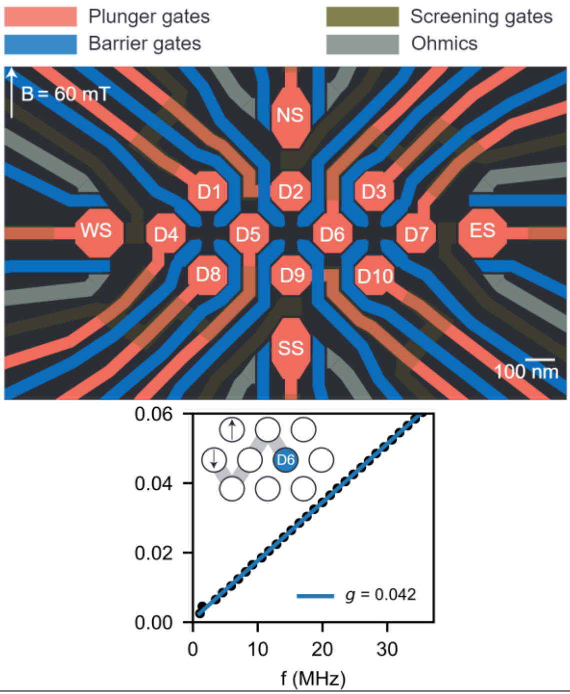

Figure 3: (top) Layout of the 10 quantum dot array. (bottom) Shuttling operations in the 10-dot device for measuring g-factor.