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Tomography of universal two-qubit logic operations in exchange-coupled donor electron spin qubits

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Scalable quantum processors require high-fidelity universal quantum logic operations, in a manufacturable physical platform, along with the capacity to couple multiple qubits together over a variable range of length scales. The spin of an electron bound to a single donor atom in silicon has shown coherence times of almost a second [1], with single qubit quantum operation fidelities of over 99.9% [2]. In addition, donors in silicon possess a number of intrinsic coupling mechanisms that can be utilised in a scalable quantum processor architecture. One such coupling mechanism is the exchange interaction between donor-bound electrons.
Here we present the experimental demonstration and tomography of universal 1- and 2-qubit gates in a system of two weakly exchange-coupled electrons, with each electron bound to a single donor phosphorus nucleus. By deterministically preparing the two nuclear spins in opposite directions, each electron spin resonance pulse constitutes a native conditional two-qubit gate [3]. We carefully benchmark the fidelity of these native operations using the technique of gate set tomography (GST), achieving qubit gate fidelities above 99% for both electrons separately. The GST method provides precious insights into the nature of the residual errors, and informs strategies for further improvement. Adding to the recent demonstration of universal 2-qubit gates for nuclear spins, and electron-nuclear entanglement [4], these electron two-qubit gates complete the toolbox for constructing a scalable spin-based quantum processor in silicon.

[1] Muhonen, J. T. et al. Storing quantum information for 30 seconds in a nanoelectronic device. Nature nanotechnology 9, 986 (2014).
[2] Dehollain, J. P. et al. Optimization of a solid-state electron spin qubit using gate set tomography. New Journal of Physics 18, 103018 (2016).
[3] Mądzik, M. T. et al. Conditional quantum operation of two exchange-coupled single-donor spin qubits in a MOS-compatible silicon device. Nature Communications 12, 181 (2021).
[4] Mądzik, M. T. et al. Precision tomography of a three-qubit electron-nuclear quantum processor in silicon. arXiv:2106.03082 (2021)

Presenter: STEMP, Holly (UNSW)

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