Quantum CNOT Gate for Spins in Silicon

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Realizing robust two qubit gates has been one of the major hurdles for semiconductor spin qubits. Extremely long coherence times and high fidelity single qubit gates have been realized in spin qubits, but conventional exchange based two qubit couplings have suffered from a high sensitivity to charge noise. We demonstrate a resonantly driven single-step CNOT gate in a regime where exchange is a small perturbation to a large magnetic field gradient [1]. By placing a double quantum dot (DQD) in the fringing field of a Co micromagnet, we are able to electrically drive single spin resonance with Rabi frequencies greater than 10 MHz. We achieve single qubit fidelities of 99.3 ± 0.2 % and 99.7 ± 0.1 % for each qubit, as determined by Clifford randomized benchmarking. By turning on an exchange coupling between the two spins we split the single qubit frequencies by 19.7 MHz and use a frequency selective drive to realize a CNOT gate in 200 ns. In addition to nearest neighbor coupling of spin qubits, long distance coupling using microwave frequency photons may relax design constraints imposed by nearest-neighbor exchange coupling. I will also present our group's recent progress in coupling single electrons to microwave photons [2]. We achieve the strong coupling regime for both charge and spin, and achieve spin-photon coupling rates above 10 MHz [3,4].

[1] D. M. Zajac, A. J. Sigillito, M. Russ, F. Borjans, J. M. Taylor, G. Burkard, and J. R. Petta, arXiv:1708.03530.

[2] X. Mi, J. V. Cady, D. M. Zajac, P. W. Deelman, and J. R. Petta, Science **355**, 156 (2017).

[3] X. Mi, M. Benito, S. Putz, D. M. Zajac, J. M. Taylor, G. Burkard, and J. R. Petta, in preparation.

[4] M. Benito, X. Mi, J. M. Taylor, J. R. Petta, and G. Burkard, in preparation.