Baseband Control of Single-electron Silicon Spin Qubits in Two-dimensions

Brennan Undseth[1]
Florian K. Unseld[1], Eline Raymenants[1], Yuta Matsumoto[1], Sander de Snoo[1], Saurabh Karwal[2], Oriol Pietx-Casas[1], Alexander S. Ivlev[1], Marcel Meyer[1], Amir Sammak[2], Menno Veldhorst[1], Giordano Scappucci[1], Lieven M. K. Vandersypen[1]

[1]QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, Delft, The Netherlands

[2]QuTech and Netherlands Organization for Applied Scientific Research (TNO), Stieltjesweg 1, Delft, The Netherlands

b.w.undseth@tudelft.nl

Abstract

Micromagnet-enabled electric-dipole spin resonance (EDSR) is an established means of high-fidelity single-spin control in silicon. However, the resulting architectural limitations have restrained state-of-the-art quantum processors to one-dimensional arrays, and heating effects from the associated microwave dissipation exacerbate crosstalk for multi-qubit operations. In contrast, spin control based on hopping spins has recently emerged as a compelling primitive for high-fidelity baseband control in sparse hole arrays in germanium [1]. In this work, we commission a ^{28}Si/SiGe 2x2 quantum dot array both as a 4-qubit quantum processor using established EDSR techniques and as a 2-qubit device using hopping spins in a low magnetic field regime. This control method is previously unexplored in the silicon platform but benefits from engineerable micromagnet-dominated stray fields that induce a measurable tip in quantization axis between adjacent quantum dots (see Figure 1). We can directly compare the two modes of operation in terms of fidelity, coherence, and crosstalk. We find that the shuttling gate fidelity of 99.5% is on par with the benchmarked resonant gate while offering a shorter gate time. Lowering the external field to the shuttling regime nearly doubles the measured T_2^{Hahn} suggesting a reduced coupling to charge noise. Motivated by recent advances in using on-chip nanomagnets for spin qubit control [2], we sketch a device architecture to enable hopping spin operation in a large two-dimensional array of quantum dots to highlight the flexibility and extensibility of this new control method.

References

[1] Chien-An Wang *et al.* *Science* 385, (2024) 447-452
[2] Michele Aldeghi *et al. Nano Lett.* 25, 5, (2025) 1838-1844

Figures

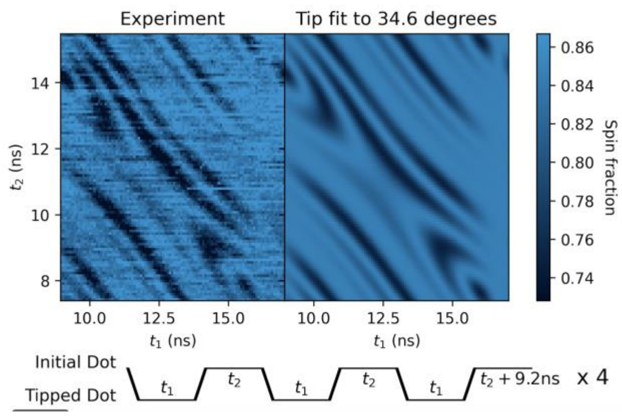

Figure 1: Using the baseband pulse sequence shown at the bottom, a single-electron spin is shuttled between two dots with varying times t_1 and t_2. The resulting spin dynamics can be fit to a unitary evolution model to extract a micromagnet-induced tip angle of 34.6 degrees.