High-fidelity spin shuttling in silicon quantum dots

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Long-range quantum links between spin qubits in quantum dots [1,2] are a key aspect in architectures that scale to the thousands of qubits that are required for practical quantum computation. In this work we create a quantum link by shuttling a single electron spin across a linear array of six tunnel-coupled quantum dots (Fig. 1). An electron can be shuttled through the array in bucket-brigade mode (Fig. 2a) by sequentially pulsing both the electrochemical potential of each quantum dot and the interdot tunnel barriers. Alternatively, sinusoidal voltage signals can be applied to the channel gates to create a traveling wave potential, which we call a conveyor (Fig. 2b). We benchmark both bucket brigade and conveyor-mode shuttling while transporting the electron back and forth through the array. In bucket brigade, the (echoed) spin is shuttled with an average single hop phase flip probability of 0.57% (0.28%), consistent with earlier work on shuttling between two dots in silicon [3,4]. We find that conveyor mode shuttling improves the phase flip probability by a factor of 3.5 for the same shuttling distance. We also introduce a two-tone conveyor concept, which reduces the spin flip probability by another factor of 2. This method achieves a shuttling fidelity of 99% for an effective distance of 10 µm, covered in under 200 ns.

References

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[2] L.M.K. Vandersypen et al., npj Quantum Information, 3 (2017) 34
[3] J. Yoneda et al., Nature Communications, 12 (2021) 4114
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Figures

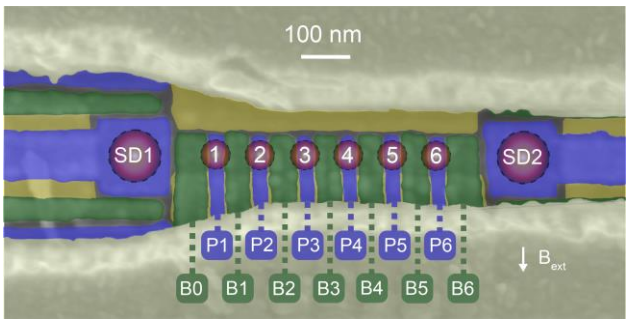

Figure 1: False-colored scanning electron microscope image of a nominally identical device to the one used. The colors indicate different metallization layers on top of an isotopically enriched ^{28}Si/SiGe heterostructure, forming a linear array of six quantum dots (indicated by numbered circles). Two sensing dots (SD) are placed at both ends of the array.

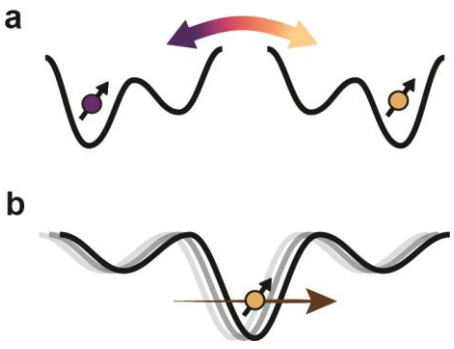

Figure 2: Schematic representation of (a) bucket-brigade mode and (b) conveyor-mode shuttling. In bucket-brigade mode, the electron tunnels from site to site in an array of static quantum dots. In conveyor-mode, the electron is transported smoothly using a traveling potential wave.