Systematic High-Fidelity Operations and Transfer of Semiconductor Spin-Qubits

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Spin-based semiconductor quantum dots qubits are a promising contender for a practical quantum processor [1]. Their similarity to classical transistor allows for lithographic fabrication techniques [2], relevant for scaling to fault-tolerant device sizes. One common feature of such spin qubits, however, is the need for electric control on the nanoscale for operation, which also couples the qubits to electrical noise sources.

Recent developments have shown that high-fidelity shuttling, movement of the charge carrier while preserving spin-coherence, can be experimentally realized, allowing for intermediate-distance qubit interconnections [3,4,5]. At the same time, novel control mechanisms that make full use of artificial or intrinsic spin-orbit interaction can be used to enable power efficient, fast and high-fidelity quantum control [5,6,7].

Systematic high-fidelity operations can be achieved by operating in regimes that provide high protection against electric noise sources, so-called sweet spots [8]. Furthermore, optimized pulse control allows for an additional dynamic protection and speed [9,10].

References

[1] G. Burkard et al., Rev. Mod. Phys. 95, 025003 (2023)
[2] A.M.J. Zwerver et al., Nat. Electron. 5, 3, 3 (2022)
[3] F. van Riggelen-Doelman et al., Nat. Comm. 15, 1, 5716 (2024).
[4] M. De Smet et al., arXiv:2406.07267.
[5] C.-A. Wang et al., Science 385, 6707, 447 (2024)
[6] M. Rimbach-Russ et al., arXiv:2412.13658.
[7] V. John et al., arXiv:2412.16044.
[8] C.-A. Wang, G. Scappucci, M. Veldhorst, and M. Rimbach-Russ, npj QI 10, 1, 102 (2024).
[9] M. Rimbach-Russ, S.G.J. Philips, X. Xue, and L.M.K. Vandersypen, Quantum Sci. Technol. 8, 045025 (2023).
[10] C. V. Meinersen, S. Bosco, and M. Rimbach-Russ, arXiv:2409.03084.

Figures

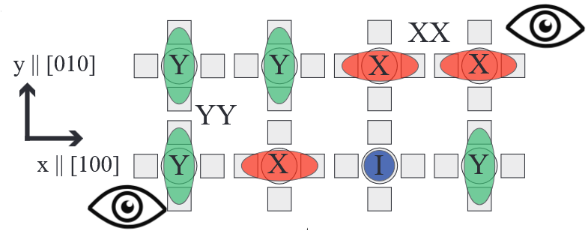

Figure 1: Schematics of a modular architecture of operating zero-frequency spin qubits [8]. Baseband control of plunger and barrier gates induce universal single and two-qubit operations [6].

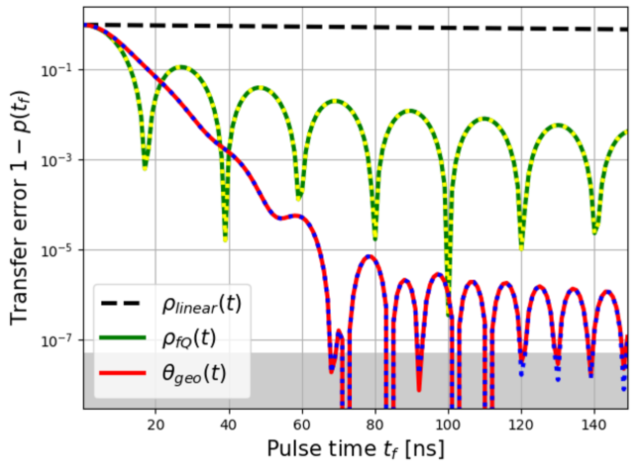

Figure 2: Transfer error of optimized pulses for rapid state transfer through a single anti-crossing as a function of pulse time with a gap of 200MHz. Three protocols are compared, a linear ramp, fastQUAD, and geometric fastQUAD [10].