Noise-Induced Readout Errors and Sweet Spots in Charge-Sensing of Silicon Spin Qubits

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We present a theoretical analysis of charge-sensing–based readout of semiconductor spin qubits hosted in double quantum dots (DQD). The readout mechanism, which relies on Pauli spin blockade for spin-to-charge conversion followed by charge sensing through a quantum point contact (QPC), is described within the Qubit Measures Qubit (QMQ) formalism [1].

Our study focuses on n-type silicon double quantum dots equipped with micromagnets for electric-dipole spin resonance control [2]. We explicitly incorporate the inhomogeneous micromagnet field [3] and analyze its stochastic modulation arising from charge-sensor shot noise. Within this framework, we derive and quantify the principal readout error channels: fidelity degradation due to longitudinal Zeeman-field fluctuations, mixedness generated in the post-measurement state, and leakage induced by transverse magnetic-field components. In addition, we include charge-sensor noise to evaluate its contribution to measurement infidelity.

By examining the dependence of these error metrics on experimentally tunable parameters, particularly the orientation of the external magnetic field, we identify operating regimes that minimize readout errors and offer insights on the conditions for optimal readout "sweet spots."

References

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[2] M. Pioro-Ladrière, T. Obata, Y. Tokura, Y.-S. Shin, T. Kubo, K. Yoshida, T. Taniyama, and S., Tarucha, Nature Phys 4 (2008) 776–779.
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Figures

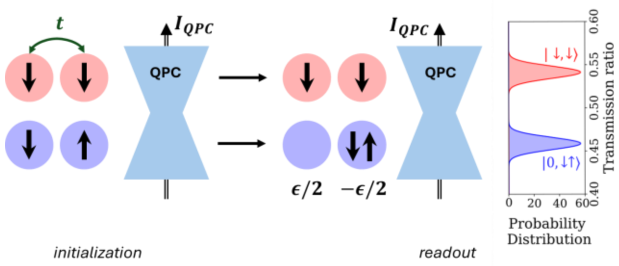

Figure 1: Charge sensing based readout of Spin DQD using QMQ model.

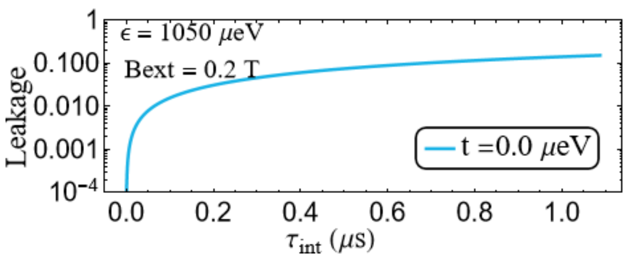

Figure 2: Leakage from the initial state $|\downarrow,\downarrow\rangle$ in the effect of an inhomogeneous micro-magnet field.