Limiting mechanisms for the lifetime and coherence of a hole-spin qubit strongly coupled to a cavity

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Spins in semiconductor quantum dots constitute a promising platform for scalable quantum information processing [1]. Coupling them strongly to the photonic modes of superconducting microwave resonators would enable fast non-demolition readout and long-range, on-chip connectivity, well beyond nearest-neighbor quantum interactions [2]. As the field of spin circuit quantum electro-dynamic (cqed) is growing, new experiments showed spin-photon coupling rates as high as 330 MHz and a 2-qubit gate mediated by a photonic interaction [3, 4]. However, up to now, all of the semiconductor spin-cqed devices have showed fast decoherence and relaxation times, mitigating the high fidelity control and readout usually achieved for spin qubits.

We present here an experimental study of a hole spin qubit embedded in a Si double quantum dot, strongly coupled to a microwave cavity thanks to the intrinsic spin-orbit interaction (SOI) of holes in Si. We measure relaxation (Γ_1) and decoherence (Γ_2) rates as a function of magnetic field, therefore controlling the qubit-cavity coupling as well as its energy through the magnetic-field dependence of the SOI. We span its energy over a range of 10GHz, crossing several cavity modes and identify photon emission (multimode Purcell effect) as one of the limiting mechanisms for the spin's lifetime. The decoherence shows signs of charge-noise induced dephasing as its magnetic-field dependence follows the second-order electrical susceptibility of the qubit. (Figure 2)

References

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Figures

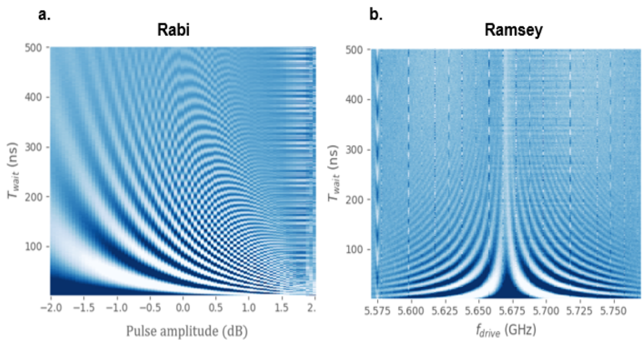

Figure 1: Power-dependence of Rabi oscillation and Ramsey interference of the spin state.

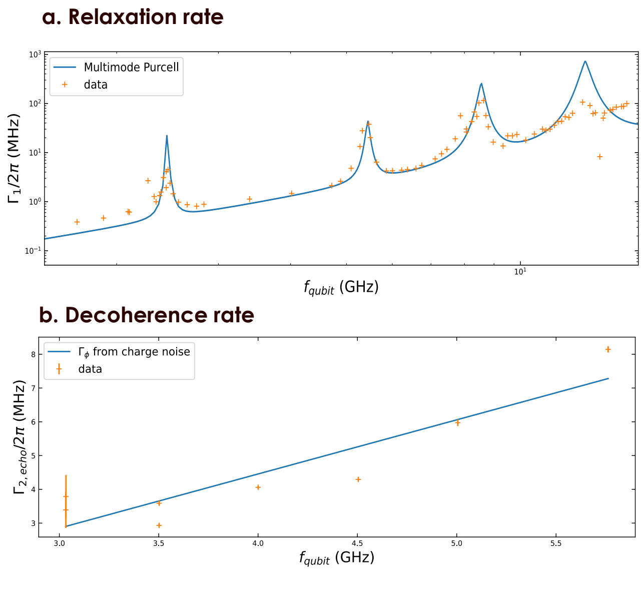

Figure 2: Energy dependence of the relaxation and decoherence rates of the spin state