

High quality hybrid spin cQED 3D architecture

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Coherent interaction of microwave photons with quantum dot based spin qubits is now routinely achieved in circuit quantum electrodynamics (cQED) [1-3]. The hybrid architecture is a promising platform for long range on-chip connectivity [4] and high-fidelity quantum non demolition readout [5]. As a key ingredient, these architectures all rely on high-impedance resonators in order to achieve sufficiently large spin-photon coupling strengths.

However, all current experimental implementations are mainly limited by the low quality of the microwave cavity. The co-integration of microwave resonators with quantum-dot based qubit platforms, suffer from lossy substrate and photon loss through unavoidable on-chip gate lines [6].

We present here a 3D integrated spin cQED architecture that takes up those microwave challenges by combining high impedance NbN microwave circuits on low-loss sapphire substrate with Si-MOS quantum dot devices, see Fig.1. Galvanic and microwave connection between the two chips is ensured by 5 μm diameter Indium bumps [7]. We have carried out a detailed characterization of the DC and RF properties of the bump interconnects down to mK temperatures and under B-field. Especially, internal quality factors above 100 000 of bump interrupted resonators demonstrate low-loss inter-chip connections.

As a final proof of concept of this novel spin cQED architecture, we demonstrate coherent interaction between charge ($g_c/2\pi=400\text{MHz}$) and spin

($g_s/2\pi=100\text{MHz}$) degrees of freedom in Si-MOS quantum dots and a microwave cavity, see Fig. 2. Consequently, this proof of concept of a strong spin-photon coupling with a flip-chip high quality microwave resonator paves the way to envision fast and high-fidelity readout.

References

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- [4] Benito et al. Physical Review B, 100 (2019)
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Figures

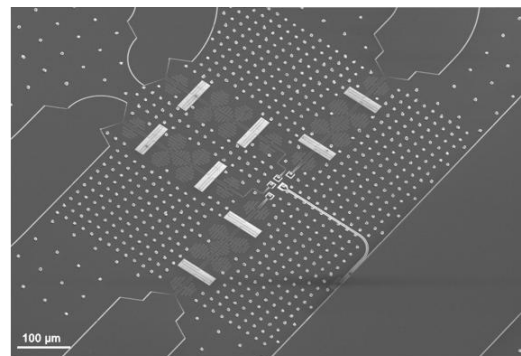


Figure 1: SEM image of a readout circuitry on Sapphire before assembly with a Si-MOS chip.

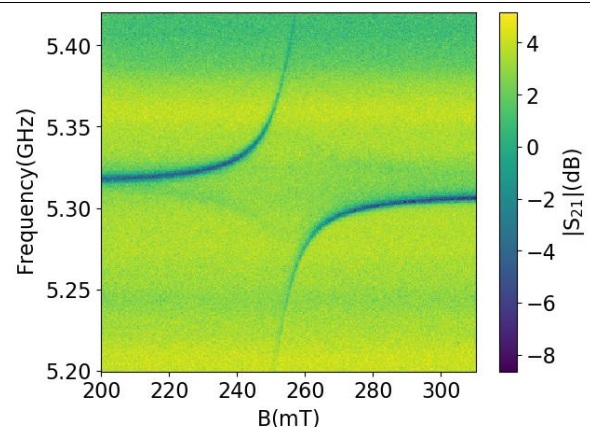


Figure 2: Hole-spin interaction with a flip-chip microwave resonator.

