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Prospective enhancement in the spin-to-photon magnetic coupling rate using tri-layer lumped-element superconducting resonators

BAHMAN SARABI, PEIHAO HUANG, National Institute of Standards and Technology (NIST) / Joint Quantum Institute (JQI), NEIL ZIMMERMAN, National Institute of Standards and Technology (NIST) — Silicon-based single-atom spin qubits currently hold the record coherence times of any single qubit in the solid state. However, there are challenges in direct magnetic coupling of an electron spin to other systems such as microwave photons. This is due the relatively small magnetic moment of the electronic spin, and the relatively weak magnetic field of quantum circuits at typical drive powers. Therefore, direct magnetic coupling usually offers insufficient spin rotation speeds and readout fidelities for practical qubit applications. To enhance the direct magnetic coupling to the spin, we propose a device consisting of a tri-layer lumped-element superconducting resonator and a single donor implanted in enriched ^{28}Si. The resonator, in contrast to coplanar waveguide resonators, includes a nano-scale spiral inductor to spatially focus the magnetic field from the photons within. The design promises approximately two orders of magnitude increase in the local magnetic field, and thus the spin to photon coupling rate g, compared to the estimated coupling rate to coplanar transmission-line resonators. This relatively large g can lead to significant improvements in the initialization time, spin rotation speed and readout fidelity of single-atom spin qubits.

Bahman Sarabi
Nat'l Inst., of Standards and Tech.,(NIST) / Joint Quantum Inst.,(JQI)

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