Supercurrent-mediated coupling between two Andreev spin qubits: theory and device

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Semiconducting spin qubits are currently one of the most promising architectures for quantum computing. However, they face challenges in realizing high-fidelity quantum non-demolition readout and multi-qubit interactions over extended distances. A recent alternative, the Andreev spin qubit (ASQ), has emerged with realizations in InAs/Al hybrid nanowire Josephson junctions [1,2]. In these qubits, the spin degree of freedom is intrinsically coupled to supercurrent via the spin-orbit coupling. The spin-dependent supercurrent of ASQs facilitates qubit readout using circuit quantum electrodynamics (cQED) techniques, as recently demonstrated and can facilitate inductive multi-qubit coupling via a shared inductance [3].

Here, we investigate the supercurrent-mediated coupling between two ASQs in separate SQUID loops that share a third gate-tunable Josephson junction. We investigate the character of the coupling using numerical simulations and find it to be either longitudinal or transverse depending on the direction of the applied magnetic field. Moreover, we calculate the expected dependence of the coupling strength on different model parameters: spin-dependent Josephson energies, superconducting phase offset across each ASQ and shared inductance. These simulations are all done with realistic parameters and set the stage for experimental realizations of supercurrent mediated spin-spin coupling.

References

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[3] C. Paduratiu and Y. Nazarov, Phys. Rev. B, **81**,144519 (2022), 144519.

Figures

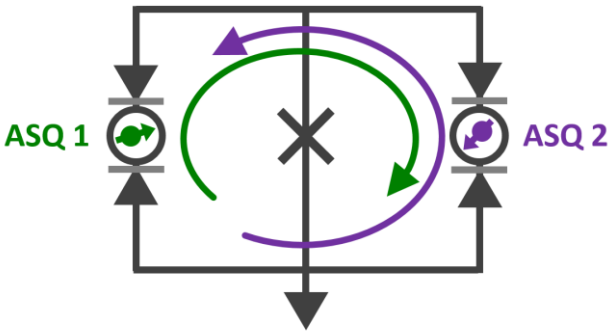

Figure 1: Circuit model of the device showing two Andreev spin qubits and a coupling Josephson junction in parallel.