Submicrometric ferromagnetic tunnel Josephson junctions for hybrid superconducting quantum architectures

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Abstract: We fabricated submicrometric Manhattan-style ferromagnetic Josephson Junctions (JJs) with electrodynamics matching state-of-the-art transmon JJs. This result enables the realization of the first *ferro-transmon* chip, potentially having a great impact on quantum circuit scalability.

Magnetic Josephson Junctions (MJJs) provide an intriguing playground to explore the interplay between superconductivity and ferromagnetism [1], [2]. A series of fascinating experiments have revealed striking phenomena at the Superconductor/Ferromagnet interface, such as the 0-π phase transition and the generation of spin-triplet correlations, paving the way for advances in applications ranging from spintronics to superconducting digital electronics [3]. Regarding quantum architectures, the intrinsic high dissipation of standard metallic ferromagnetic barriers has traditionally limited the use of MJJs to passive π-phase shifters [4]. However, the integration of either insulating ferromagnets [5] or multi-layered insulator/thin-superconductor/ferromagnet barriers allows for combining ferromagnetic switching properties with low quasiparticle dissipation [6]. These advancements have significantly enhanced the potential of MJJs as active elements in quantum circuits [7]. In this work, we demonstrate the first generation of submicrometric tunnel MJJs in a Manhattan-style configuration, specifically designed to operate within the energy range of transmon qubits [8]. Low-frequency characterization confirms that our junctions operate in the quantum phase diffusion limit, consistent with conventional tunnel JJs of similar characteristic energies implemented in state-of-the-art transmons [9]. These results, alongside the development of on-chip *airbridge* flux coils [10], mark a decisive step toward the first *ferro-transmon* qubit and the realization of control and readout devices for scalable pulsed architecture. This hybrid quantum platform enables alternative frequency tuning via magnetic field pulses, potentially offering a significant impact on the scalability of superconducting quantum circuits [7].

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