Plasma Modes in Fluxonium Qubits

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The fluxonium qubit [1] offers long coherence times and strong anharmonicity, relying on a small Josephson junction shunted by a large superinductance. Achieving high inductance typically requires long junction arrays [2], but this introduces stray ground capacitance C_g, which lowers plasma mode frequencies [3] and limits coherence [4]. We demonstrate a dry etching technique that selectively removes silicon around the fluxonium loop, reducing C_g by 60–70%, shifting plasma modes to higher frequencies, and preserving qubit coherence.

We also model the fluxonium qubit together with its electromagnetic environment, including the small Josephson junction, pad capacitance, and the full junction array forming the superinductance, we adopted the method proposed by Nigg *et al.* [5] and Smith *et al.* [6]. Using the linear admittance of the circuit, obtained via an ABCD-matrix description, this approach identifies the resonance frequencies, impedances, and zero-point phase fluctuations of the plasma modes, which are then incorporated into the fluxonium Hamiltonian [6]. By comparing the microscopic model to the measured spectrum, the routine extracts key device parameters such as the Josephson energy of the small junction, the plasma mode frequencies and the zero-point fluctuations λ that quantify their coupling to the qubit. Additional quantities such as effective capacitances, inductances, and quality factors are also extracted, offering insight into potential loss channels and providing valuable information about the qubit geometry.

This framework reproduces the observed qubit transitions, explains avoided crossings from qubit–plasma mode hybridization. It links device geometry to the measured spectrum and shows good agreement between experimental data and theoretical predictions.

References

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