Protecting Fluxonium, Taming Plasma Modes : Superinductance Engineering for Robust Qubits

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We investigate fluxonium [1] circuits that exploit large superinductances to encode quantum states with disjoint wave-function support and noise-insensitive energies, providing partial protection against decoherence [2]. By engineering the wave functions and enabling bifluxon tunneling [3] at zero external flux, our design realizes qubit states distinguished by fluxon parity. This approach yields enhanced coherence, as demonstrated by long relaxation and dephasing times, and offers a minimal yet practical route toward protected qubits. In parallel, we analyze plasma modes originating from Josephson-junction arrays used as superinductors [4]. These collective excitations, arising from distributed capacitance to ground, can degrade coherence [5] ; however, we show that substrate engineering—specifically dry etching techniques to suppress parasitic capacitance—can shift plasma-mode frequencies upward and mitigate their detrimental impact. Taken together, these results demonstrate how combining wave-function engineering with optimized superinductor design provides a promising pathway toward more robust and scalable superconducting qubits.

In closing, we will also discuss why current devices remain only partially protected, outline strategies we are pursuing to overcome these limitations, and briefly address a crucial challenge facing the wider qubit community : the problem of reliable and efficient qubit readout [6].

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