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Decoherence of Majorana Qubits by $1/f$ Noise

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Qubits based on Majorana zero modes (MZMs) in superconductor–semiconductor nanowires have attracted intense interest as a platform for utility-scale quantum computing, due to their promise of intrinsically low error rates enabled by topological protection. These error rates are expected to be suppressed exponentially with increasing nanowire length or decreasing temperature. Here we identify a fundamental decoherence mechanism that challenges this expectation. The high-frequency components of $1/f$ charge noise, ubiquitous in semiconductor devices, can excite pairs of quasiparticles in the bulk of the topological superconductor, which travel to the ends of the nanowire to poison the MZMs. This mechanism leads to qubit errors that grow with the length of the nanowire. We calculate the excitation rates for clean nanowires and show that this noise imposes a strict limit on the coherence times of the qubits currently being developed [1], reducing them to less than one microsecond even under ideal conditions. These timescales are significantly shorter than those required for gate operations, posing a serious obstacle to the scalability of Majorana-based quantum computing.

[1] M. Aghaee et al. (Microsoft Azure Quantum), Nature 638, 651 (2025).

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