Two-level systems, quasiparticles, and decoherence of Majorana qubits in super-semiconducting hybrid structures

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Qubits based on Majorana zero modes (MZMs) in superconductor–semiconductor heterostructures have attracted intense interest due to claims that their topological protection will ensure extremely high qubit fidelities [1]. However, our work shows that current experiments realizing these qubits in InAs heterostructures are subject to substantial decoherence resulting from the high-frequency components of the fluctuations of two-level systems (TLSs) that are ubiquitous in the materials surrounding the nanowire [2,3]. This process excites quasiparticle pairs in the bulk of the topological superconductor that cause qubit decoherence even under otherwise ideal conditions. Increasing nanowire capacitance suppresses this mechanism but exposes the qubits to decoherence from externally-generated quasiparticles. Therefore, achieving high-fidelity MZM qubits using superconductor–semiconductor nanowires will require engineering strategies and compromises very similar to those needed for other solid state qubits.

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