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Passive two-photon dissipation for bit-flip error correction of a cat code

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Bosonic codes offer a resource-efficient method to quantum error correction [1]. Of particular interest, autonomous correction was successfully demonstrated for cat codes [2–5], where the logical $|0\rangle$ and $|1\rangle$ states are coherent states of opposite amplitudes $|\alpha\rangle$ and $|-\alpha\rangle$ in a superconducting resonator with single-photon loss rates κ1 as low as possible. They correct bit-flip errors by either using the non-linearity of the oscillator or parametrically pumping couplers to produce two-photon dissipation at a rate κ2.

The bit-flip time increases exponentially with |α|^2 while the phase-flip rate only increases linearly with |α|^2. In this work, we introduce and experimentally demonstrate a new superconducting circuit designed to correct for bit-flip errors of cat codes. Crucially, the two-photon dissipation does not require any pump, so that a single drive is required to stabilize the qubit manifold. This is obtained by nonlinearly coupling the cat qubit to a buffer mode that resonates at twice the frequency of the cat qubit.

We experimentally demonstrate unprecedented ratios κ2/κ1, so that bit flip times well over a ms can be reached with a few photons only. We also demonstrate quantum gates on this corrected cat qubit.

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