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 $\kappa 1$ 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 $\kappa 2$. The bit-flip time increases exponentially with $|\alpha|^2$ while the phase-flip rate only increases linearly with $|\alpha|^2$. 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 $\kappa 2/\kappa 1$, so that bit flip times well over a ms can be reached with only a few photons [6]. We also demonstrate quantum gates on this corrected cat qubit [7].

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References

[1] Z. Leghtas et al., Phys. Rev. Lett. 111, 120501 (2013).
[2] R. Lescanne et al., Nature Physics 16, 509 (2020).
[3] S. Touzard et al., Phys. Rev. X 8, 021005 (2018)
[4] C. Berdou et al., PRX Quantum 4, 020350 (2023).
[5] N. Frattini et al., Phys. Rev. X 14, 031040 (2024).
[6] A. Marquet et al., Phys. Rev. X 14, 021019 (2024).
[7] A. Marquet et al., Phys. Rev. Applied 22, 034053 (2024).