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Demonstrating Quantum Error Correction is a key step toward the realization of a large-scale quantum computer. In contrast to strategies using a register of physical qubits to store the protected logical qubit, bosonic codes offer a resource-efficient alternative to reach the same goal. In these codes, the large ensemble of physical qubits is replaced by the many energy levels of a harmonic oscillator. Various bosonic codes have been proposed and implemented in superconducting circuits [1] and trapped ions [2]. Of particular interest, some implementations enable an autonomous error correction without resorting to measurement-based feedback. Recently, such autonomous schemes were successfully demonstrated for cat codes [3–6], 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 are able to correct bit-flip errors by either using the non-linearity of the oscillator or parametrically pumping couplers to activate a swap interaction between 2 photons of the resonator and 1 photon of the environment, a.k.a. two-photon dissipation at a rate κ2. This bit-flip correction comes at the expense of additional phase-flip errors, but importantly, the bit-flip time Tbf increases exponentially with |α|2 while the phase-flip rate only increases linearly with |α|2. This drastically lowers the number of components that are needed to design the additional layer of repetition code that protects against phase flips [7], or of the tailored surface code when the noise bias is not strong enough [8, 9]. As the ratio between two-photon and single-photon dissipation rates κ2/κ1 gets larger, the exponent λ in Tbf ∝ eλ|α|2 is expected to get larger. Previous works managed to demonstrate Tbf as high as several minutes but only for dozens of photons in the resonator owing to a low value of λ < 2, and without an ancillary transmon qubit to perform the tomography [5]. 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 non-linearly 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, leading to reaching exponents λ > 3 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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