Controlling a High-Q Cavity with a Kerr-cat Qubit

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Biased-noise qubits have been proposed as a key resource for practical quantum error correction, enabling fault-tolerant measurements of error syndromes [1] and improved thresholds of surface codes [2]. One promising biased-noise qubit is the Kerr-cat, which is realized by squeezing a Kerr-nonlinear oscillator [3]. Kerr-cats have been experimentally realized [4] but to date have not been coherently coupled to another system, which is essential for delivering on the proposed applications of biased-noise qubits. Here we experimentally realize driven parametric coupling of a Kerr-cat qubit to a high-quality-factor microwave cavity and demonstrate universal control of the combined system. We measure the decoherence of the cavity in the presence of the Kerr-cat and discover excess dephasing due to heating of the Kerr-cat outside its computational subspace. By engineering frequency-selective dissipation to counteract this heating [5] we are able to mitigate this dephasing. Our results pave the way toward integrating Kerr-cats into practical quantum computing architectures.

References

[1] Puri et al., PRX 9, 041009 (2019)
[2] Tuckett et al., PRL 120, 050505 (2018)
[3] Puri et al., npj Quantum Inf 3, 18 (2017)
[4] Grimm, Frattini, et al., Nature 584, 205-209 (2020)
[5] Putterman et al., PRL 128, 110502 (2022)
[6] Eickbusch et al., Nat. Phys. 18, 1464-1469 (2022)

Figures

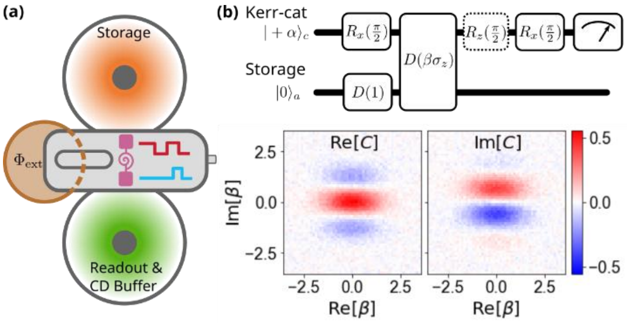

Figure 1: (a) Schematic of the experimental architecture for coupling a Kerr-cat qubit (realized in a SNAIL mode, pink) to a high-Q storage cavity. (b) Experimental characteristic function tomography of a coherent state in the storage cavity, demonstrating universal control of the composite Kerr-cat-cavity system [6].

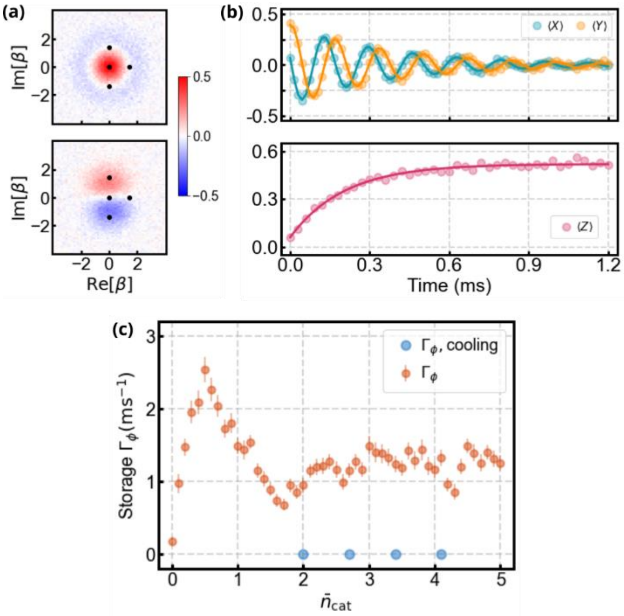

Figure 2: (a) Measured characteristic function (CF) of the $(|0\rangle + |1\rangle)/\sqrt{2}$ state prepared in the storage cavity. By measuring the CF at four distinct points we can reconstruct the expectation values of the Pauli operators of the cavity fock qubit (spanned by the $|0\rangle$ and $|1\rangle$ states). (b) Evolution of the expectation values $\langle X\rangle, \langle Y\rangle, \langle Z\rangle$ of the cavity fock qubit as a function of time, from which we can determine T_1 and T_2. (c) Excess dephasing of the storage cavity in the presence of the Kerr-cat, which we are able to mitigate by engineering frequency-selective Kerr-cat cooling [5].