Efficient decoupling of a non-linear qubit mode from its environment

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To control and measure the state of a quantum system it must necessarily be coupled to external degrees of freedom. This inevitably leads to spontaneous emission via the Purcell effect, photon-induced dephasing from measurement back-action, and errors caused by unwanted interactions with nearby quantum systems. To tackle this fundamental challenge, we make use of the design flexibility of superconducting quantum circuits to form a multi-mode element -- an artificial molecule -- with symmetry-protected modes. The proposed circuit consists of three superconducting islands coupled to a central island via Josephson junctions. It exhibits two essential non-linear modes, one of which is flux-insensitive and used as the protected qubit mode. The second mode is flux-tunable and serves via a cross-Kerr type coupling as a mediator to control the dispersive coupling of the qubit mode to the readout resonator. We demonstrate the Purcell protection of the qubit mode by measuring relaxation times that are independent of the mediated dispersive coupling. We show that the coherence of the qubit is not limited by photon-induced dephasing when detuning the mediator mode from the readout resonator and thereby reducing the dispersive coupling. The resulting highly protected qubit with tunable interactions may serve as a basic building block of a scalable quantum processor architecture, in which qubit decoherence is strongly suppressed [1].

Figures

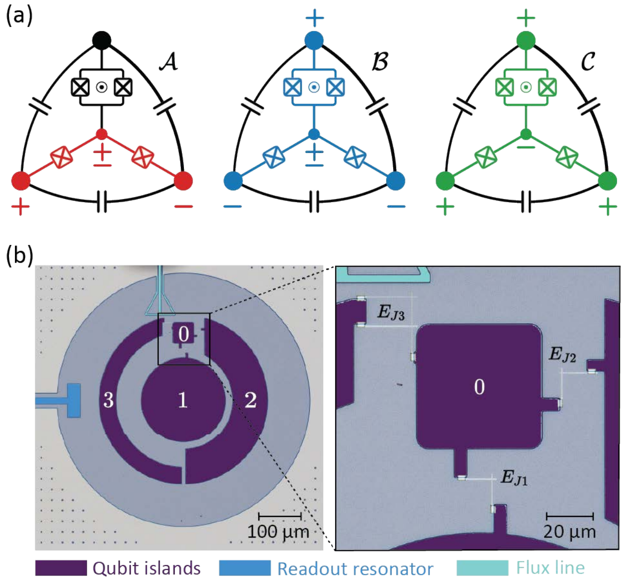

Figure 1: Oscillating charge distributions of the circuit modes indicated by positive ('+') and negative ('-') charge, '±' indicates charge neutrality. (b) False-color microscope image of the qubit sample.

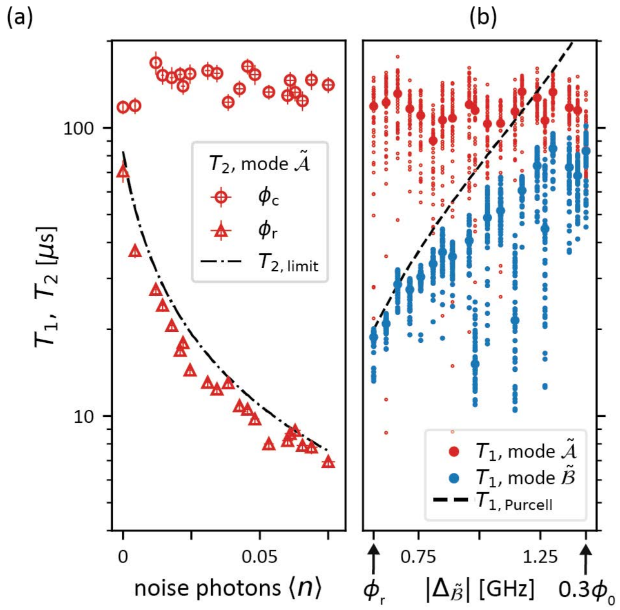

Figure 2: (a)T_2 of the qubit mode vs. noise photon-number at operation points of maximal and suppressed dispersive coupling.
(b) T_1 of qubit and mediator mode vs. resonator-mediator detuning.

References

[1] F. Pfeiffer et al. arXiv:2312.16988 (2023)