Robust strong-coupling architecture in circuit quantum electrodynamics

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Ongoing research from the past few decades in the field of superconducting quantum circuits, have provided an edge over other quantum physical systems for realization of superior quantum devices. The derived architecture for quantum device hardware, incorporating superconducting qubits and resonators, is coined by the name of circuit quantum electrodynamics (c-QED): a new variant of 'cavity QED'. Superconducting qubits as a two-level system, also known as artificial atoms, are one of the most researched and robust candidates for various applications in the field of circuit quantum QED. The advancement in realization of the interaction between these artificial atom and cavity has developed enormously in past few decades and is recognized with the term 'coupling'. Employing the framework of quantum hardware device architecture, the realization of various qubit-cavity coupling regimes has been explored. The atom-cavity strong coupling regime and ultra-strong coupling regime where an artificial atom and the cavity exchanges a photon more often before the coherence is vanished, have emerged, and recognized notably.

We experimentally demonstrated a simple, systematic, and robust architecture to achieve ultra-strong coupling between a superconducting flux qubit and a high-quality quarter-wavelength coplanar waveguide resonator. To achieve this, the geometric inductance and nonlinear kinetic inductance of the coupling element is exploited by increasing its length and/or decreasing the cross-sectional area and ultimately achieving a qubit-resonator coupling strength of 655 MHz, 10% of the resonator frequency. In future, when realizing the heat transport in quantum heat devices, this strong coupling will potentially benefit in terms of power and efficiency of a heat engine, around which this project revolves.

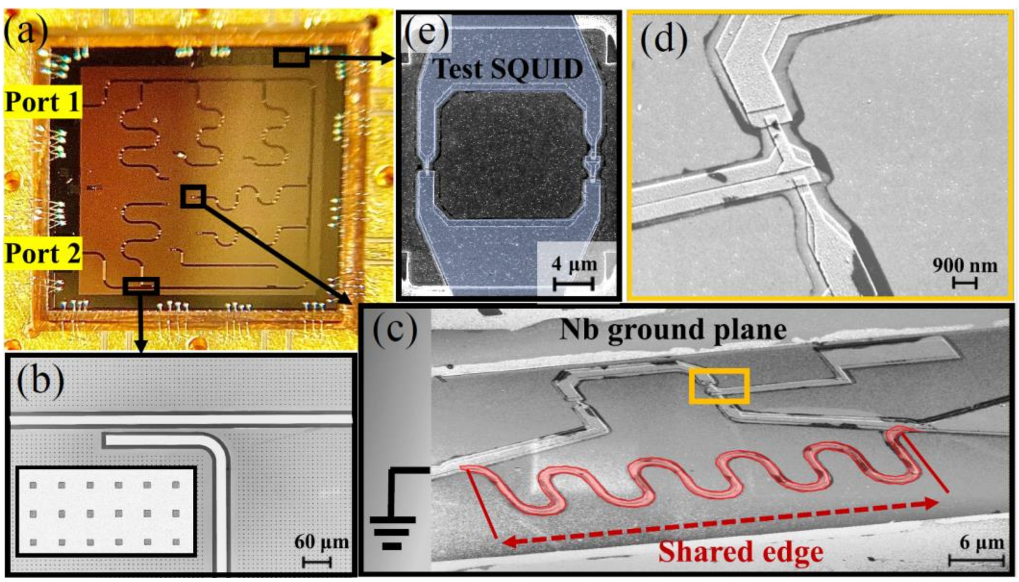

Fig. The studied structure **(a).** Microscopic view of the reported device. **(b).** Electron micrograph showing the capacitive coupling of a diagnostic resonator to a common feedline and an enlarged array of flux trapping holes in the inset. **(c).** 3 junction flux qubit with 120 µm long meander element producing the large coupling (shared edge highlighted with false color). The qubit is galvanically coupled to the resonator from one end and shunted to the ground plane from the other end. **(d).** Electron micrograph of two large identical junctions of a flux qubit. **(e).** Electron micrograph of the test SQUID (highlighted with false color).