# Integration of overlap Al/Al-Ox/Al Josephson junctions in superconducting quantum circuits: from transmon qubits to novel devices

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**Abstract**: We developed scalable, state of the art overlap Al/Al-Ox/Al Josephson junctions for quantum applications, including transmon qubits and a novel cryogenic on-chip microwave frequency shifter.

Josephson junctions are one of the fundamental building blocks of superconducting quantum devices. With applications ranging from circuit quantum electrodynamics experiments to quantum information processing and quantum sensing, reliable and reproducible devices, and related microfabrication processes, represent a corner stone for every experimental group in the field. There are different microfabrication approaches to produce Josephson junctions. Our effort focuses on the development of cross-type or overlap Al/Al-Ox/Al Josephson junctions [1]. This method allows for scalability and high geometrical flexibility. We achieve a large flexibility in the critical current tuning, allowing for a wide range of applications. As first step we show how we have integrated our Josephson junctions into a transmon qubit, the dominant superconducting qubit design in the community. We report and outline the spectroscopic characterization of the qubit, see Fig. 1. We then describe a novel Josephson junction based cryogenic on-chip microwave frequency shifter relying on the fast modulation of a tunable microwave resonator, which can find application both in superconducting quantum processors as well as in the investigation of lattice physics in synthetic dimensions [2].

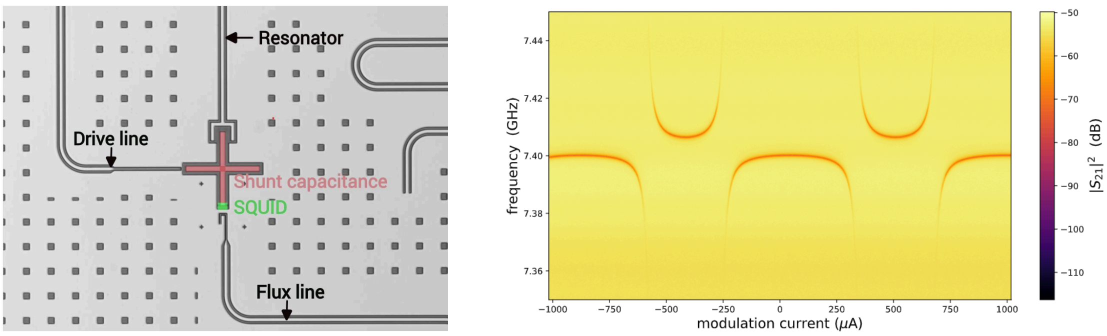


**Fig. 1** On the left side, the design of the flux tunable transmon qubit. On the right side, flux sweep of the frequency of the read out resonator coupled to the qubit.

## References

[1] M. Bal et al., “Overlap junctions for superconducting quantum electronics and amplifiers”, Appl. Phys. Lett. **118**, 11, 112601 (2021)

[2] F. Ahrens et al., "Synthetic-lattice Bloch wave dynamics in a single-mode microwave resonator." *preprint arXiv:2409.00760* (2024)