Design and Realization of Nb-based JTWPA

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Abstract: JTWPA provide high gain, large bandwidth and quantum limited noise in the microwave frequency range, fundamental for quantum technologies. We report design, modelling and fabrication of JTWPA based on the Nb-trilayer technology.

Josephson Traveling Wave Parametric Amplifiers (JTWPAs) are a key enabling technology for broadband, quantum-limited signal amplification, crucial for the readout of superconducting qubits and quantum sensors operating in the microwave regime. We have designed and fabricated several JTWPAs optimized for operation in the C- and X-bands, using a Nb/AlOx/Nb trilayer process. Each device comprises a nonlinear transmission line formed by a periodic array of Josephson junctions, with engineered dispersion to support efficient three- and four-wave mixing. This architecture enables high gain across multi-GHz bandwidths. The amplifier design is specifically tailored for fabrication using Nb trilayer technology, which provides superior junction uniformity, higher critical magnetic fields, and lower quasiparticle densities compared to Al-based approaches. These advantages are critical for reliable performance in realistic cryogenic environments, offering enhanced superconducting properties over multiple thermal cycles and supporting improved scalability for multi-qubit systems and large detector arrays. We present details of the Nb-JTWPA design, highlighting considerations related to fabrication constraints and lithographic resolution, as well as modelling and numerical simulations of the amplifier's expected performance.

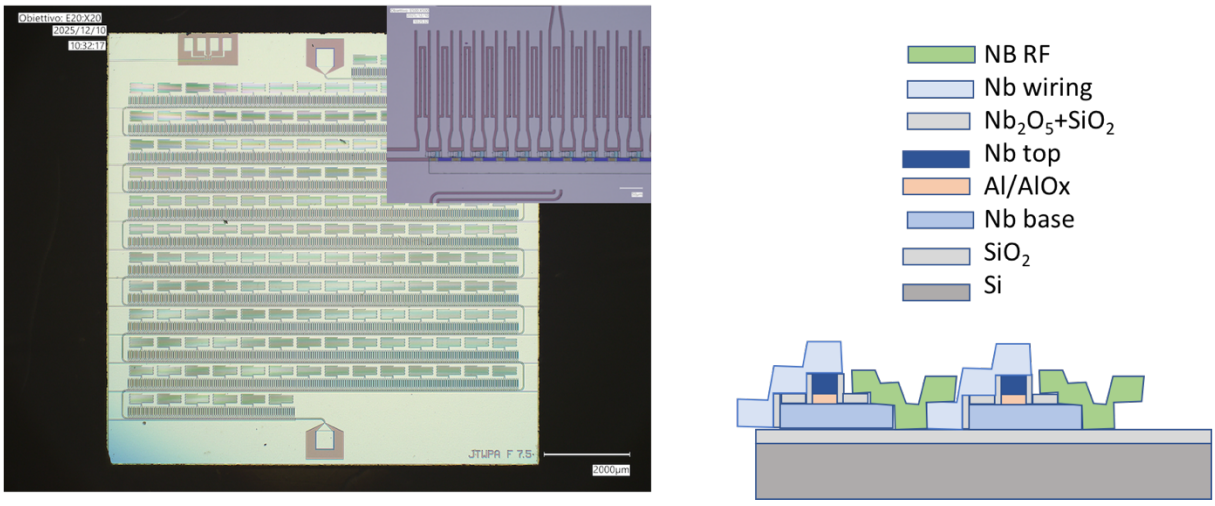

Fig. 1 (Left) microphotograph of the realized JTWPA chip. In the inset a magnification of the first cells. (Right) a draft of the cross-section of the device, where the different layers are visible (not in scale).

In Fig. 1 (Left) is shown a microphotograph of one of the realized chips. The chip contains a transmission line with 2163 cells, each consisting of a Josephson junction and an interdigital capacitor. Every 13 cell there is a resonant circuit to ground to realize Resonant Phase Matching. The Nb-trilayer technology used to realize the JTWPAs requires several fabrication steps, resulting in a complex structure, shown in Fig.1 (Right) as cross section and as the different metals and insulator layers.