



SENSORS
AND DEVICES

Introduction of FBK

Present and future activities

24 July 2024

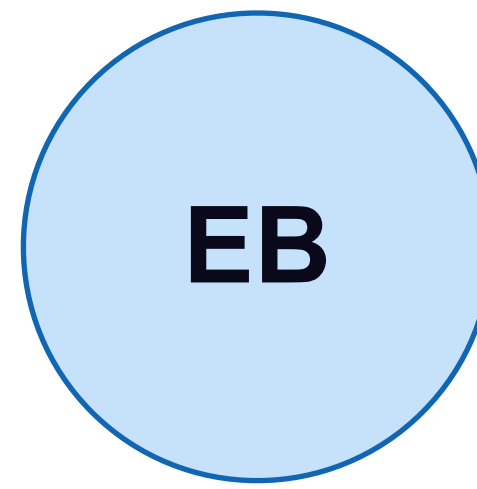
Nicolò Crescini

ncrescini@fbk.eu

www.fbk.eu

A growing team at FBK

3 Researchers + 1 Senior Fellow + 2 PhD students + 1 Master student



Felix Ahrens, Nicolò Crescini, Benno Margesin, Alessandro Irace, Enrico Bogoni, Marcello Faggionato, Federica Mantegazzini

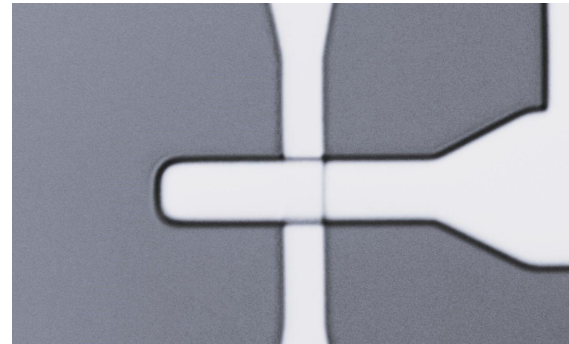
Other collaborators in Trento

Experimentalists: Paolo Falferi, Renato Mezzena, Andrea Vinante

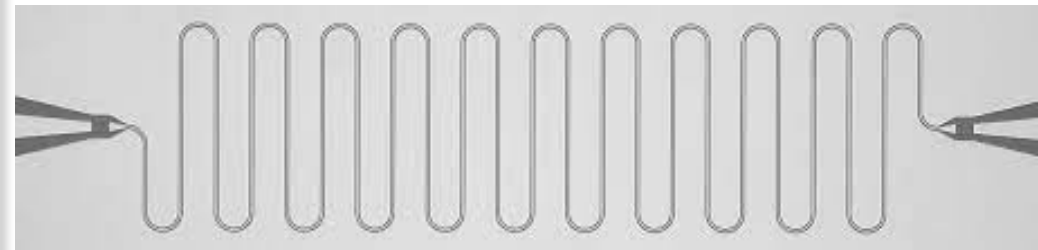
Theoreticians: Iacopo Carusotto, Gianluca Rastelli, Alberto Biella, Stephanie Matern

Superconducting building blocks

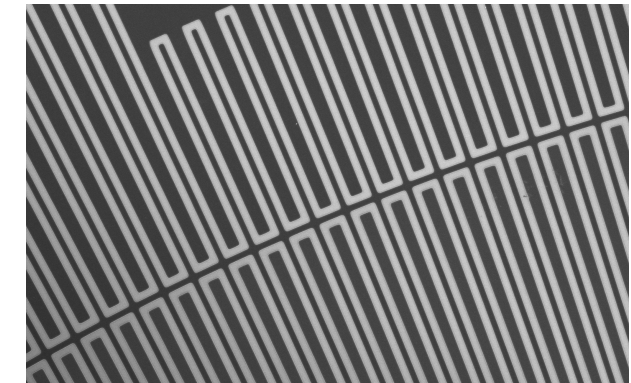
Josephson junctions



Superconducting resonators



High kinetic inductance films



SQUIDs

Parametric Amplifiers

Qubits

Cryogenic sensors

Microwave multiplexers

...

Multi-qubit systems with Quantum limited noise read-out

Hybrid superconducting magneto-mechanical systems

...



... for experimental applications

Multi-qubit systems with Quantum limited noise read-out

Hybrid superconducting magneto-mechanical systems

...

cQED EXPERIMENTS

QUANTUM SENSING

Synthetic dimensions

READ-OUT

Light-matter interaction

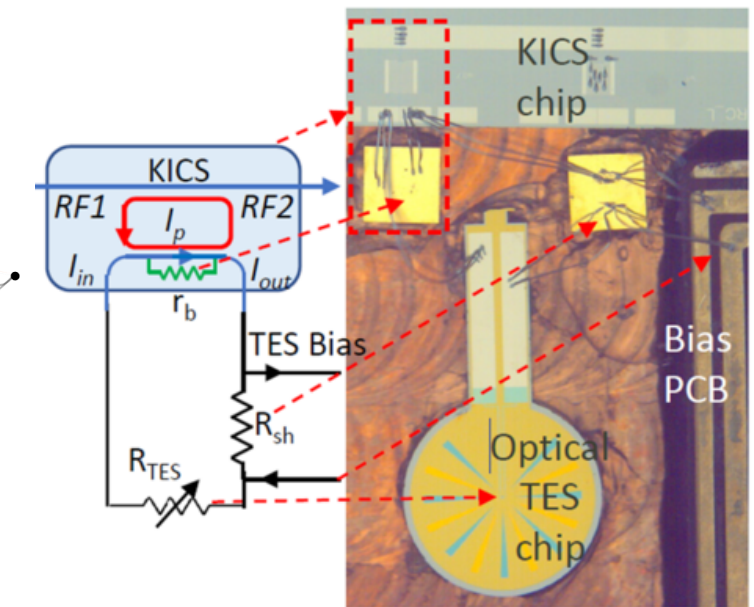
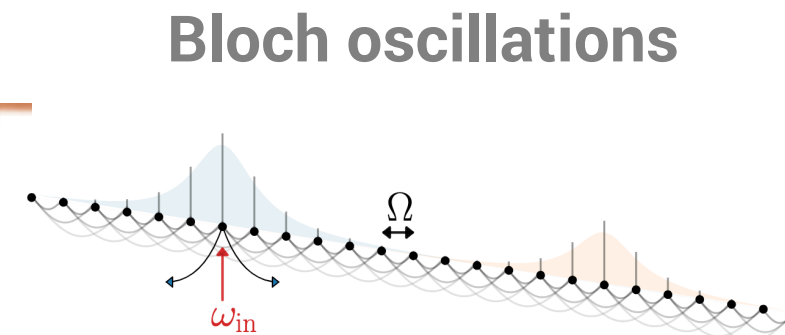
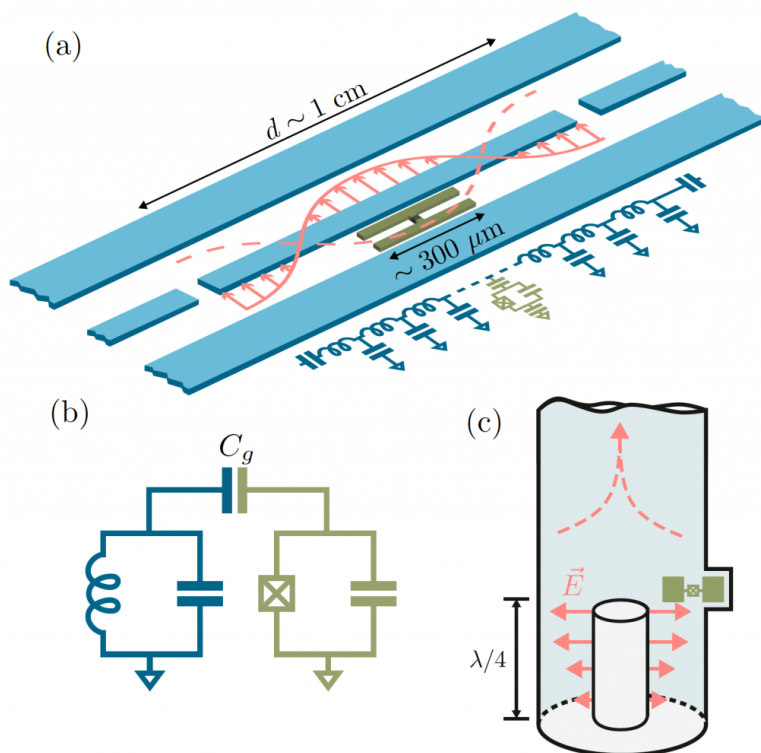
Hybrid quantum systems

Lattices in frequency domain

Neutrino mass experiments

Dark matter searches

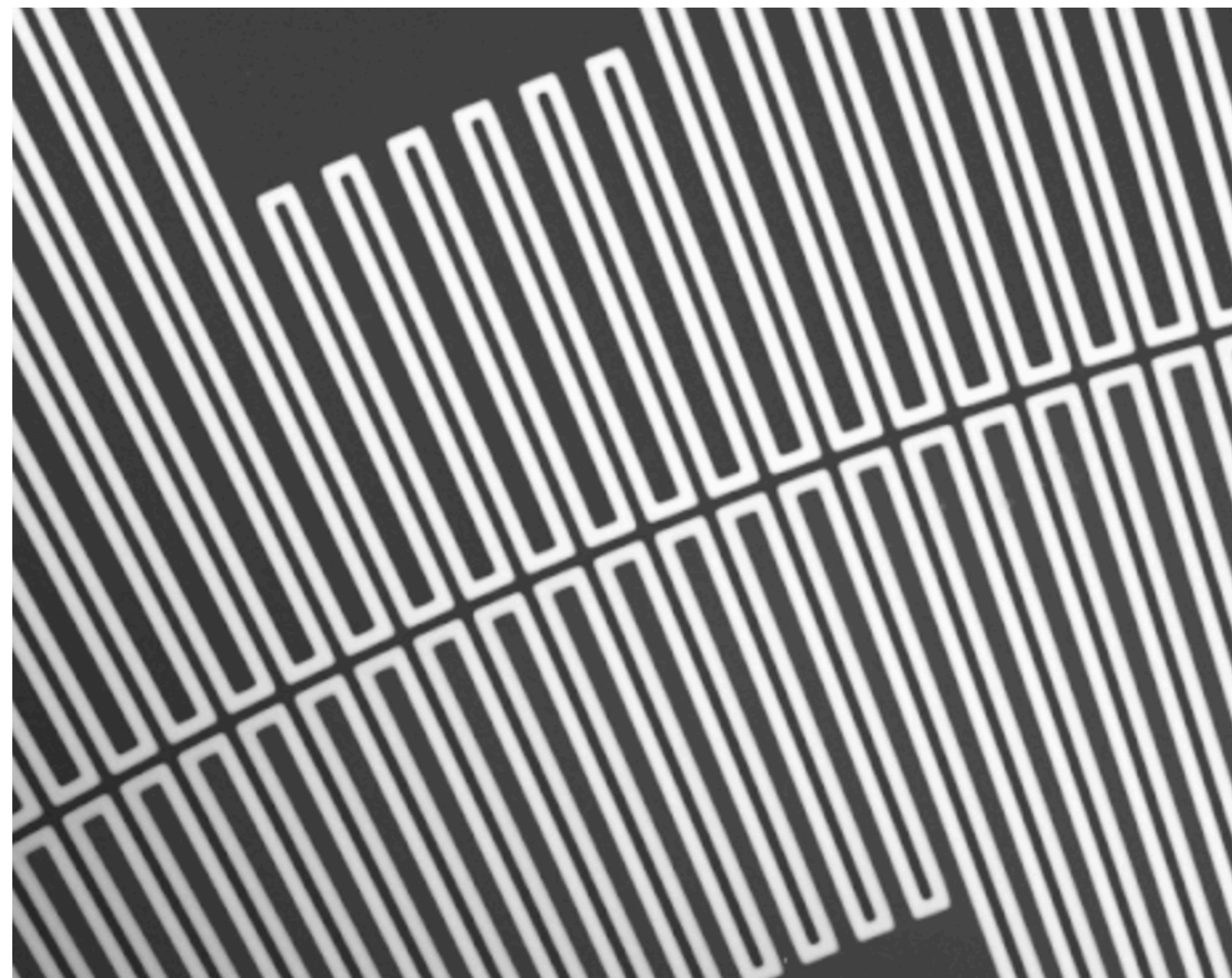
Kinetic Inductance Current Sensors (KICS)



technology

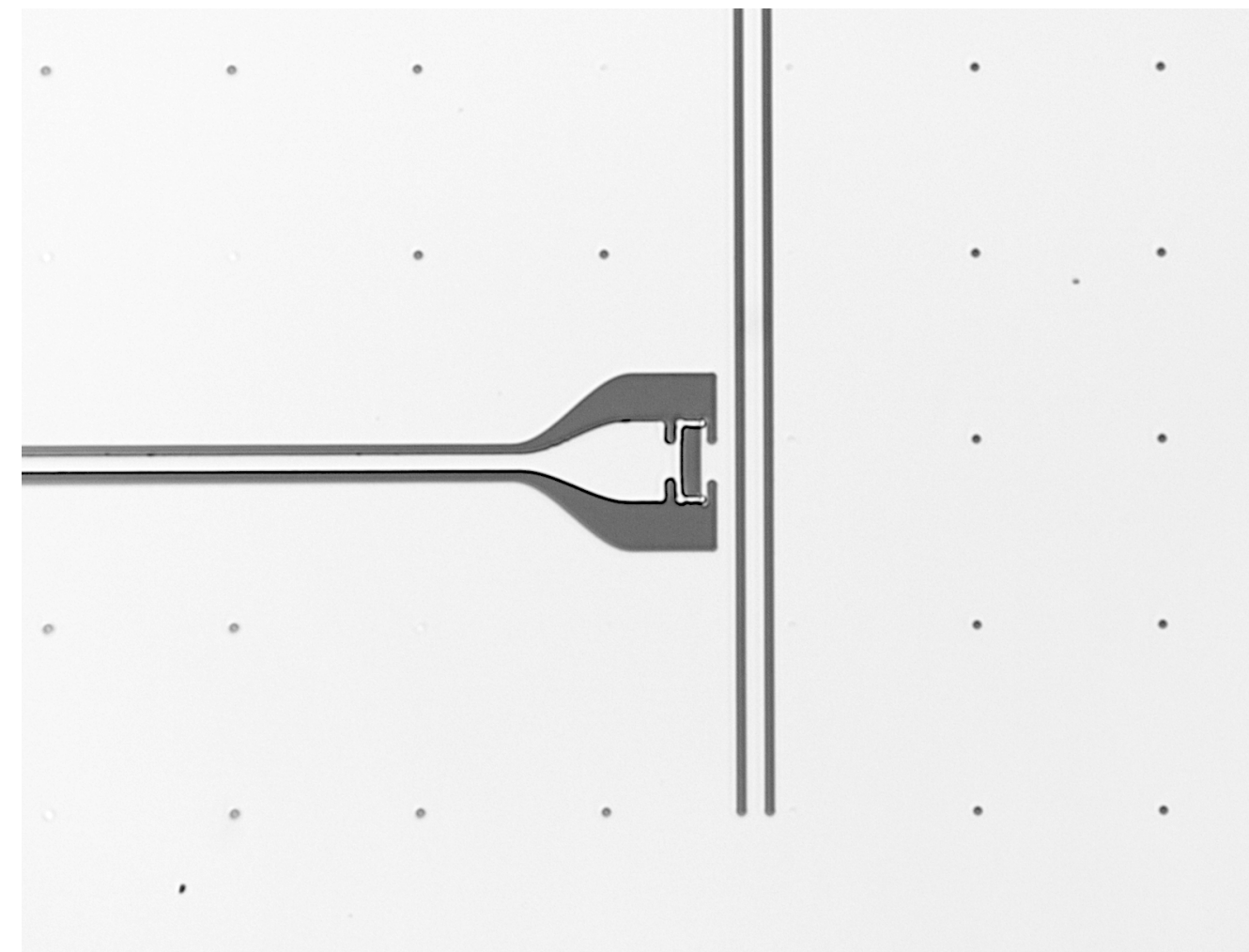
NbTiN matched transmission lines, TWPAs, resonators and maybe Josephson junctions

Aluminium resonators, Josephson parametric amplifier, Josephson arrays and qubits



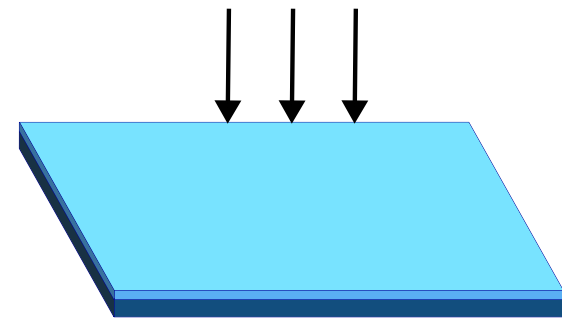
High kinetic inductance materials, such as NbTiN were developed in FBK in the last 2 years

Josephson junctions were recently developed in FBK, so far stable and reproducible

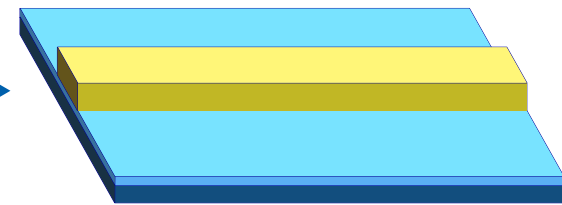


the process

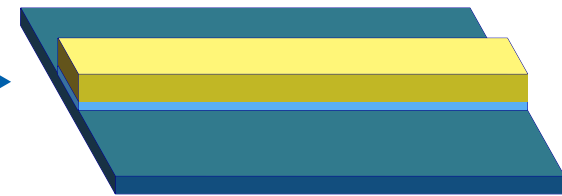
Al deposition (sputtering)



first lithography

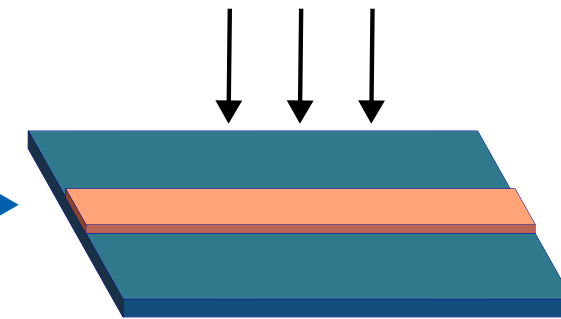


etching



resist removal

natural oxidation

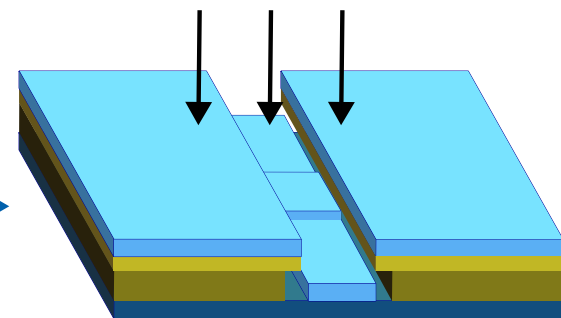
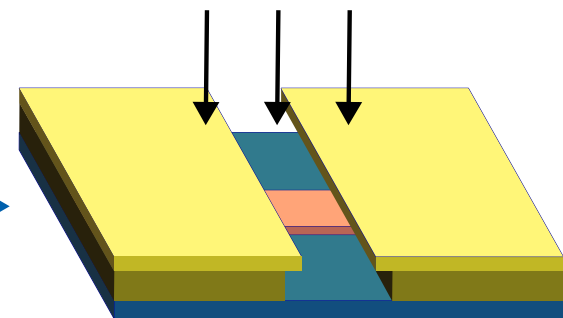
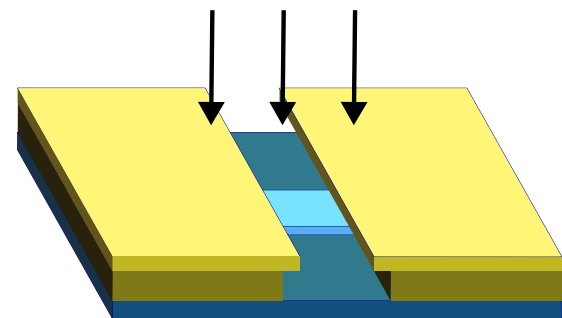


second lithography

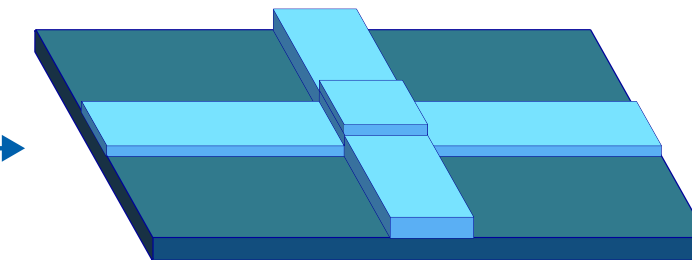
Ar plasma cleaning

controlled oxidation

Al deposition (sputtering)



lift-off



■ Silicon

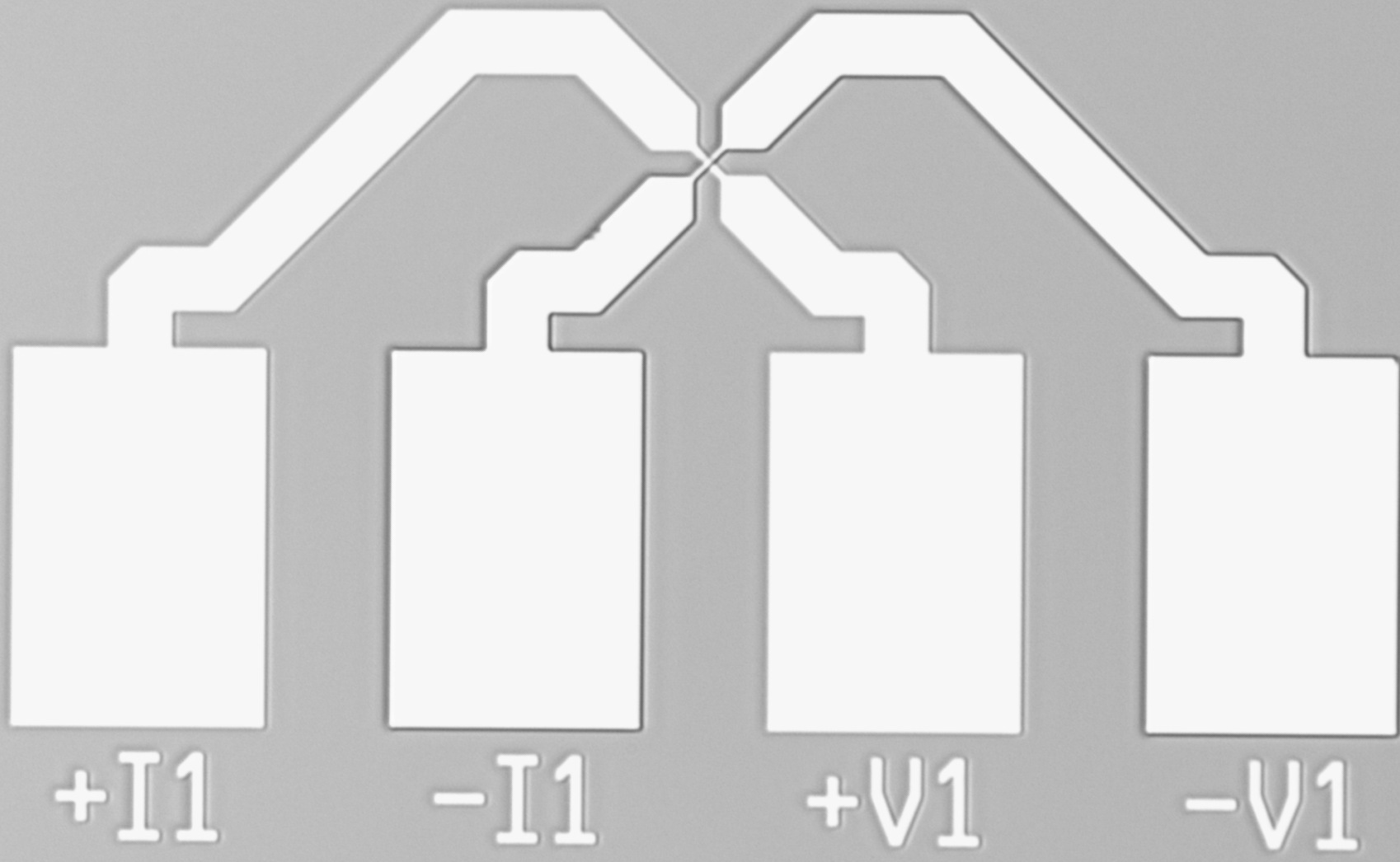
■ Photoresist

■ Aluminum

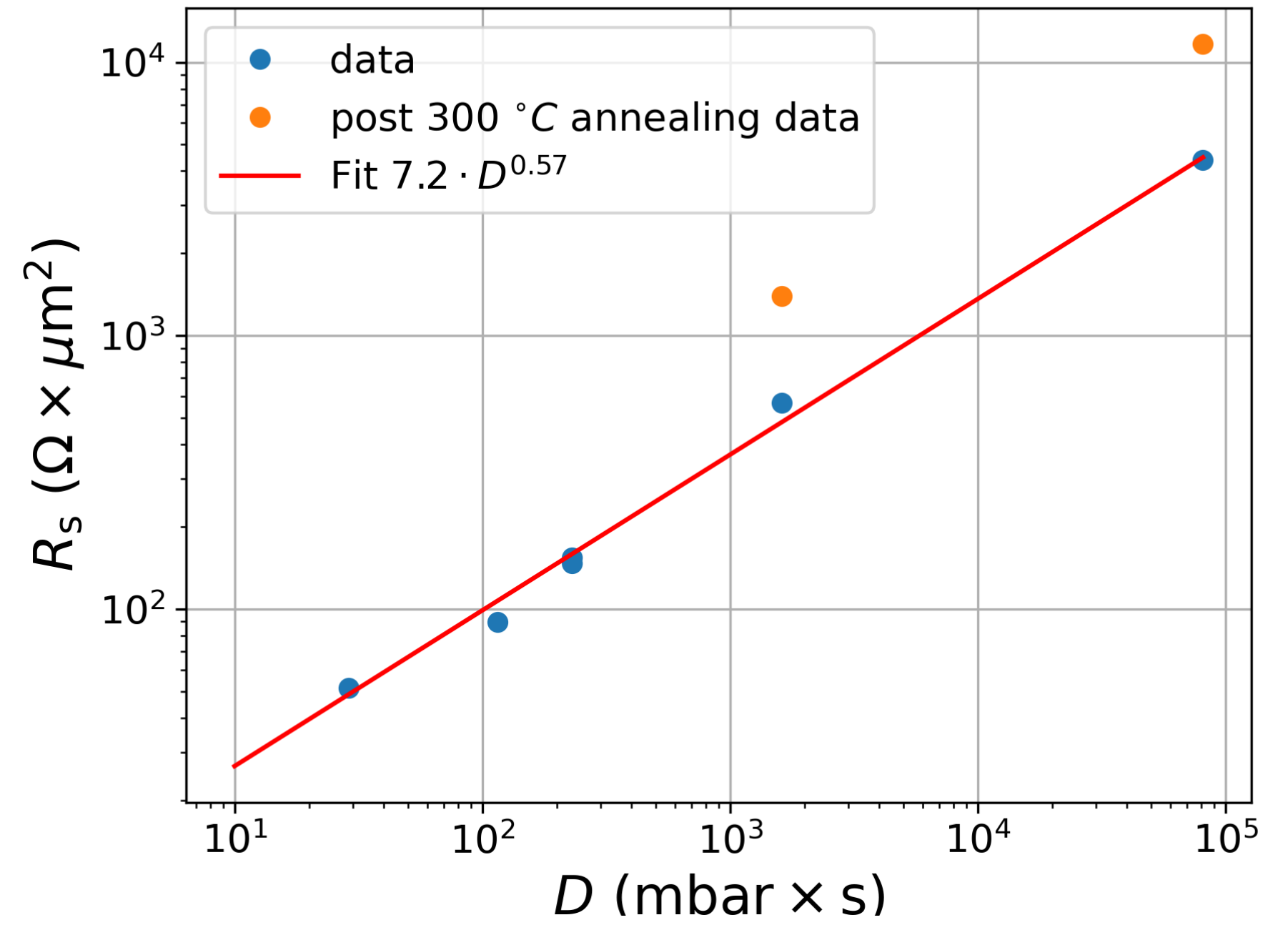
■ Lift-off resist

■ Aluminum Oxide

JUNCTION 5 X 5



Josephson junction

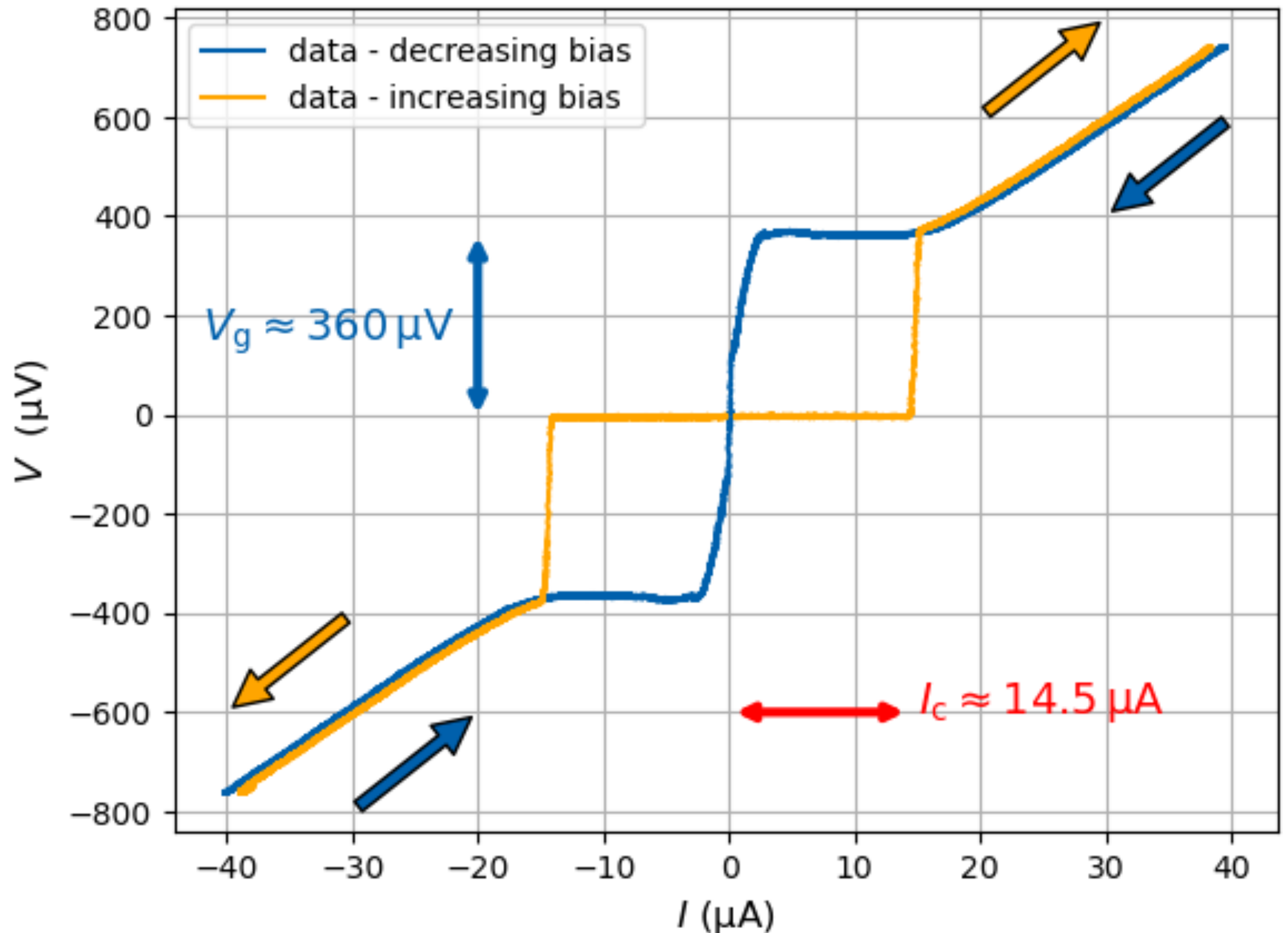


millikelvin

The same junctions were tested at ultra-cryogenic temperatures.

Results were consistent with the ones obtained at room temperature.

Next: future measurements planned with a 24 bit ADC/DAC, planning on measuring JJ arrays and high order Shapiro steps.

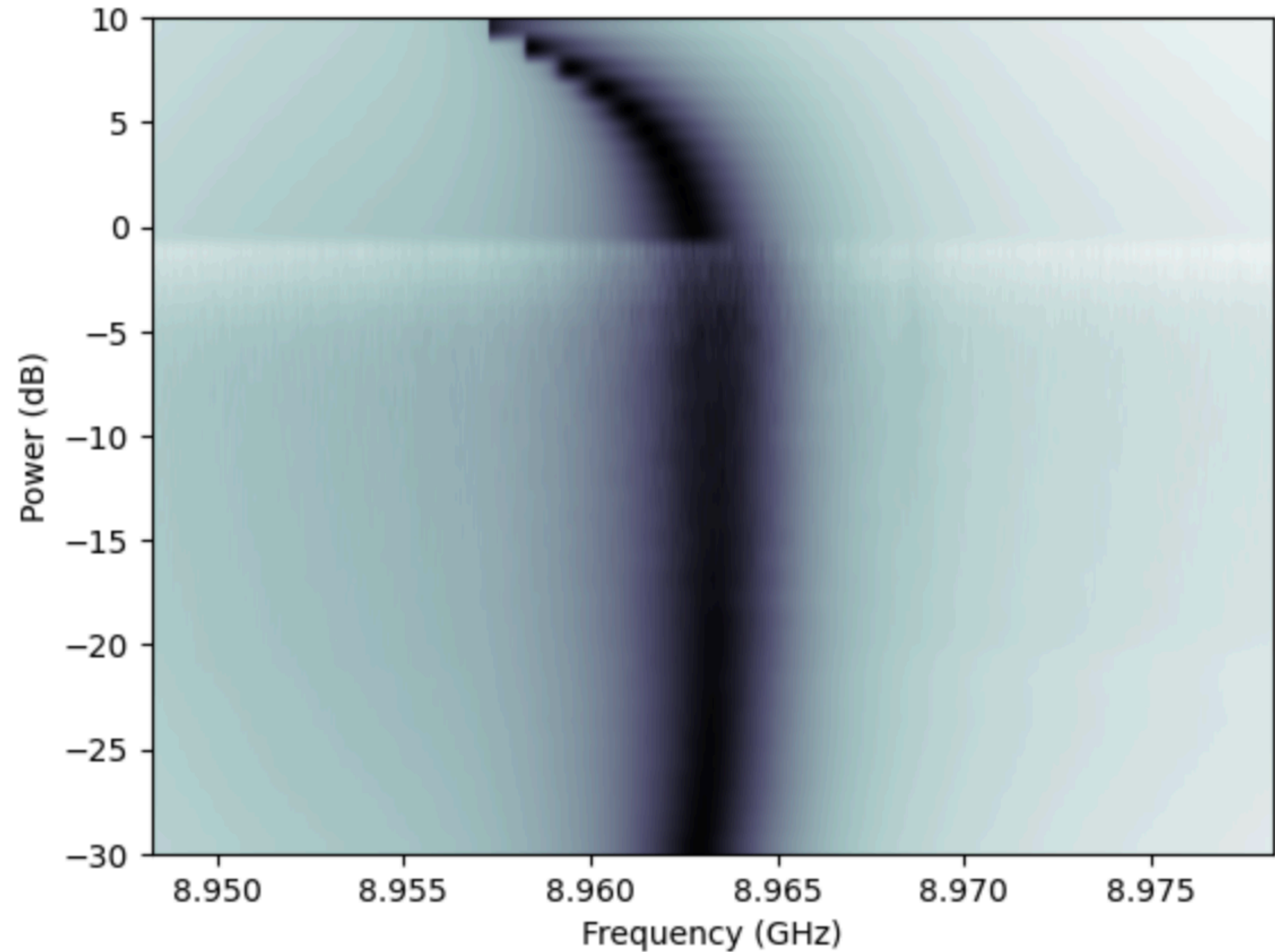


Moving on to some devices



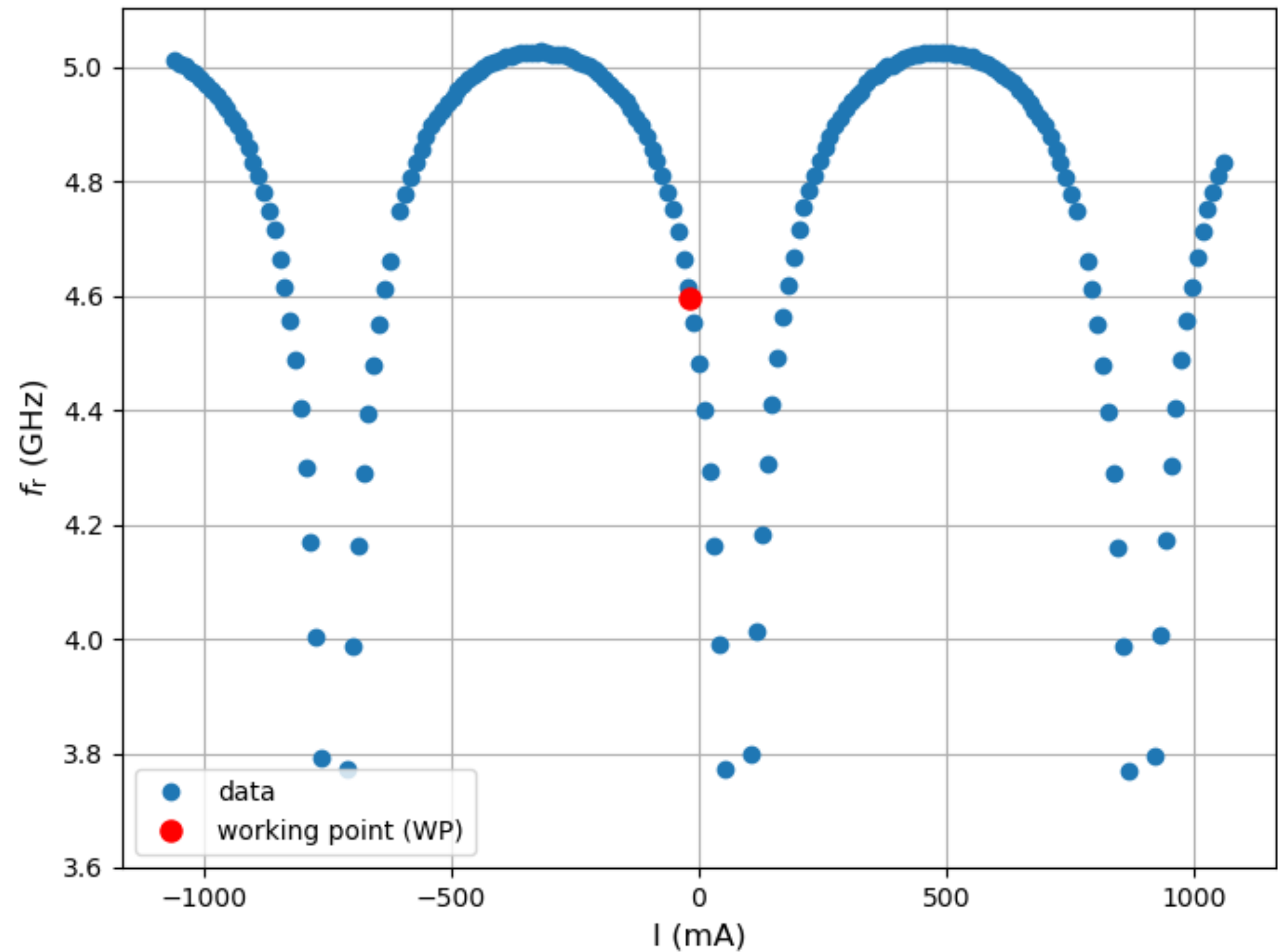
JJ array

So far the array is short (300 JJ)
and the junctions are large, so
we are able to identify only one
resonance. But it's there!



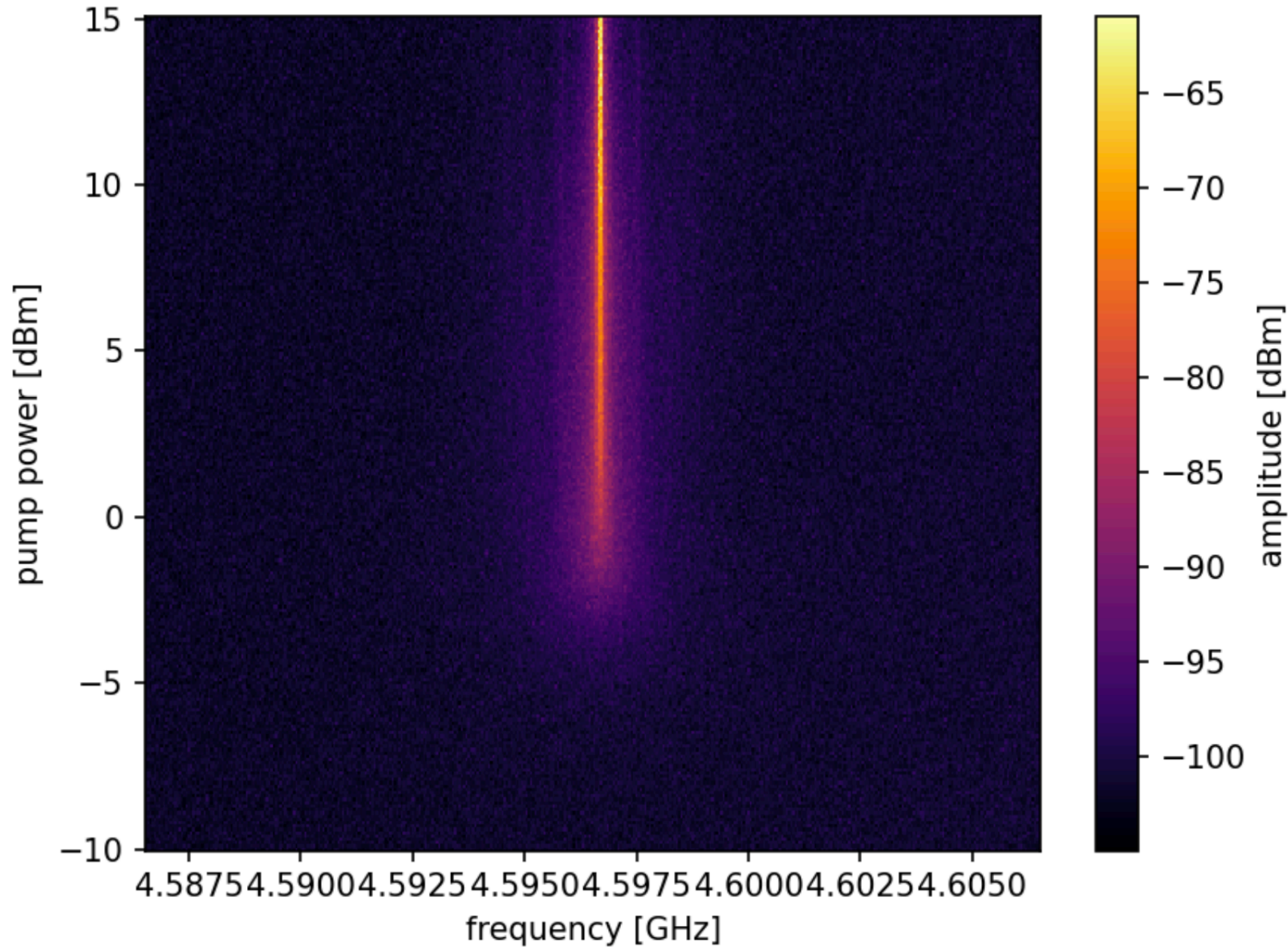
Flux tuning

The SQUID is verified to tune the frequency of the resonator in the expected range, and has roughly the right periodicity.

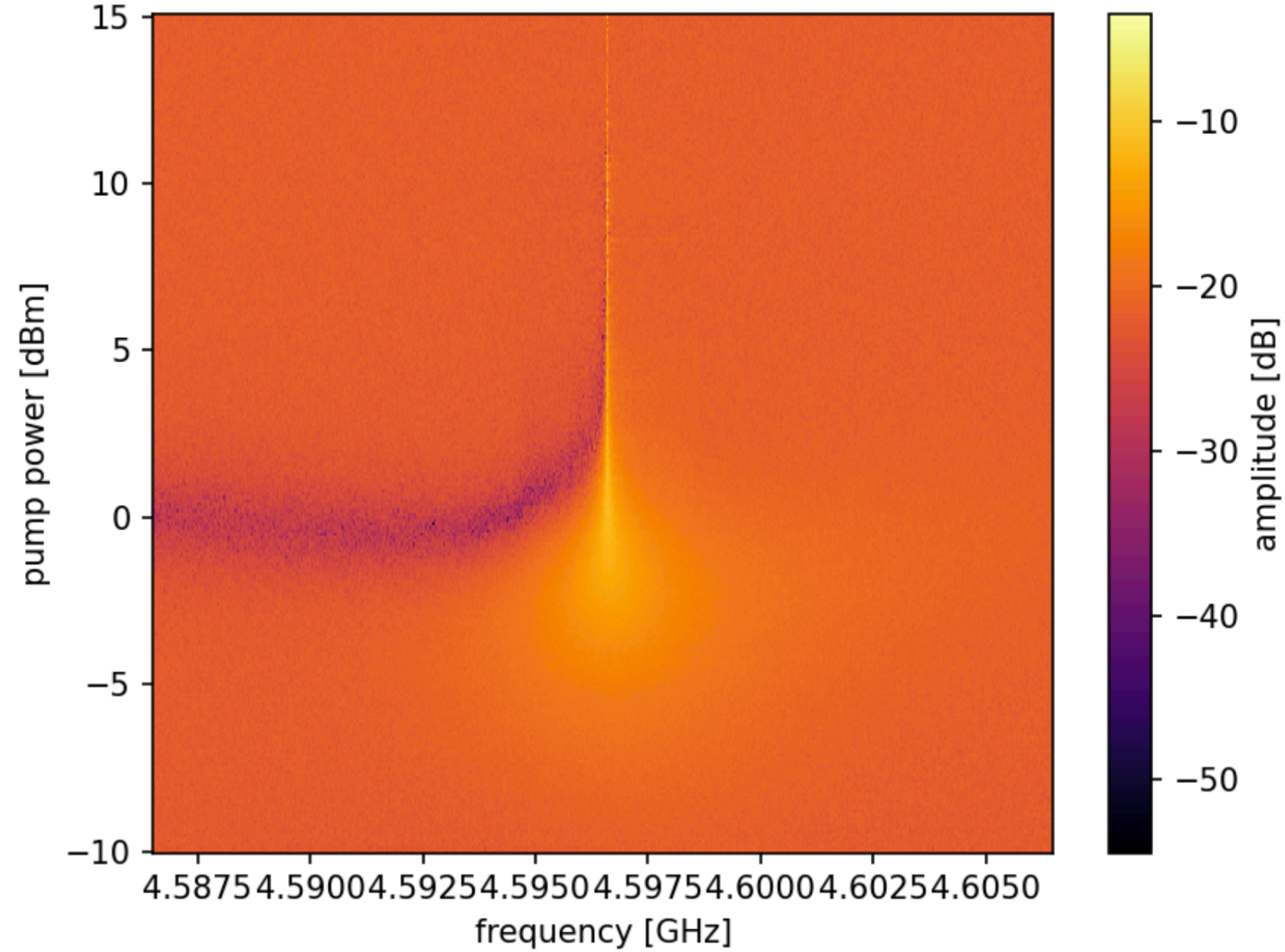


Parametric amplification

PSD



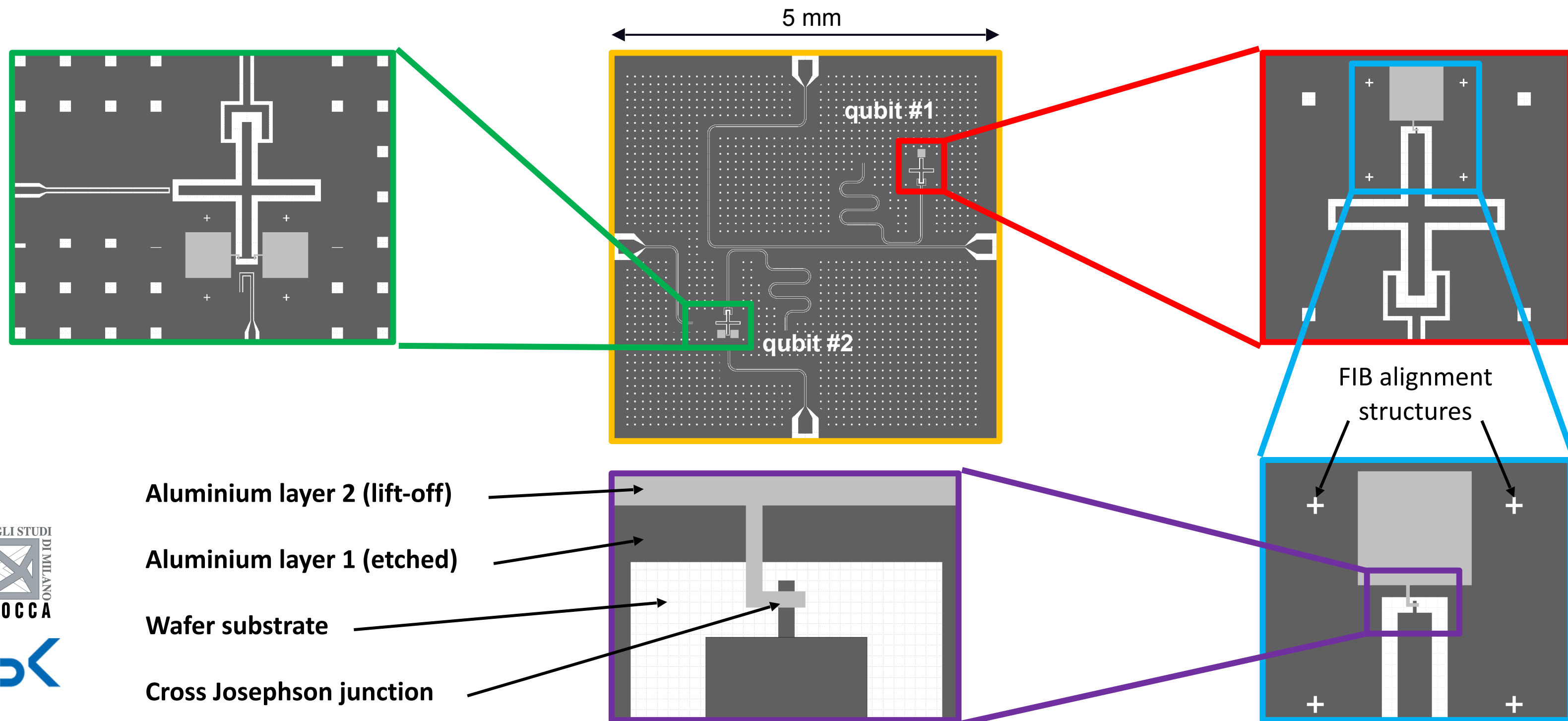
S21



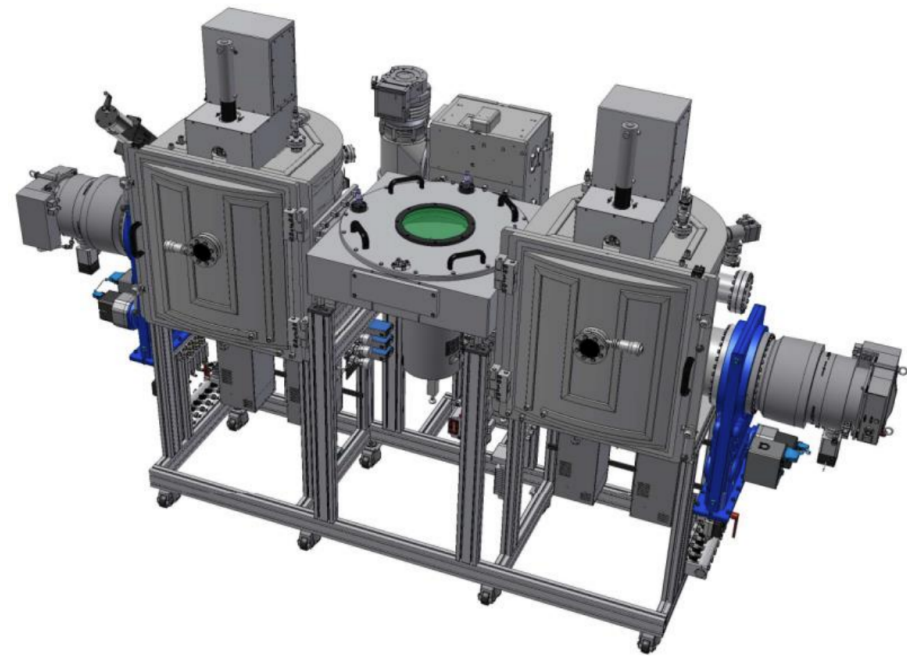
Transmon qubits

Chip design: **qubit #1**: fixed-frequency resonator driven transmon

qubit #2: tunable-frequency transmon with dedicated drive-line



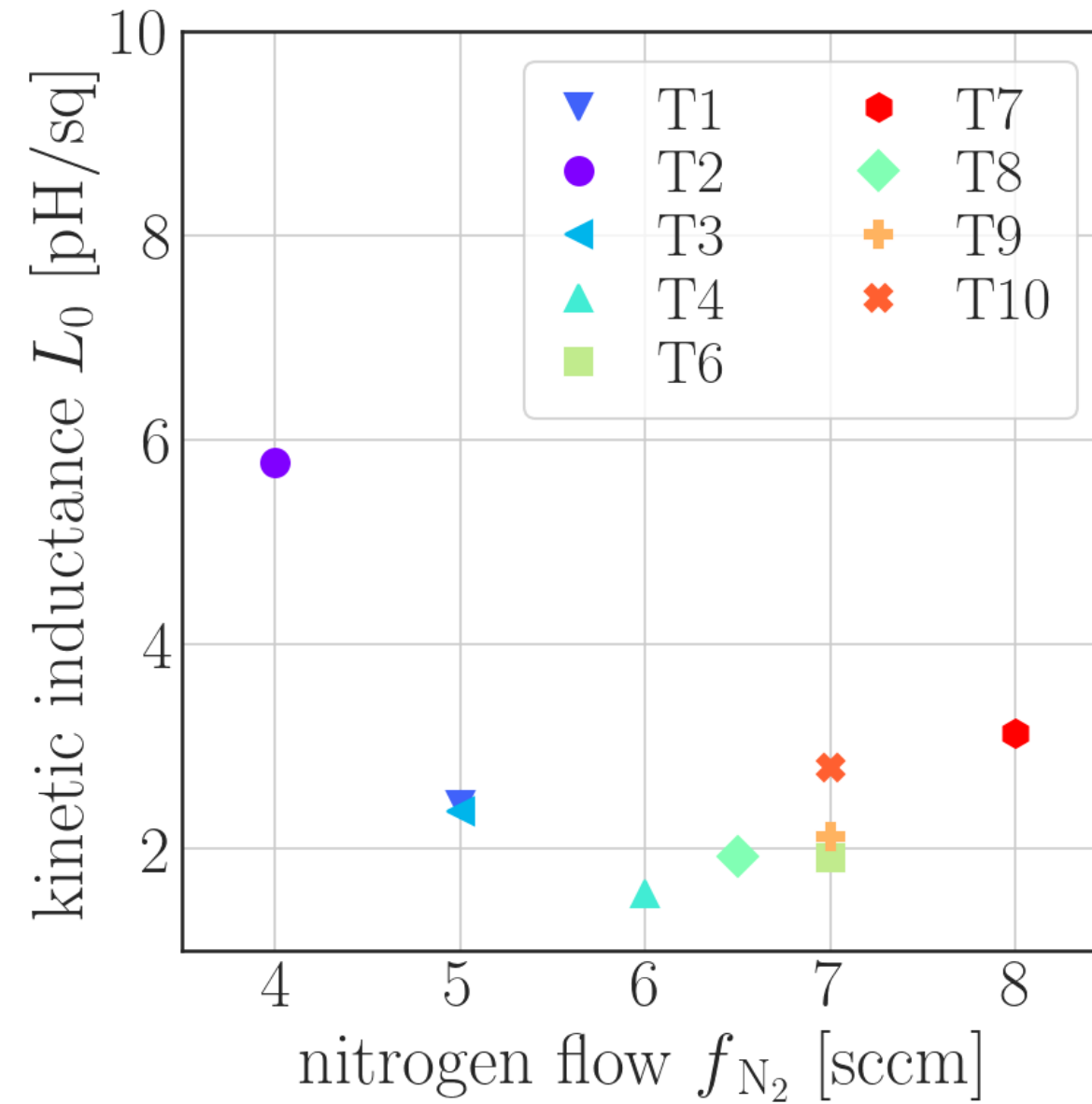
NbTiN films



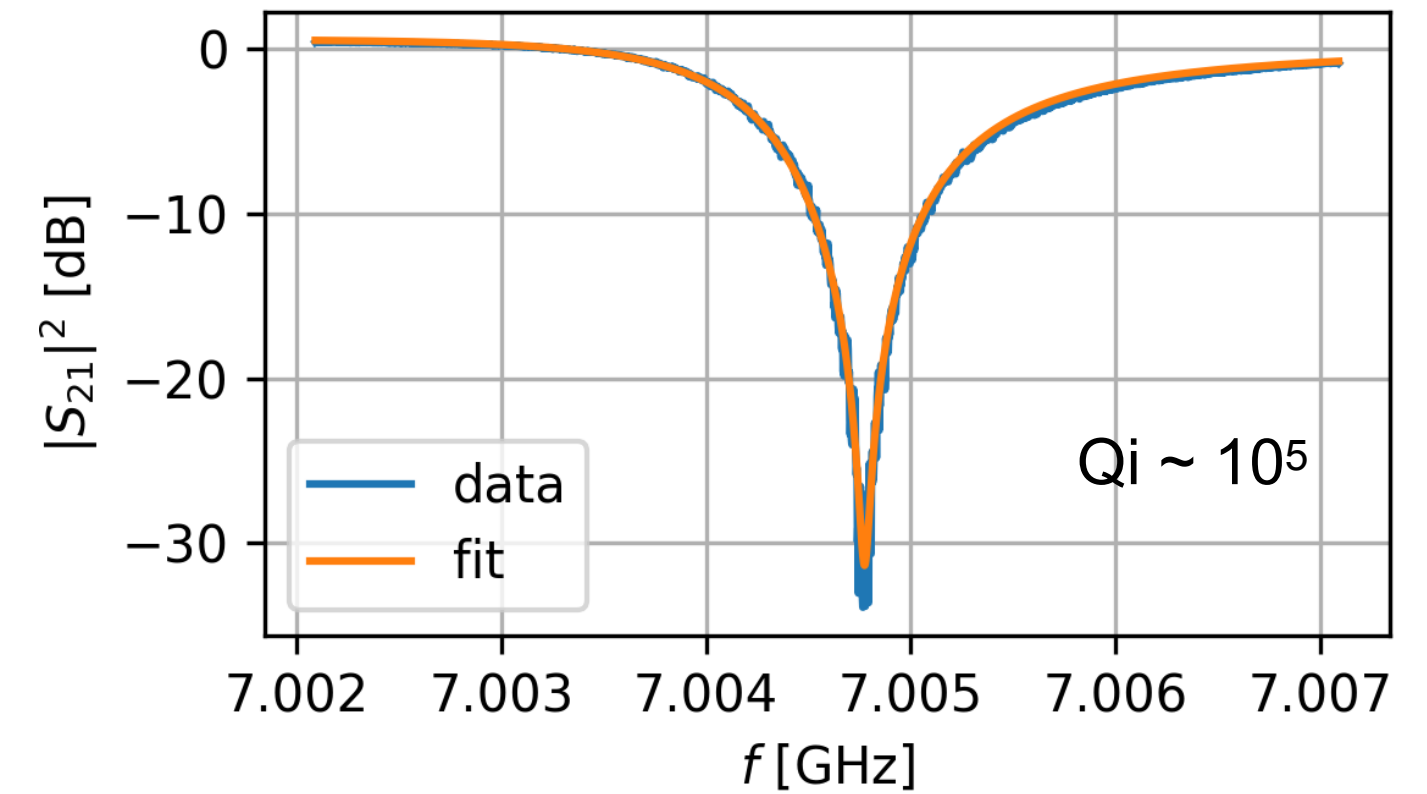
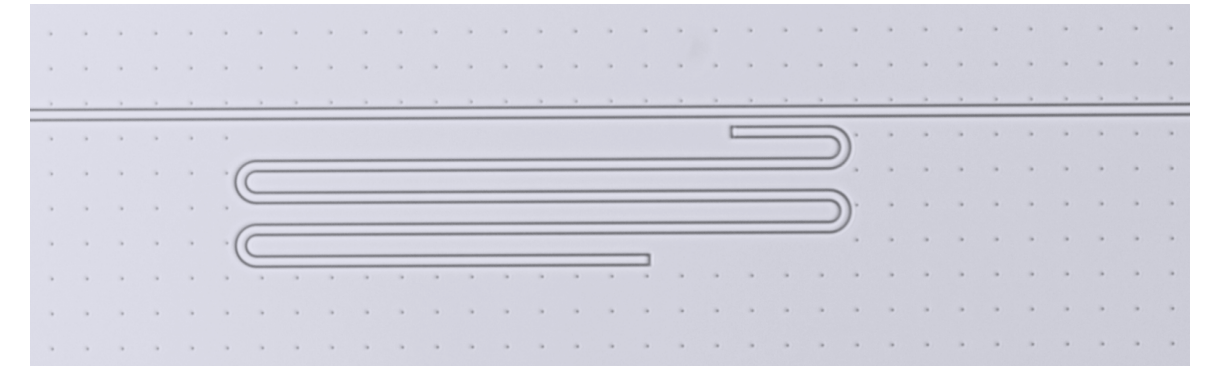
Sputter system: PVD
Kenosistec 800 C

Sputter target: $\text{Nb}_{80\%}\text{Ti}_{20\%}$

NbTiN film optimisation

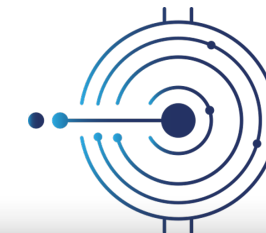


Cryogenic film characterisation



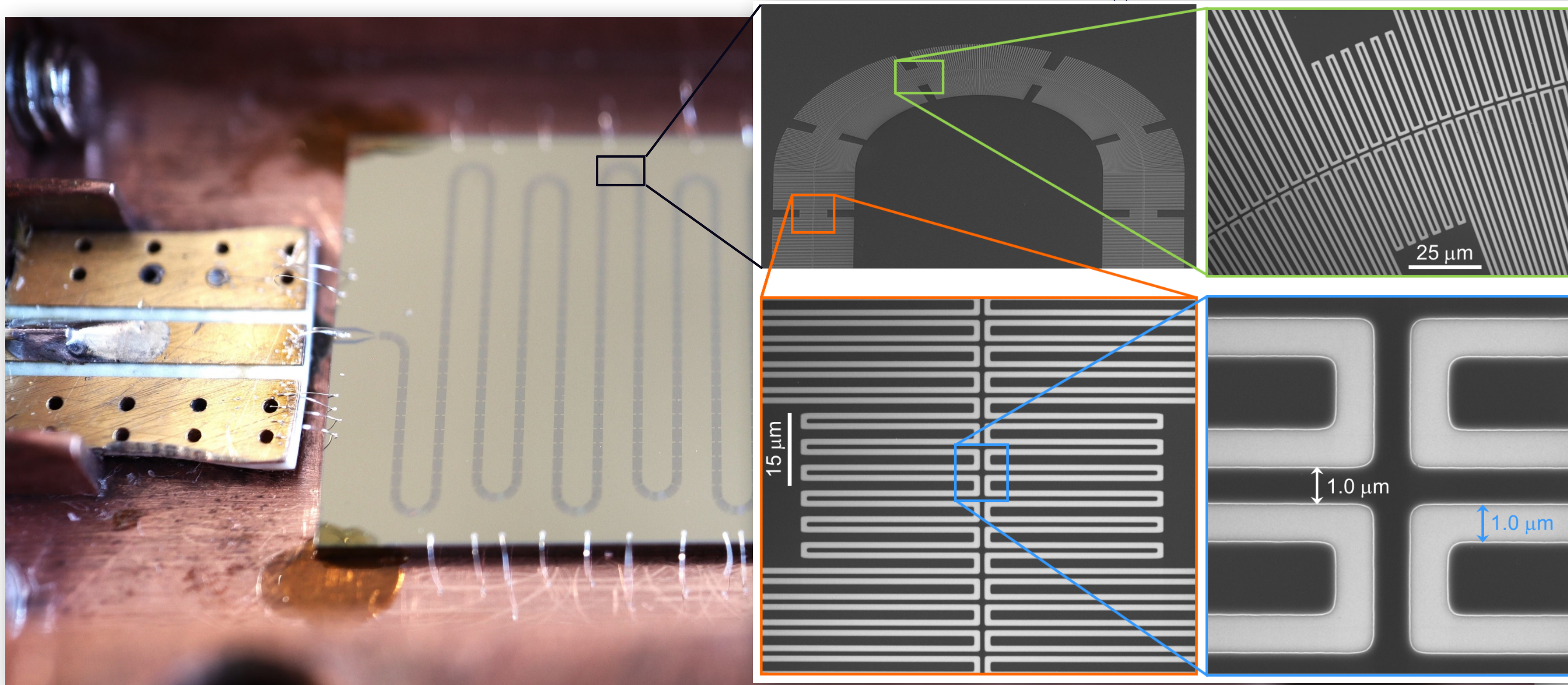
Exploration of ALD TiN starting

... for KI-TWPAs

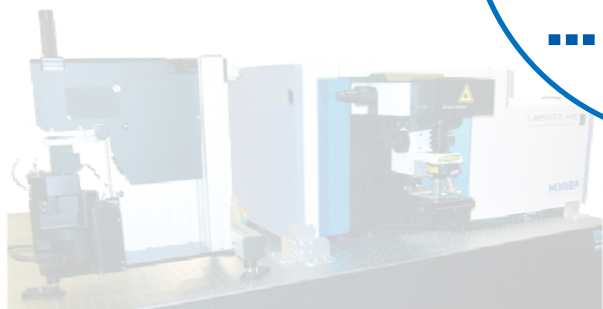


DARTWARS

Detector Array Readout with Traveling Wave Amplifiers



Characterisation facility



Cryogenic laboratory

Dry dilution fridge Bluefors LD, $T_b = 10$ ✓

Pulse tube cooler, $T_b = 2$ K ✓

Vector Network Analyser ✓

Spectrum Analyser ⚠

Microwave generators ✓

...

XRD/XRF X-ray Diffraction / X ray Fluorescence

Composition depth profile

ppb

Resolution: 1mm



Analysis resolution: 5 mm

Microscopy; Energy Dispersive X-ray Scattered Diffraction

Resolution: 5 nm

to SPM microscopy

Elemental, crystallographic phase and stress analyses
Spatial resolution: 1cm; Sensitivity: 0.1-1%

Conclusions

Two technological platforms available

- Overlap **Josephson junctions**
- High **kinetic inductance** films

FBK offers:

- Large range of **microfabrication** and **diagnostic tools**
- **Cryogenic laboratory** under construction