Qub-IT meeting

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Thanks to the Superconductive Electronics Group

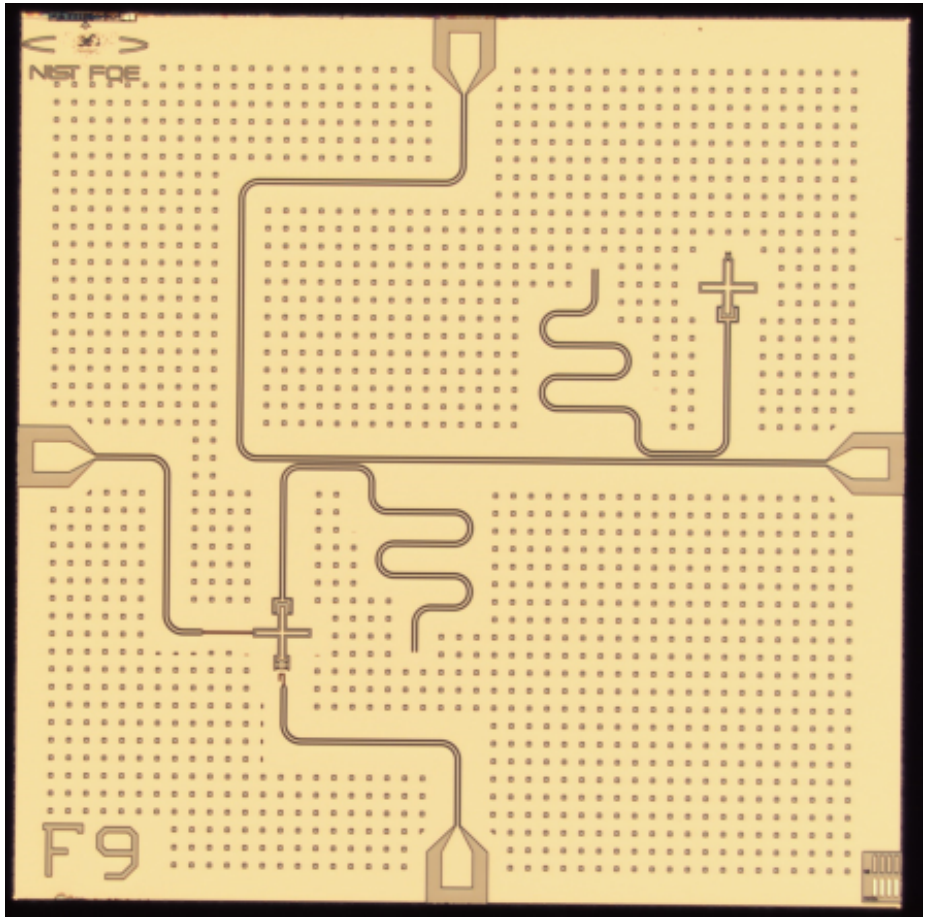
- Fabrication: David Olaya
- Measurements: Manuel Beltran Castellanos

  Adam Sirois, Pete Hopkins, Samuel Benz

The first design

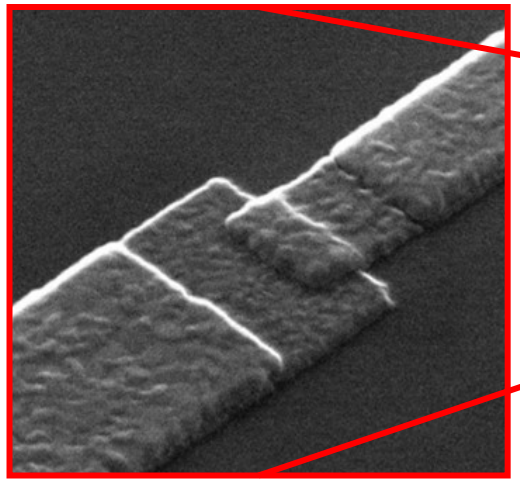
Goals:

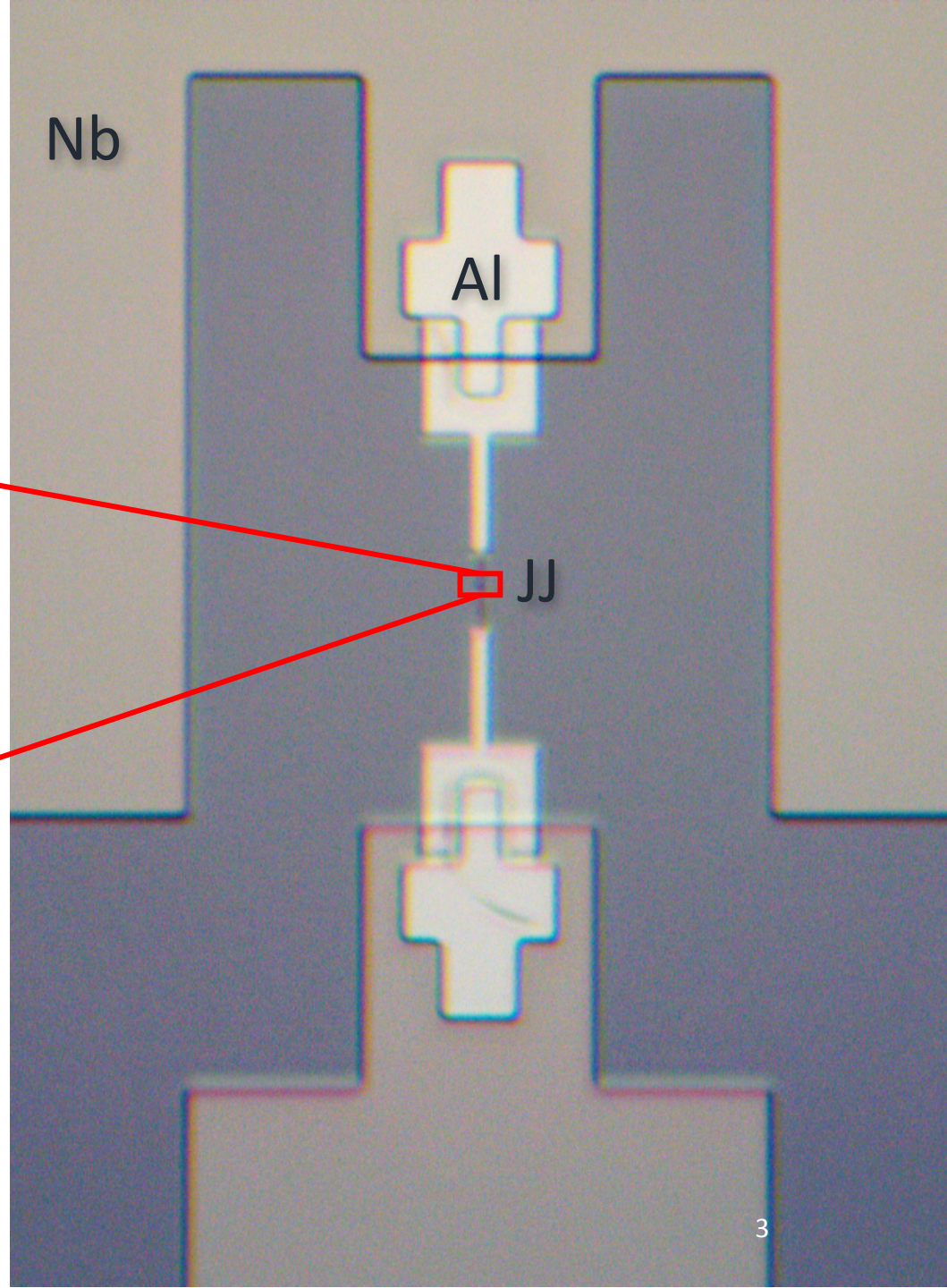
- Test **simulation/measurement** agreement
- Verify the ability to **control the qubit** state
- Measure the **coherence times**
- Measure qubit/cavity **couplings**
- Test **qubit tunability** and **mutual inductance**



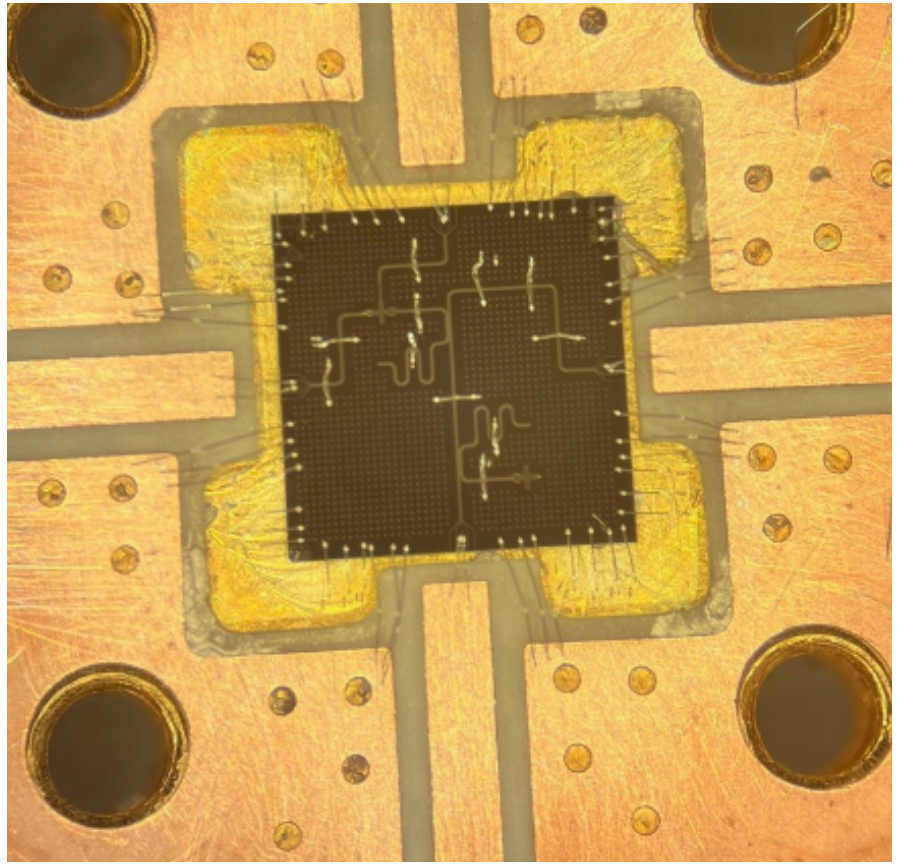
Qubit fabrication @ NIST

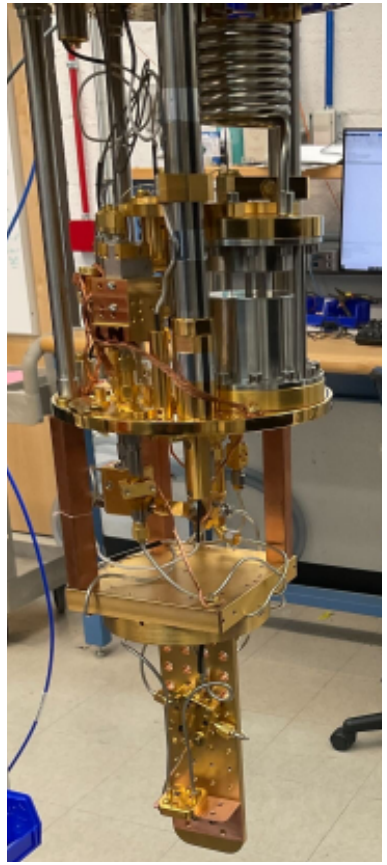
- Substrate: 380 nm high-resistive silicon
- Metal: 100 nm **Niobium**
- Junctions: **Al-AlOx-Al**
- Niobium etched also in the JJ area

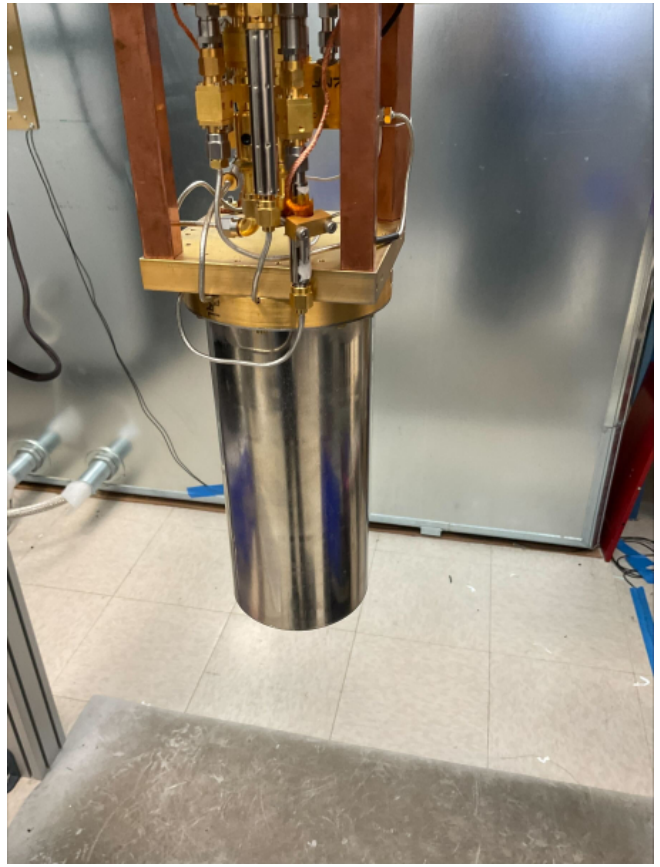




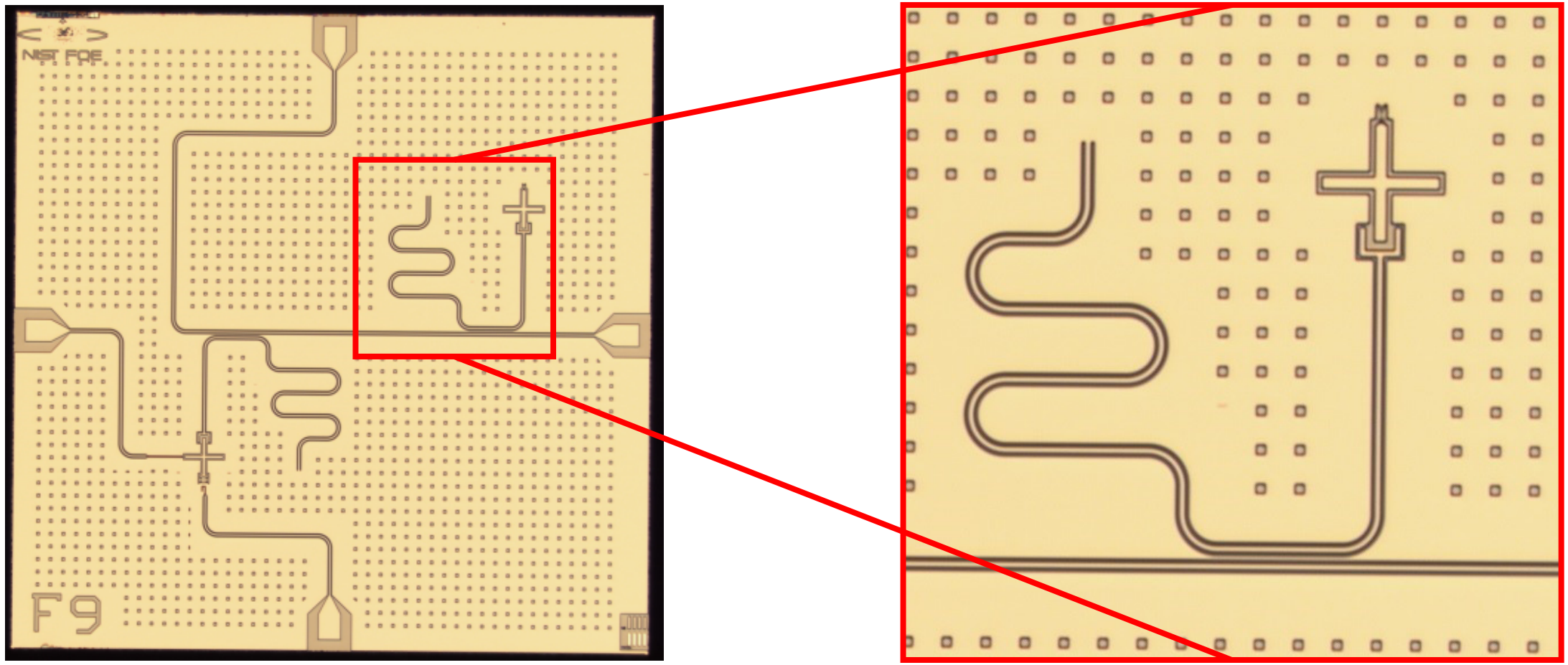
Qubit measurements @ NIST







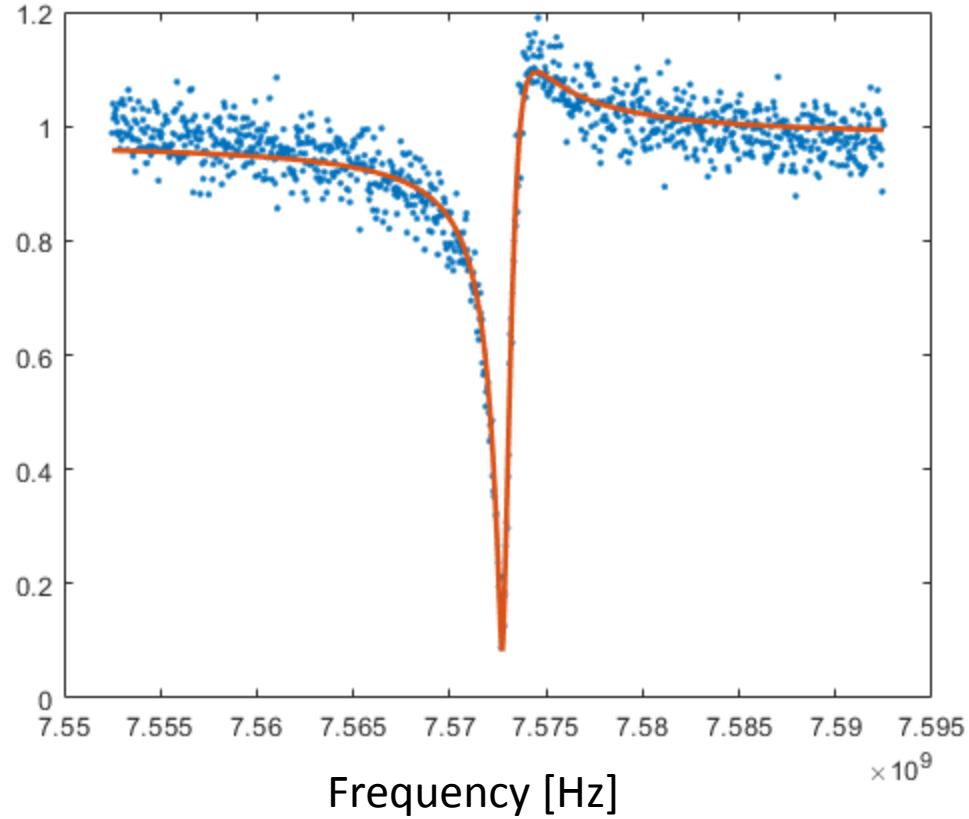
Single JJ qubit



Single JJ qubit – Cavity spectroscopy

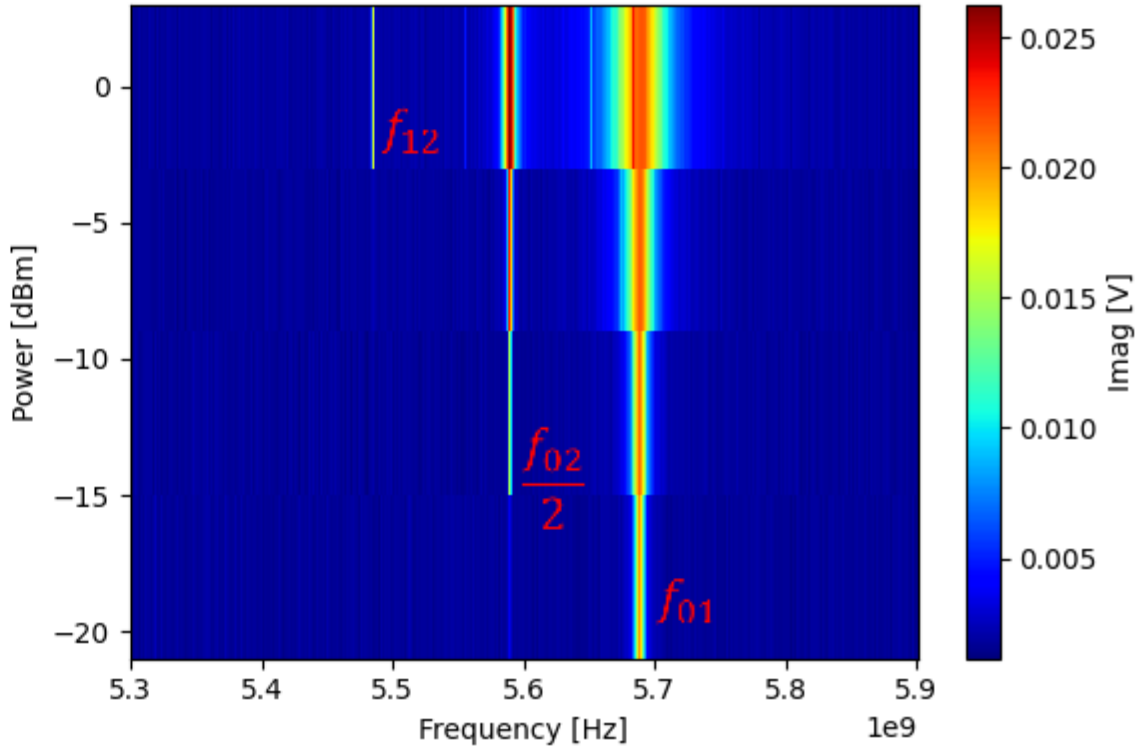
- $f_r = 7.573\ GHz$
- $Q_i = 5.624 \times 10^4$
- $Q_C = 5.063 \times 10^3$
- $\phi = -0.5099\ rad$
- $A = 0.9759$

Low internal quality factor: suspects on this wafer because of other design showing same problems



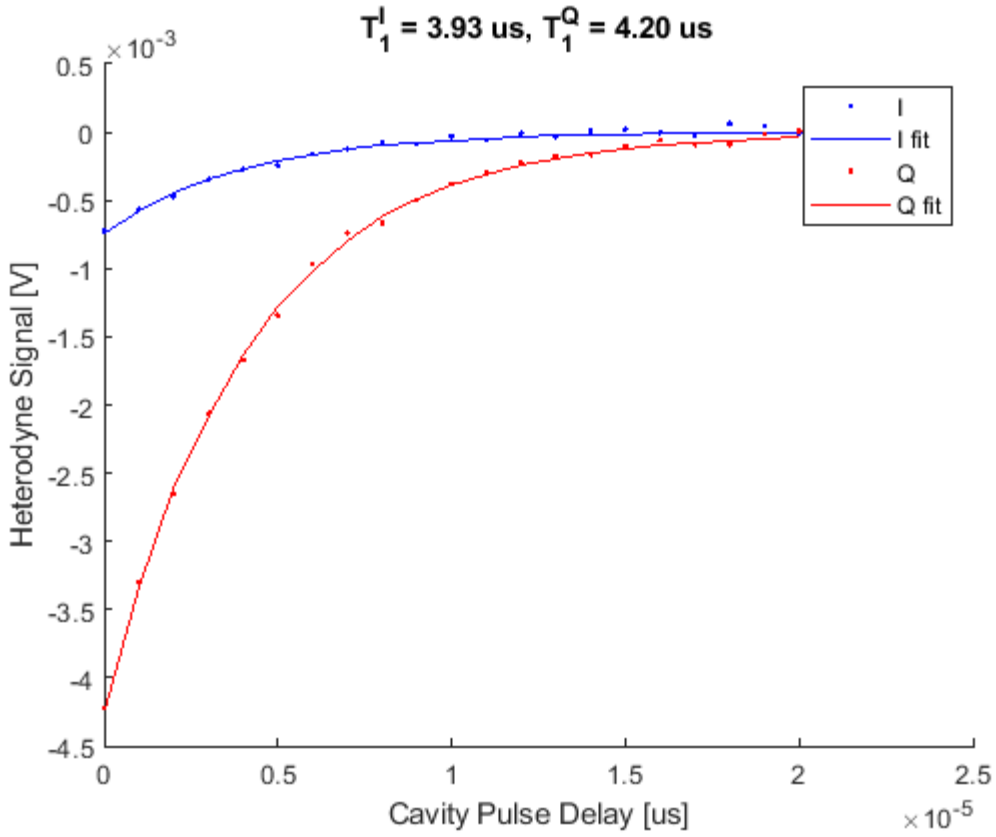
Single JJ qubit – Qubit spectroscopy

- Val = Measured (LOM closest frequency)
  - $f_{01} = 5.689\ GHz\ (5.682 GHz)$
  - $\frac{f_{02}}{2} = 5.589\ GHz\ (5.579\ GHz)$
  - $f_{12} = 5.485\ GHz\ (5.476\ GHz)$
  - $\frac{\alpha}{2\pi} = -204\ MHz\ (-206\ MHz)$
  - $L_J = 7.641\ nH\ (7.2\ nH)$

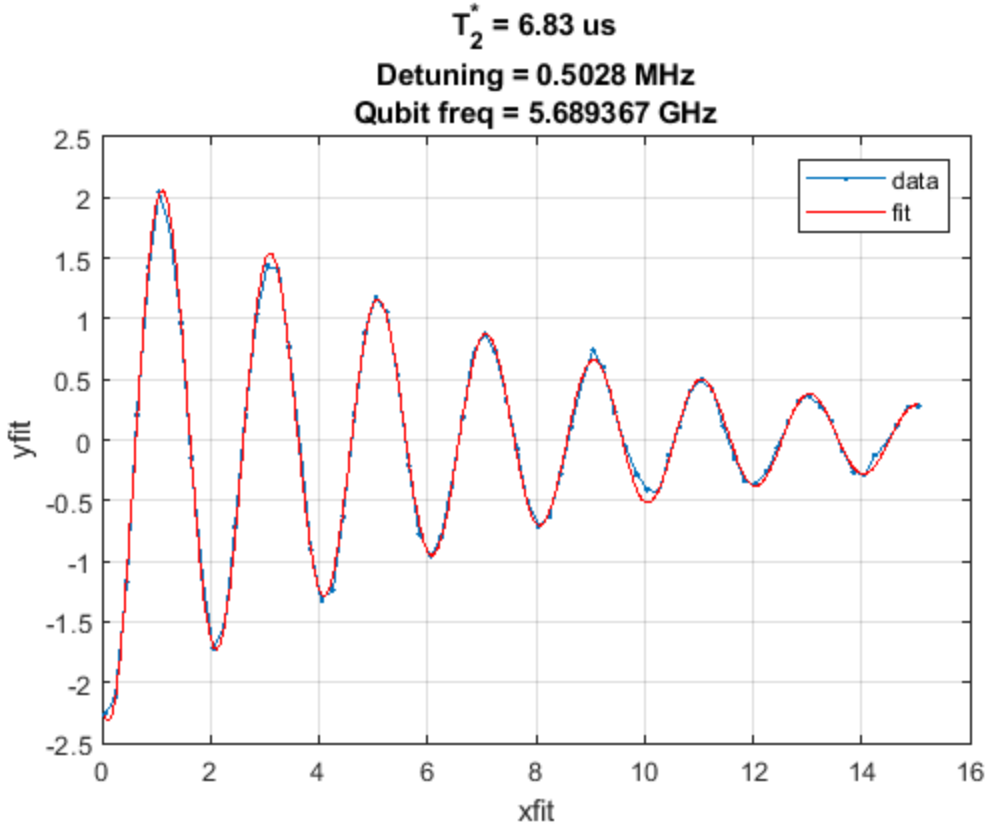


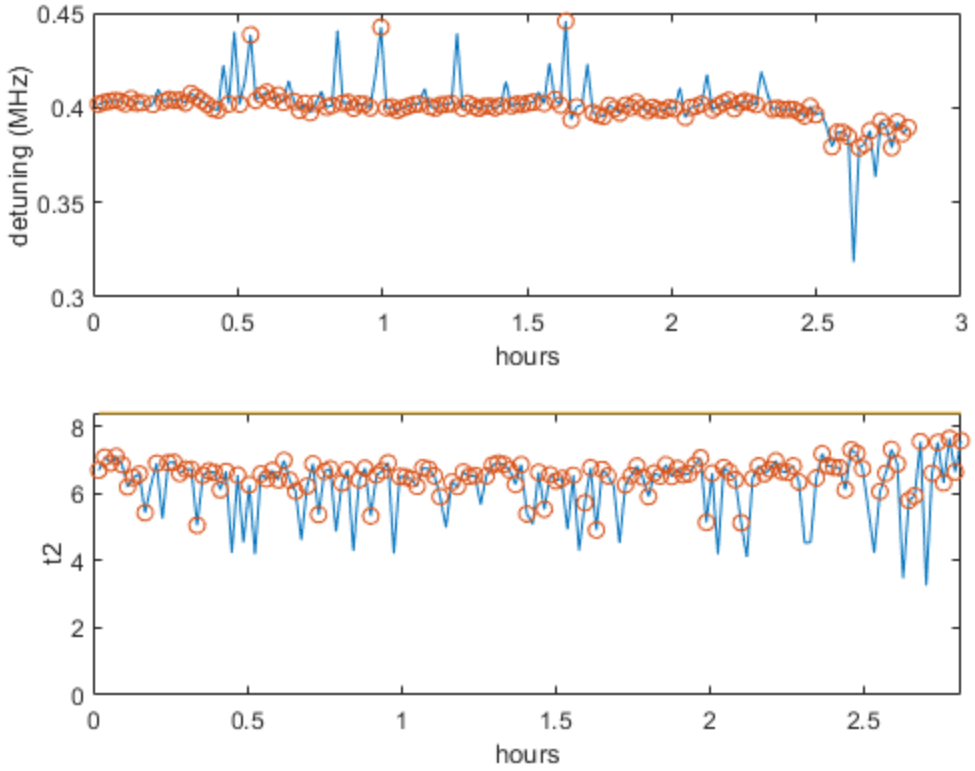
Single JJ qubit – T_1 measurements

- Low T_1 related to low Q_i, suspected fabrication issue
- Different designs showed the same issue
- Expected T_1 from Purcell should be about 40 us
- New production will be done

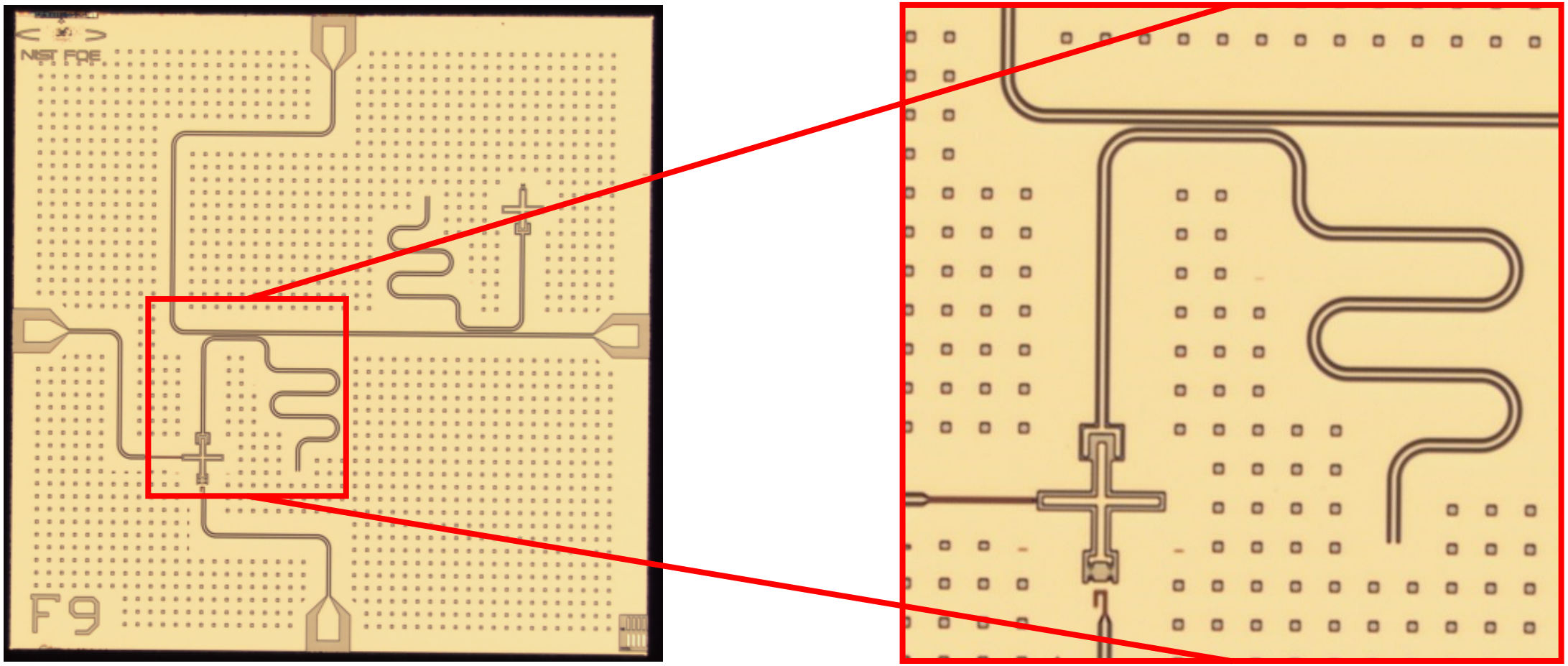


Single JJ qubit – T_2 measurements





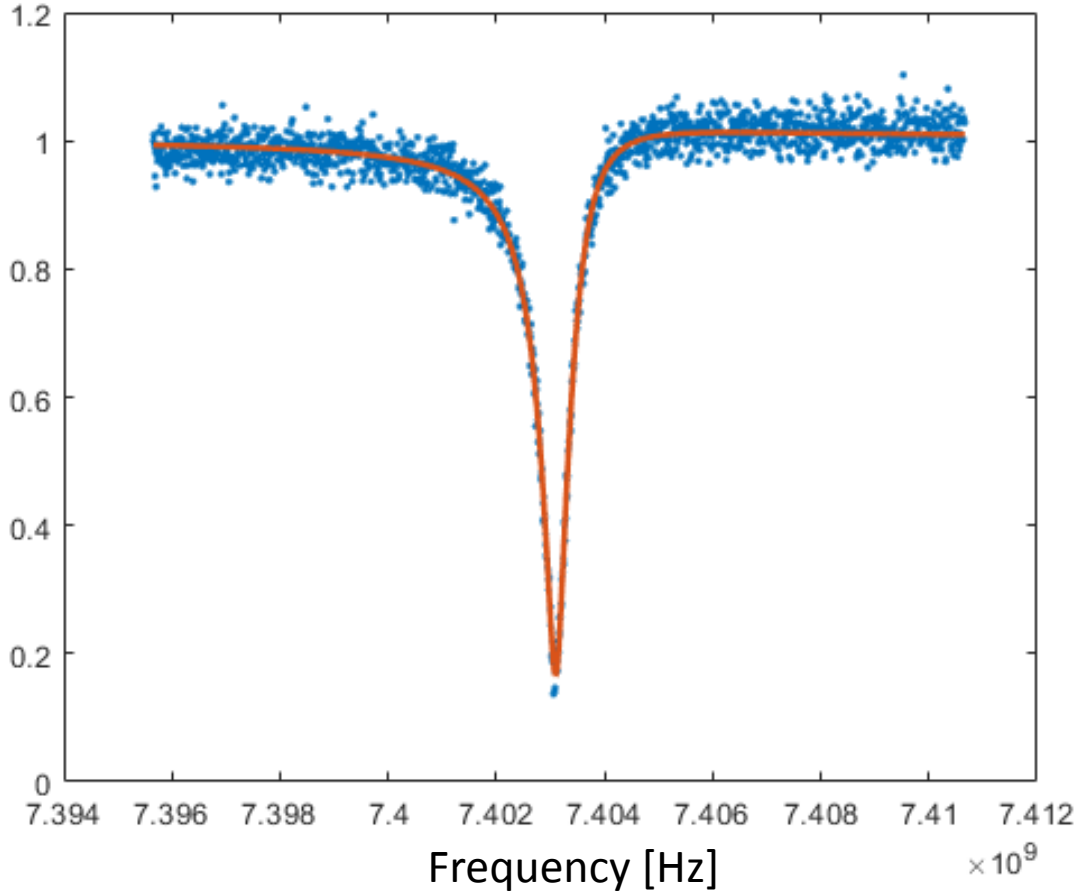
SQUID qubit



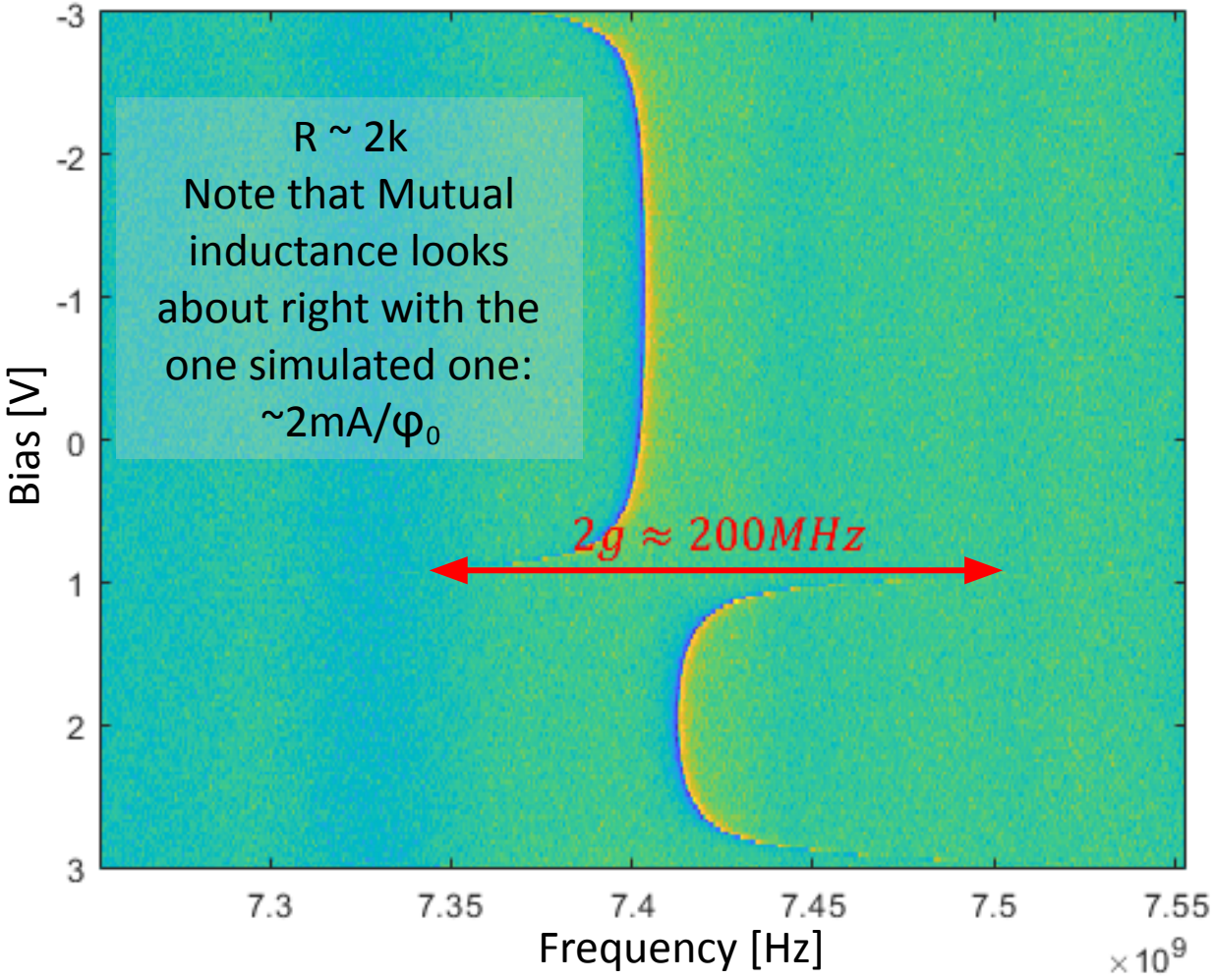
SQUID qubit – Cavity spectroscopy

- $f_r = 7.403\ GHz$
- $Q_i = (4.927 \pm 0.339) \times 10^4$
- $Q_C = (9.673 \pm 0.124) \times 10^3$
- $\phi = -0.1634 \pm 0.078\ rad$
- $A = 1.003 \pm 0.001$

Low internal quality factor: suspects on this wafer because of other design showing same problems

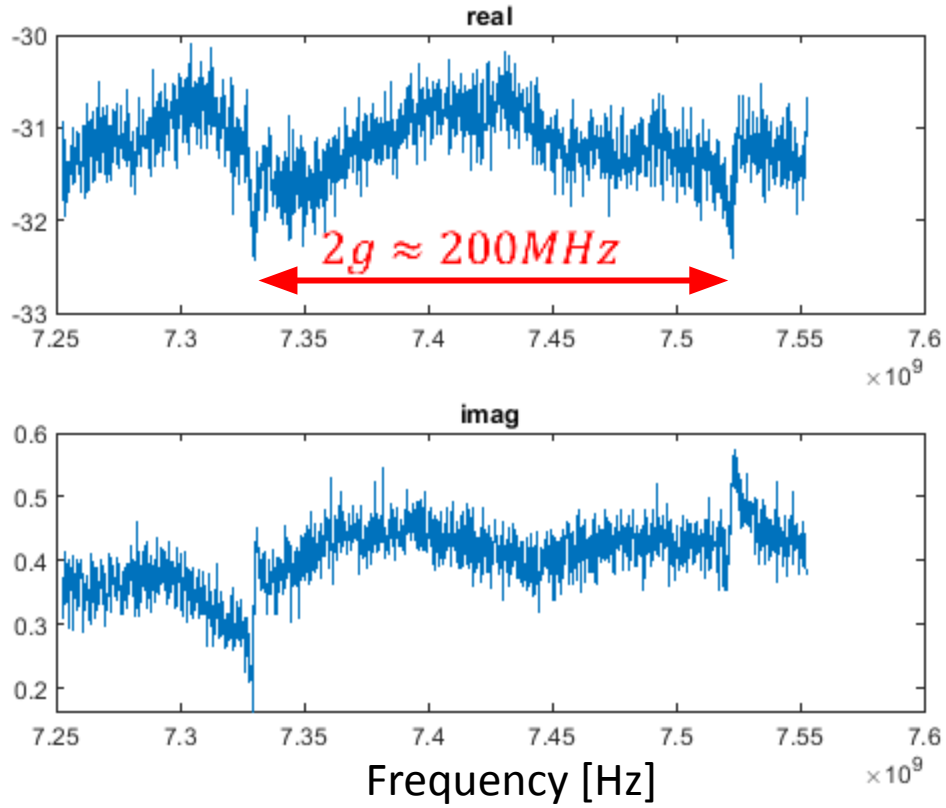


SQUID qubit – Cavity spectroscopy



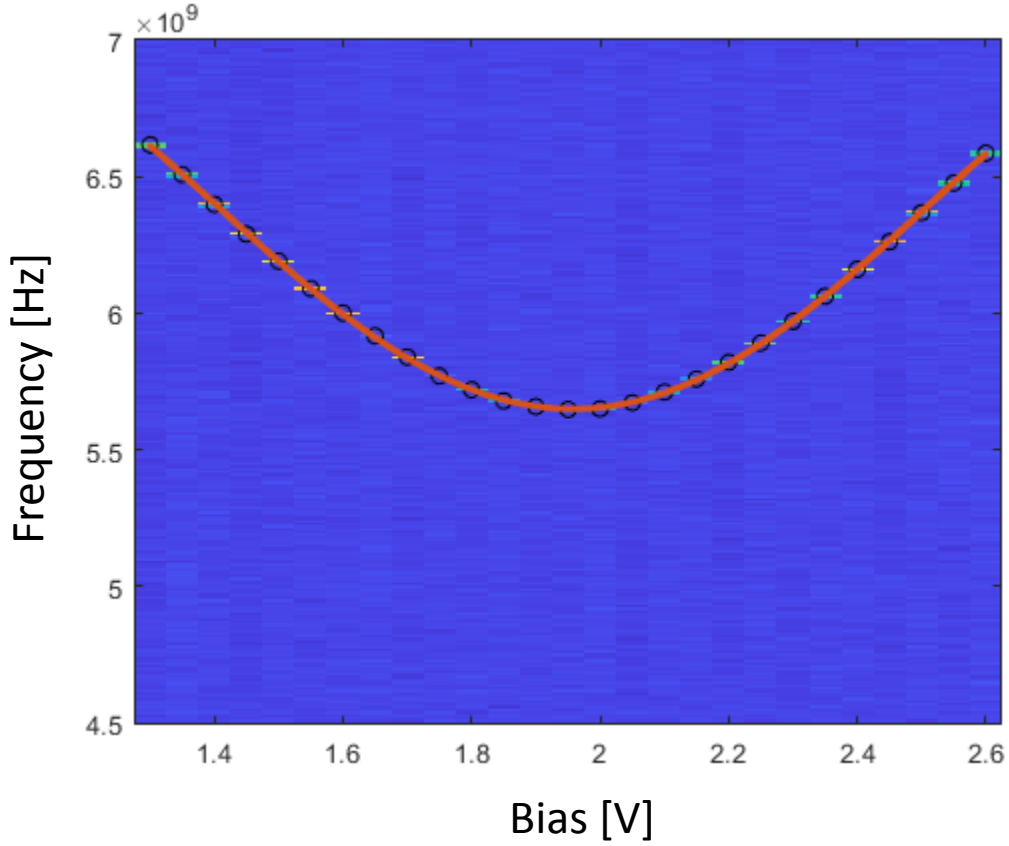
LOM: Look for the quarter-wave resonator (factor of 2)

$g_{EPR} = 104\ MHz\ \ g_{LOM} \approx 49\ MHz$

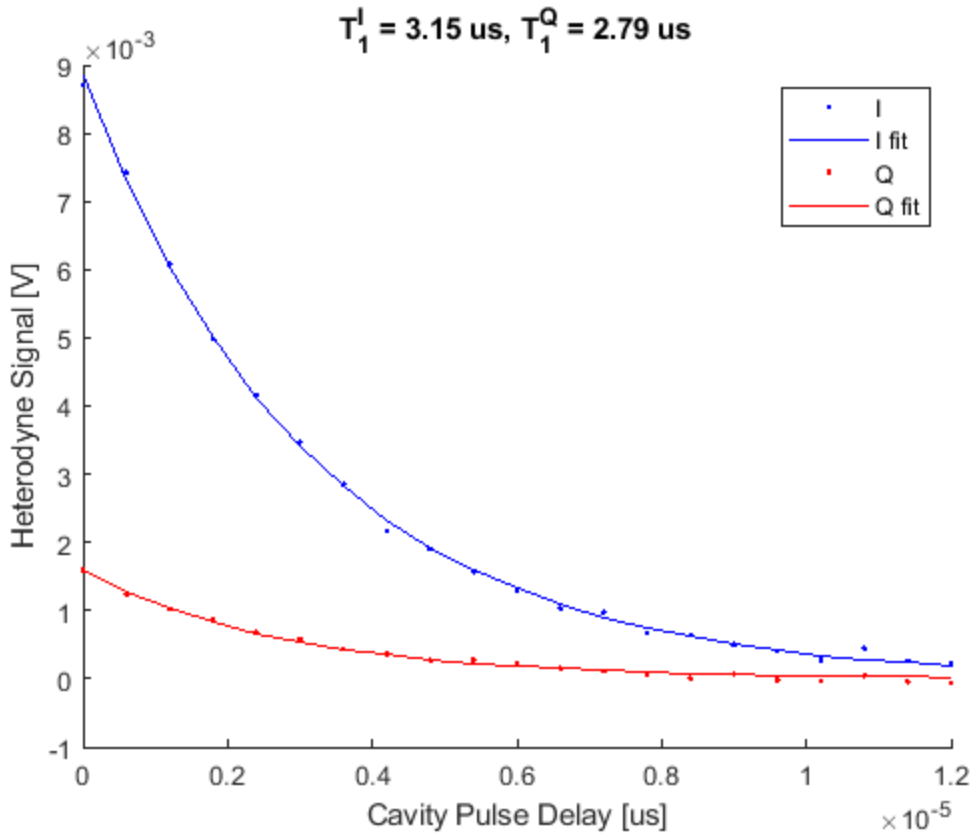


SQUID qubit – Qubit spectroscopy

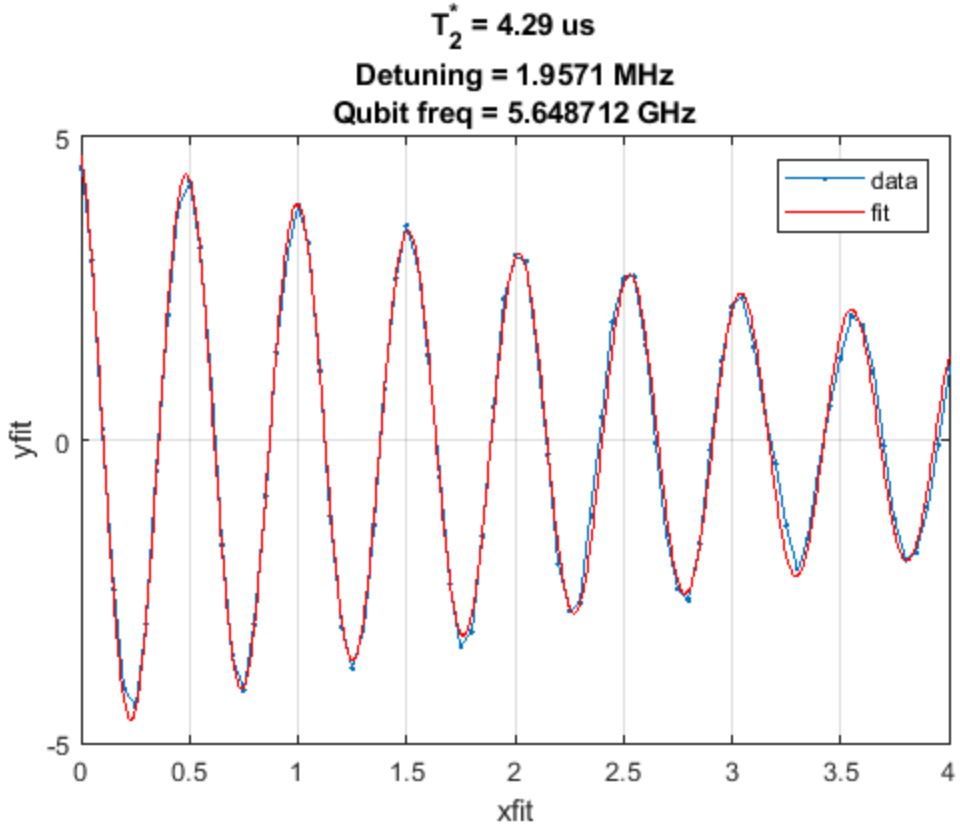
- Val = Measured (LOM closest frequency)
- $f_{01}^{MIN} = 5.649\ GHz\ (5.649\ GHz)$
- $L_J = 8.364\ nH\ (7.9\ nH)$

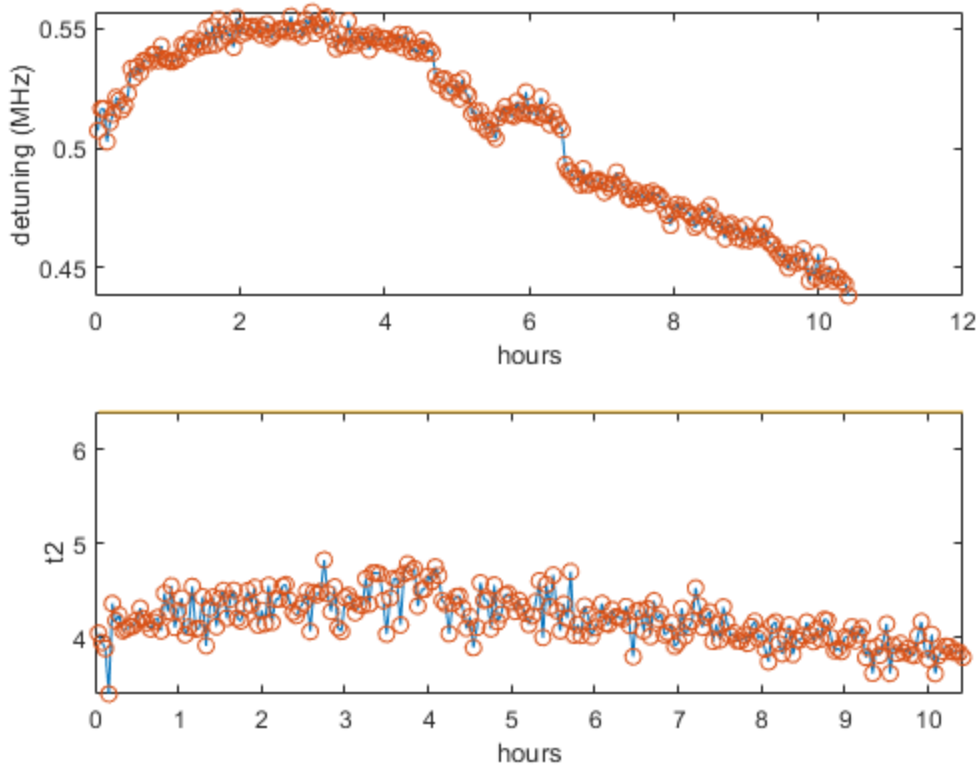


SQUID qubit – T_1 measurements



SQUID qubit – T_2 measurements

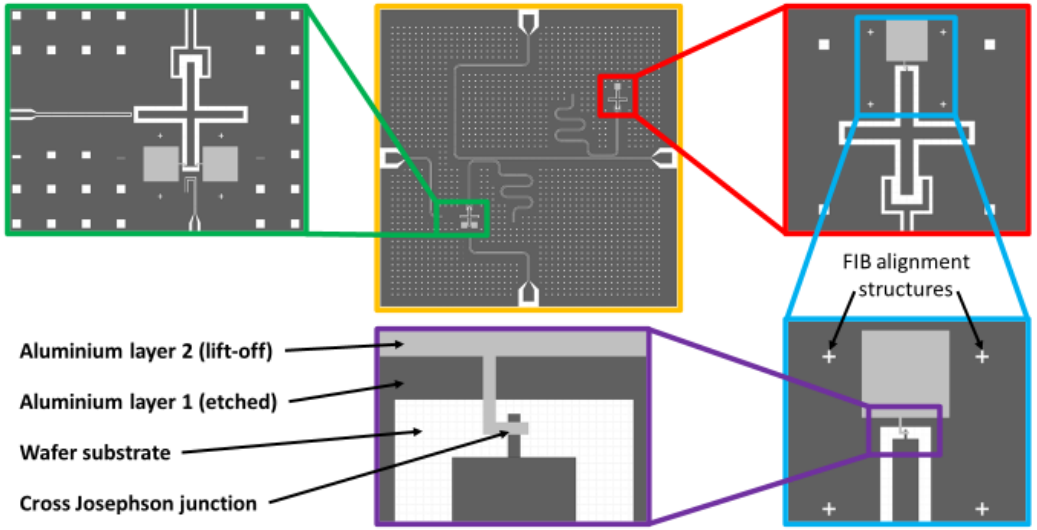




Design adapted for qubit fabrication @ FBK

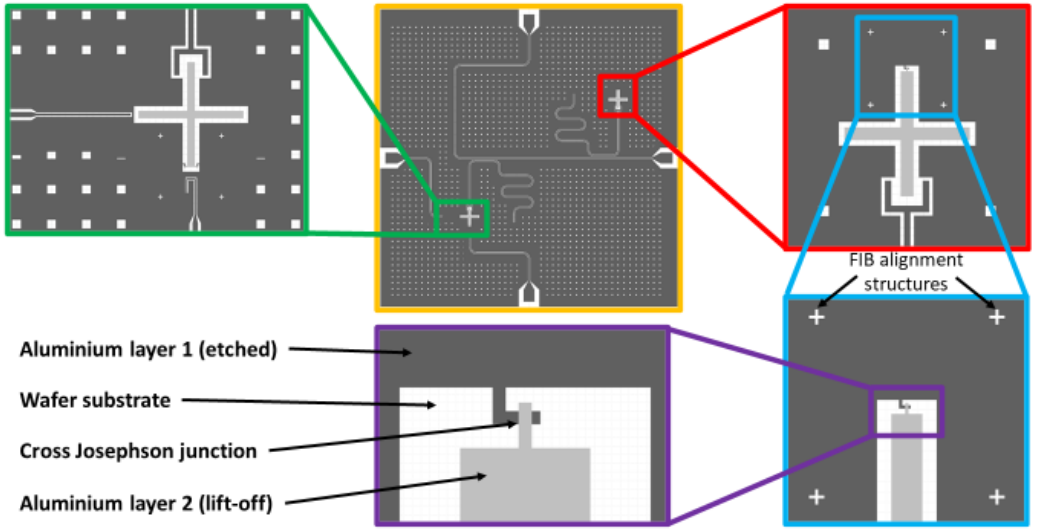
Qubit design adapted to FBK fabrication process – design 1

Cross-JJ area limited to ≥ 3x3 μm^2 (mask lithography @ FBK)
→ use Focused Ion Beam (FIB) to reduce JJ area after production



Qubit design adapted to FBK fabrication process – design 2

Cross-JJ area limited to ≥ 3x3 μm^2 (mask lithography @ FBK)
→ use Focused Ion Beam (FIB) to reduce JJ area after production



Conclusions and future perspectives

- Simulations and measurements are in **good agreement**
- All predicted **frequencies and couplings** are close to the measured ones
- **New wafer production** will be done to confirm low T1 and Qi was due to fabrication and not design issue (note: contribution could also come from fridge grounding, to be investigated)
- **Flux line** contribution to dissipation could be an issue, we may need to investigate it more
- Same design was adapted for **FBK fabrication**
- **Coupled qubits** design is under development