Qub-IT

Fabrication of Resonators & JPAs

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24/11/2022

Designs: Stepper reticle QubIT-1, Resonators

- Resonators (14 designs, one layer each)

Die name	Size	Description
GPL2_Meander_10700_1+1dig	5 x 2.5 mm^2	$\lambda/2$ resonator 10.7 mm → $f_r \sim$ 5.5 GHz, IDC coupling (1+1 digits) → Cc ~ 3.6 fF
GPL2_Meander_10700_2+2dig	5 x 2.5 mm^2	$\lambda/2$ resonator 10.7 mm → $f_r \sim$ 5.5 GHz, IDC coupling (2+2 digits) → Cc ~ 10.9 fF
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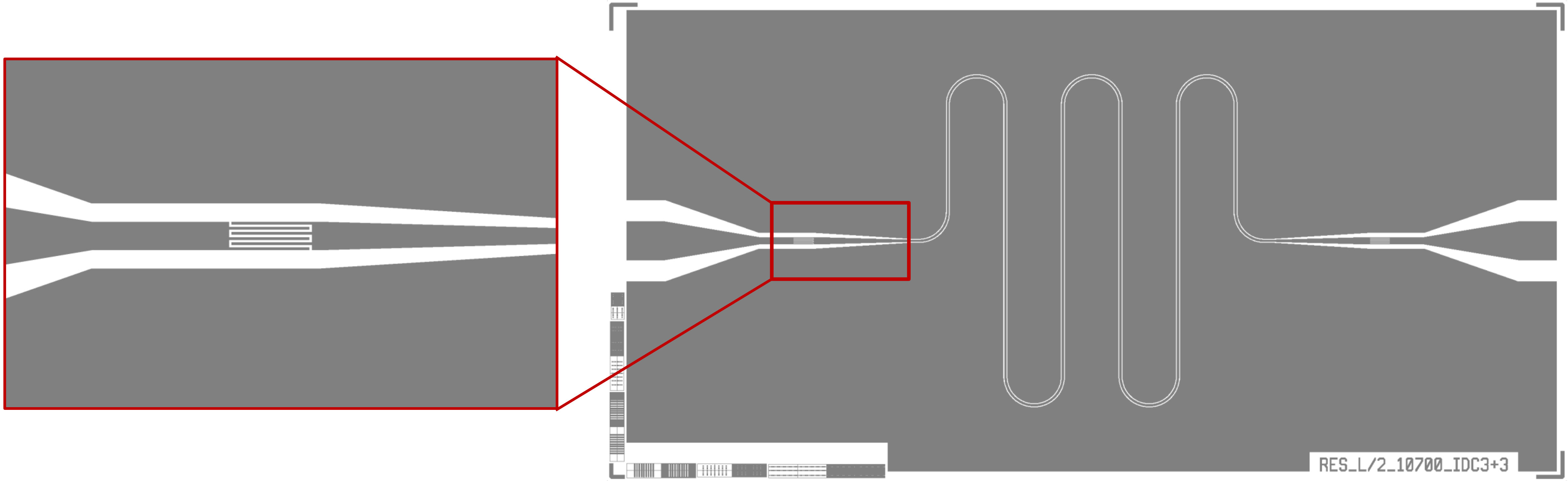

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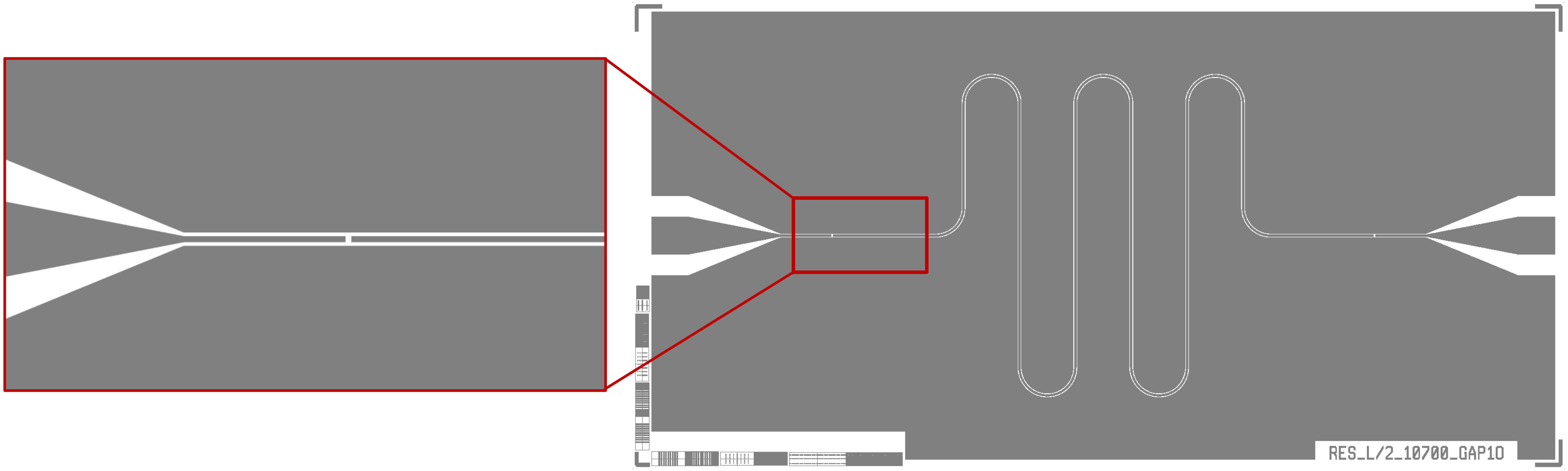

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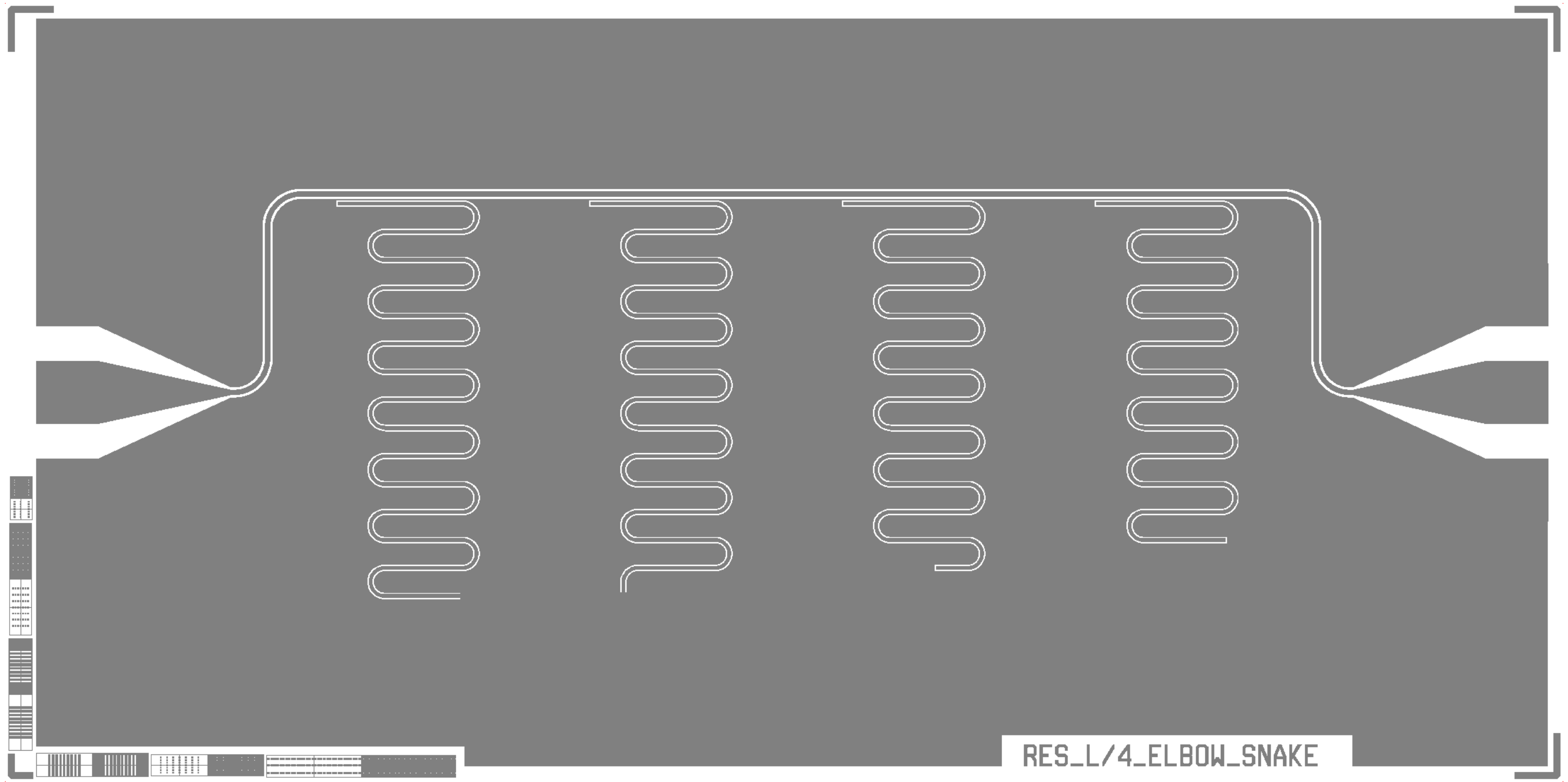

f_0 [GHz]	l_{elb}[um]	C [fF]	f_r [GHz]	Q_C	L [mm]	bw [kHz]
5.01	400	1.82	5.00	192335	5.8733	26.0
5.26	400	1.82	5.25	174519	5.5941	30.1
5.51	400	1.82	5.50	159070	5.3403	34.6
5.76	400	1.82	5.75	145588	5.1085	39.5

$$f_r = \frac{f_0}{1 + 4f_0CZ} \; with \; Z = 50\,\Omega$$

$$Q_C = \frac{\pi}{2Z^2(2\pi f_r C)^2}$$

$$bw = \frac{f_r}{Q_C}$$

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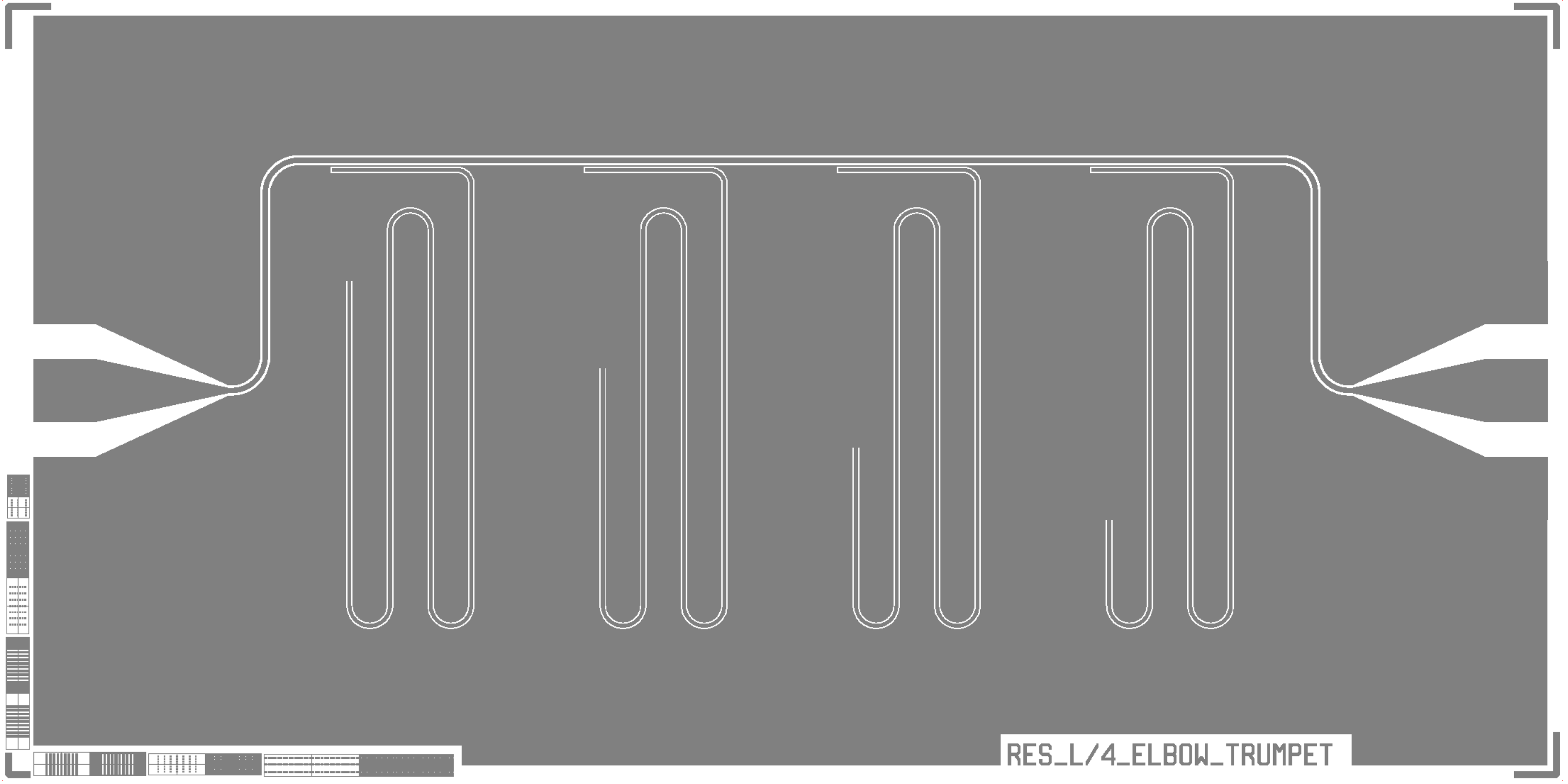

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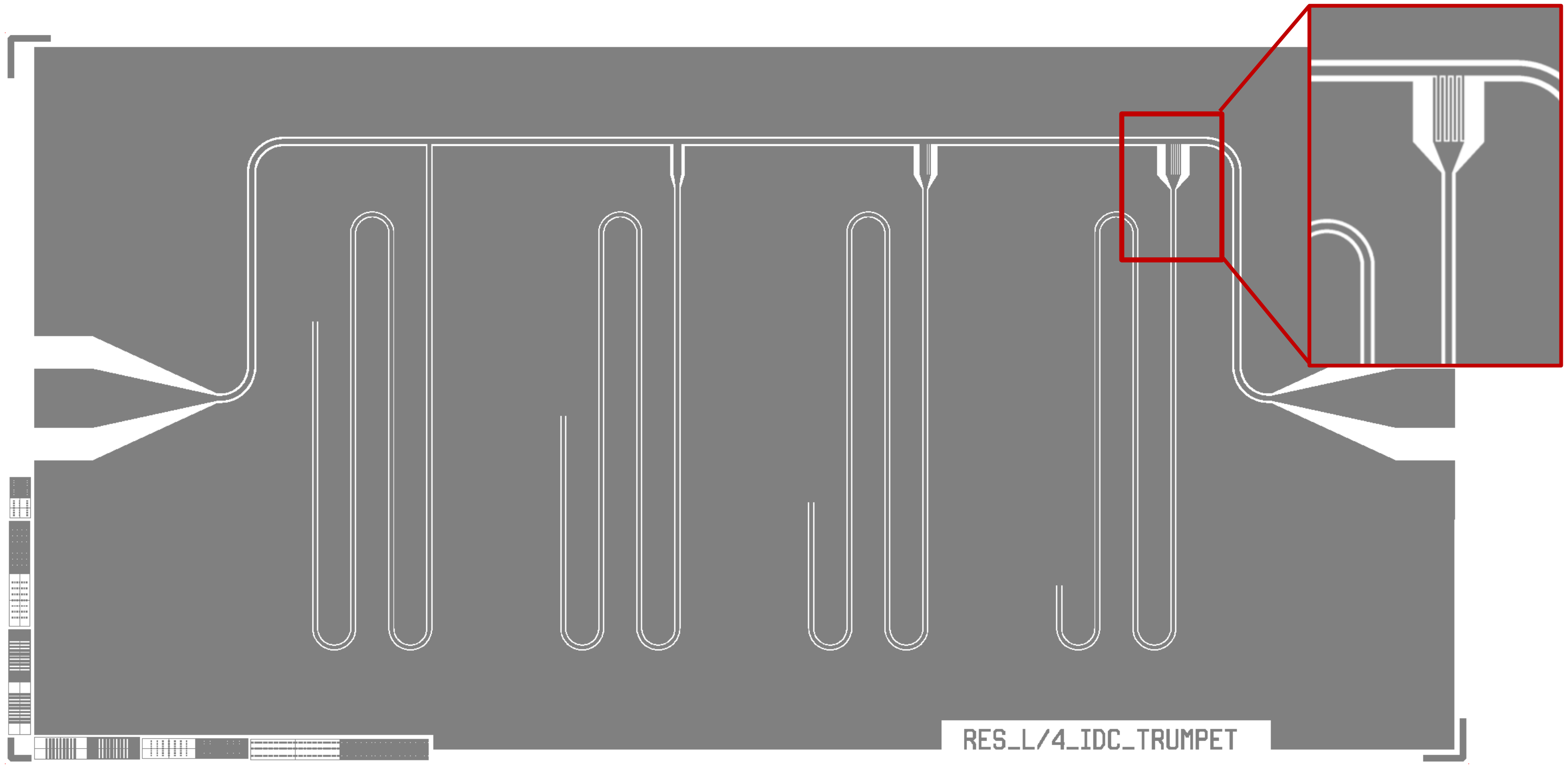

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5.02	1+1	3.98	5.00	40189	5.8616	0.124
5.31	2+2	11.30	5.25	4527	5.5414	1.159
5.61	3+3	18.00	5.50	1625	5.2451	3.385
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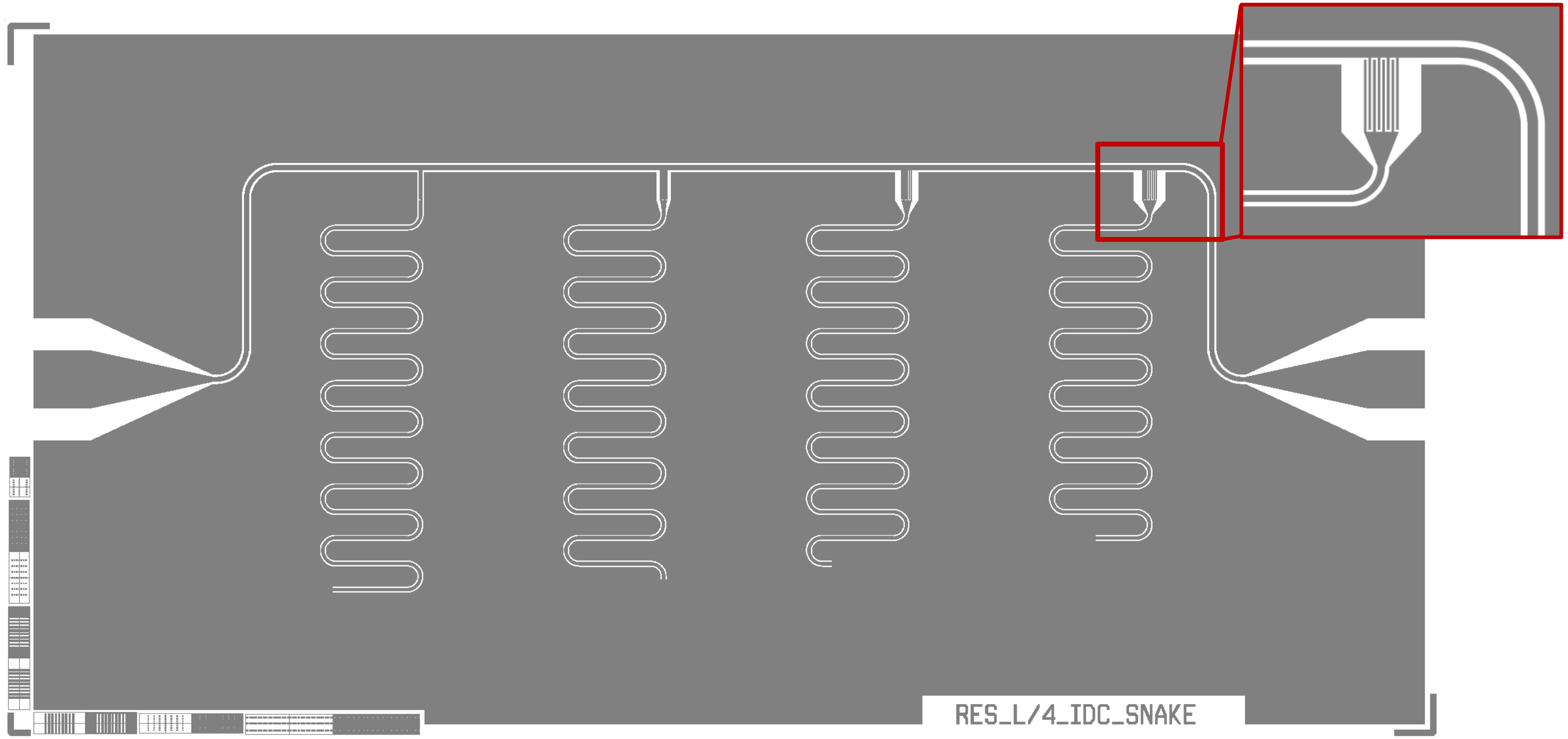

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GPL2_Multiple_Elbow_w10	5 x 2.5 mm^2	4 λ/2 resonators, f_r ~ 5.0, 5.25, 5.5, 5.75 GHz, elbow coupling → 0.3 < Cc < 0.6 fF, w=10 μm
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GPL2_Multiple_Elbow_w3

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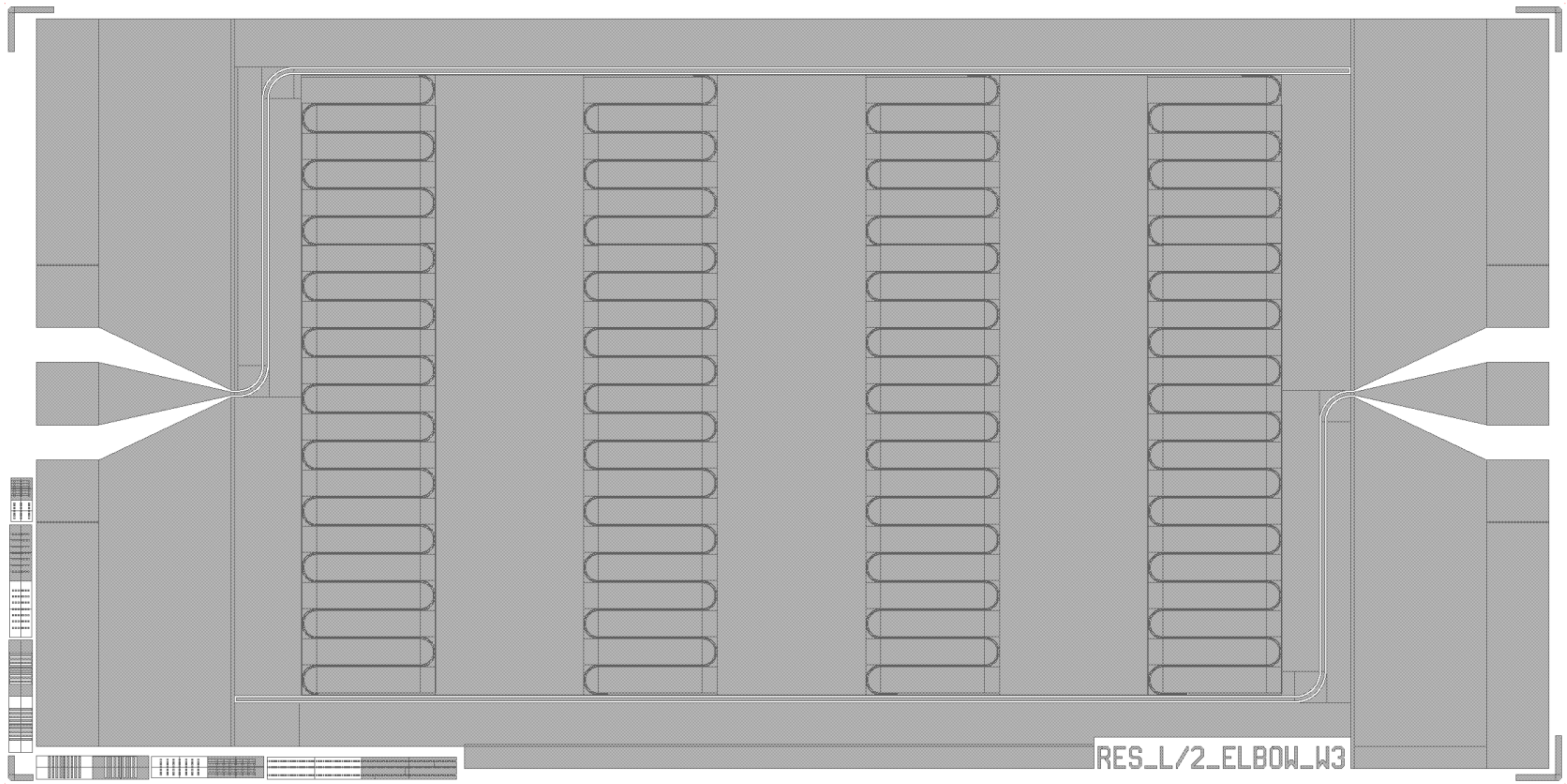
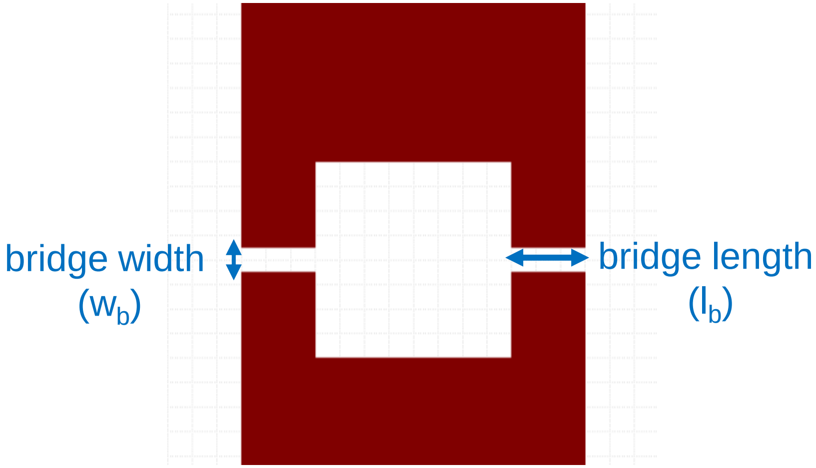


L [mm]	f_0 [GHz]	C [fF]	Elbow length [um]
11.77	5.00	0.30	1.75
11.21	5.25	0.40	26.75
10.70	5.50	0.50	51.75
10.23	5.75	0.60	76.75

Designs: Stepper reticle QubIT-1, Flux-JPAs

- Flux JPAs (3 designs, two layers each)

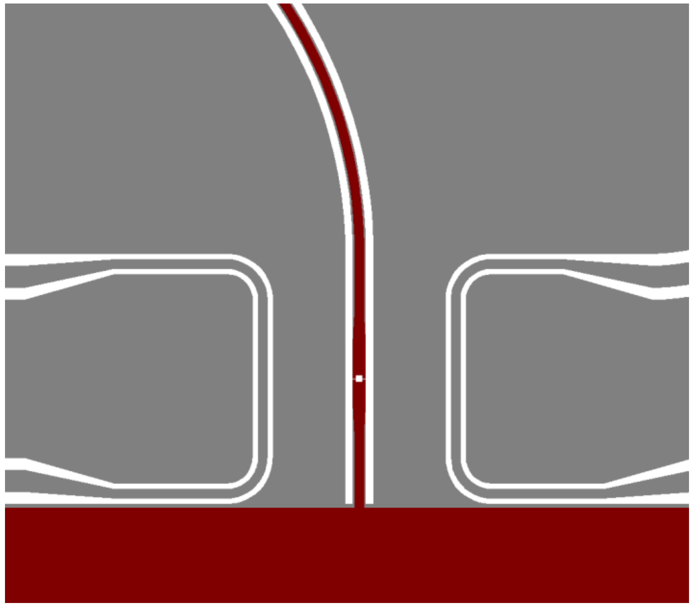
Die name	Size	Description
JPA-4	10 x 2.5 mm^2	Two JPAs, IDC coupling (3+3 dig.), $f_r \sim 8$ GHz, Junctions bridge: l = 1.5 μm, w = 0.5 μm, 0.6 μm, design “Delsing”
JPA-5	10 x 2.5 mm^2	Two JPAs, IDC coupling (3+3 dig.), $f_r \sim 8$ GHz, Junctions bridge: l = 1.5 μm, w = 0.5 μm, 0.6 μm, design “Nakamura”
JPA-6	10 x 2.5 mm^2	Two JPAs, IDC coupling (3+3 dig.), $f_r \sim 5.6$ GHz, Junctions bridge: l = 1.5 μm, w = 0.5 μm, design “Nakamura”



Junction area: $A = l_b \times w_j$

Larger w_b → smaller w_j

Design “Delsing”



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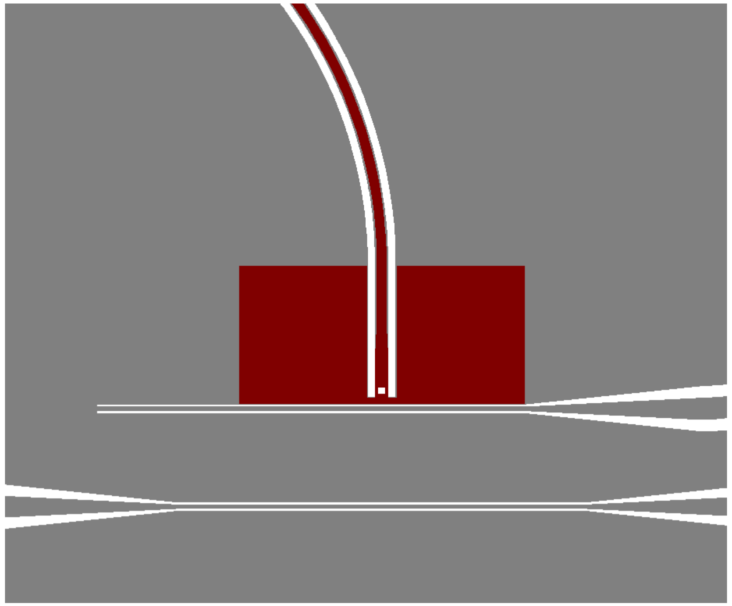


Designs: Stepper reticle QubIT-1, Flux-JPAs

→ Open gds files!

Fabrication steps

1. Substrate: Si 625 μm
2. Dry oxide (~ 50 nm)
3. Al layer 1: rf-sputtering, thickness: 150 nm
4. Al layer 2 (with Josepghson junction): evaporator

   Al layer 2a: thickness: 50 nm

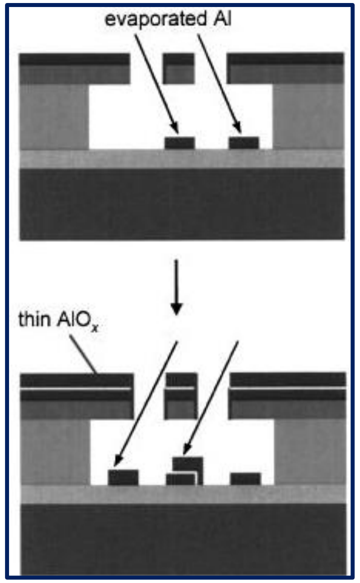
   Tilting

   Oxidation

   Al layer 2b: thickness: 60 nm

Dolan technique:

- Bilayer photoresist stack (LOR+positive) with undercut
- Tilting of for double angle evaporation



Fabrication: Run QT-1

- Wafer w1 (→ fabricated and measured)

  Wafer layout: all JPAs, all resonators from reticle QubIT-1 + dc-SQUIDs (reticle cQED-1)

  Junction fabrication: oxidation with p = 2 Pa, t = 2'24'', angle = 30°

  Expected junction areas (according to SEM pictures from other fabrications):
  JPA, bridge 0.5 μm: $A_{JJ} \sim 0.57\ \mu m^2$
  JPA, bridge 0.6 μm: $A_{JJ} \sim 0.35\ \mu m^2$

- Run QT-1, wafer w2-w4 → waiting for junction fabrication (2nd Al layer)

- Measurements at room temperature of QT-1 w1 (needle-prober):

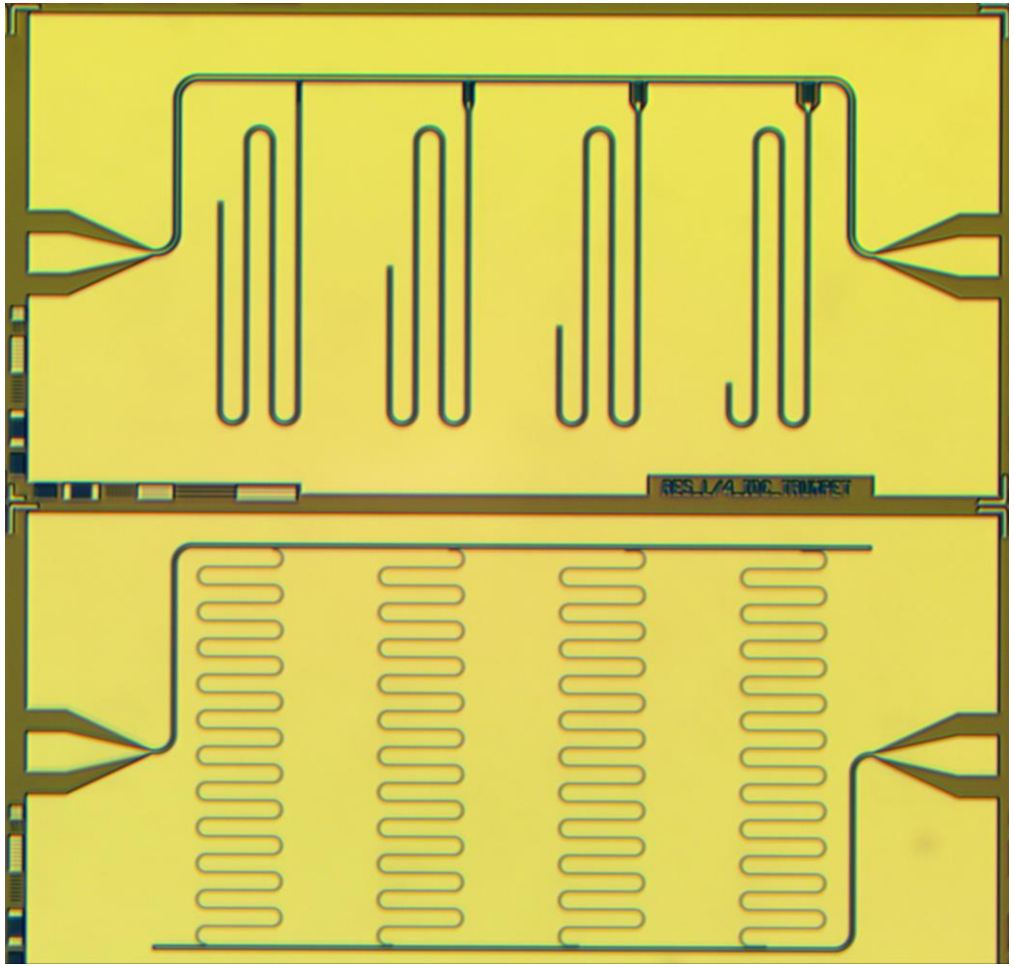
  $R_{SQ} \sim 173\ \Omega\mu m^2$ → $R_{JJ} \sim 346\ \Omega\mu m^2$ (from dc-SQUIDs)
  → JPA, bridge 0.5 μm: $R_{SQ\text{-}JPA} = 303.3\ \Omega$ → $I_c = 0.93\ \mu A\ (*)$
  → JPA, bridge 0.6 μm: $R_{SQ\text{-}JPA} = 501.2\ \Omega$ → $I_c = 0.56\ \mu A\ (*)$

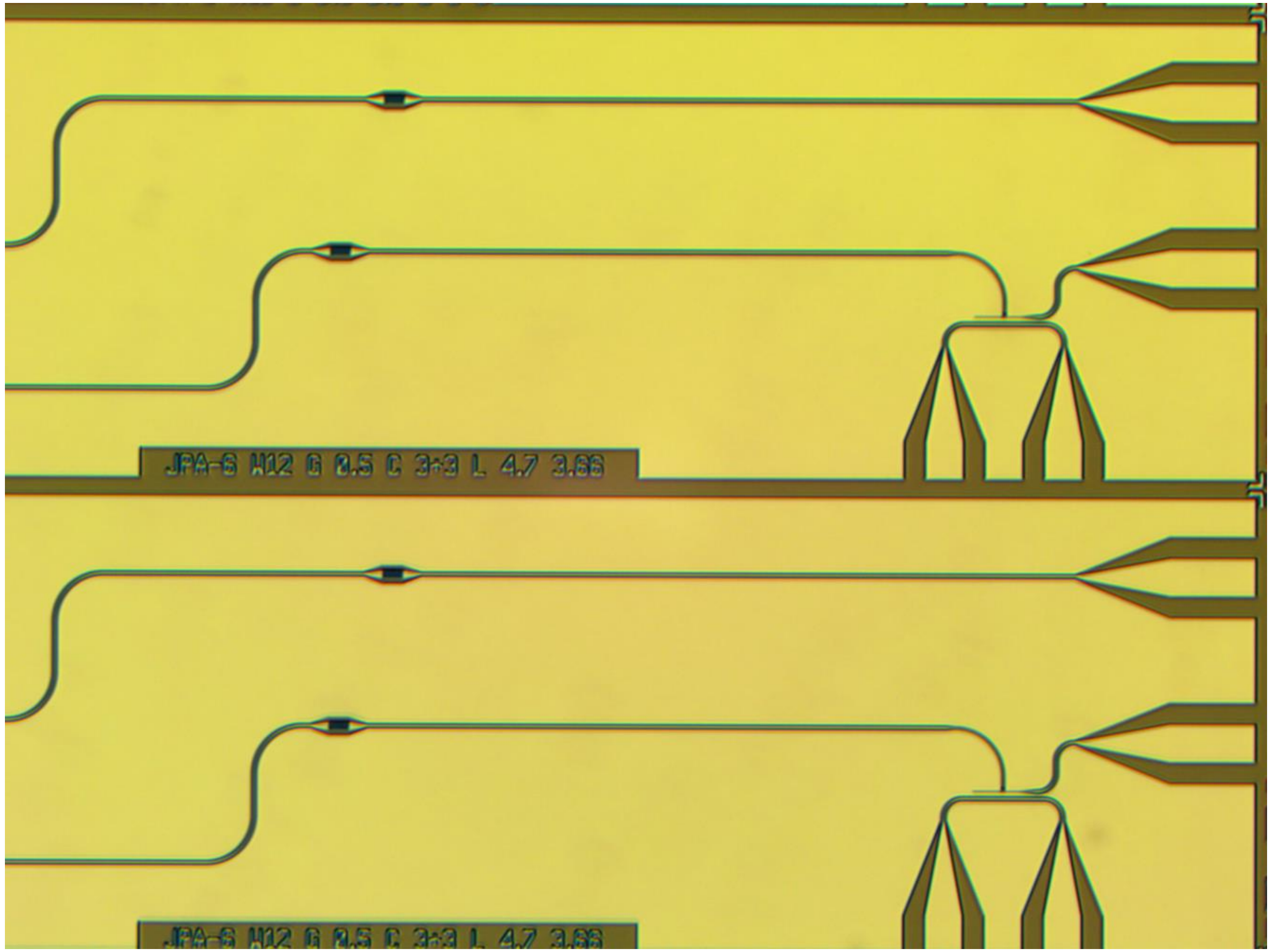
  Plan: direct measurement of I_c ("shorted" JPA) to check the validity of the formula $(*)\ I_c R \approx \pi/4 \cdot V_{gap}$

- Measurements at millikelvin → slides by Andrea Vinante

Note: Possible design improvement: resonator only on single Al layer (see gds)

Run QT-1: Pictures (Al-bottom)





Run QT-1: Pictures (Al-bottom + Al-top)