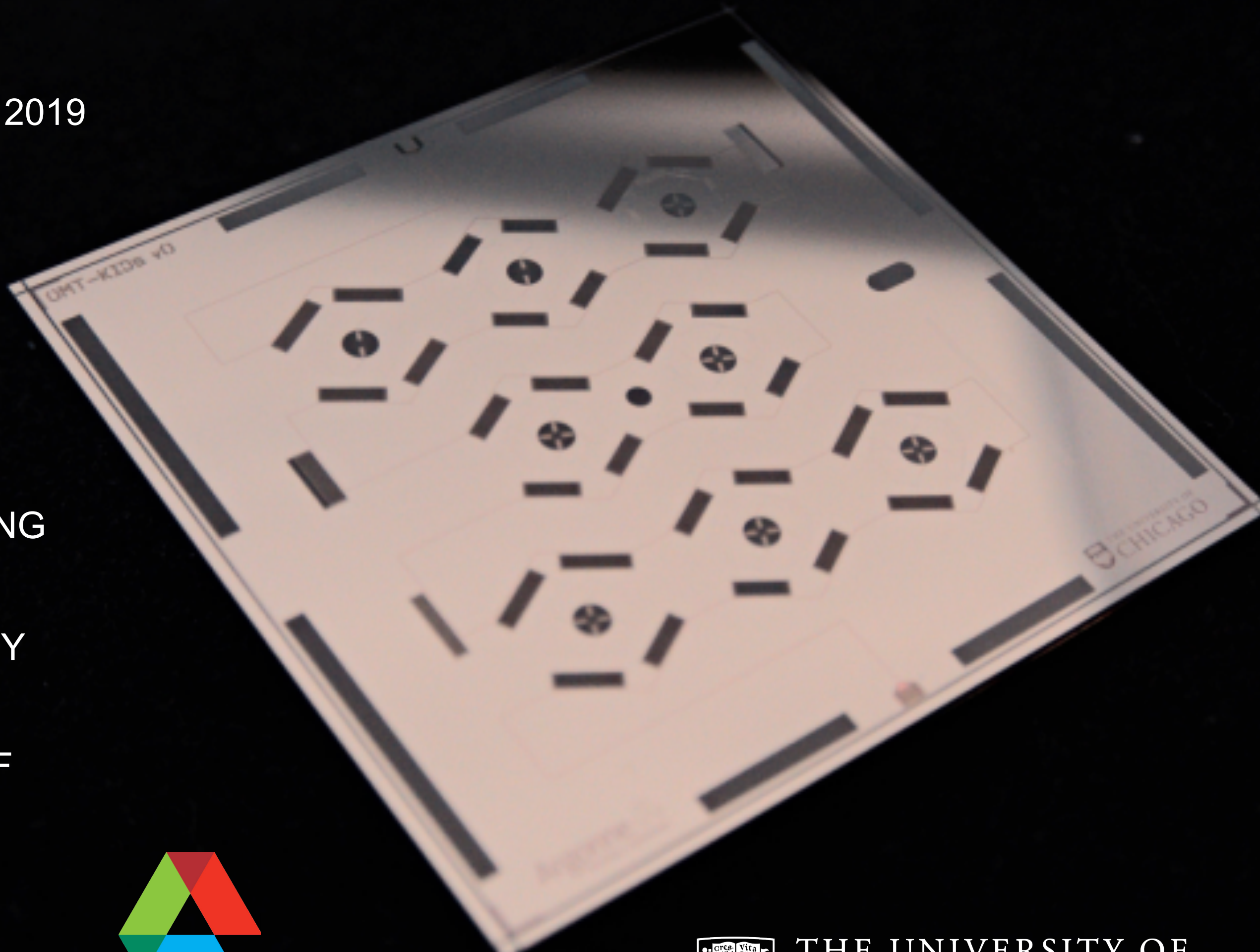
DESIGN AND OPTIMISATION OF THE MICROSTRIP-COUPLED LUMPED-ELEMENT KID

LTD18 – 22nd July 2019



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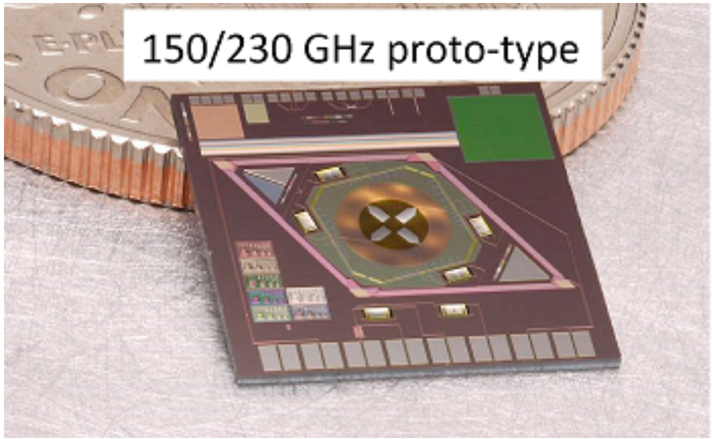
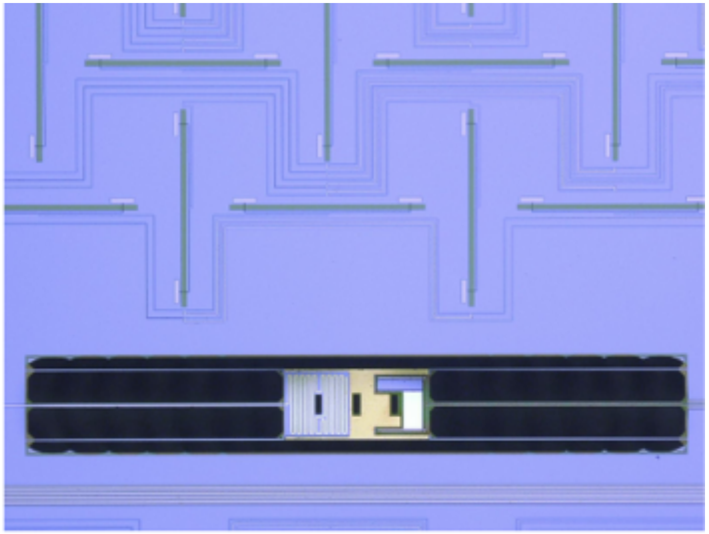
SOME CONTEXT…

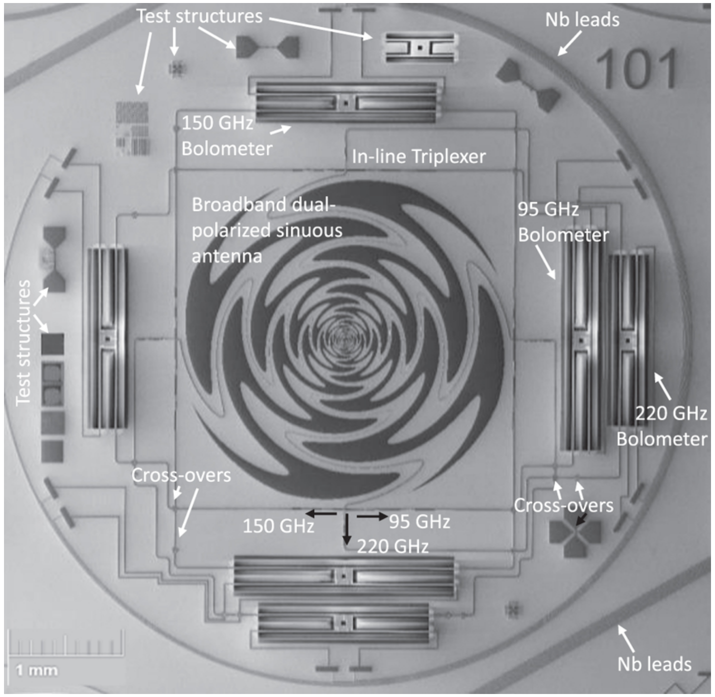
- Motivation: want simple, drop in replacement for TES for multi-chroic detector arrays
- Challenging to readout fully sampled focal planes with TES arrays at high frequency



Adv ACTpol (NIST)



BICEP/KECK (JPL)



SPT-3G (ANL)

SOME CONTEXT…

- Motivation: wanted simple, drop in replacement for TES for multi-chroic detector arrays
- Challenging to readout fully sampled focal planes with TES arrays at high frequency
- **Example (CMB-S4 DSR RD)**:

Bands	Lenses	Field of view	Min. edge taper	Modulation (Pole/Chile)	Detectors / tube	Tubes
30 / 40	2× 55 cm Al	29°	−9.3 dB	scan	576	2
85 / 145	2× 55 cm Al	29°	−6.2 dB	scan / HWP	7048	6
95 / 155	2× 55 cm Al	29°	−8.4 dB	scan / HWP	7048	6
220 / 270	3× 44 cm Si	35°	−13.4 dB	scan / HWP	16876	4
				total:	153,232 detectors, 18 tubes	

Table 4-14. *Summary of small-aperture telescopes for the reference design.*

- With proposed mc-lekid design → 2 cryostats

Use additional focal plane space to increase sensitivity at primary CMB bands

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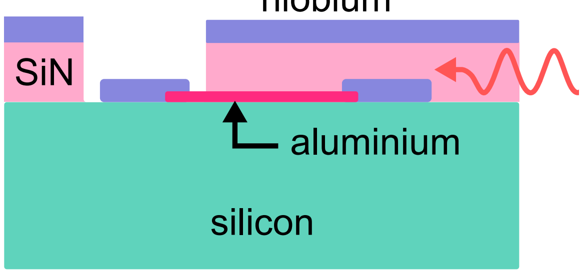
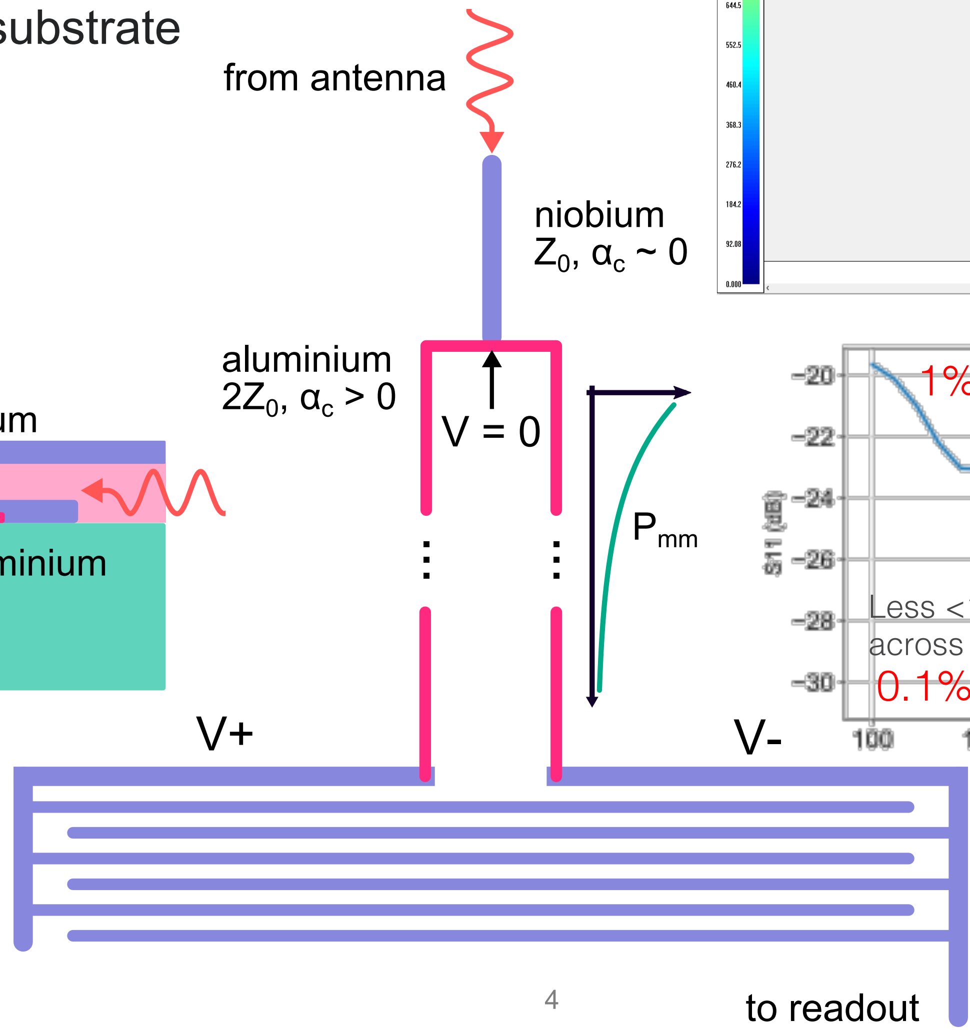
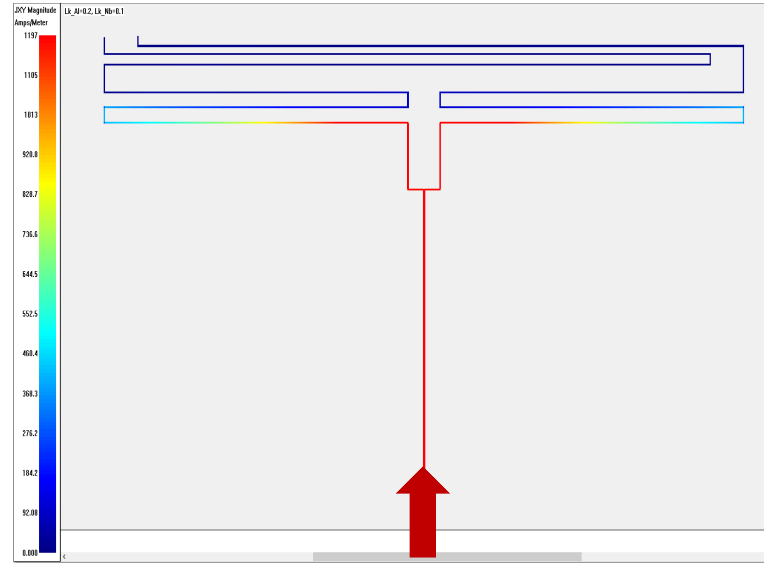
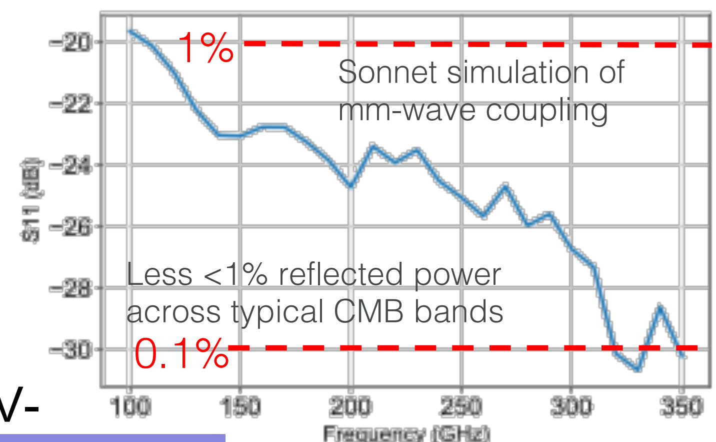
MICROSTRIP-COUPLED LE-KID

- Simple broadband galvanic mm-wave coupling
- Feed center of le-KID resonator at the virtual ground
- Inverted microstrip allows le-KID fabrication on clean silicon substrate









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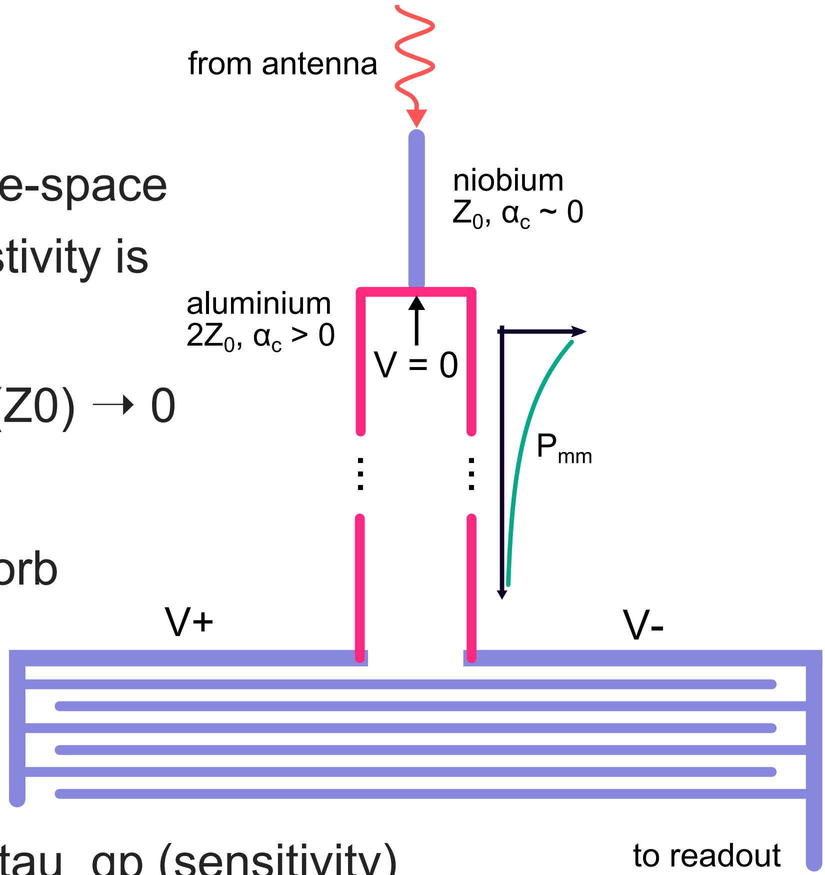
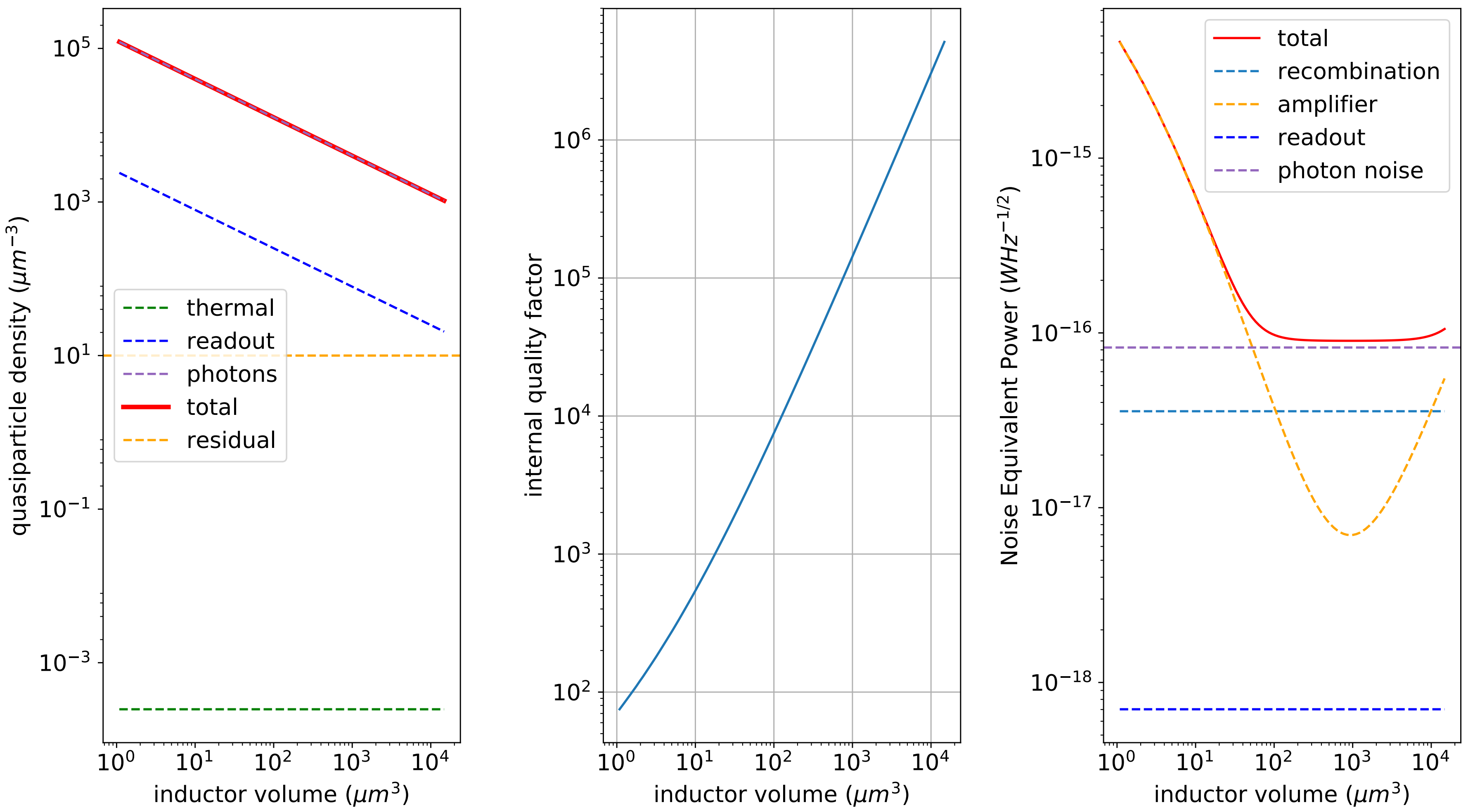
DETECTOR OPTIMISATION

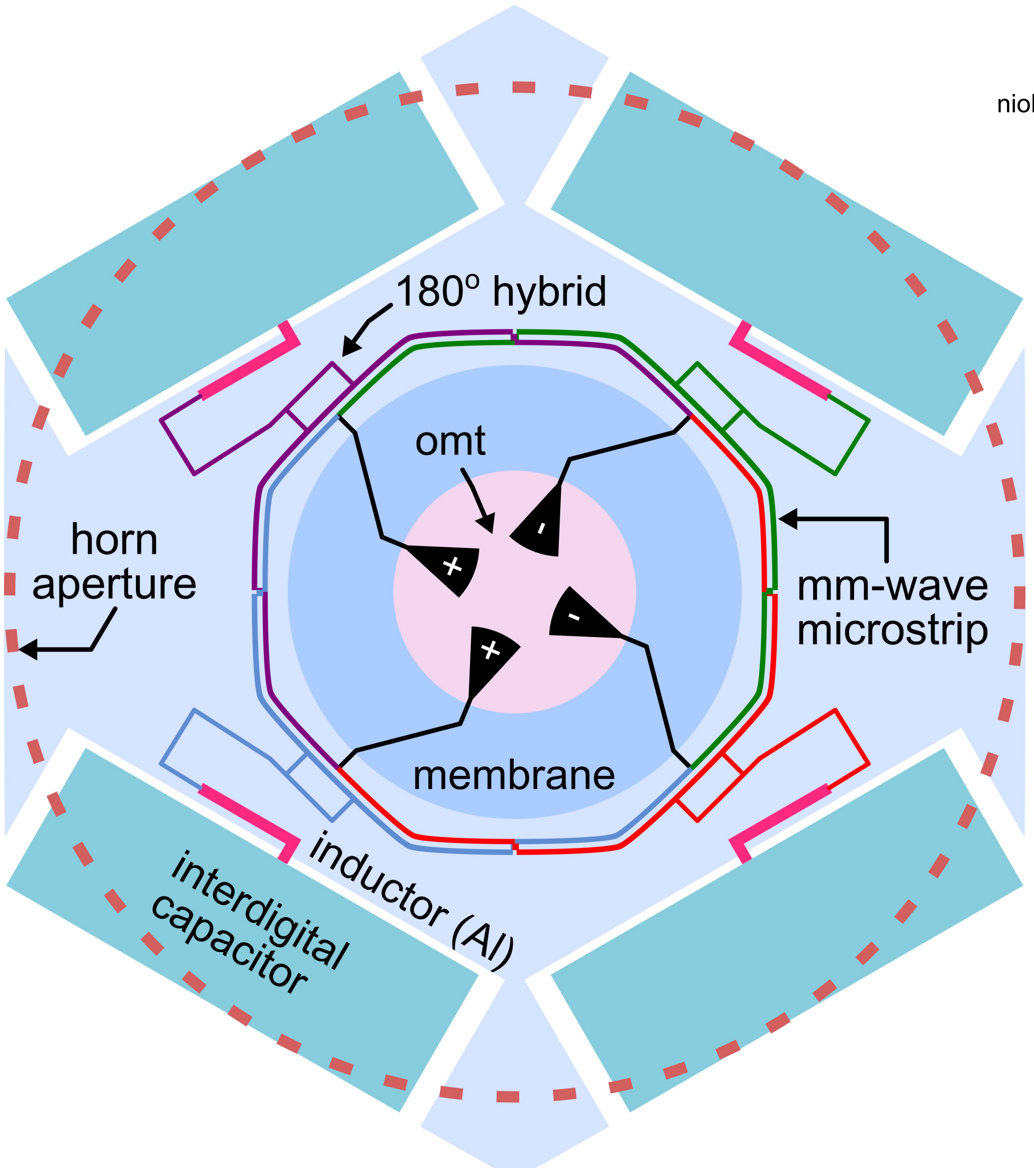
- Unlike traditional direct absorbing le-kid, the constraints on the film resistivity are relaxed
  - Couple to microstrip mode Z0 instead of free-space
  - From a mm-wave perspective, a lower resistivity is favorable
    - Al is lossy → as thickness increases, Im(Z0) → 0 → better mm-wave match
- Reduction in Rs requires longer length to absorb mm-wave signal
  - Resonator frequency increased due to lower Lk, but reduced for given Z0
  - In addition, increases Qi (multiplexing) and tau_qp (sensitivity)
  - Lk ~ Rs
    - alpha_k reduces → <u>OK/required for high loading!!</u>
  - Take away point:
    - All quantities are interrelated – require holistic approach to optimization

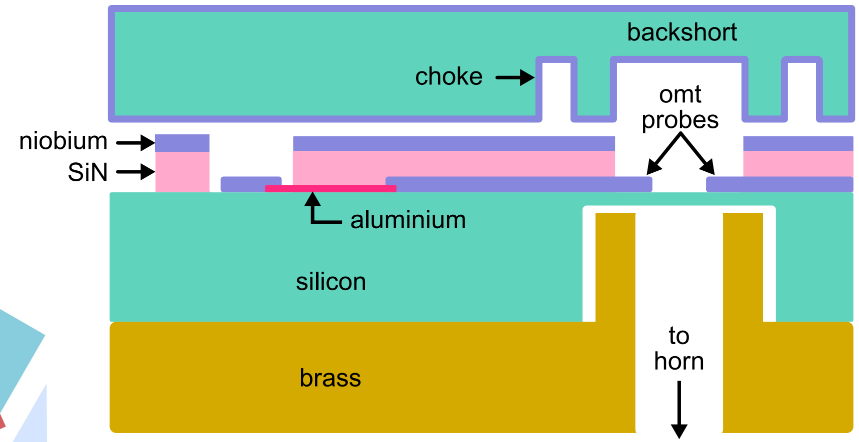


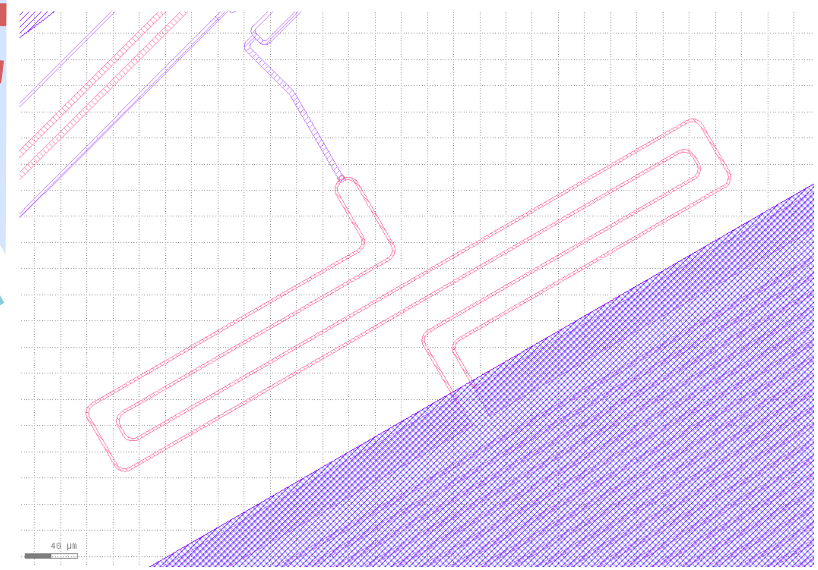
DETECTOR OPTIMISATION - NEPS



HORN COUPLED OMT DESIGN

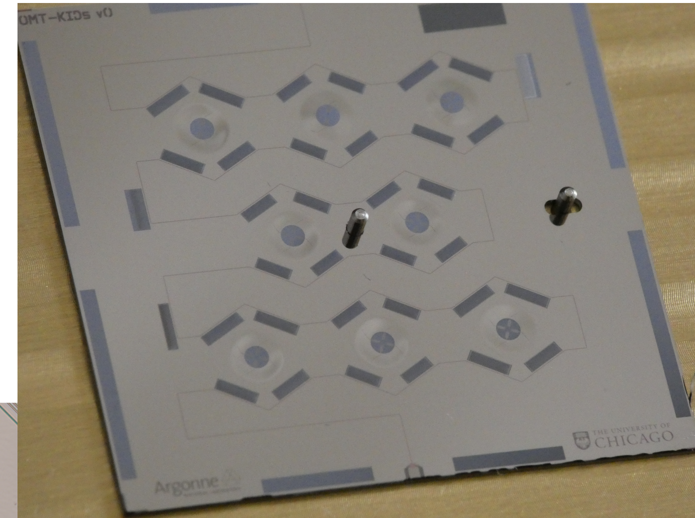


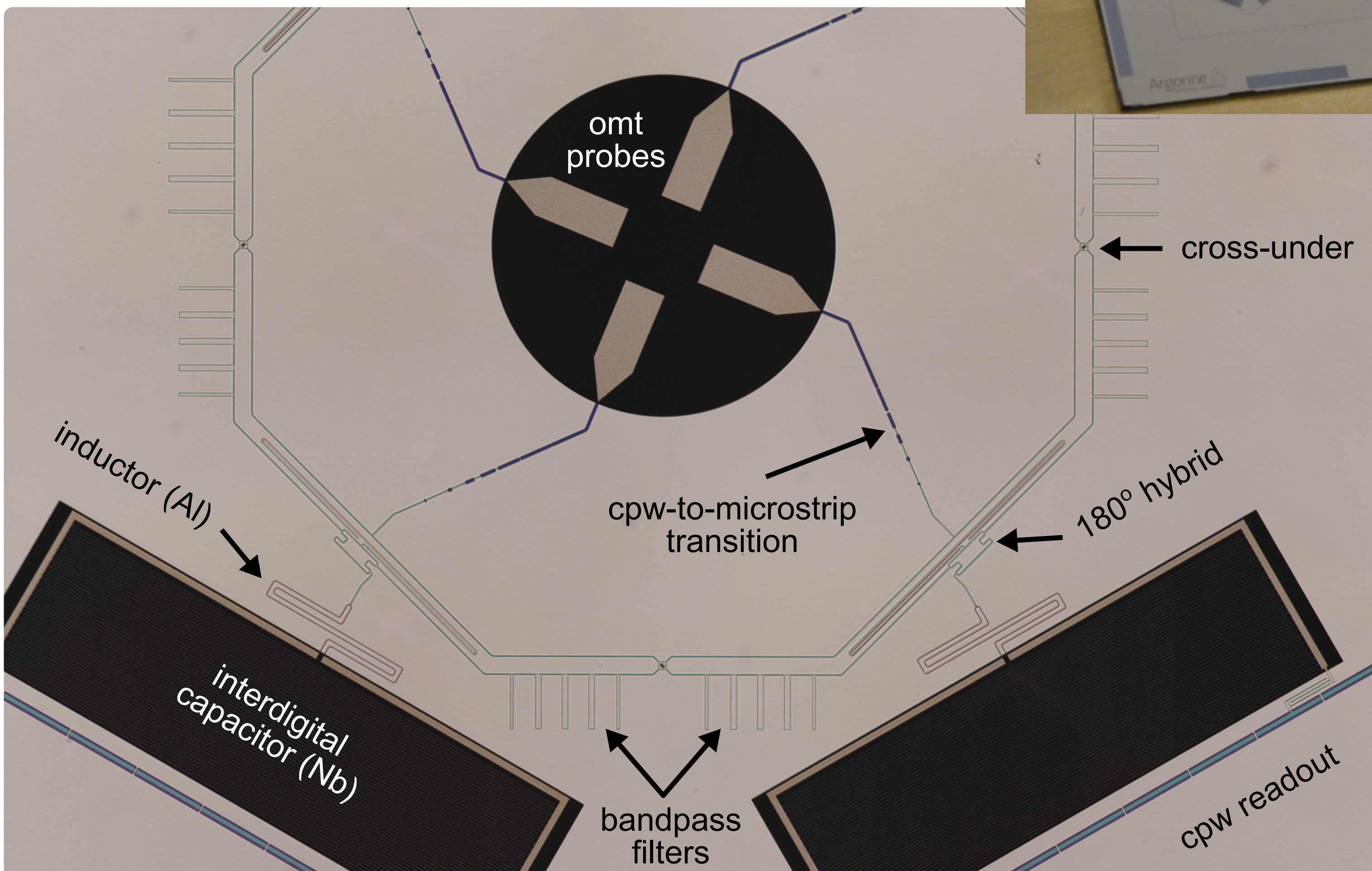




PROTOTYPE DEVICES

- Fabrication of first released devices now completed (**see A. Tang poster for all the details…**)
- **Optical testing to begin immediately**





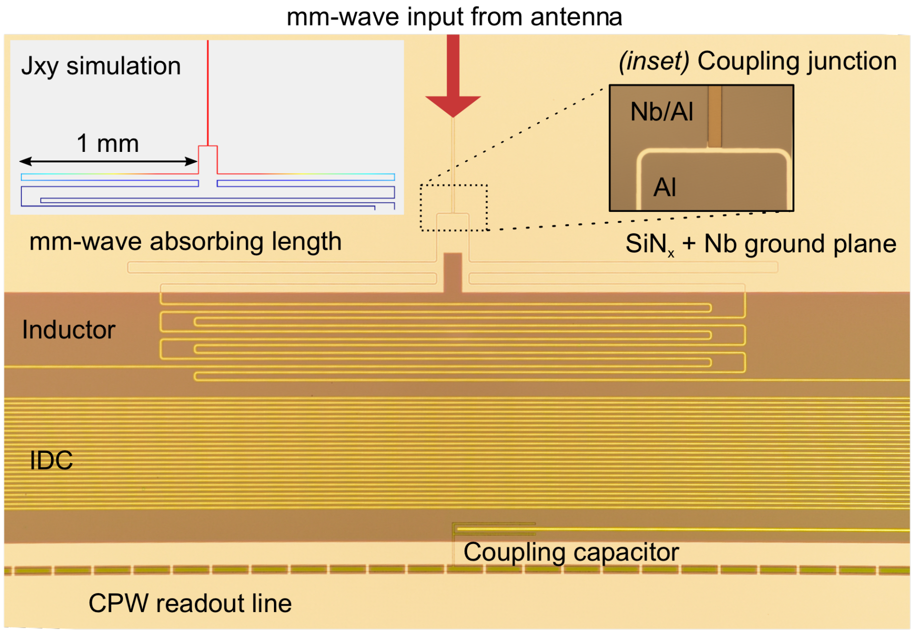
SUMMARY

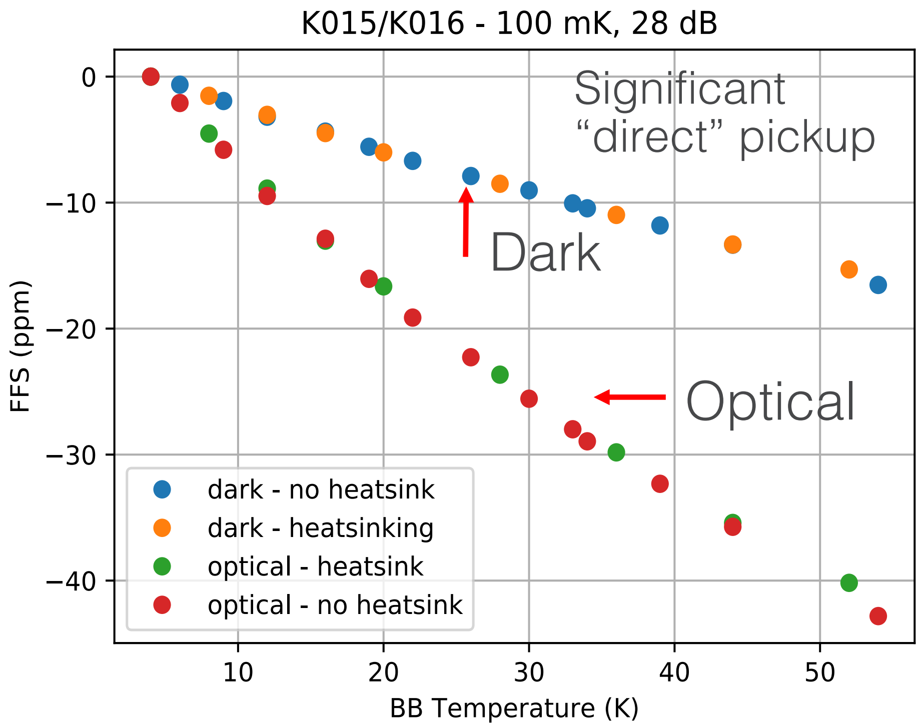
- Microstrip-coupled lumped-element KID is a promising path toward drop-in replacement for TES bolometers
  - Particularly motivated at high-frequencies
- Prototype lens-coupled twin-slot antenna devices demonstrated principle works, but highlighted issues
- OMT-coupled design will mitigate this
- First round of fabrication complete
- Full optical testing to begin soon

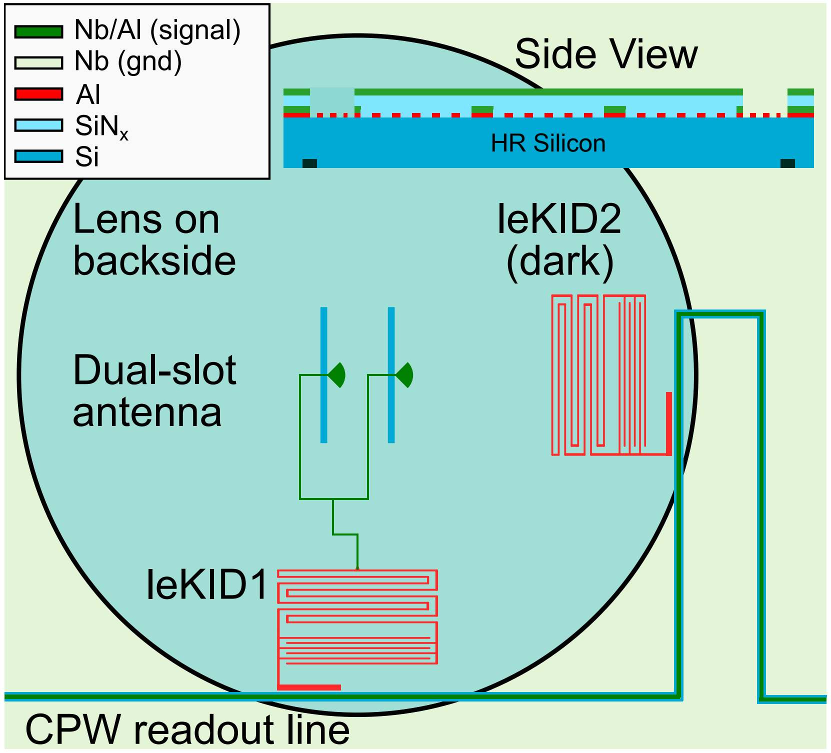
EXTRA SLIDES

PROTOTYPE RESULTS

- Demonstrated that optical coupling scheme works!
- But, identified that stray/direct pickup is an issue

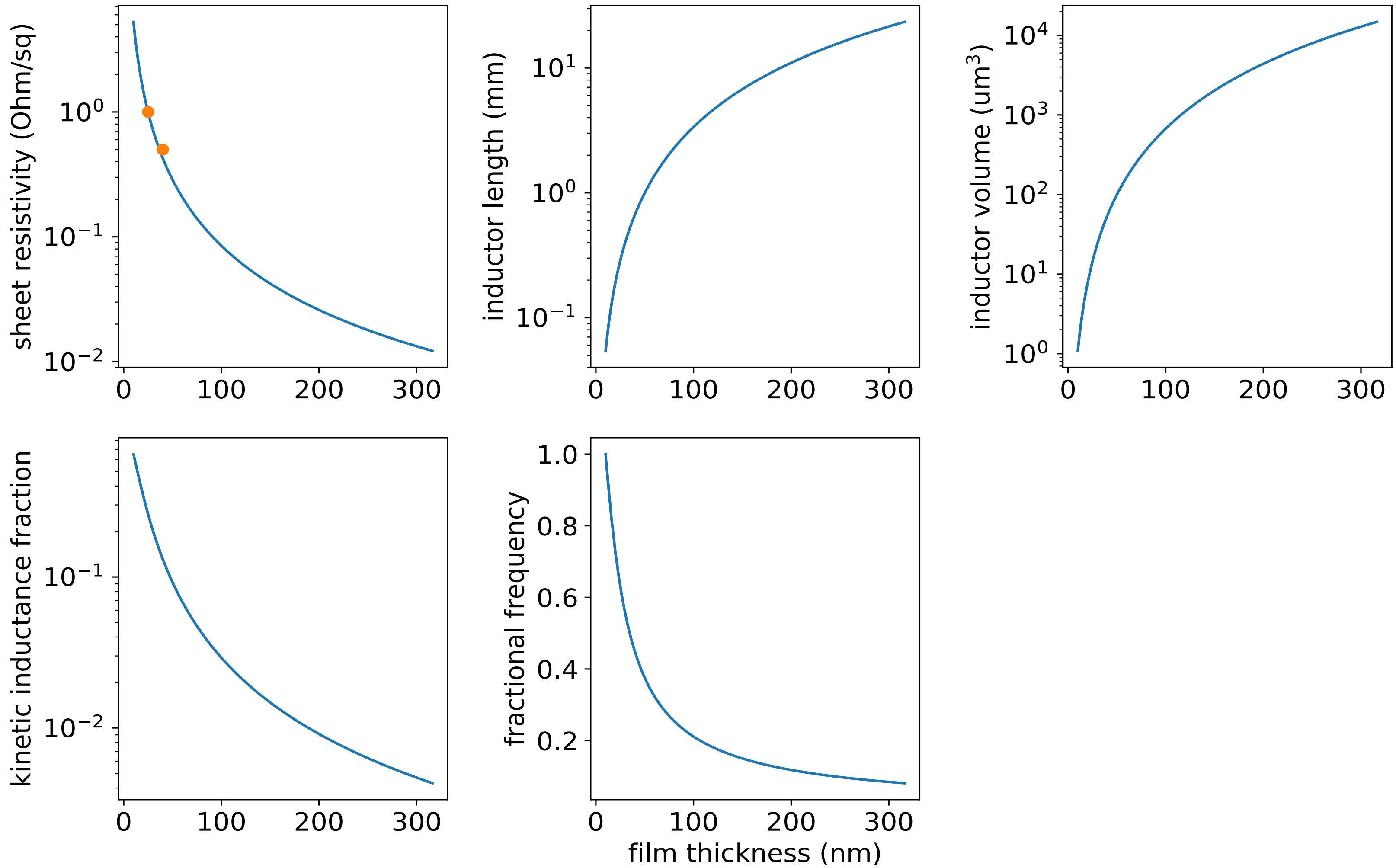






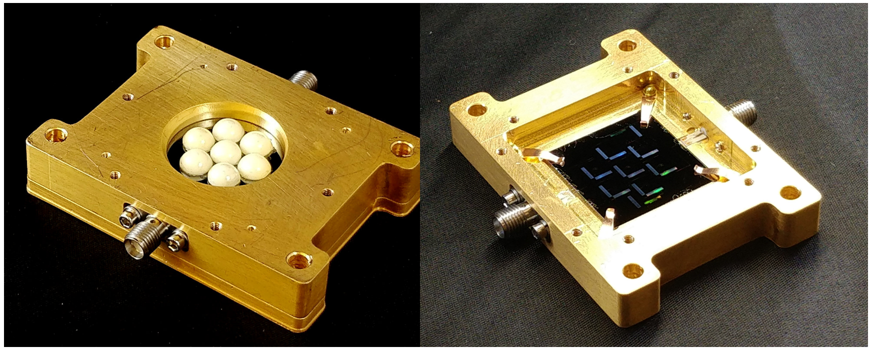
DETECTOR OPTIMISATION – PARAMETERS

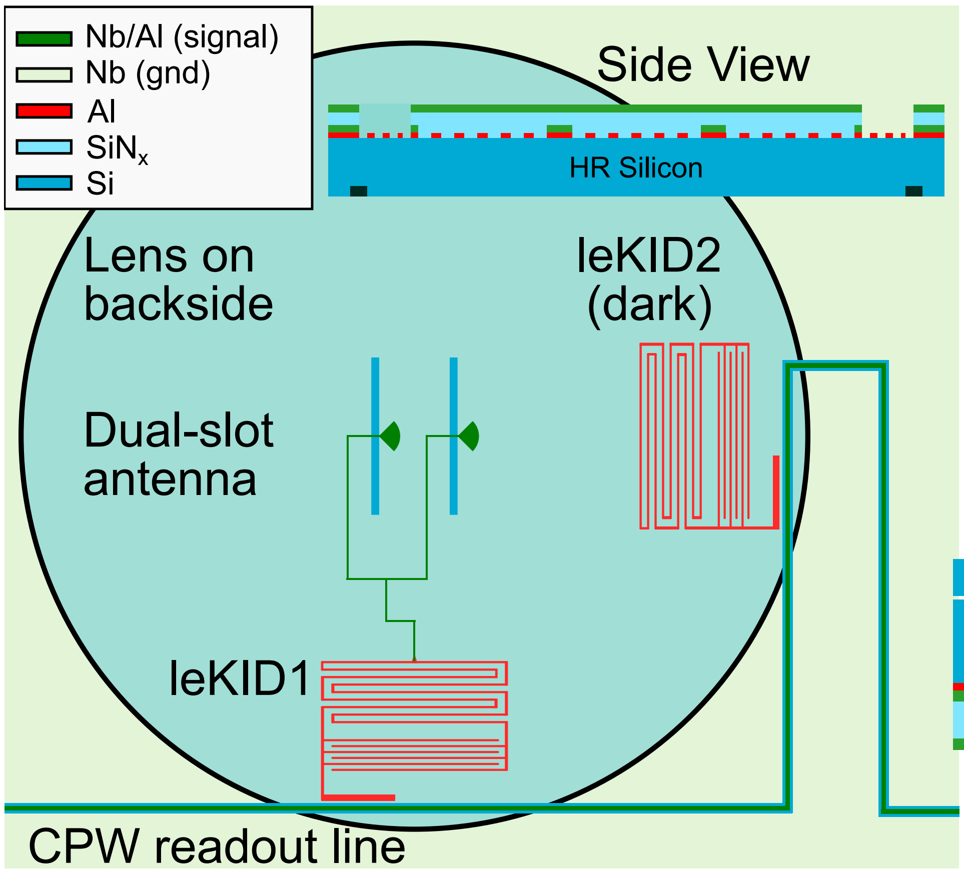
- Simulation calculates n_{qp} (P_{opt}, P_r, T_b…etc)
  - Constrain problem by requiring inductor length is sufficient enough to absorb < 20 dB

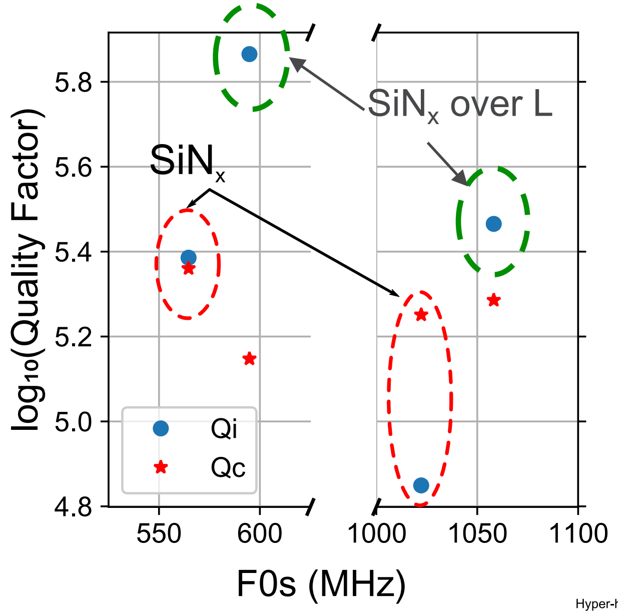


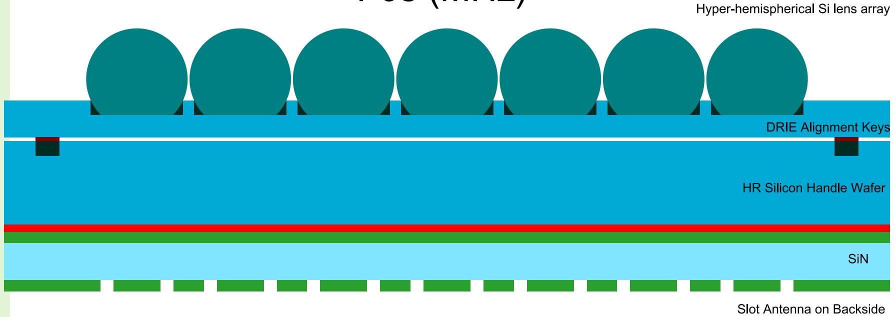
LENS-COUPLED DEVICES

– Simple prototype devices to test concept
– Demonstrated that dielectric over inductor has minimal effect on resonator loss









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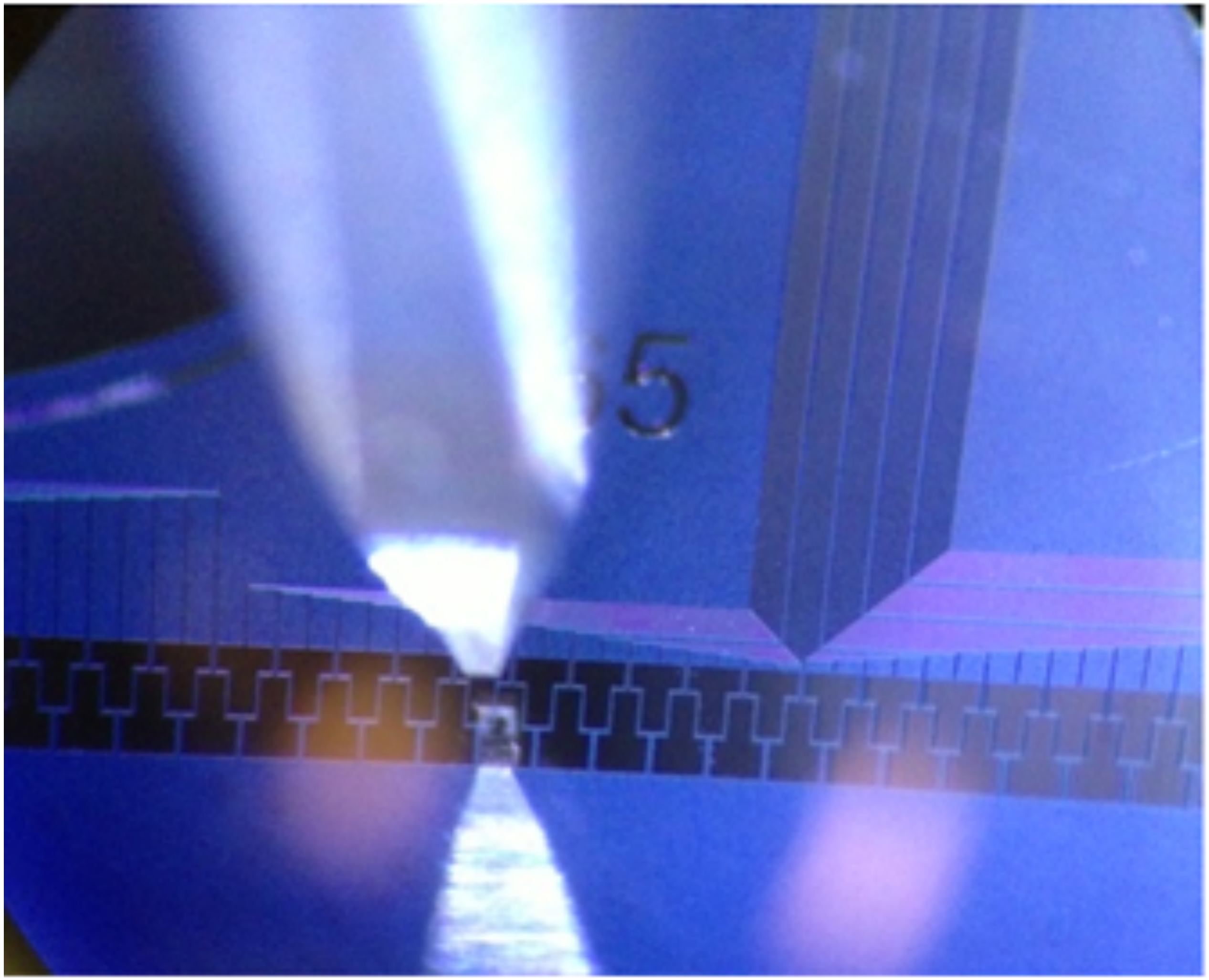
EXTRA SLIDES

Array of wire bond pads for the PolarBear2 detector array with a wire bond head. Pads are 90 micron wide with 10 micron gap between pads



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