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
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- 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):

<table>
<thead>
<tr>
<th>Bands</th>
<th>Lenses</th>
<th>Field of view</th>
<th>Min. edge taper</th>
<th>Modulation (Pole/Chile)</th>
<th>Detectors / tube</th>
<th>Tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 / 40</td>
<td>2× 55 cm Al</td>
<td>29°</td>
<td>−9.3 dB</td>
<td>scan</td>
<td>576</td>
<td>2</td>
</tr>
<tr>
<td>85 / 145</td>
<td>2× 55 cm Al</td>
<td>29°</td>
<td>−6.2 dB</td>
<td>scan / HWP</td>
<td>7048</td>
<td>6</td>
</tr>
<tr>
<td>95 / 155</td>
<td>2× 55 cm Al</td>
<td>29°</td>
<td>−8.4 dB</td>
<td>scan / HWP</td>
<td>7048</td>
<td>6</td>
</tr>
<tr>
<td>220 / 270</td>
<td>3× 44 cm Si</td>
<td>35°</td>
<td>−13.4 dB</td>
<td>scan / HWP</td>
<td>16876</td>
<td>4</td>
</tr>
</tbody>
</table>

**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
MICROSTRIP-COUPLLED 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

from antenna

niobium 
$Z_0, \alpha_c \sim 0$

aluminium 
$2Z_0, \alpha_c > 0$

V = 0

P_{mm}

1%

Sonnet simulation of mm-wave coupling

Less <1% reflected power across typical CMB bands

0.1%

V+ 
V-

to readout
DETECTOR OPTIMISATION

- Unlike traditional direct absorbing le-kid, the constraints on the film resistivity are relaxed
  - Couple to microstrip mode $Z_0$ instead of free-space
  - From a mm-wave perspective, a lower resistivity is favorable
    - Al is lossy $\rightarrow$ as thickness increases, $\text{Im}(Z_0) \rightarrow 0$
    $\rightarrow$ better mm-wave match

- Reduction in $R_s$ requires longer length to absorb mm-wave signal
  - Resonator frequency increased due to lower $L_k$, but reduced for given $Z_0$
  - In addition, increases $Q_i$ (multiplexing) and $\tau_{qp}$ (sensitivity)
  - $L_k \sim R_s$
    - $\alpha_k$ reduces $\rightarrow$ OK/required for high loading!!

- Take away point:
  - All quantities are interrelated – require holistic approach to optimization
DETECTOR OPTIMISATION - NEPS

The diagram shows the relationship between quasiparticle density and inductor volume, with the thermal, readout, photons, total, and residual components plotted. The internal quality factor is also plotted against the inductor volume, with the total, recombination, amplifier, readout, and photon noise components distinguished. Finally, the Noise Equivalent Power (WHz$^{-1/2}$) is plotted against the inductor volume, with the total, recombination, amplifier, readout, and photon noise components clearly marked.
HORN COUPLED OMT DESIGN

Diagram showing a 180° hybrid, horn aperture, memran, mm-wave microstrip, inductor, capacitors, and the overall design layout.
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
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
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.