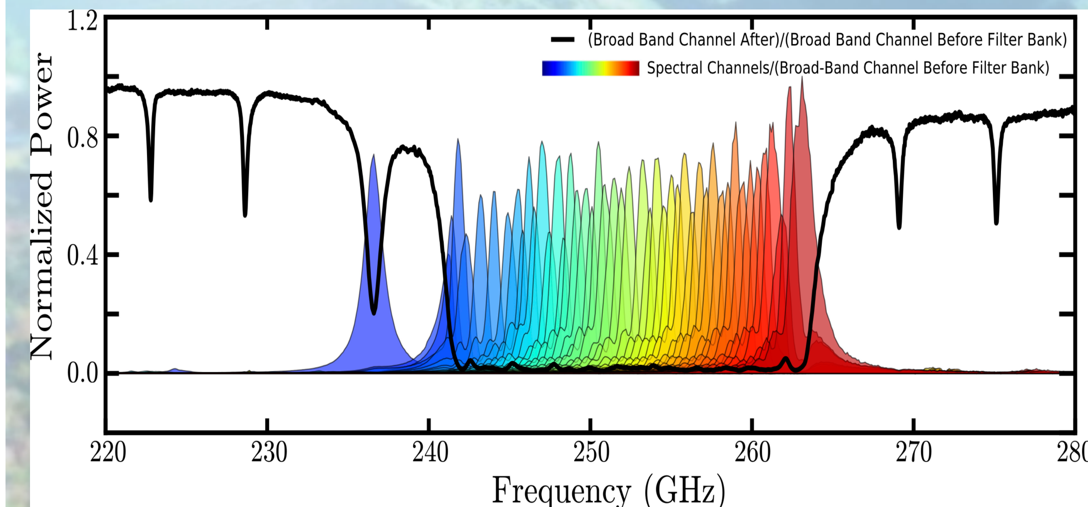
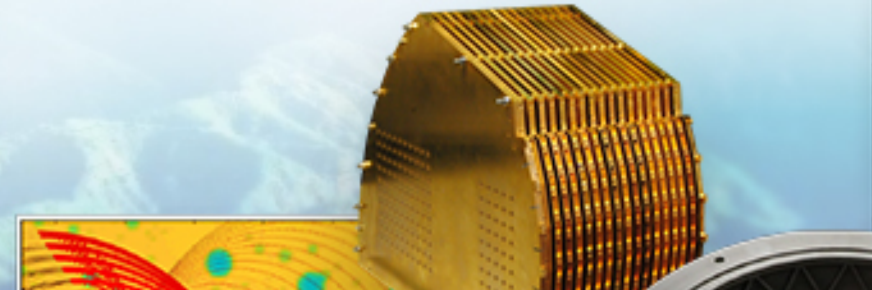
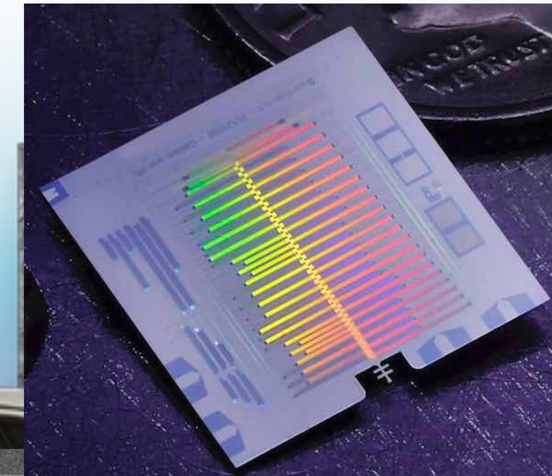
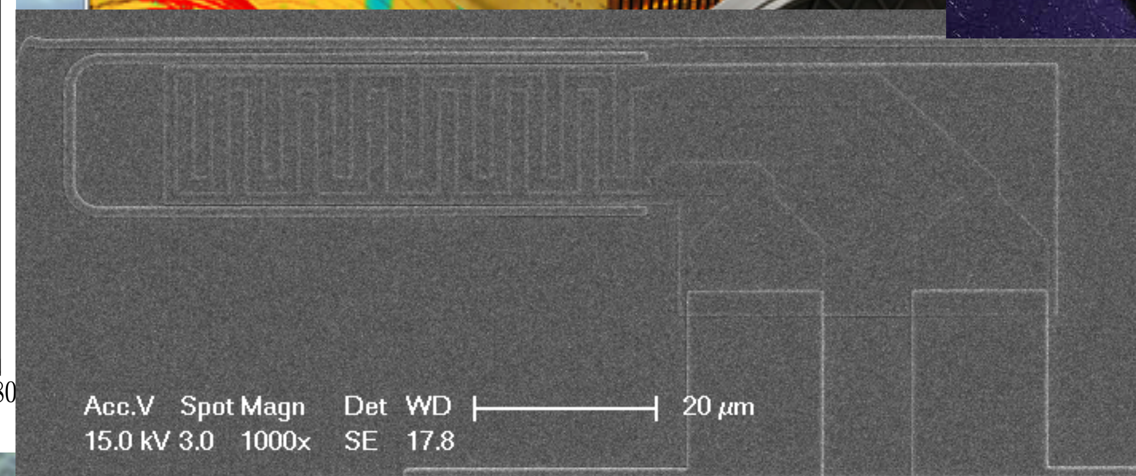
RPC 2020









Virtual Research Presentation Conference

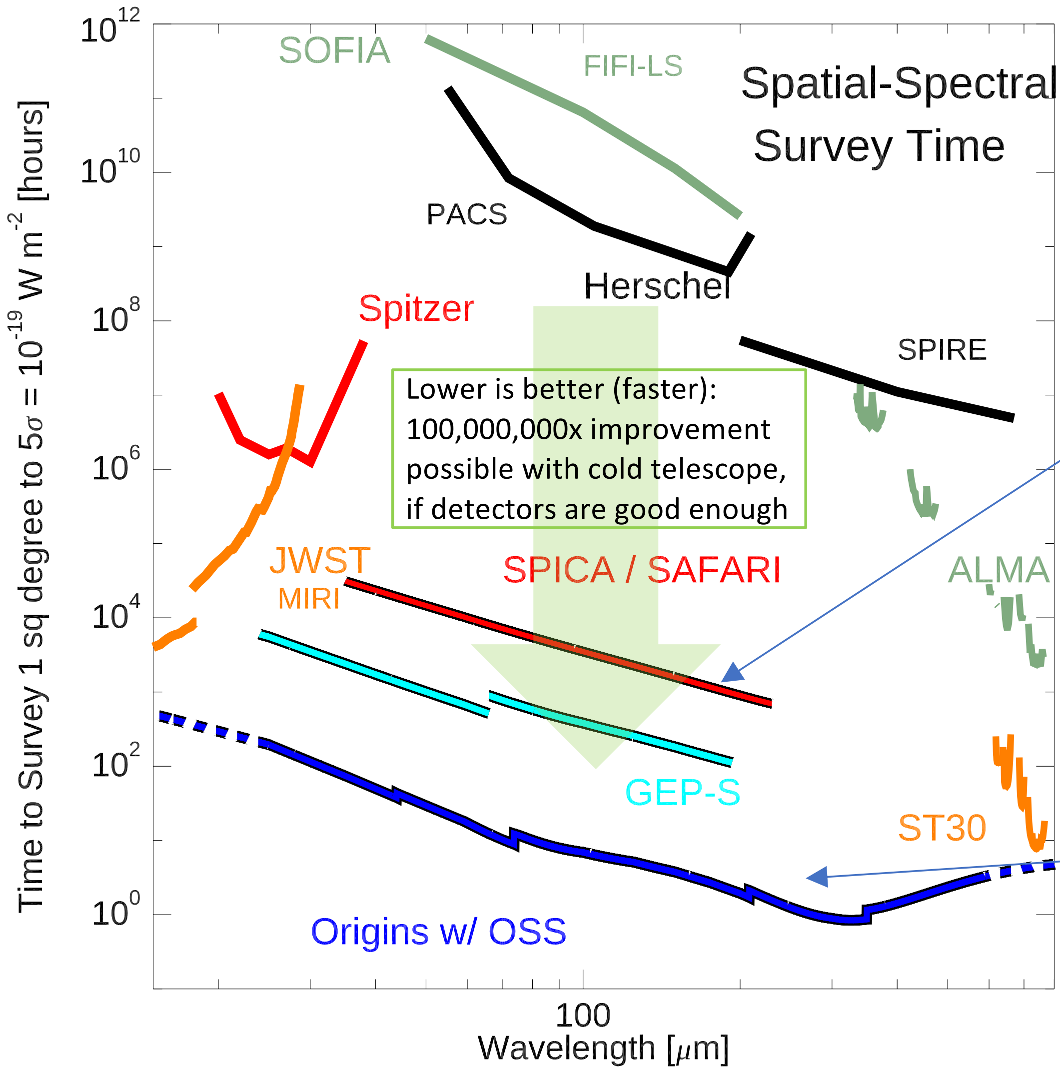
Technology for the Future Far-IR Missions: Demonstration of Wideband Millimeter-Wave Spectroscopy with SuperSpec

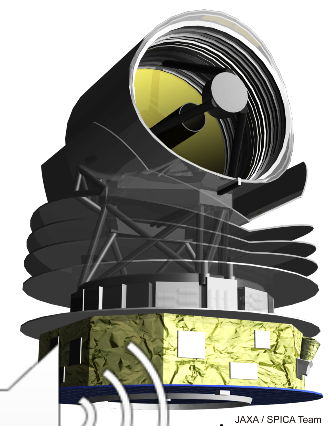
Principal Investigator: Charles M. Bradford (326)
Co-Is: Steve Hailey-Dunsheath (Caltech), Joseph Redford (Caltech), Reinier Janssen (326)
Program: Strategic Initiative

Assigned Presentation # RPC -105

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction





SPICA: 2m class 8 K telescope under study by ESA.

Origins: 5.6m 4 K telescope studied by NASA for 2020 Decadal.

- Far-infrared is vital to understand the evolution of galaxies and formation of planetary systems, most of which takes place under cover of dust.
- Far-IR measurements, particularly spectroscopy, have lagged other wavebands, but are now at the cusp of a major advance possible by simply cooling a space telescope to a few degrees Kelvin. Multiple missions are now under study worldwide, with JPL participation in most.
- Cooling the telescope is relatively easy, but the key technical tall pole is detector sensitivity and array size. Far-IR detectors are built by scientists since there is no commercial or industrial base. JPL has been a world leader in this area.
- This R&TD readies kinetic inductance detectors for these missions with a ground-based scientific demonstration.

Problem Description

Far-IR detectors are the key to future cryogenic astrophysics missions.

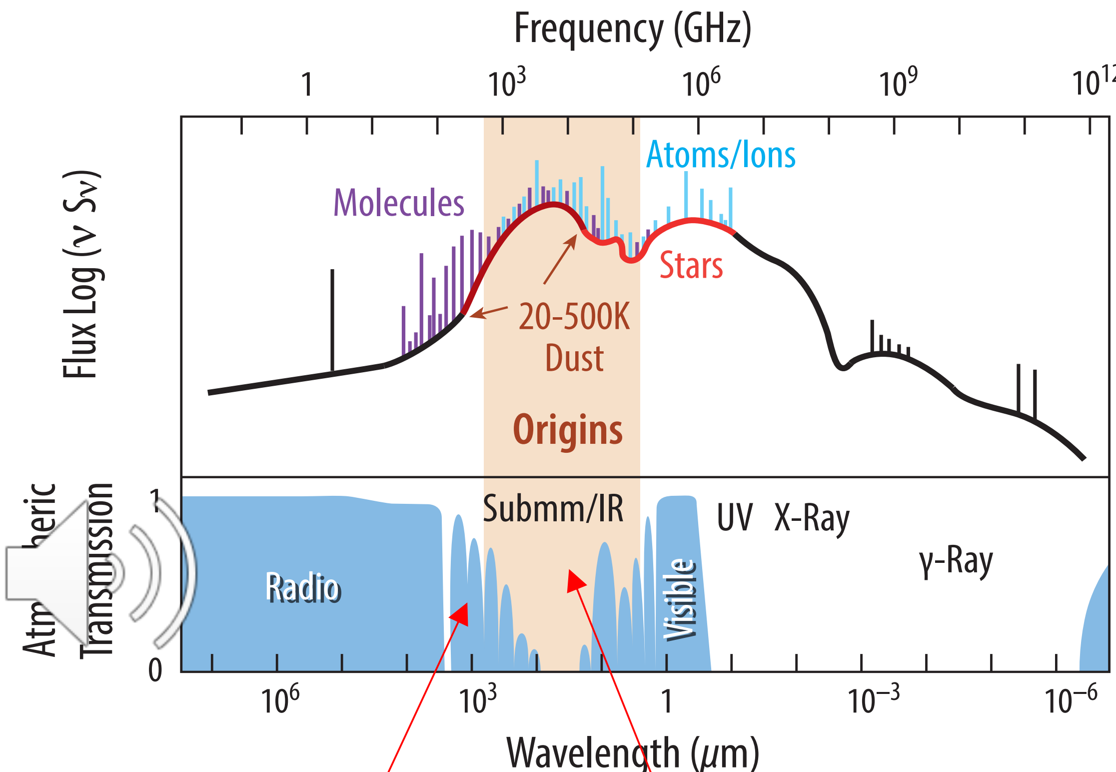
Instruments require total pixel formats of 100,000 or more, with a readout system compatible with cooling to below 100 mK.

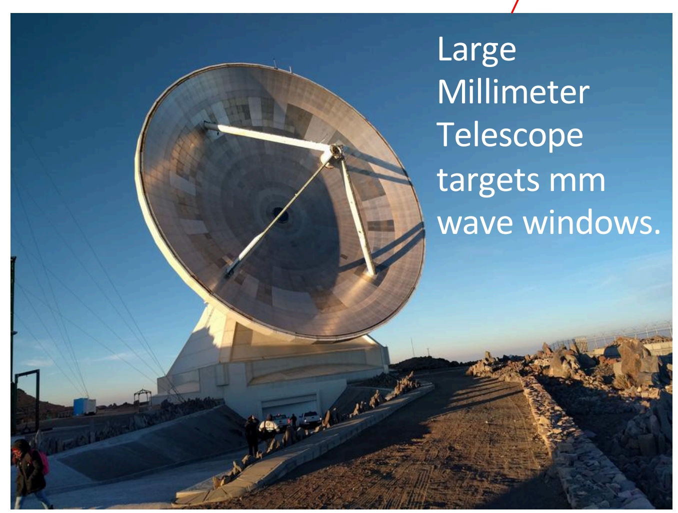
RF / microwave frequency multiplexing is a powerful approach which fits within the cryogenic design of facilities like Origins and the Galaxy Evolution Probe.

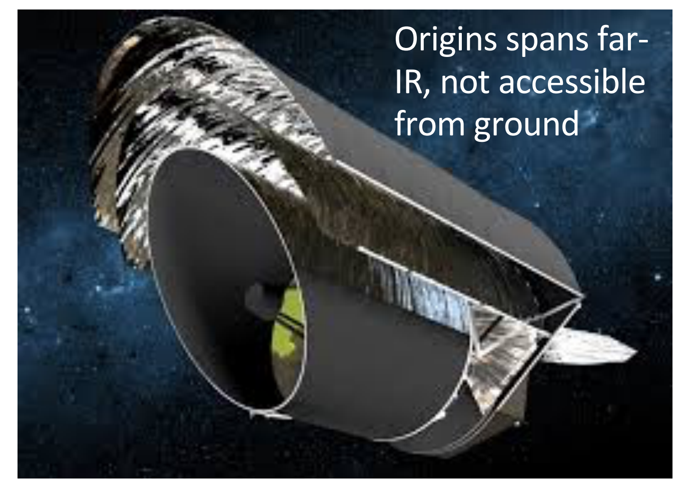
Detectors must also be more sensitive than those fielded to date.

And finally, they must be demonstrated in a scientific setting on the ground to provide confidence prior to implementation of a multi-billion-dollar flight mission.

How to demonstrate from the ground? We are building and fielding a mm-wave spectrometer on a chip with a integrated array of kinetic inductance detectors.







Methodology

Mm-wave direct-detection spectroscopy requires a compact spectrometer architecture – gratings are large and bulky.

Our on-chip filterbank spectrometer SuperSpec solves this problem and includes the detector array directly.

Uses superconducting Nb on silicon-nitride microstrip as the transmission line.

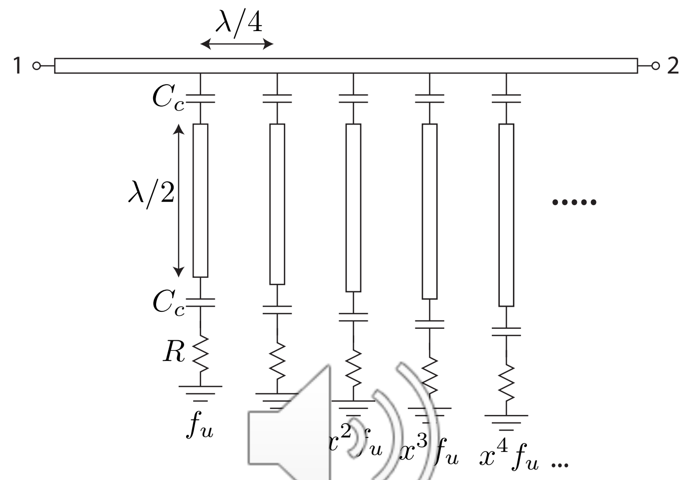
Detectors are titanium-nitride KIDs with very low volume to improve the noise equivalent power (NEP).

Our chips target the 200-300 GHz band.

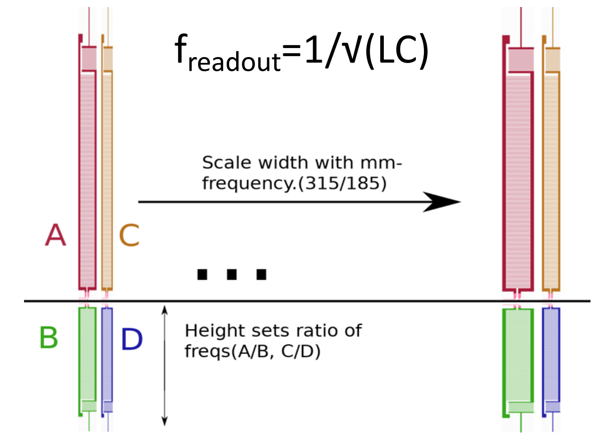
Each channel features a half-wave resonator coupled by proximity to the main feed line.

Photons are absorbed in a meandered titanium-nitride inductor.

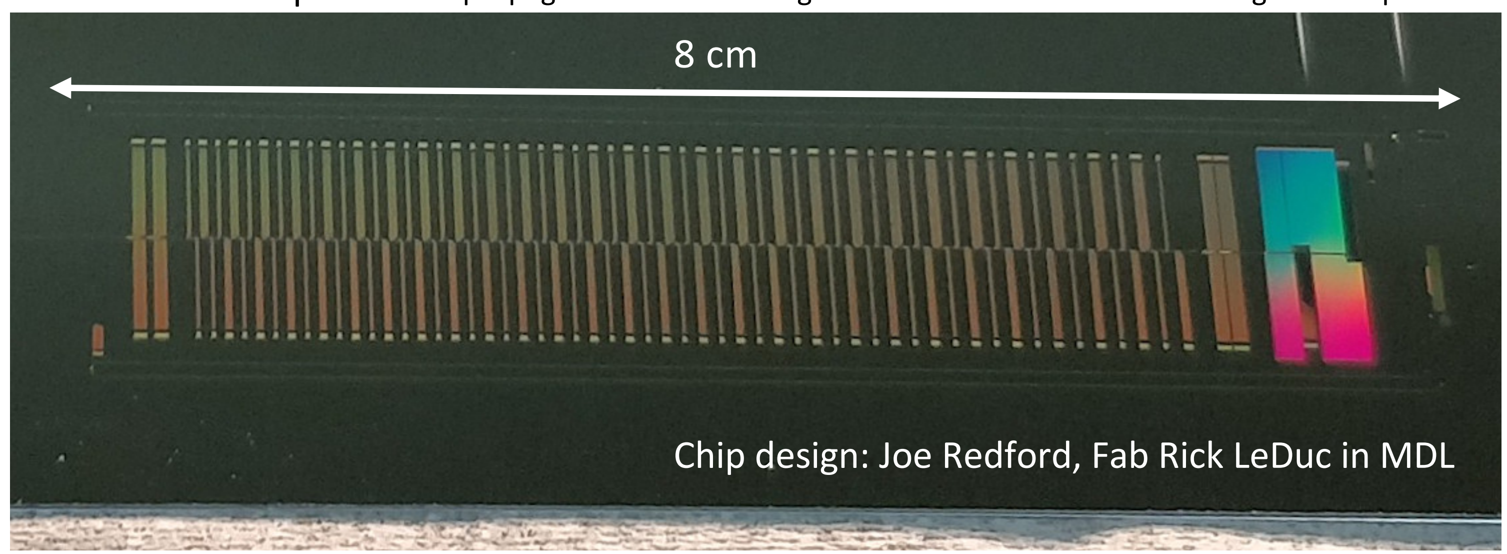
Filterbank Concept.
Couplings shown schematically as capacitors, in reality is proximity coupling of microstrip



Readout scheme. 110 channels are read out in four frequency banks which also scale with frequency. Chip area is dominated by interdigitated capacitors



110-channel chip. Feedline propagates from left to right. Vertical structures are interdigitated capacitors.



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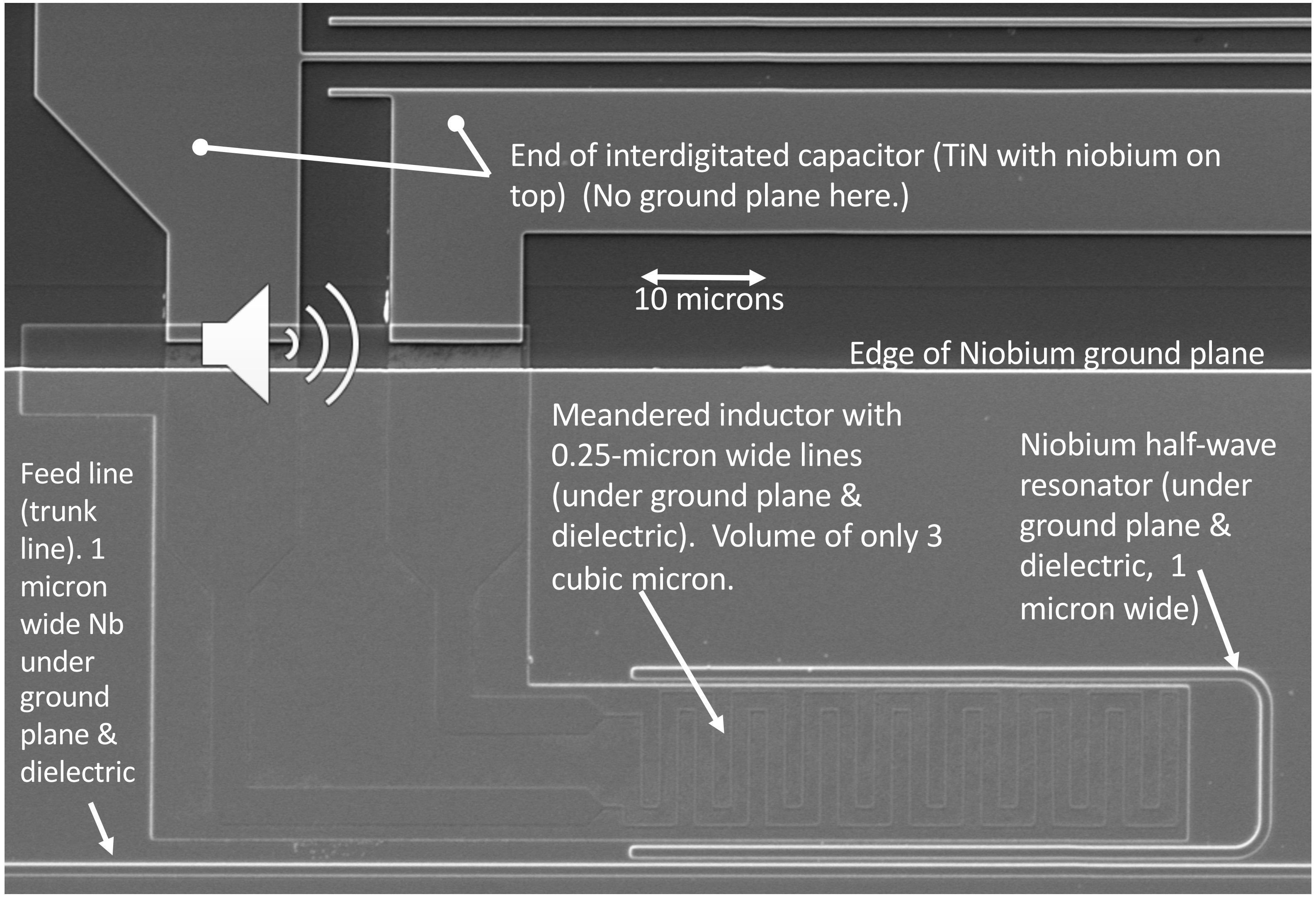
Zoom in of one filterbank channel



Results

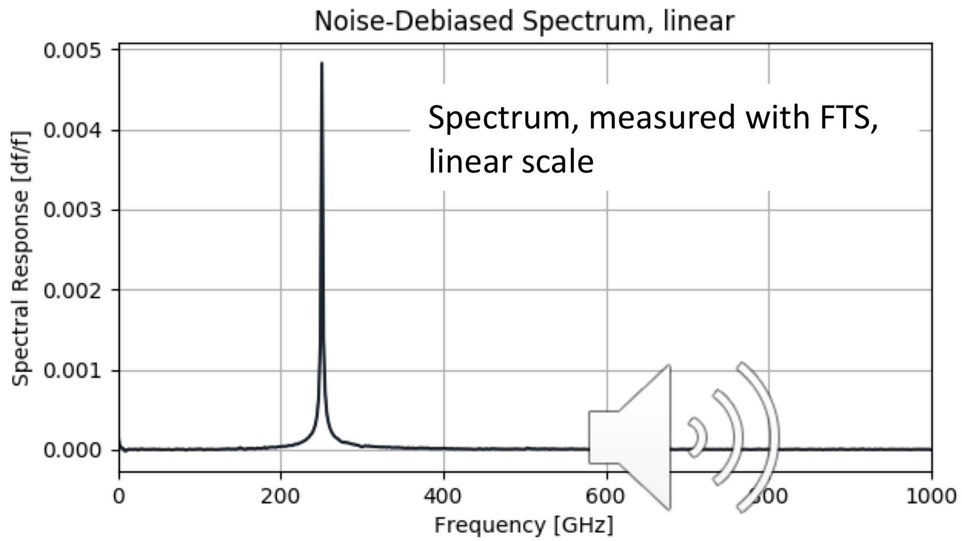
After challenges in optical efficiency in 300-channel chips, we are now finding good yield, efficiency and sensitivity in 110 channel chips.

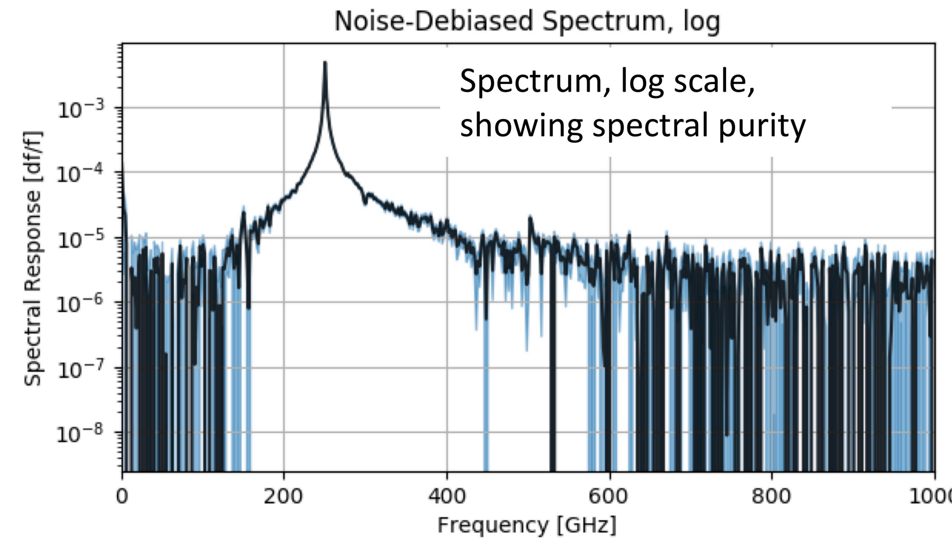
Currently screening chips as they come out of the microdevices lab.

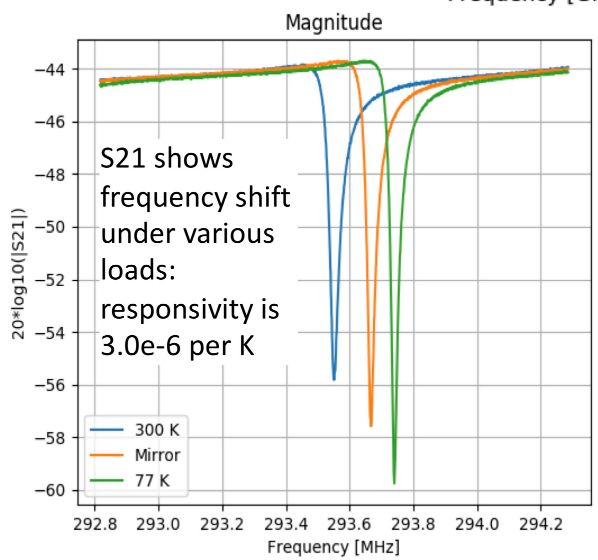
Preparing for a demonstration at the LMT.

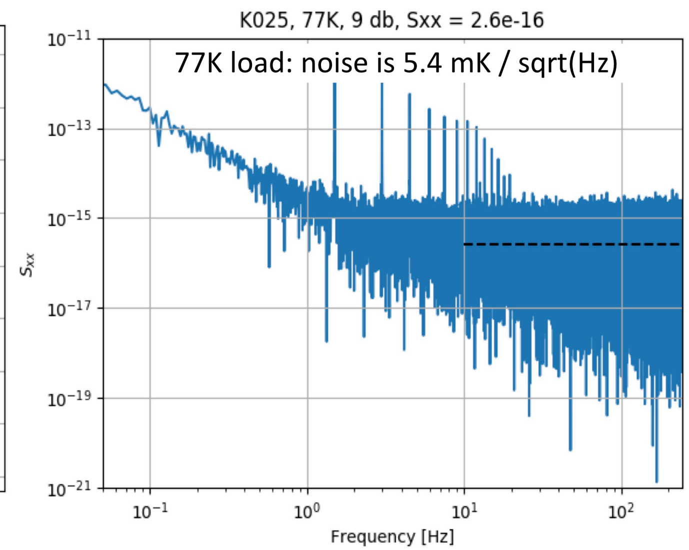
Will field an instrument with 6 chips coupling to 3 beams in both polarizations. Aiming for 2021 early.

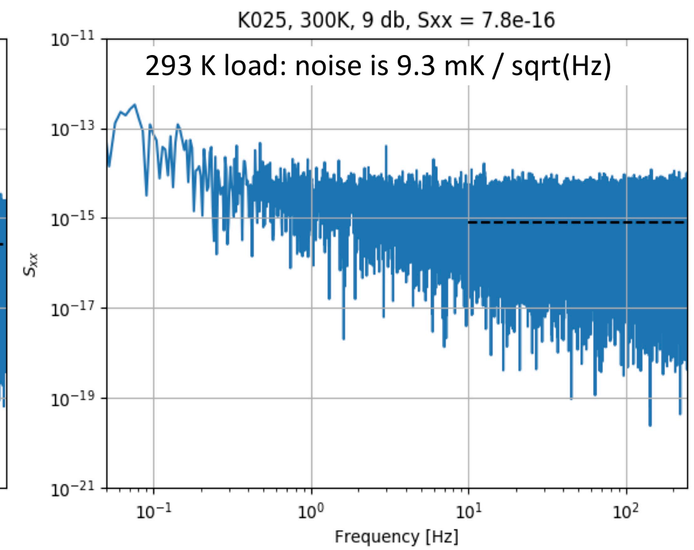
Initial spectral characterization and sensitivity measurement of 110 channel chip – example channel











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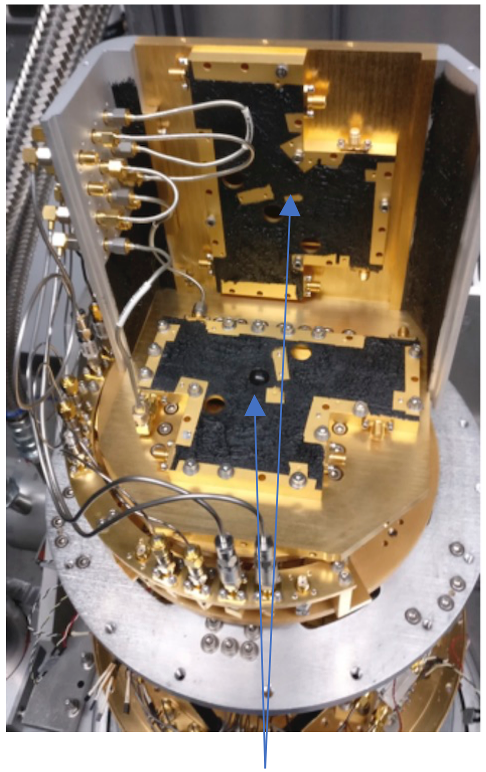
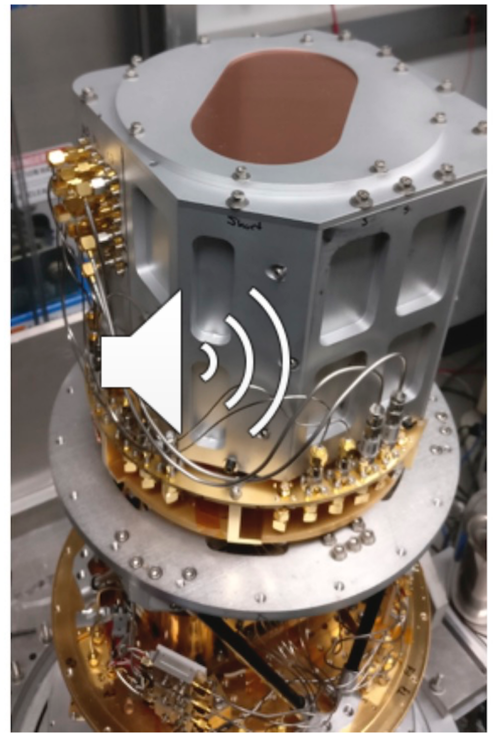
Preparation for deployment at LMT

Cryogenic assembly



3-chip packages (two). Chips are housed in aluminum enclosures. For each chip, a 1 cm hyperhemispherical lens is used for coupling to planar antenna.



Full assembly includes polarizing grid and filters, cooled to 220 mK. One readout circuit per chip.

Readout and software coming along

Readout uses ROACH-2 electronics with firmware developed by ASU and software developed by KID consortium including Caltech, NIST, Chicago/Argonne

Publications and References

Karkare, K. S.; Barry, P. S.; Bradford, C. M.; Chapman, S.; Doyle, S.; Glenn, J.; Gordon, S.; Hailey-Dunsheath, S.; Janssen, R. M. J.; Kovács, A.; LeDuc, H. G.; Mauskopf, P.; McGeehan, R.; Redford, J.; Shirokoff, E.; Tucker, C.; Wheeler, J.; Zmuidzinas, J. 2020. Full-Array Noise Performance of Deployment-Grade SuperSpec mm-Wave On-Chip Spectrometers. In Journal of Low-Temperature Physics. 199, 849K.