Full-Array Noise Performance of Deployment-Grade *SuperSpec* mm-wave On-Chip Spectrometers

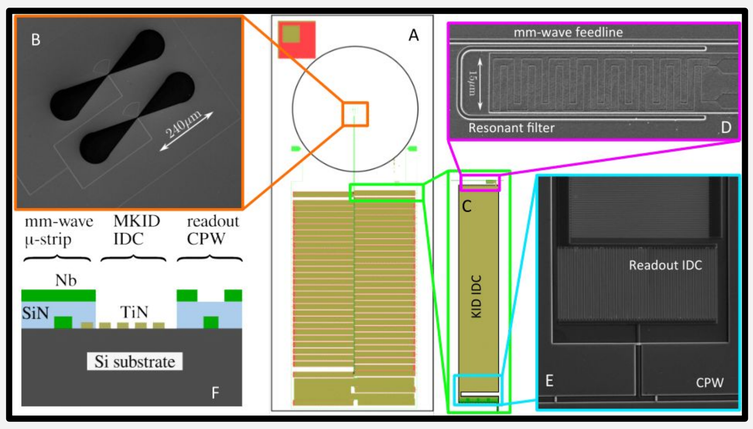
Kavli Institute for Cosmological Physics at The University of Chicago

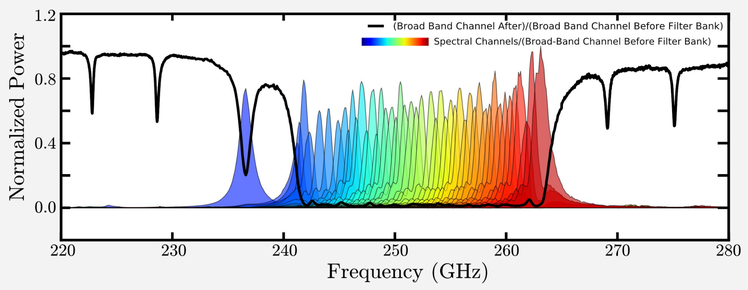
Kirit S. Karkare (KICP/University of Chicago)

P. Barry, C. M. Bradford, S. Chapman, J. Glenn, S. Hailey-Dunsheath, R. Janssen, H. Leduc, P. Mauskopf, R. McGeehan, J. Redford, E. Shirokoff, J. Wheeler, J. Zmuidzinas

SuperSpec Overview

SuperSpec is an on-chip spectrometer that employs a filter-bank architecture to perform moderate-resolution (R~100-300) spectroscopy at mm wavelengths on a few cm^2 of silicon [1]. We use TiN kinetic inductance detectors, read out with microwave tones in the 100-200 MHz band.

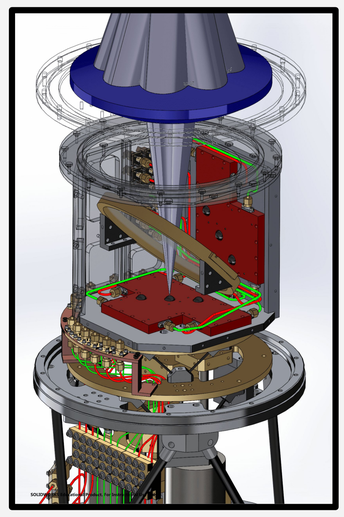


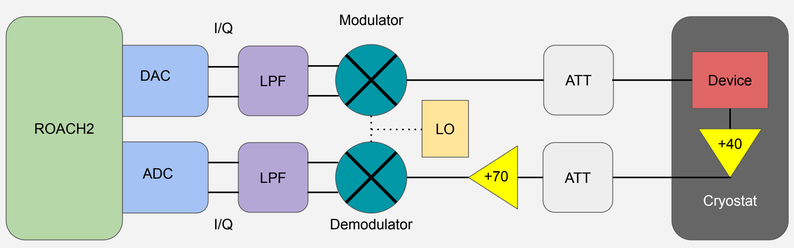


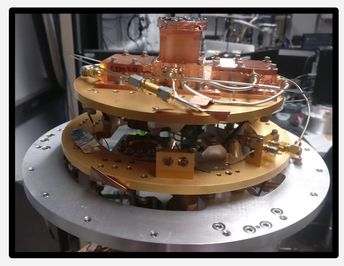
Spectroscopy from 200-300 GHz [2] is sensitive to far-IR emission lines from early galaxies. Future SuperSpec devices will enable sensitive multi-object spectrographs and integral field units suitable for line intensity mapping at high redshift.

Deployment Hardware

In preparation for an on-sky demonstration at the Large Millimeter Telescope in 2019, we are now testing a full-scale instrument in lab.
We plan to deploy 6x R ~ 100-300 devices (3 beams on the sky, dual-polarization), operating at 230 mK base temperature.
The readout system is based on ROACH2 boards and MUSIC ADC/DAC cards [3].

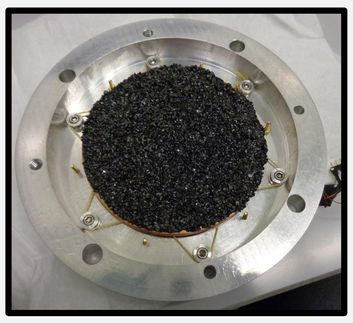






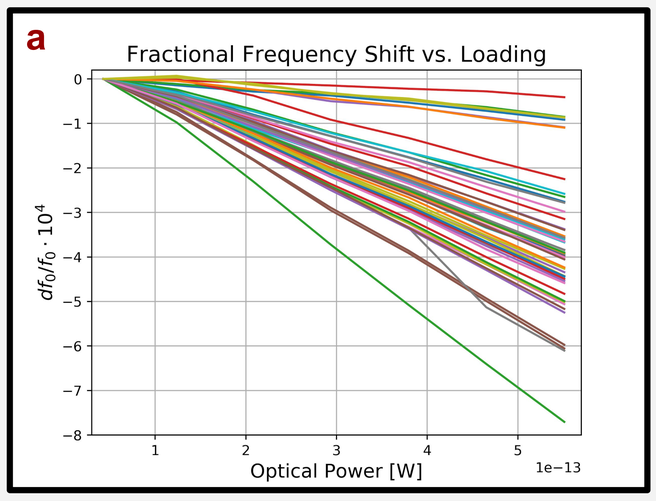
Array Measurements

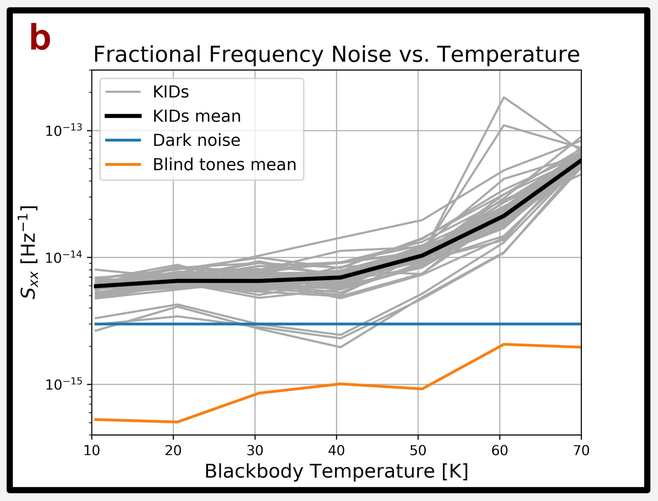
We took noise measurements of a deployment-grade 50-channel R~275 SuperSpec device using a beam-filling cryogenic blackbody load with an adjustable temperature from 4-70 K.
The warm electronics and readout system are identical to what we will use at the LMT.

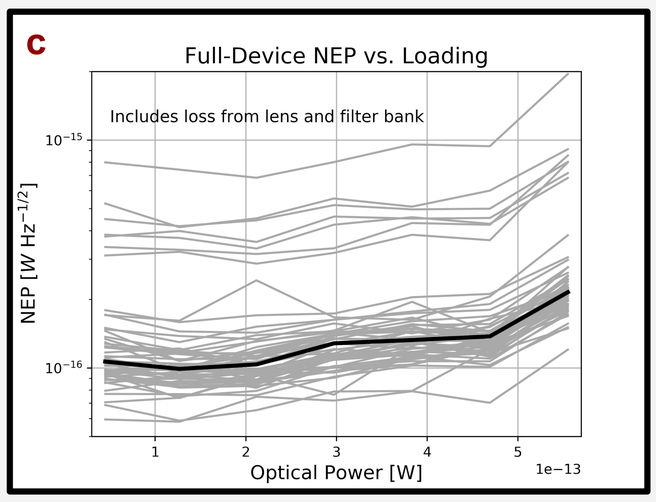


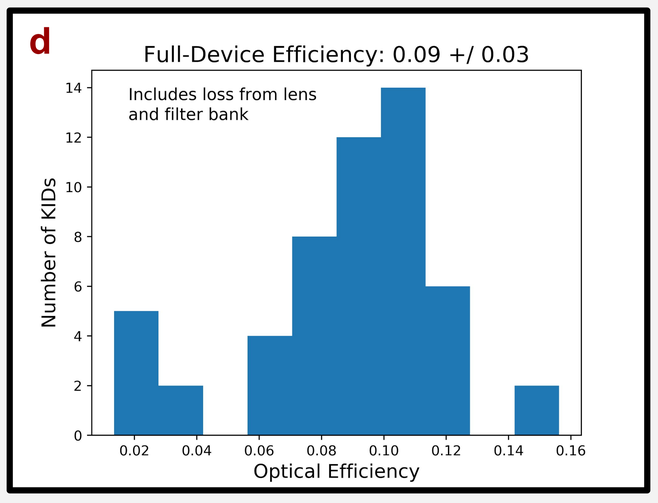
From the fractional frequency shift vs. loading **(a)** we determine device responsivity. Fractional frequency noise **(b)** is estimated by finding the white noise level of 200 s timestreams above the optical chop frequency of ~1 Hz. Dark noise measured on the same device is lower than Sxx we measure here, as are several blind tones placed throughout the band, indicating that we measure photon noise.

We then convert Sxx to NEP **(c)** using the responsivity. The NEPs reported here *incorporate losses in the entire device, including the lenslet and full filter bank*. Finally, comparing to the incident blackbody optical power in the loading range that we expect to see at the LMT, we derive a full-device optical efficiency of 9% **(d)**.



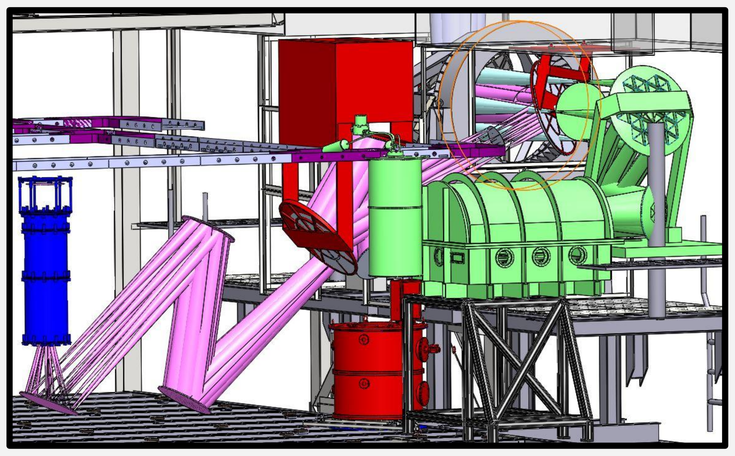




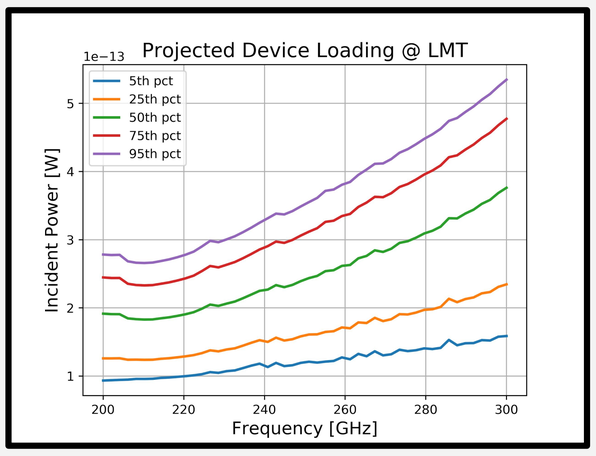


On-Sky Demonstration at the Large Millimeter Telescope

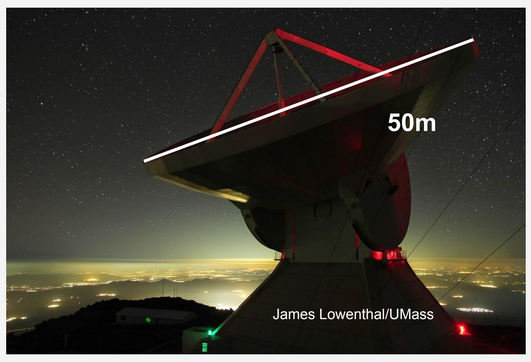
In Fall 2019 we plan to deploy a demonstration SuperSpec instrument to the 50-m Large Millimeter Telescope.
Located in Puebla, Mexico, on Volcan Sierra Negra at 15,000 feet, the LMT is an excellent mm-wave site.
SuperSpec will complement the LMT instrumentation suite, adding broadband spectroscopic capability at 1 mm.



SuperSpec (blue) will be located in the LMT receiver cabin alongside MUSCAT (red) and TolTEC (green)



Expected R~300 device loading for various PWV percentiles [4]



References

[1] Shirokoff, E. et al. 2012, Proc. SPIE 8452, 84520R
[2] Wheeler, J. et al. 2016, Proc. SPIE 9914, 99143K
[3] Gordon, S. et al. 2016, JAI 541003G
[4] Paine, S. 2018, The *am* atmospheric model