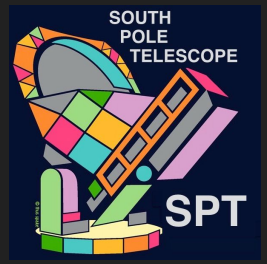
MKID array development for measurement of the CMB

Karia Dibert

Snowmass - 24 July 2022

(on behalf of the SPT collaboration)



The South Pole Telescope

- The SPT is a 10m diameter, sub-mm quality telescope with a 2.5 deg^2 FOV
- Currently equipped with the SPT-3G camera
  - TES bolometers - observes at 95, 150, and 220 GHz
  - Survey runs from 2017-2024
- The SPT-3G+ camera will be installed in Austral summer 2024
  - MKIDs - observes at 220, 285, and 345 GHz
  - Science cases include CIB measurement, kSZ, Rayleigh scattering, and cluster finding.

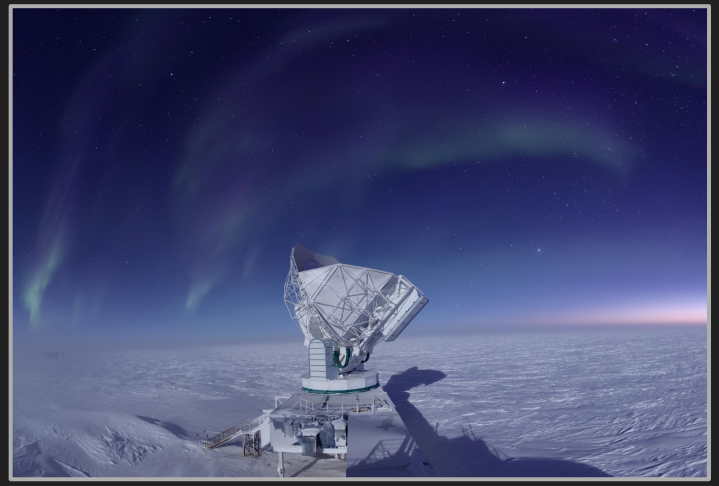
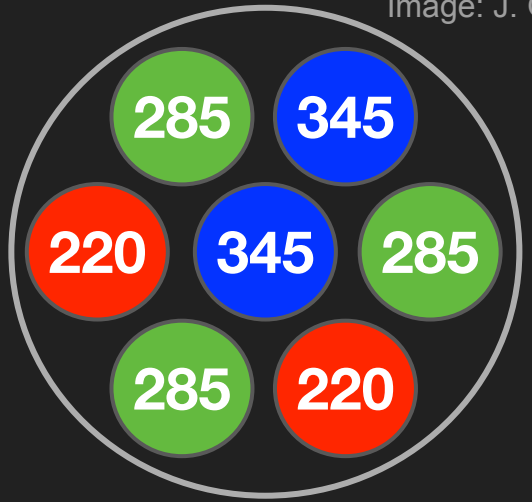
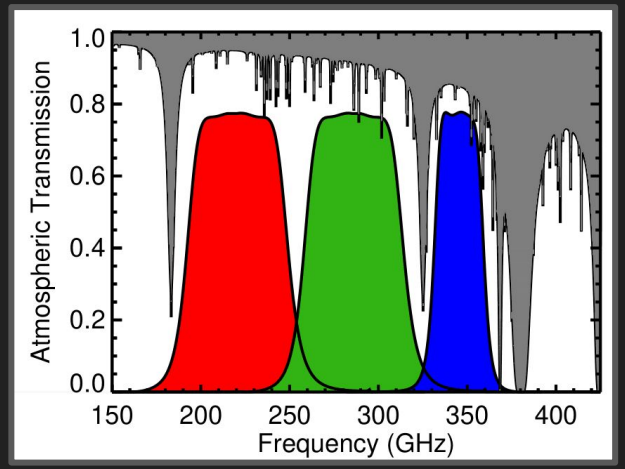


Image: J. Gallicchio

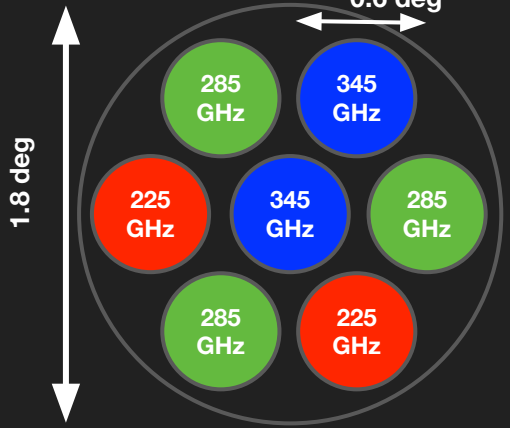


The SPT-3G+ Focal Plane

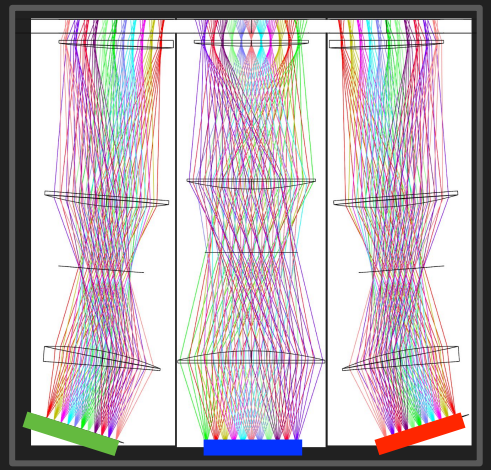
B. Benson



SPT-3G+ Focal Plane Layout

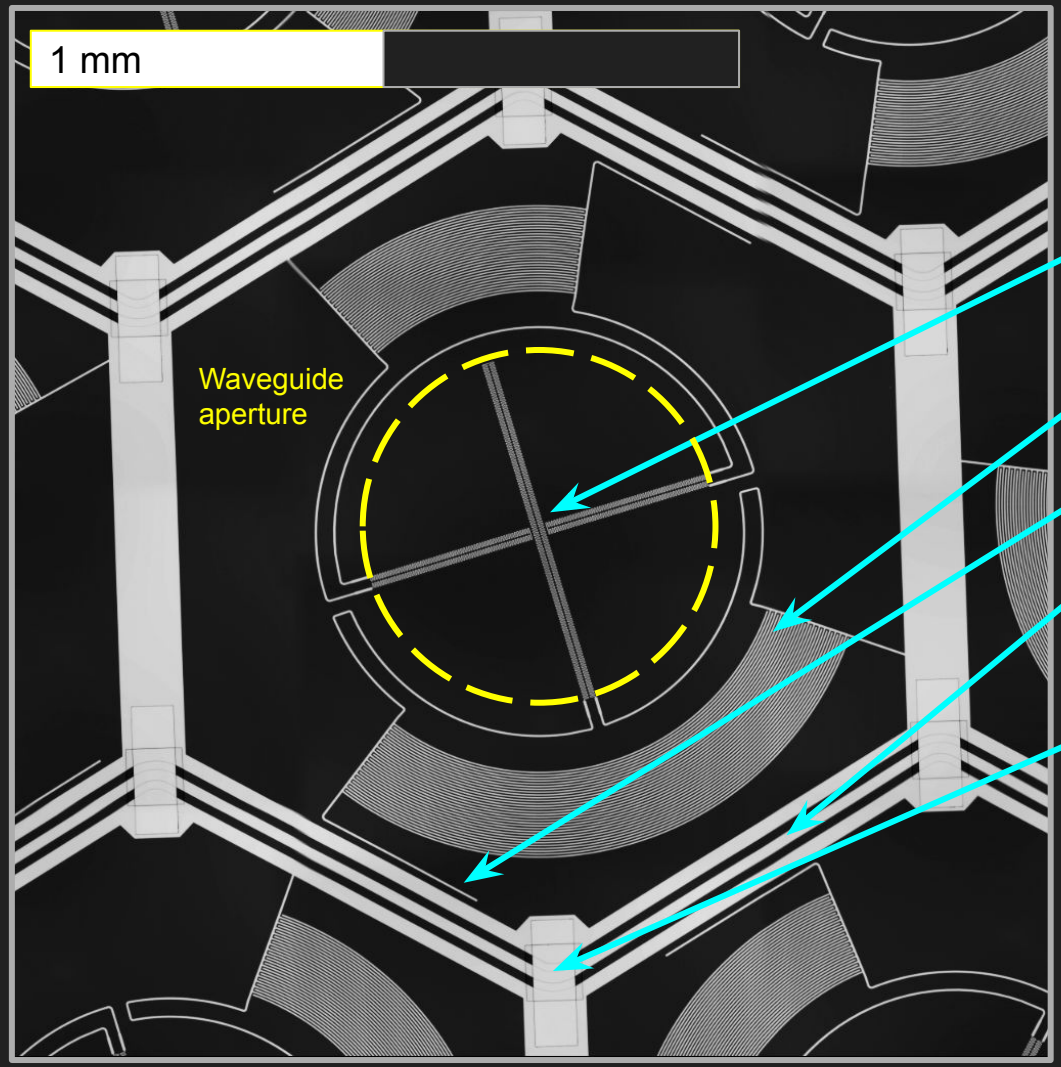


A. Stark, N. Halverson



- 7 wafers of MKIDs at 220, 285, and 345 GHz
  - 7 separate optics tubes
- ~5k detectors per wafer = ~35k total MKIDs
- Multiplexing goal is ~1000 detectors per 500MHz

220 GHz pixel
(microscope photo)



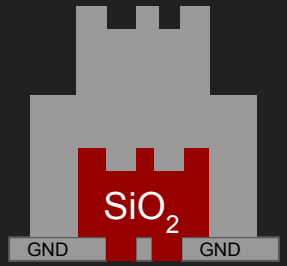
Dual-polarization absorbers/inductors (Al)

Interdigitated capacitor (Nb)

Feedline coupling finger (Nb)

Coplanar waveguide (CPW) feedline (Nb)

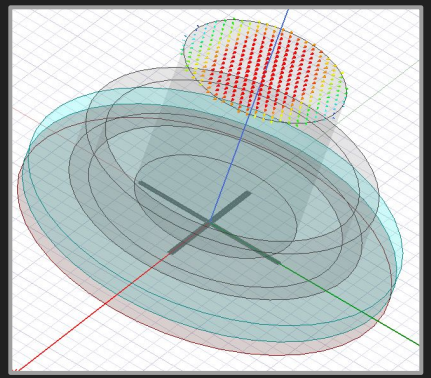
CPW bridges (Nb)

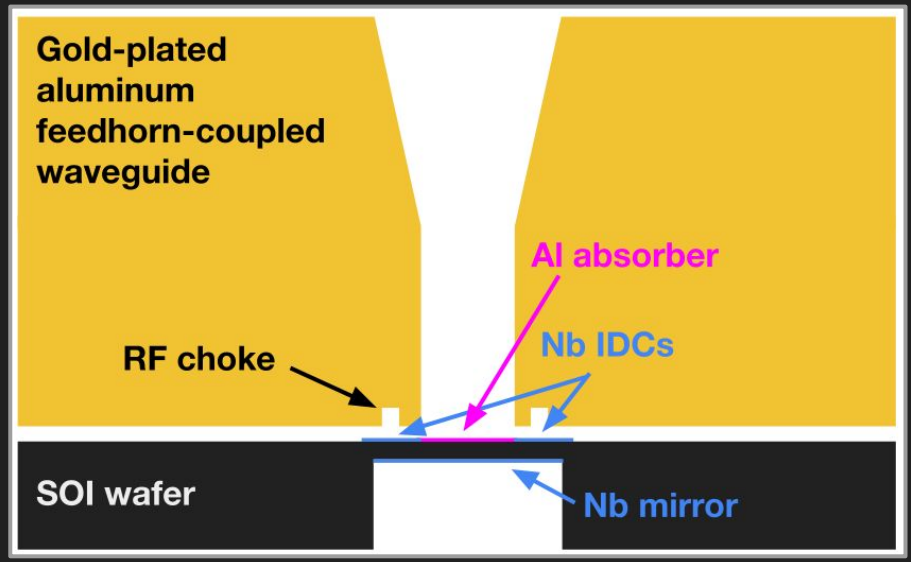


CPW bridge cross section

Pixel housing

- The two orthogonal Al absorbers are positioned beneath a feedhorn-coupled waveguide.
- A quarter-wavelength optical backshort is integrated into the silicon SOI wafer.

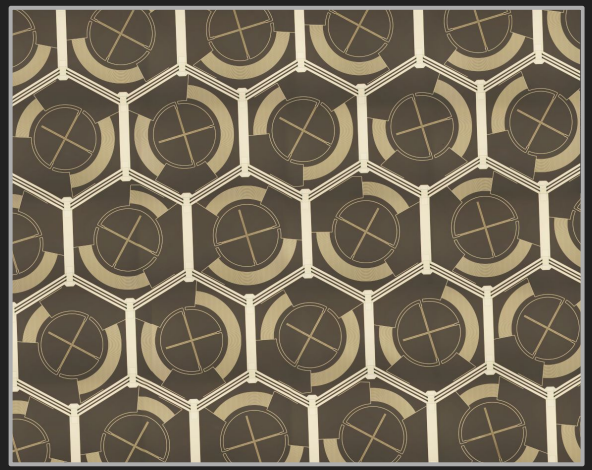




220 GHz array prototypes

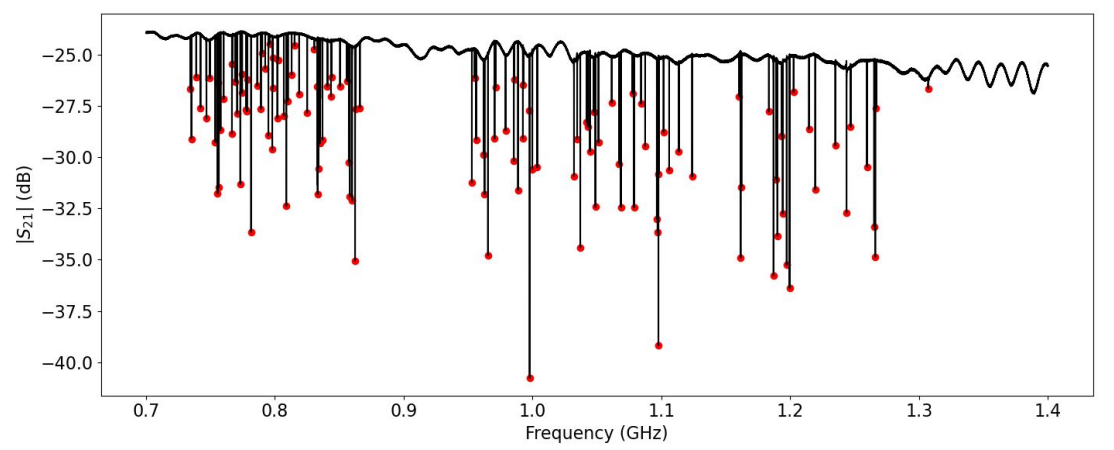
- We are fabricating “miniarrays” of 220 GHz pixels
  - 12-81 pixels per miniarray
  - 2.2mm center-to-center spacing
  - 4 pixel orientations
- Quick fabrication enables a rapid testing cycle
  - Metal deposition + lithography take 1 day
  - CPW bridges take 2 days
  - Si etches (for optically coupled chips) take 1 day

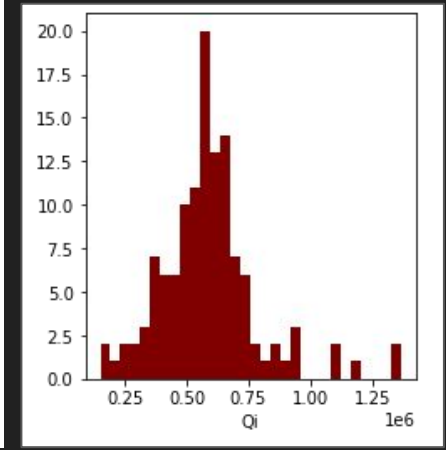

Photo by K. Fichman



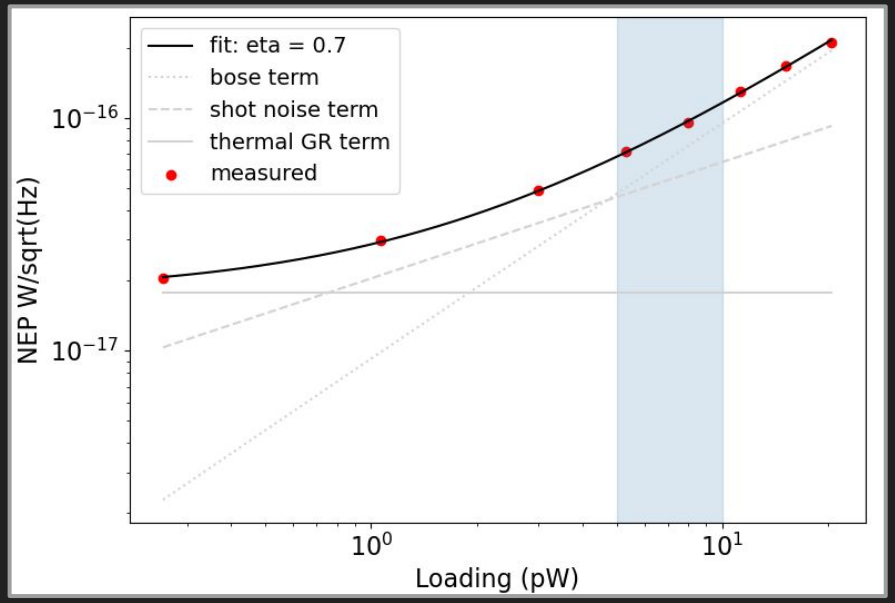
Dark testing

- UC fabrication has demonstrated high yield with Qi sufficiently above our goal of 100k
- Plots below are for a miniarray of 124 220 GHz detectors
- Work remains to improve fine control of frequency placement



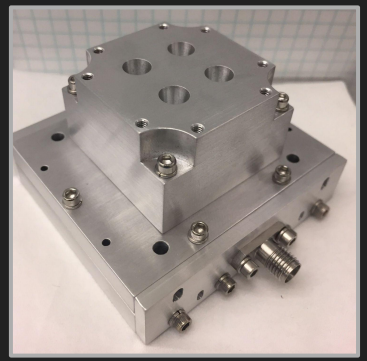


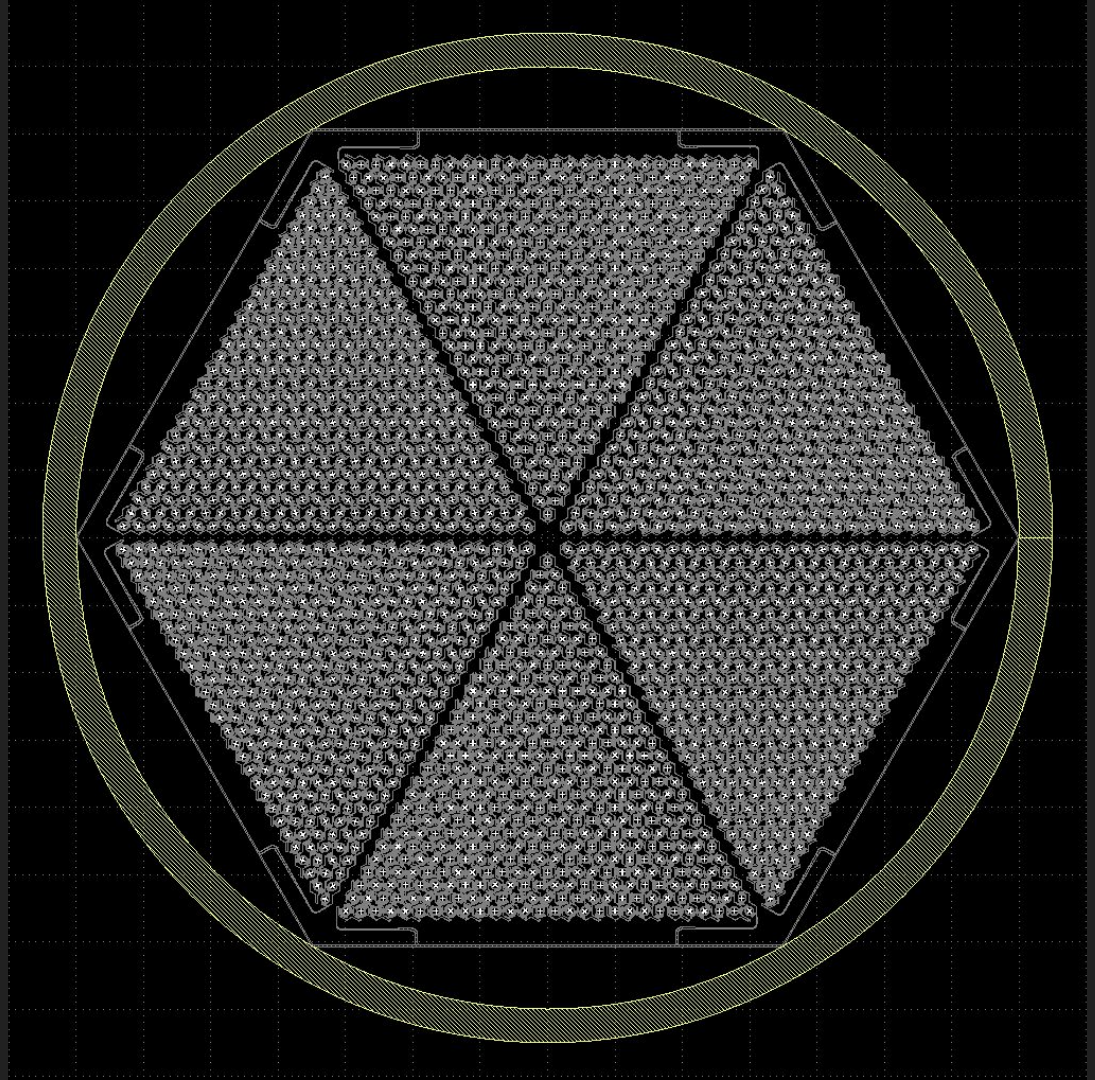
Optical testing



- Fit to NEP vs optical load gives an optical efficiency of ~70%.
  - From frequency response and photon noise level, extract an NEP for each optical load.
  - Fit a theoretical loaded NEP model to the measured points, with optical efficiency as a parameter.

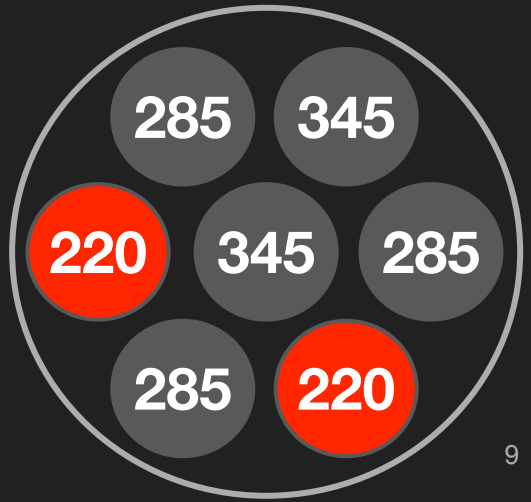
$$\mathrm{NEP}^2 = 2\eta_{\mathrm{opt}} P_{\mathrm{opt}} h\nu(1 + \eta_{\mathrm{opt}} \bar{n}_{\mathrm{ph}}(\nu, T_{bb})) + \mathrm{NEP}^2_{\mathrm{therm}}$$





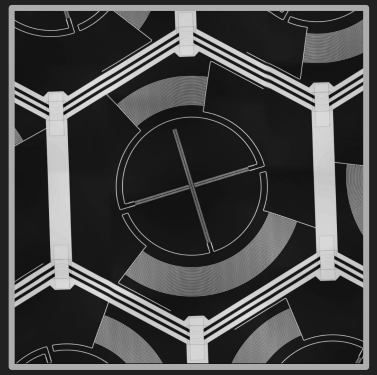
Full 220 GHz array design

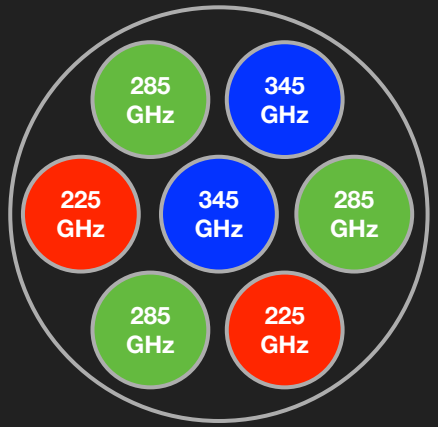
- 6-inch wafer
- Consists of 6 triangular subarrays
  - Each has 812 detectors on one feedline
- 4872 total detectors



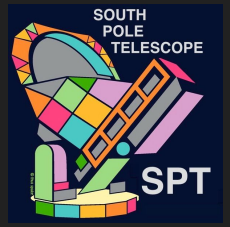
Summary

- Dark tests of initial 220 GHz prototypes indicate sufficient quality factors for our 2000/GHz multiplexing goal.
- Optical tests indicate ~70% optical efficiency.
- Fabrication and testing of other bands and larger arrays are underway!





Thank you!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