Characterization and Performance of a Kilo-pixel Array for ACTPol

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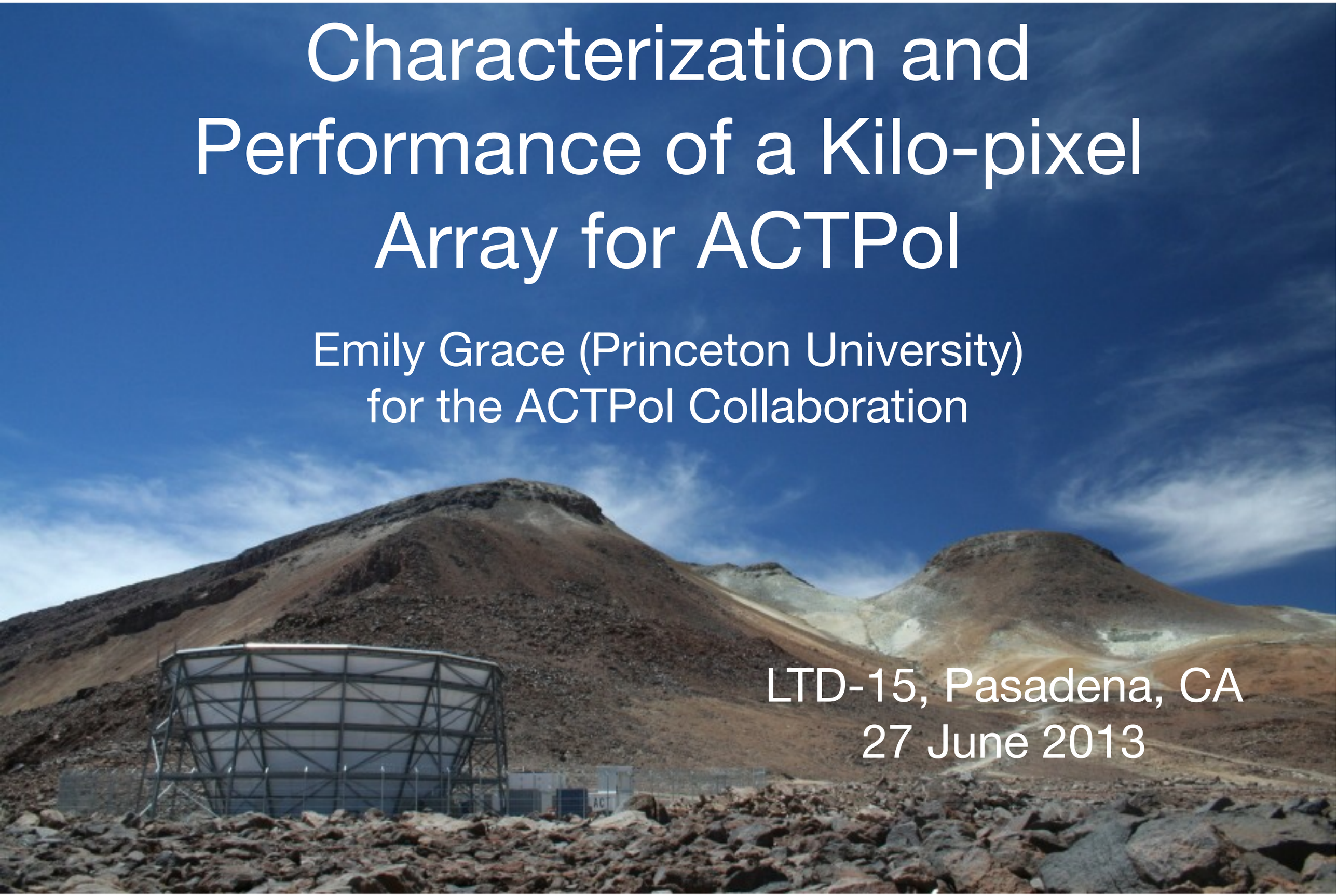
for the ACTPol Collaboration

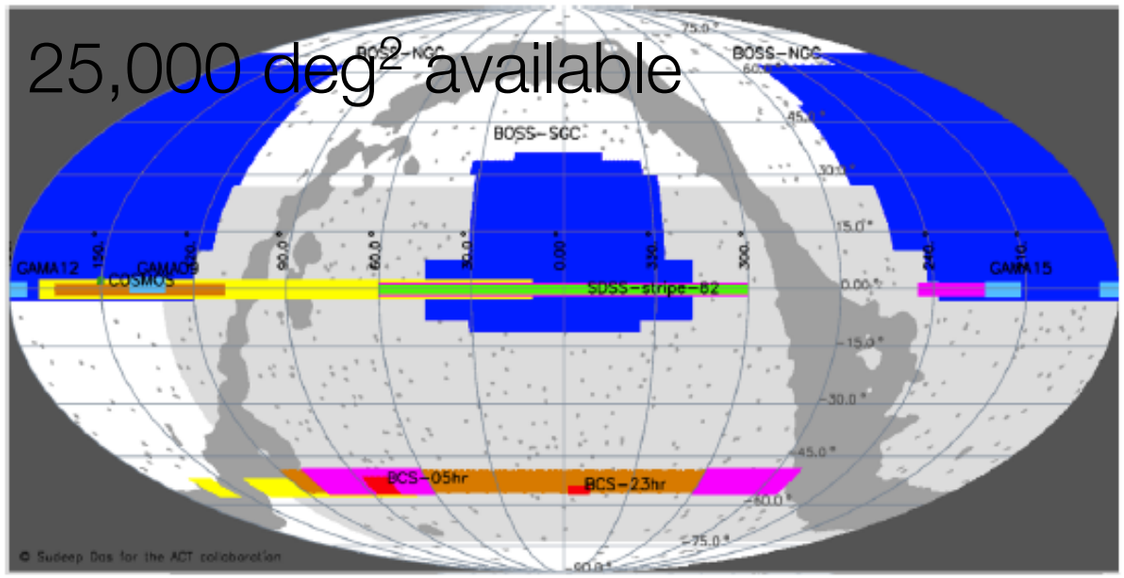


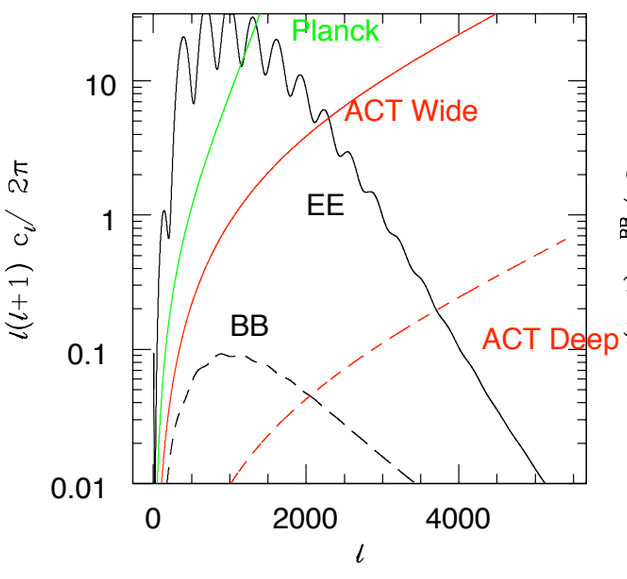
Science Goals

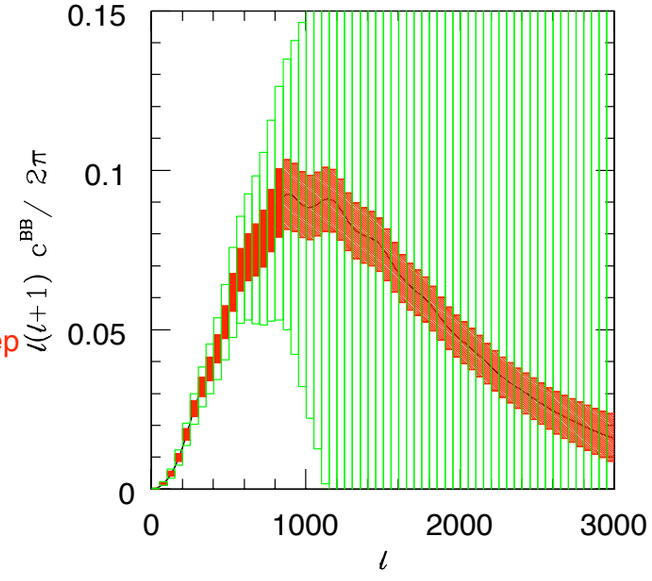
Characterize small scale CMB in temperature and polarization with sensitive measurements of high-ℓ TT, TE, EE, and BB spectra

TT and EE: Neutrino number, spectral index of inflation, primordial helium

Lensing B-modes: Sensitive to the sum of the neutrino masses and properties of dark energy





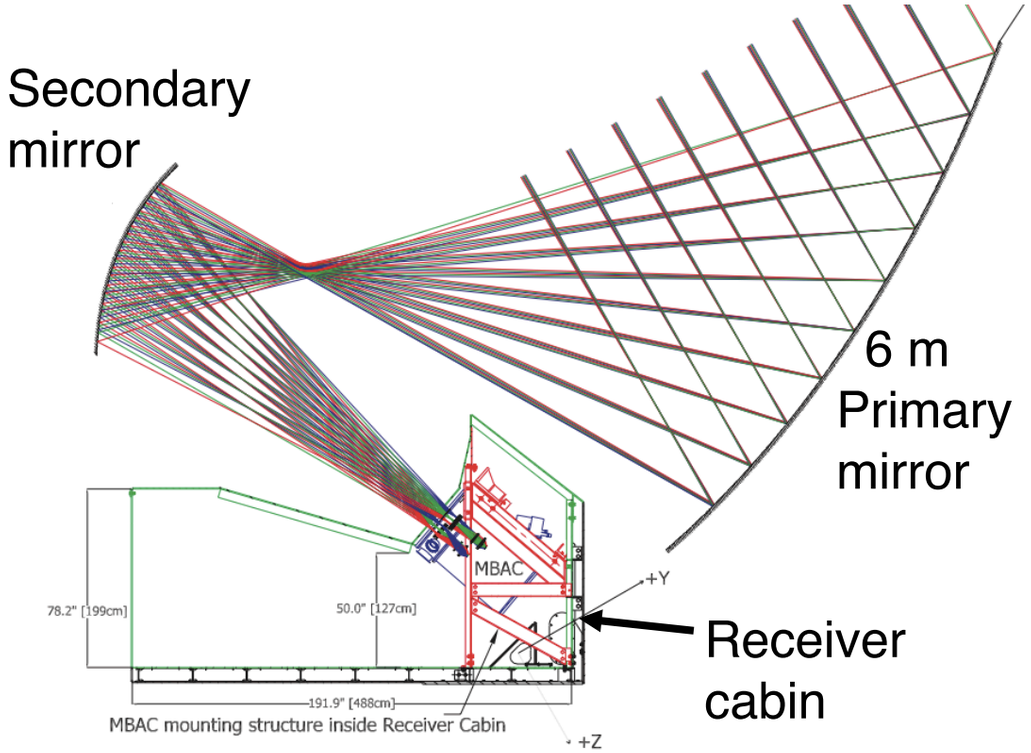


Cross-correlation science:
Wide Survey (~4000 deg^2)
Overlap with SDSS-III BOSS

Deep Survey (5 ~25 deg^2 fields)
Overlap with XMM-LSS, CFHTLS, HerMES,UKIDSS, DES, GAMA, etc

Cluster Catalog: Detect SZ clusters

ACTPol Instrument



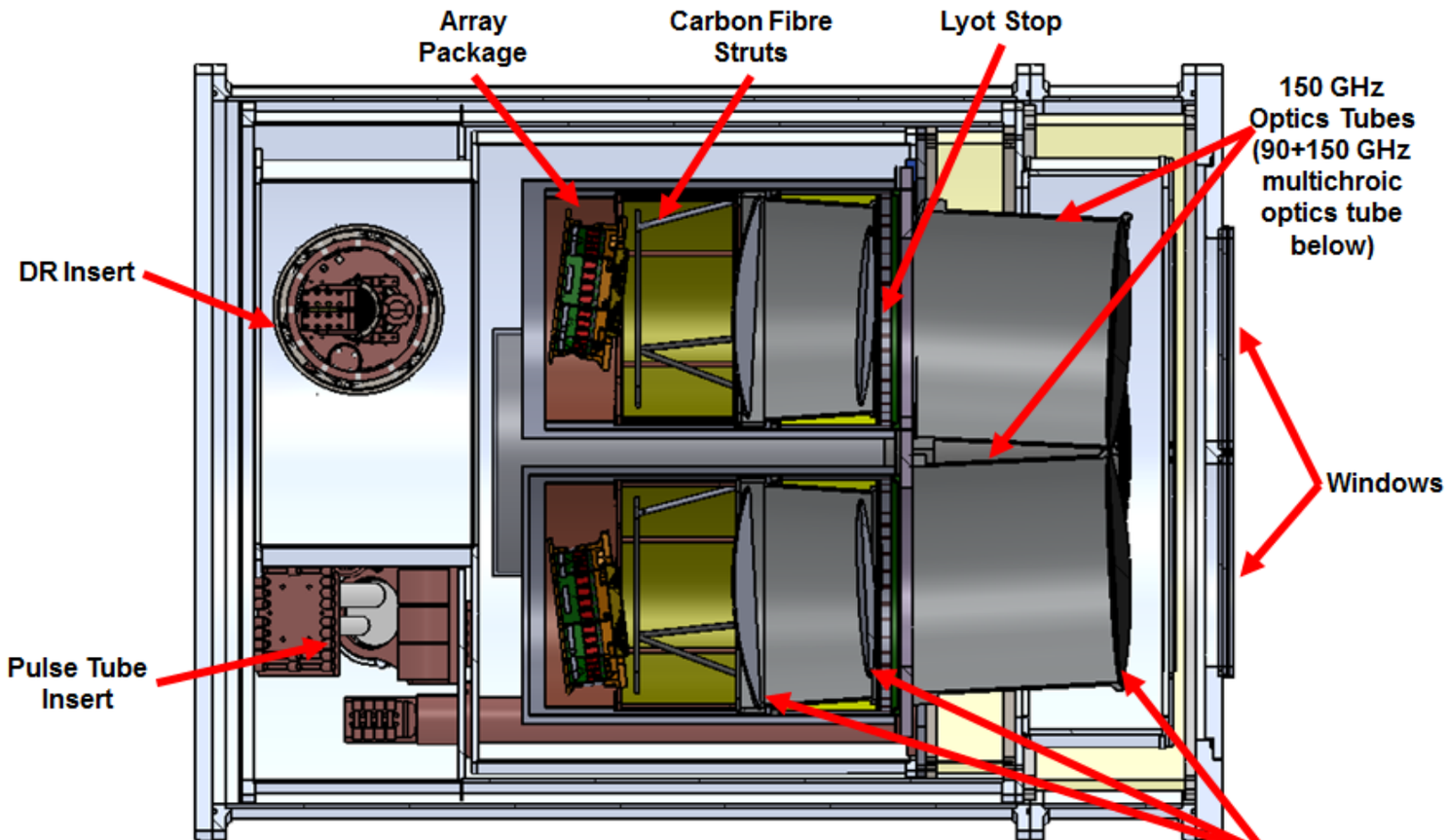
Off-axis Gregorian mirrors

Three independent optics tubes

Cryogenic silicon lenses with two-layer simulated-dielectric AR coating

Two 150 GHz focal planes and one multichroic 90/150 GHz focal plane

Pulse-tube backed dilution refrigerator cooling: ~100 mK bath temperatures



ACTPol Cryostat Cross-Section Across Dual 150 GHz Polarimeter Arrays and Optical Assemblies

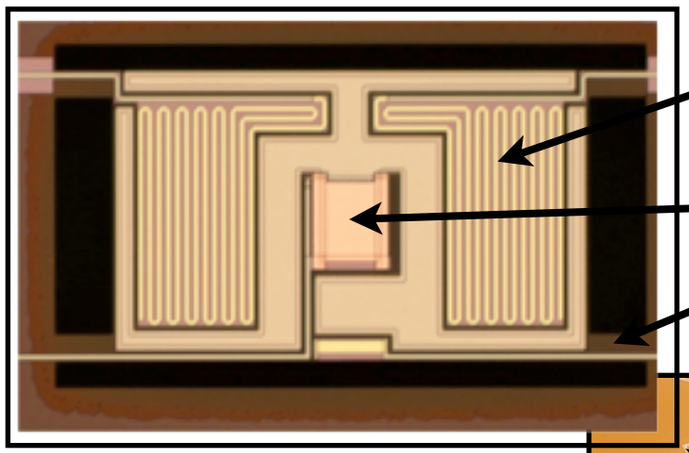
ACTPol Instrument

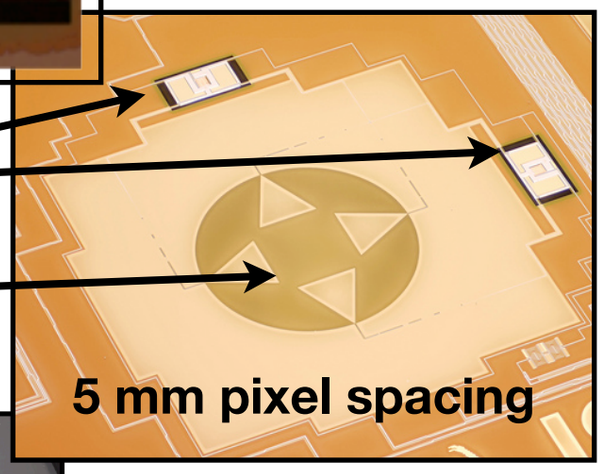
See posters:

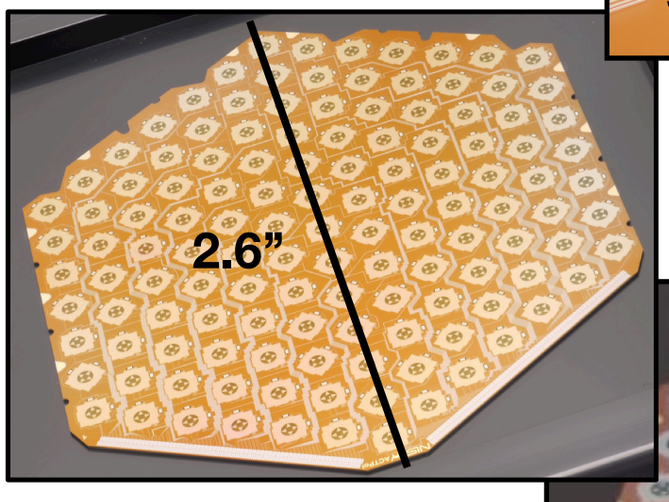
207: “Design and Operation of ACTPol, a Millimeter-wavelength, Polarization-sensitive Receiver for the Atacama Cosmology Telescope” - Ben Schmitt

108: “Metamaterial Antireflection Coatings: Meeting the Optical Requirements for Large Format Detector Arrays” - Charles Munson

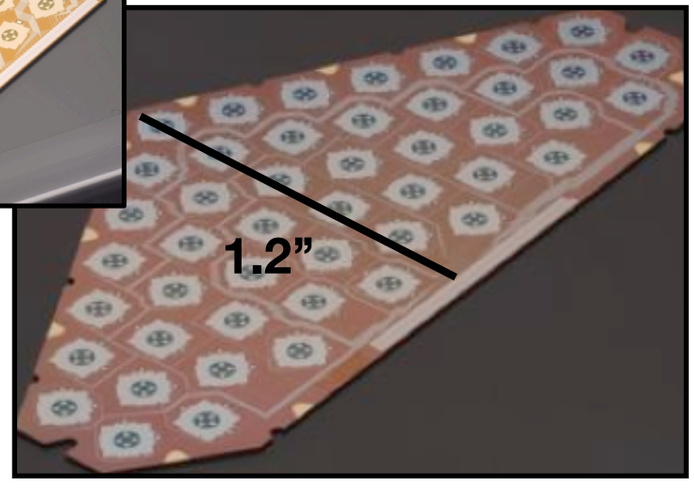
ACTPol Detectors







Hex Wafer:
127 pixels



Semihex Wafer:
47 pixels

Ortho-mode transducer (OMT) coupled transition edge sensor (TES) bolometers

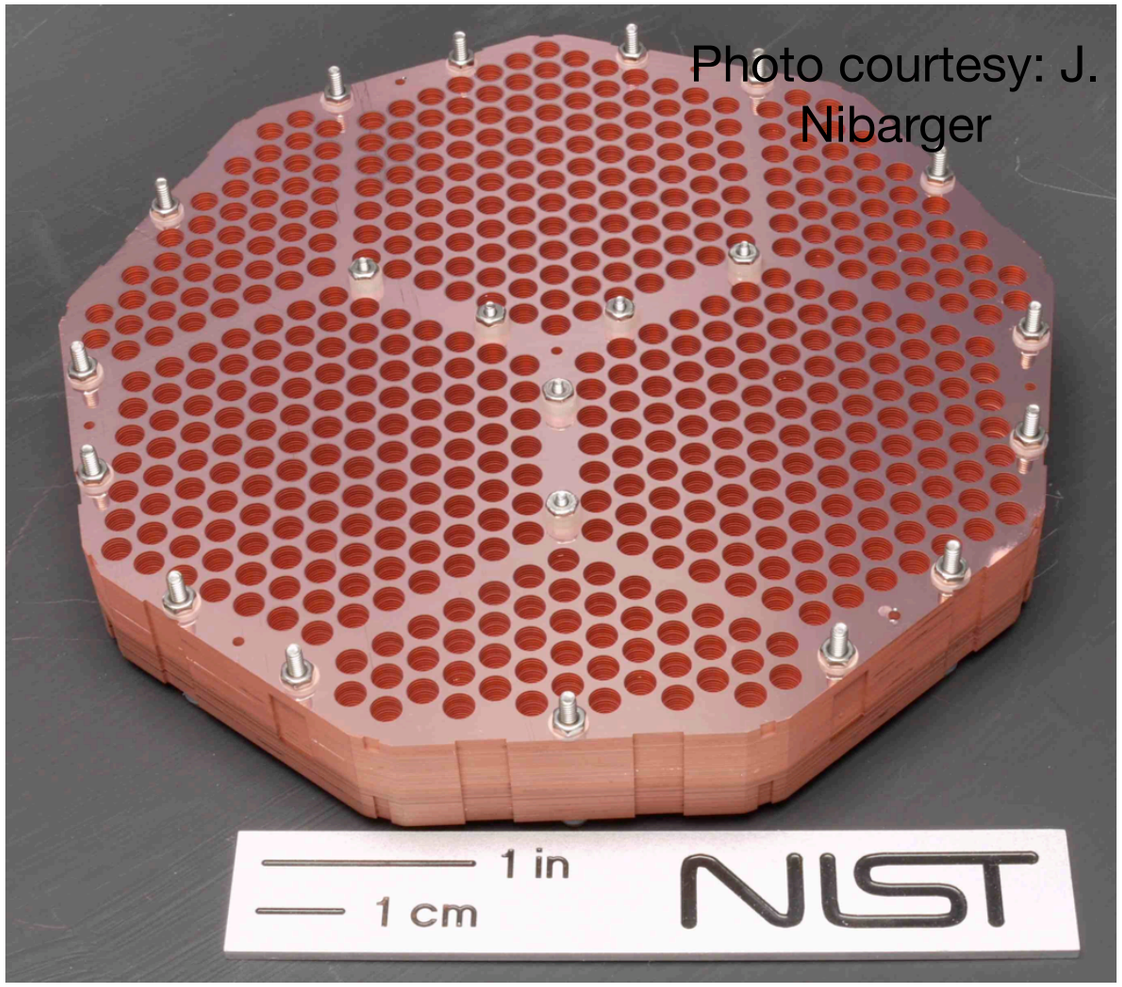
MoCu bilayer targets T_c = 150 mK

Two wafer shapes:
hex and semihex

Detector wafers fabricated at NIST

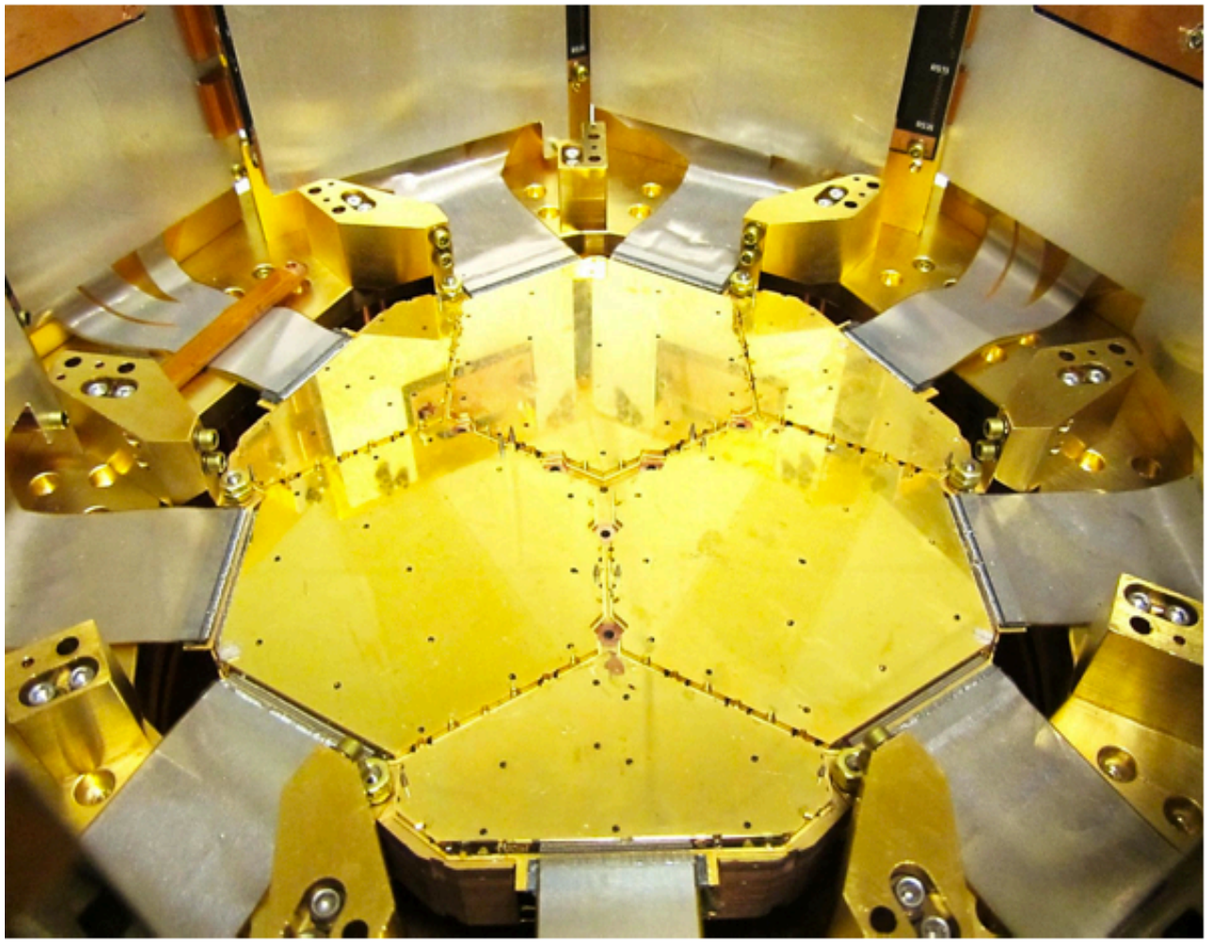
Readout using time domain multiplexing with three stages of SQUID amplification

Array Package



3 hex wafers and 3 semihex wafers selected for first array

512 pixels (1024 TESes) per array

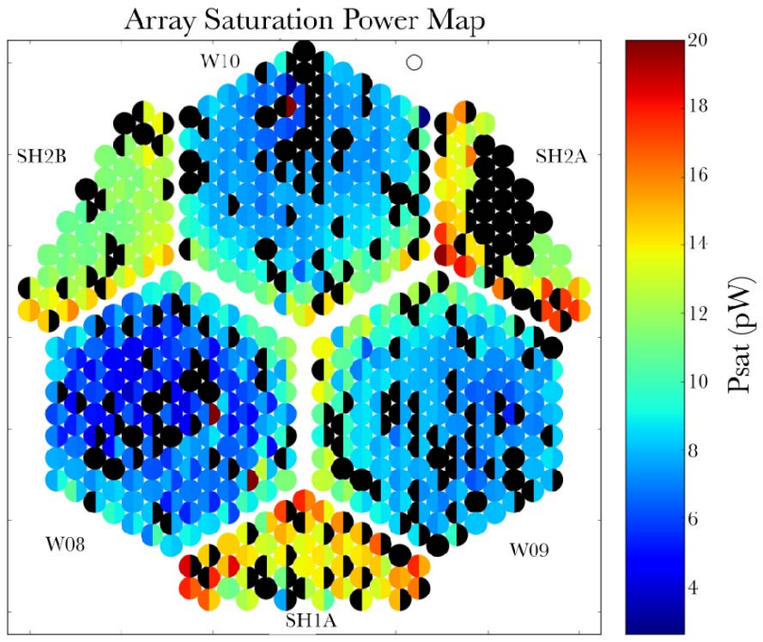


Monolithic corrugated feedhorn stack fabricated from stacked silicon wafers

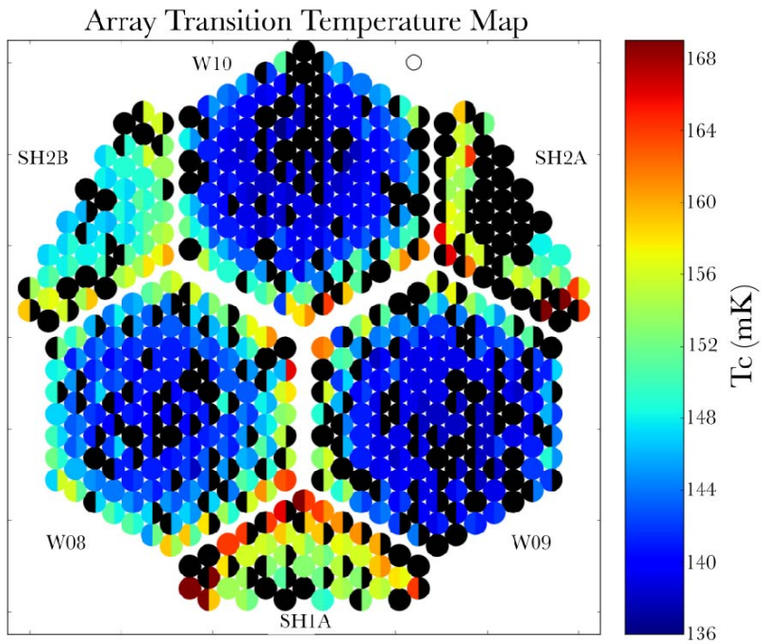
Array Characterization

Extensive characterization of full array in the ACTPol receiver conducted in the lab prior to deployment

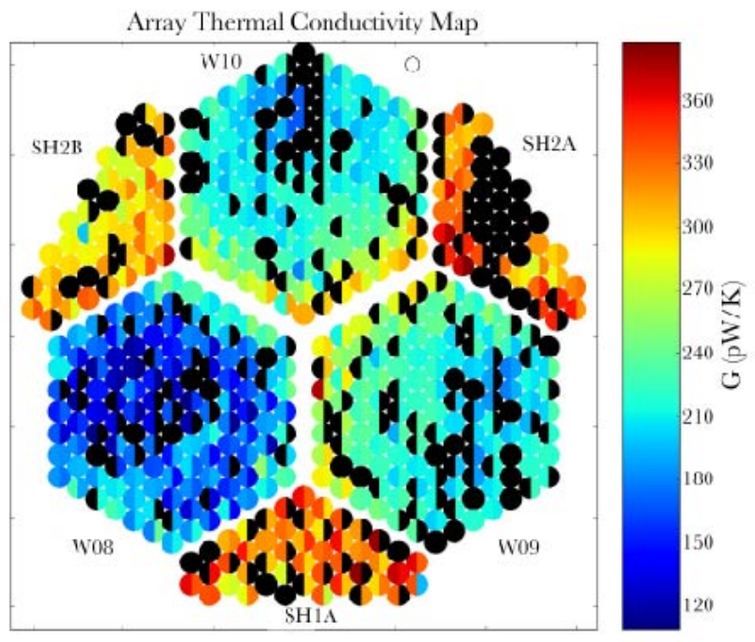
P_{sat}*: Target = 13.5 pW

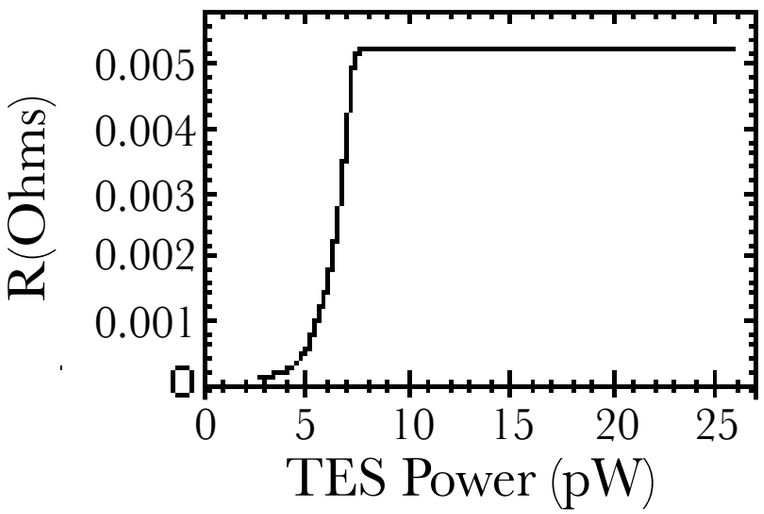


T_c: Target = 150 mK



G: Target = 240 pW/K

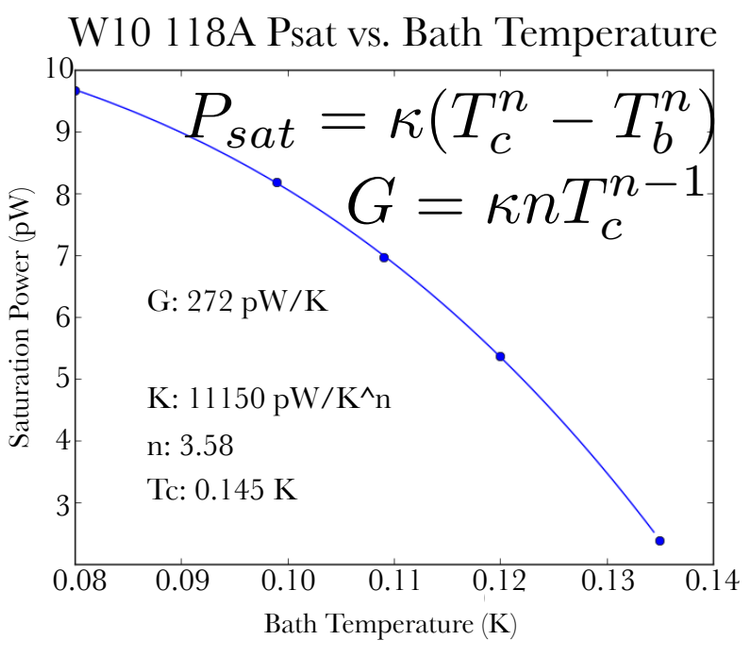




* measured with window cover at T_{bath} = 80 mK

Average array values:

	Hexes	Semihexes
Psat (pW)	8	13
Tc (mK)	144	155
G (pW/K)	210	320



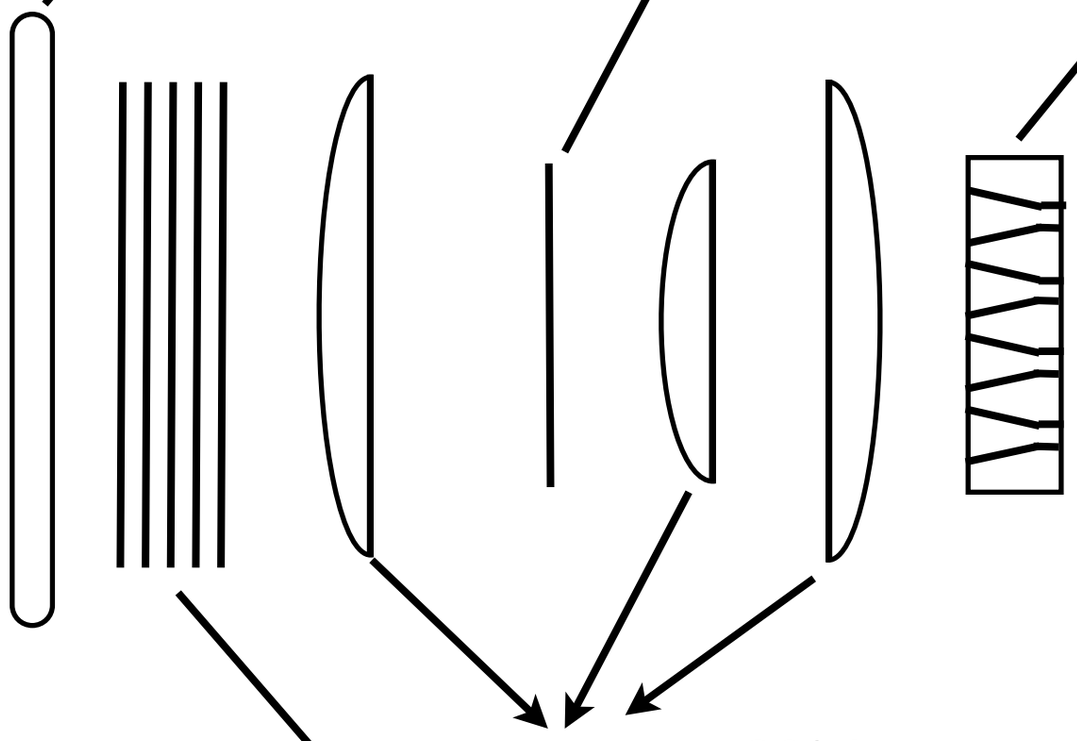
Optical Characterization

LN2 and room temperature blackbodies

Window: 1% loss

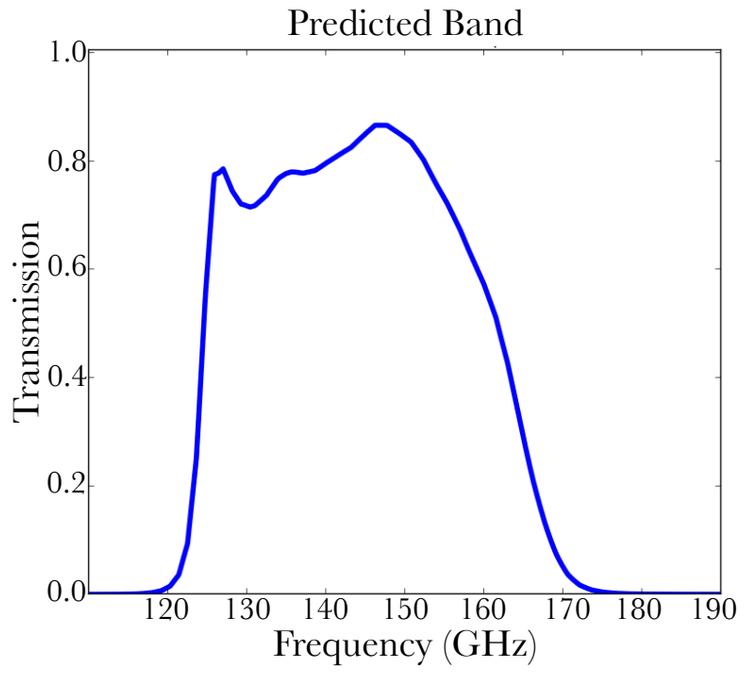
Reduced Lyot stop: 5% spillover efficiency

Waveguide cutoff



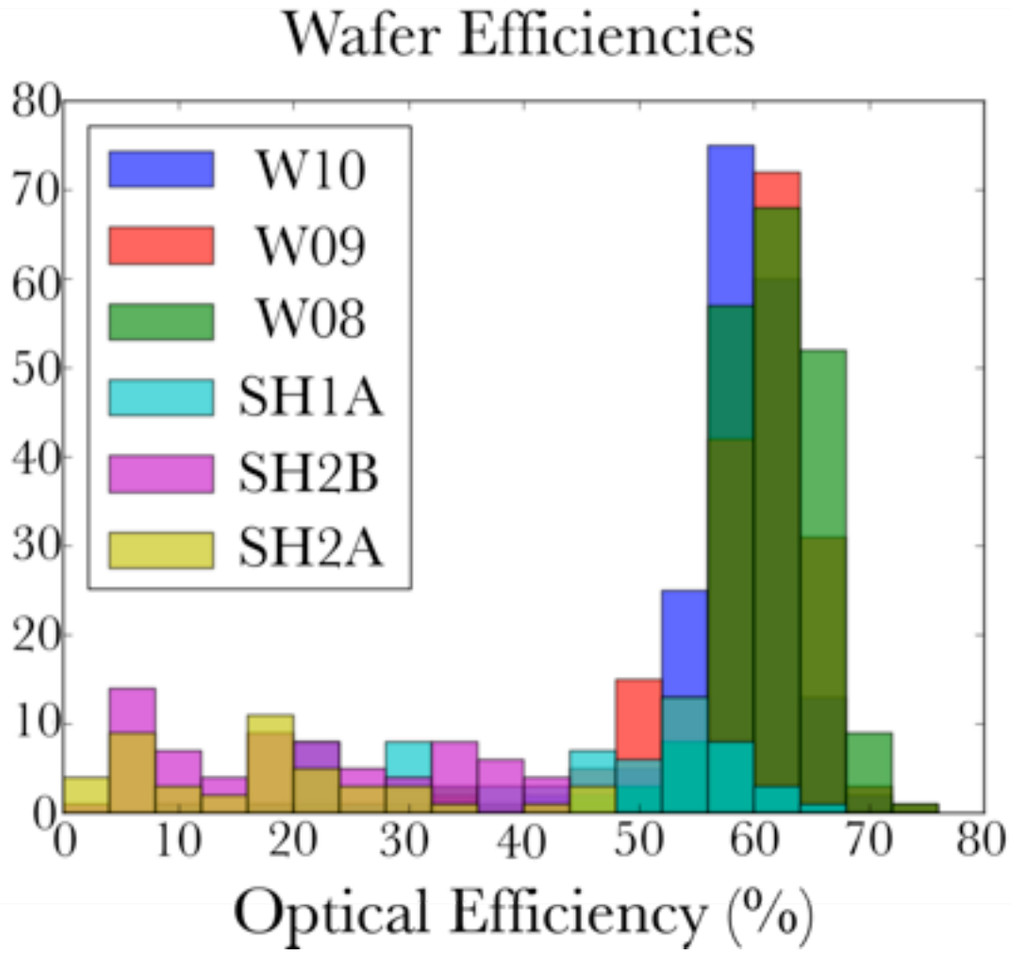
Lenses: <1.2% loss each

Filter transmission measured by Cardiff



$$\eta = \frac{P_{sat,77K} - P_{sat,300K}}{\Delta P_{\gamma,predicted}}$$

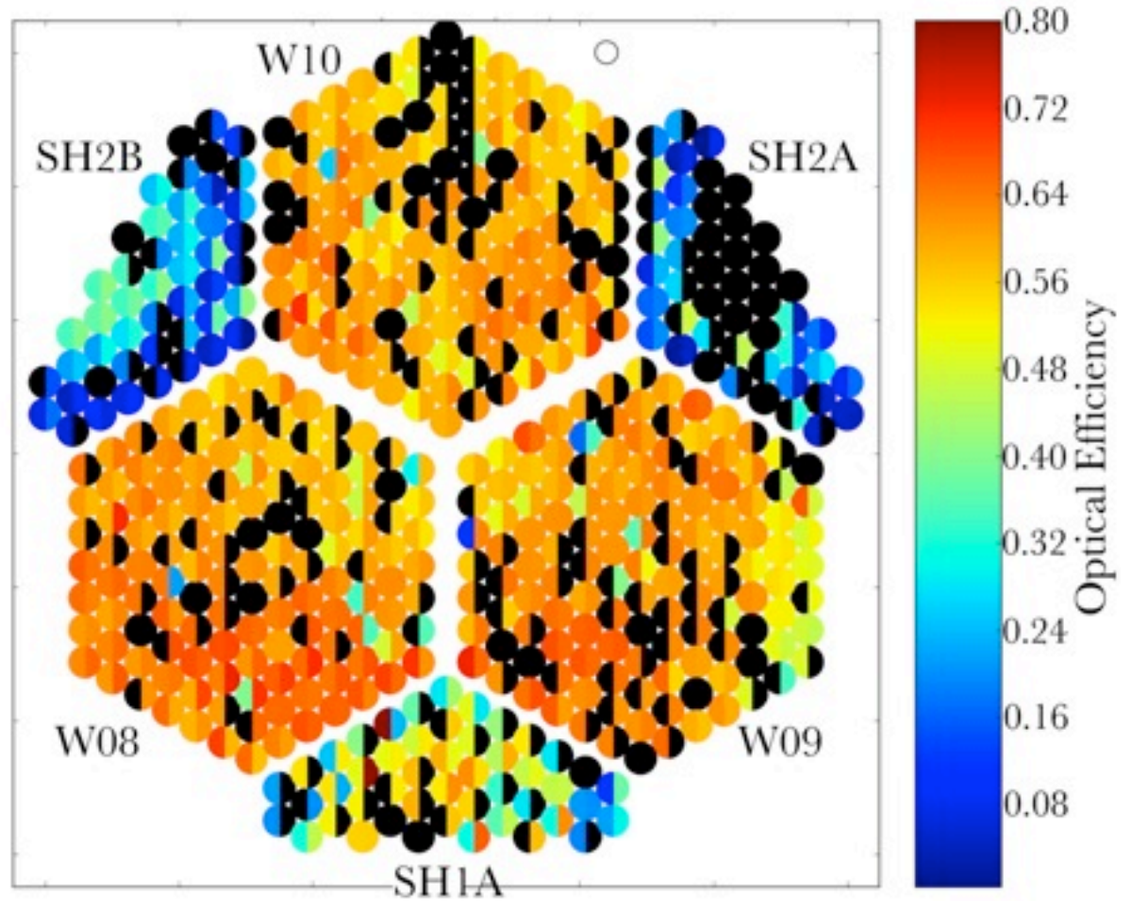
Optical Characterization



Results to be confirmed with planet measurements

See poster:
310: “Characterization of Transition Properties and Optical Efficiencies of ACTPol Transition-edge Sensors” - Christine Pappas

Detector Optical Efficiencies:
W10, W09, W08: 60%
SH1A: 47%
SH2B and SH2A: 21%

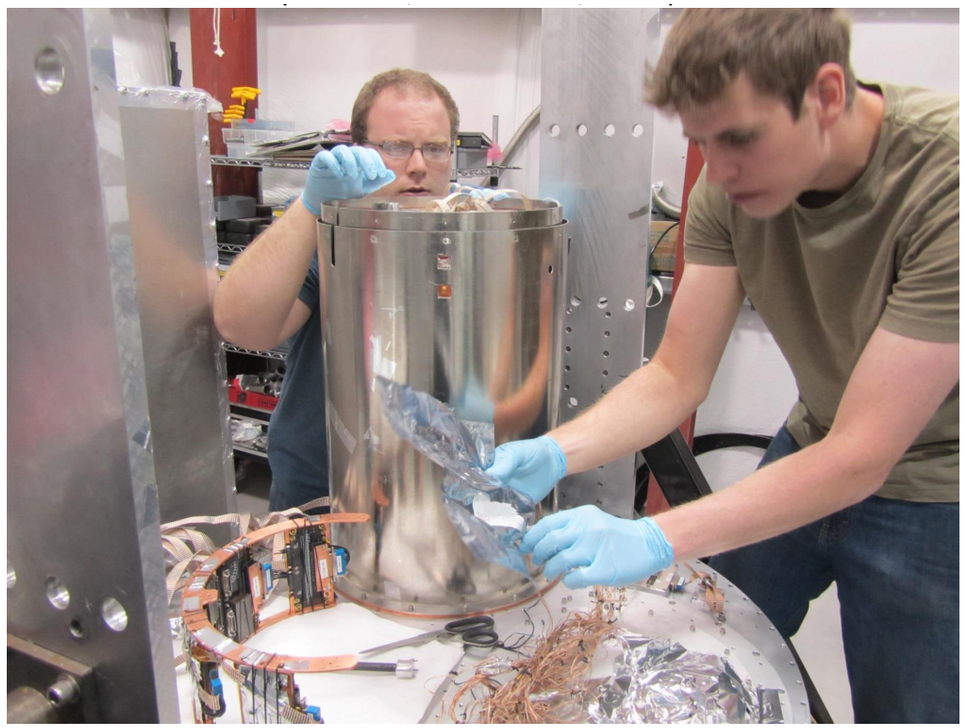


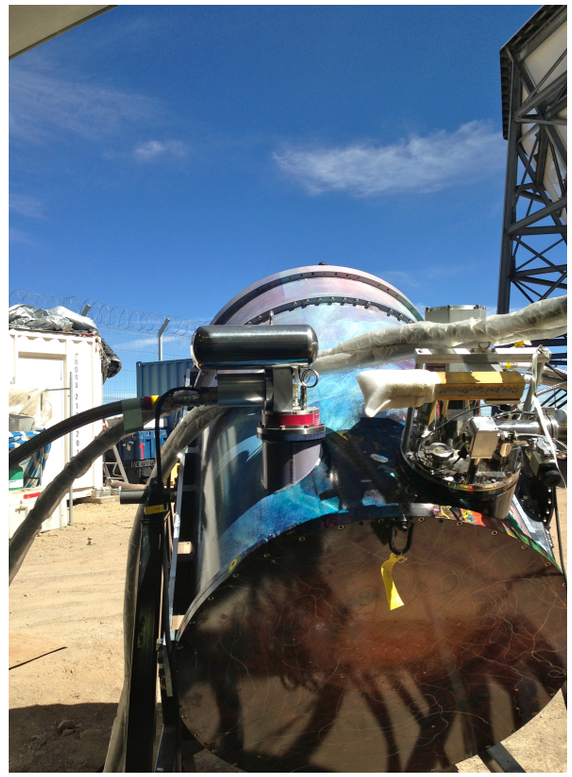
Deployment

February 2013: Receiver arrives at site in Chile

March - April 2013: Final on-site receiver integration

April - May 2013: Post-shipping cooldown for validation of cryogenic and detector performance





Time Constants

Intrinsic thermal time constant of detector:

$$\tau = \frac{1}{2\pi f_{3db}} \sim \frac{C}{G}$$

Low pass filters the response of the detectors

Three methods of measurement:

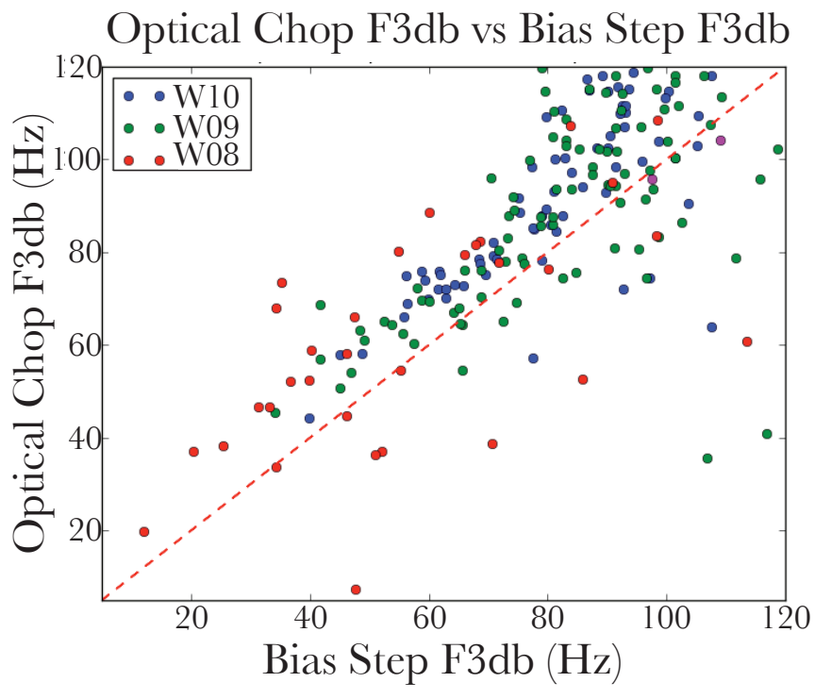
1) Optical chop

$$I_{peak} = I_0 \sqrt{\frac{1}{1 + (\frac{f}{f_{3db}})^2}}$$

2) Bias step

$$I(t) = I_0 + \Delta I e^{\frac{t}{\tau}}$$

3) Planet scans



Initial comparison between optical chop and bias step measurements shows good correlation

Want a fast and repeatable method of calibration -> bias steps

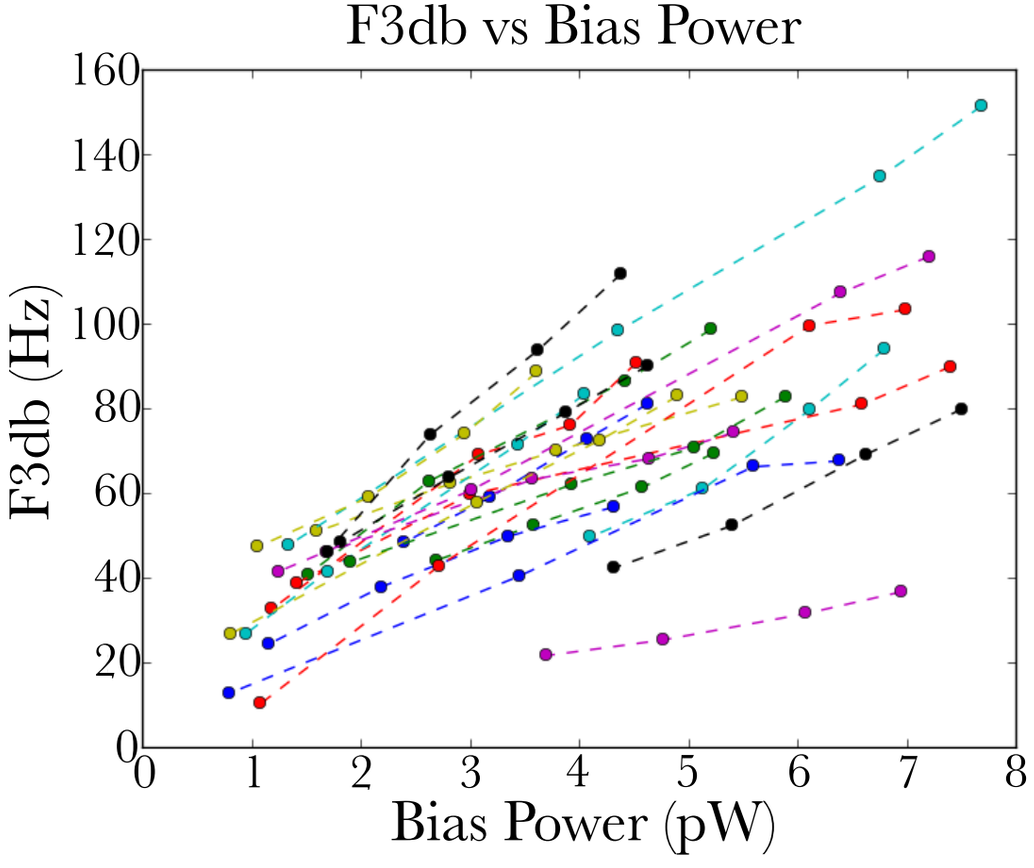
Further comparison of methods soon with planet scans

Time Constants

Effect of bias conditions on time constant:

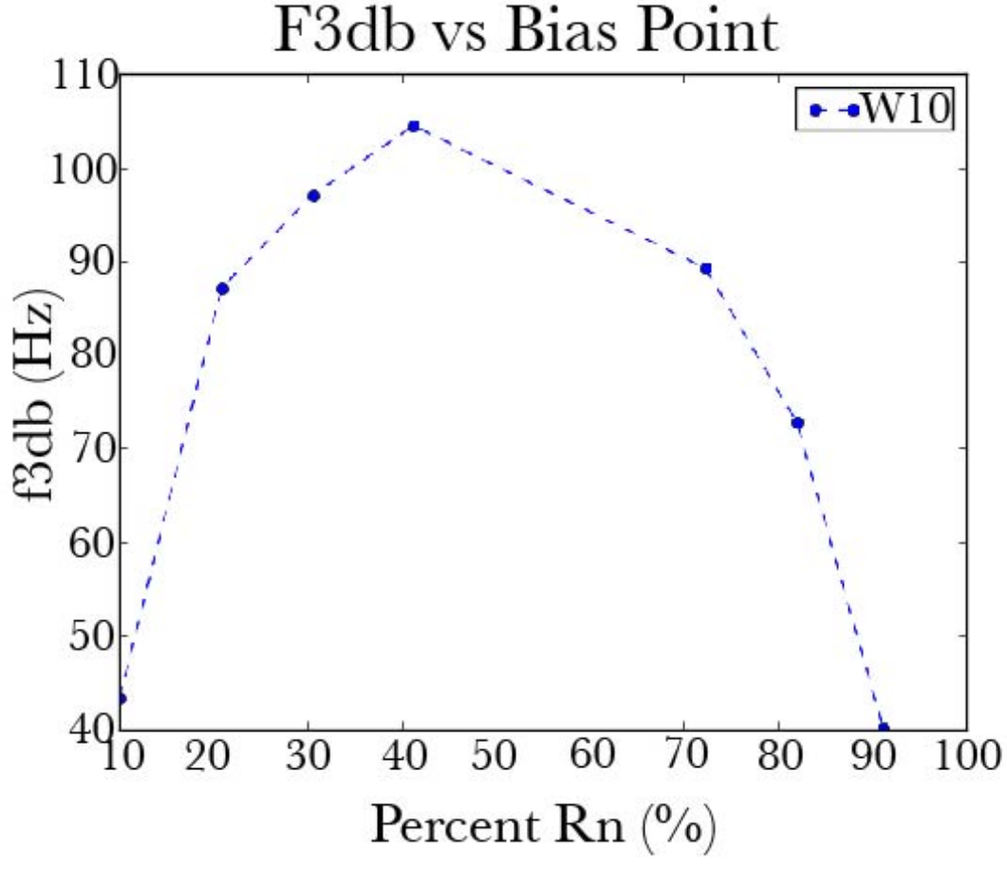
$$f_{3db} = \frac{G}{2\pi C}(1 + \frac{(1 - \frac{R_{sh}}{R_0})\alpha_I}{(1 + \beta_I + \frac{R_{sh}}{R_0})GT_0}P_{J0})$$

Detectors slow with decreased bias power:



Fastest response achieved in middle of transition

Adequate time constants achieved across broad range of transition:



Status

Installed on telescope for first light in May

Initial on-telescope characterization recently conducted

Detector performance optimization and calibration tests to be performed

CMB observations to commence this (northern) summer

Thank you!

This work was supported by a NASA Office of the Chief Technologist's Space Technology Research Fellowship."