Optics Updates

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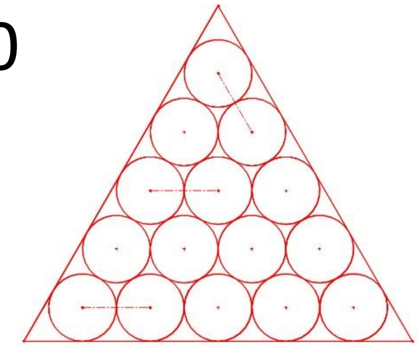
Summary

- First iteration of focal plane layout
- Mirror emissivity
- Effect of changing temperatures of various components
  - Stop at 4 or 6.5 K.   40 % effect at 200 GHz.
  - Primary at 30 or 45 K. 40 % effect at highest frequency
  - Focal plane at 50, 100, 150 mK. 7% effect at lowest frequency
- Rough estimate of alignment tolerances
- Sensitivities for version 2.7, posted to wiki

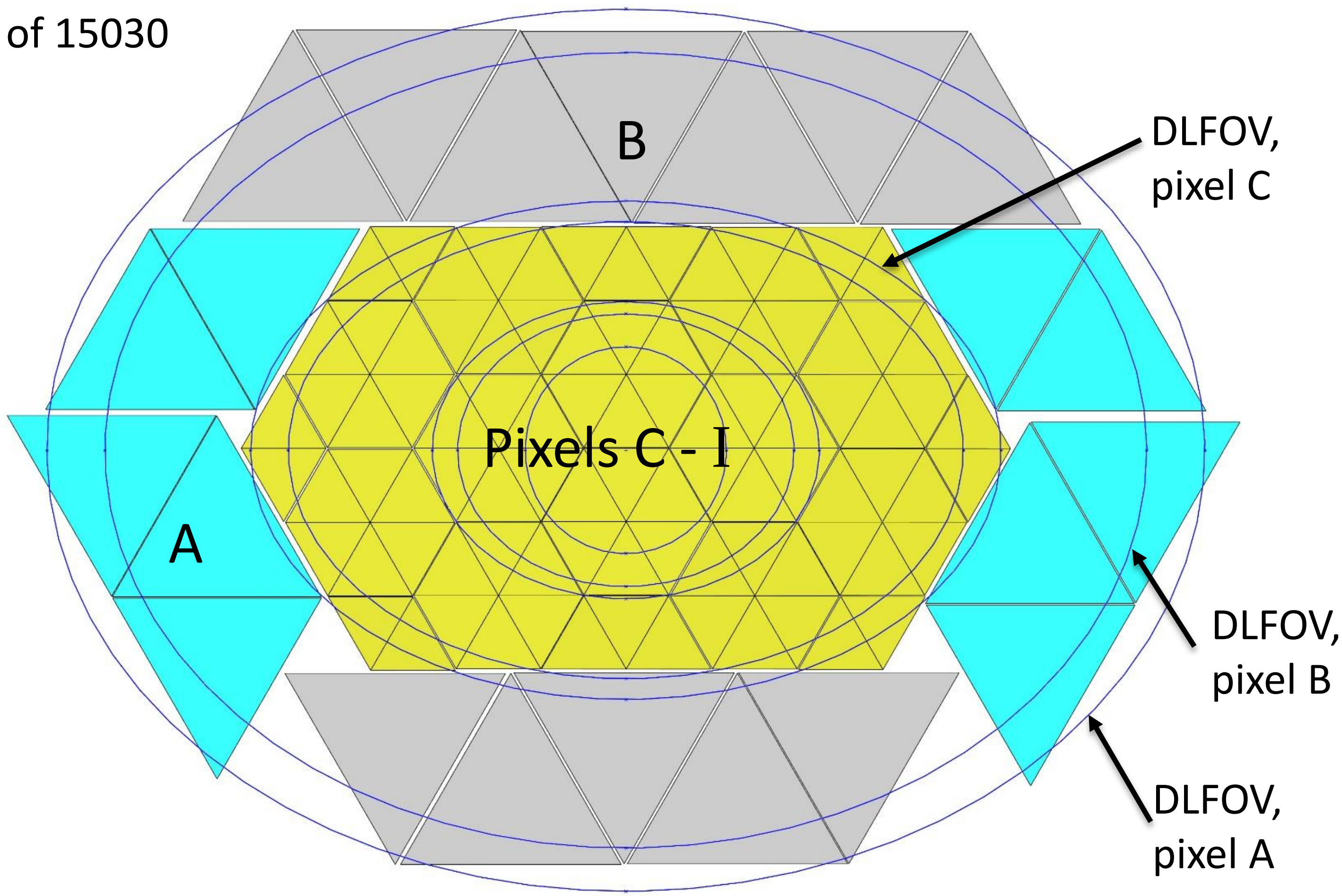
- Miscellaneous items in response to past telecom questions
  - Single band pixels instead of multichroic
  - 120 cm crossed system at 4 K

Open Dragone, Focal plane layout, version 0



- Assuming pixels hex-packed on triangular wafers
  - Sets of 6 triangles could be hexagons instead
  - No spacing for wiring
- Pixels C - I all on 45 mm triangles.
- Pixel A FOV in horizontal direction increased from +/- 8 deg to +/- 9
  - Still diffraction limited, mirrors will be slightly wider
- 14866 px vs goal of 15030

Pixel type	Number	
	Goal	Achieved
A	65	60
B	130	120
C	460	460
D	550	540
E	670	637
F	520	544
G	120	135
H	110	110
I	100	105



Mirror Emissivity

- Measurements of Planck (Tauber 2010) mirrors give 0.1 % at 150 GHz, 110 K, we've used 1%
  - Scales with sqrt(frequency).   This scaling has always been assumed.
  - Scales with temperature, below is at 296 K and 110 K.
  - Suggests up to 0.5% emissivity at highest frequencies is possible due to dust contamination on mirrors

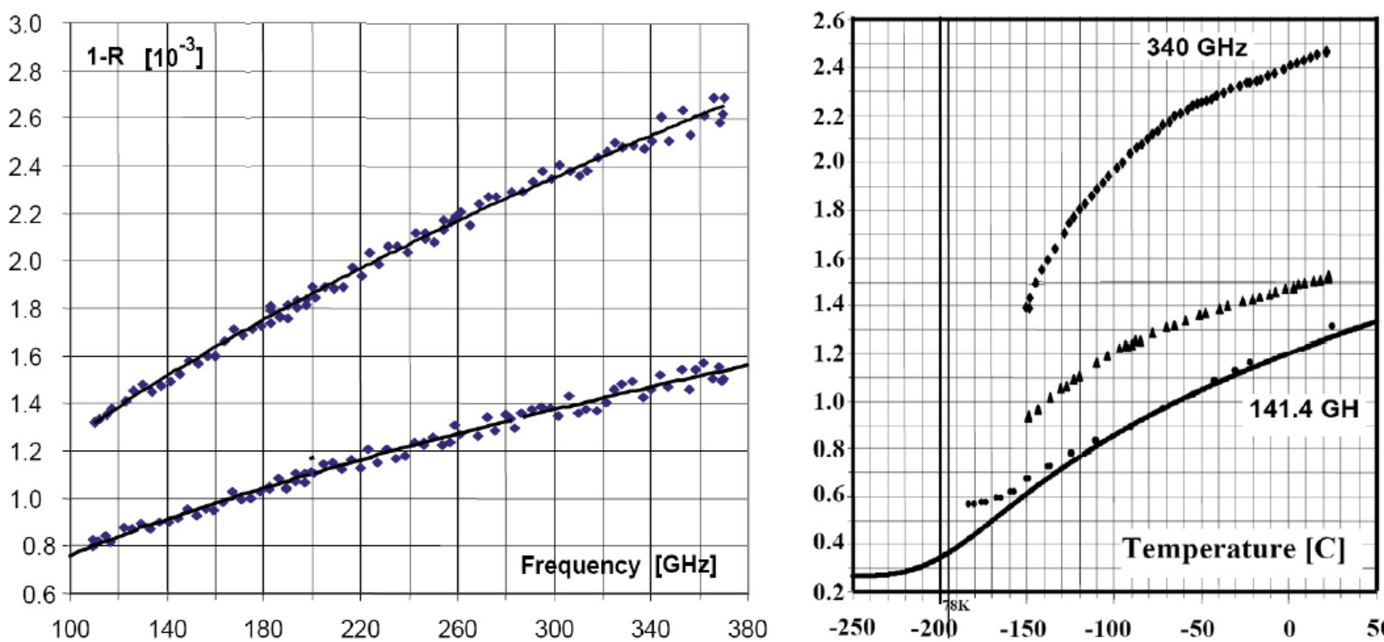
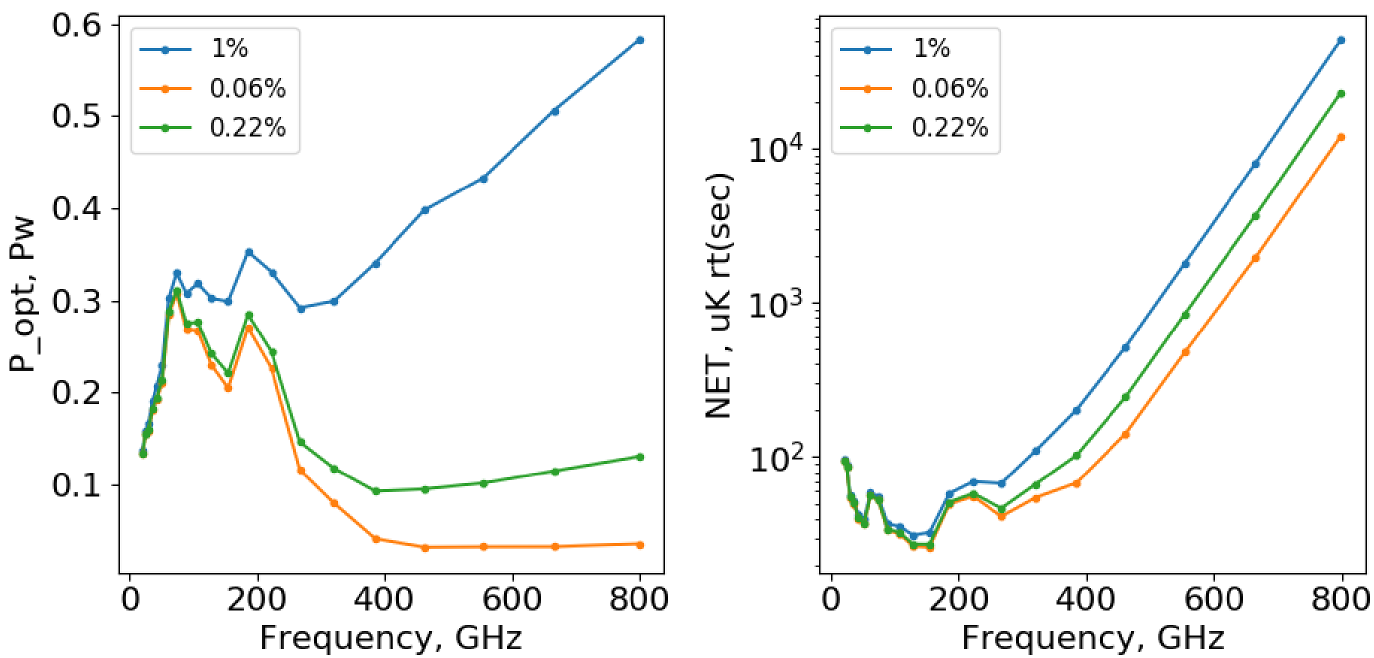


Fig. B.1. (*Left*) Measured dependence of the reflection loss (1 – *R*) of a sample of *Planck* reflector material as a function of frequency, when the sample is at room temperature (296 K, upper curve), and at ~110 K (lower curve). The solid lines are fits to the expected root-square dependence on frequency and (temperature-dependent) resistivity. (*Right*) Dependence of the reflection loss of the same sample as a function of temperature, for two frequencies: 340 GHz (diamonds) and 141 GHz (triangles). The solid line is a theoretical calculation of the reflectivity of pure aluminium, including the abnormal skin effect, which sets in at a temperature below ~60 K. The dots are measurements of a 0.3 mm thick sheet of pure aluminium.

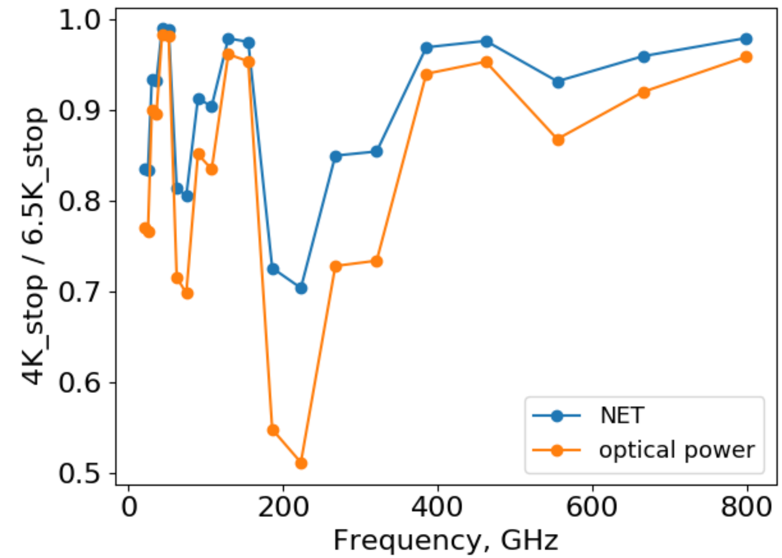
Mirror Emissivity

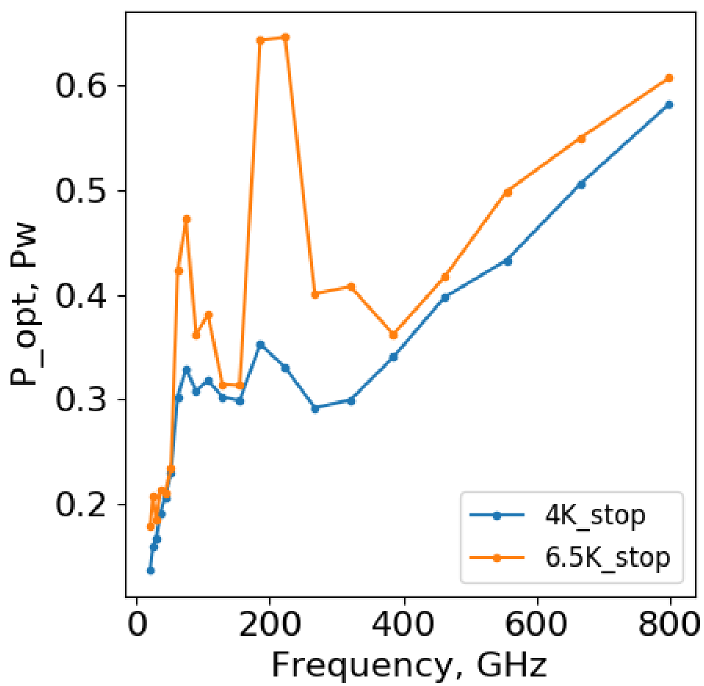
- Calculated 140 cm Open case with 30 K primary, 4 K secondary,
  - 0.06 % emissivity at 150 GHz
    - Aluminum at 4 or 30 K is 0.04%. Plus 0.02% for offset seen with thin films.
  - 0.22% emissivity at 150 GHz
    - Assuming 0.5% at 800 GHz (from Planck worst preflight case of dust contamination) scale by sqrt(frequency)
- NET / pixel improves by 4x and 2x at 800 GHz.
- Planck in flight measurements were fit by a constant emissivity of 0.07%.

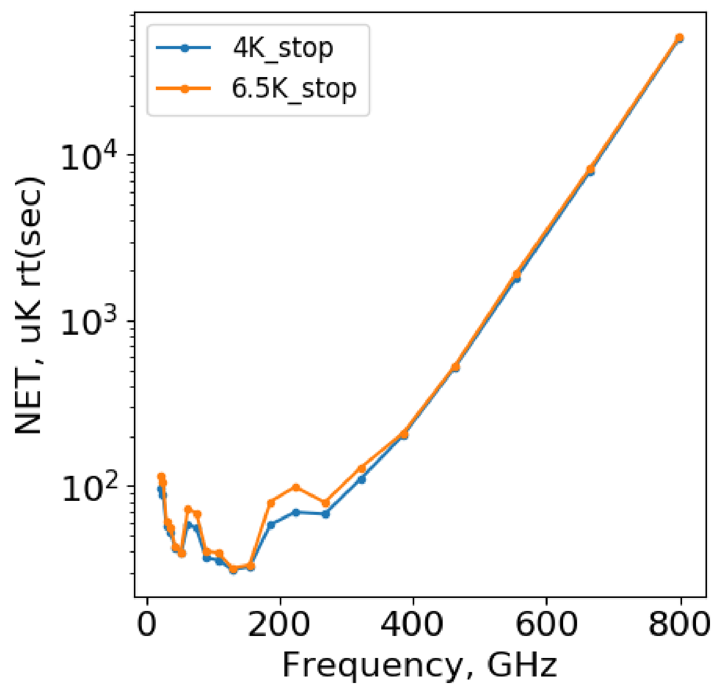


Stop temperature

- Comparing 4 K and 6.5 K stop and secondary
- Load increase largest for lowest band in pixel
  - Lowest band has 30% spillover
- Worst at 200 GHz where NET is higher by a factor of 1.4

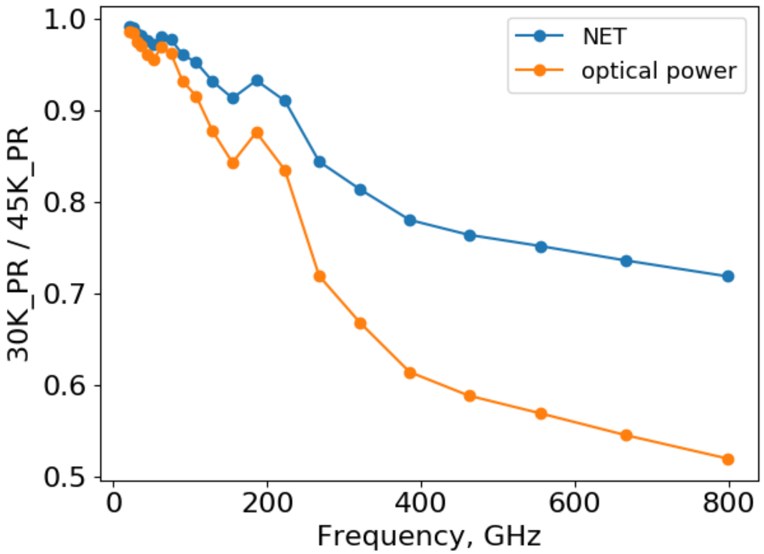


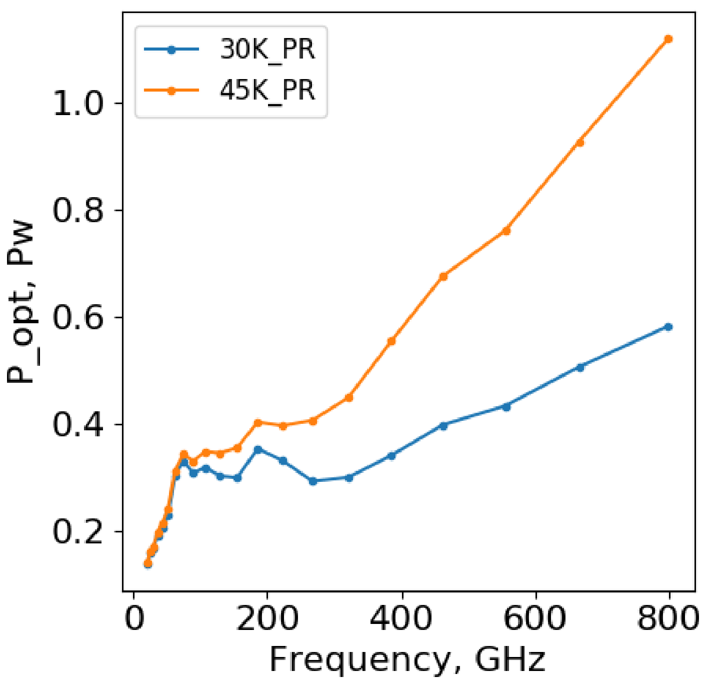


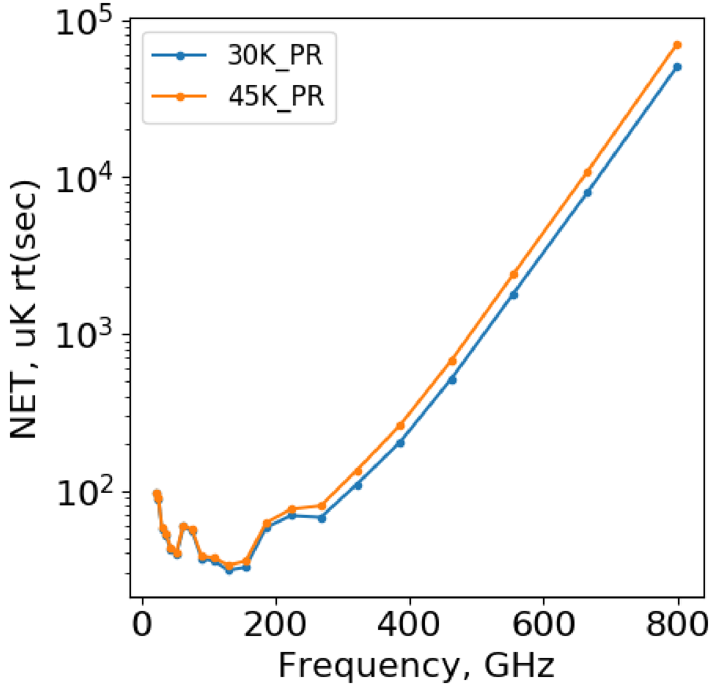


Primary temperature

- Comparing 30 K and 45 K primary
- NET worse by 1.4 at 800 GHz

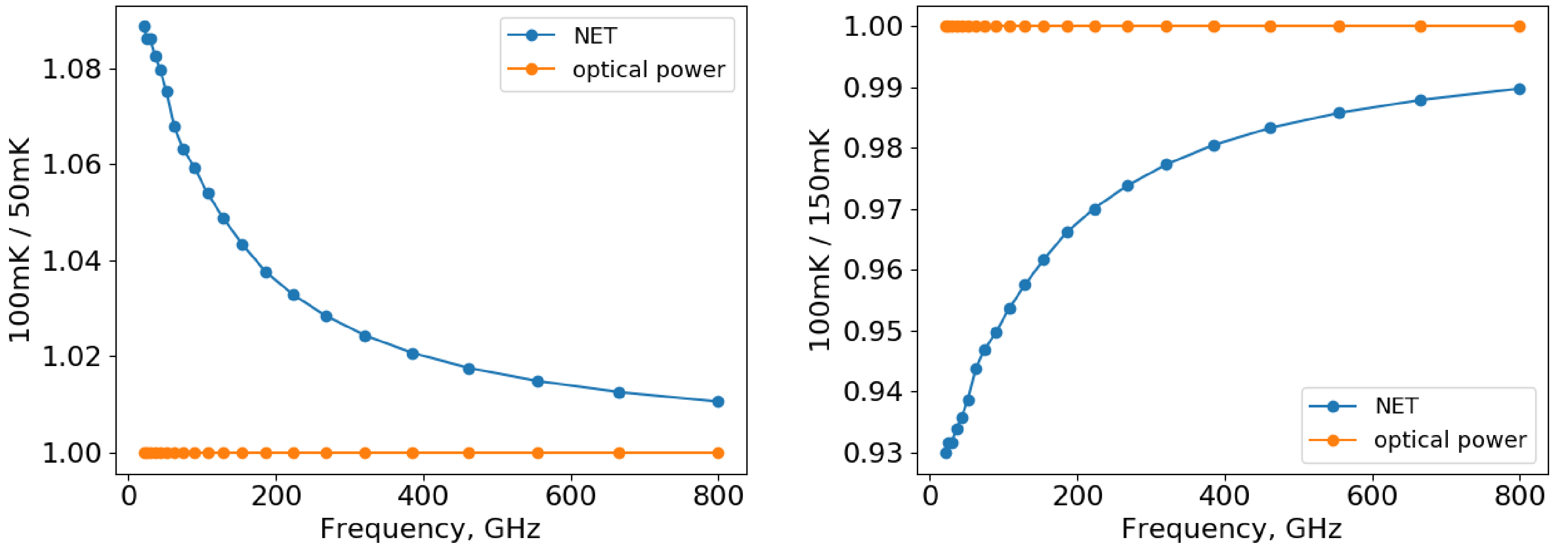






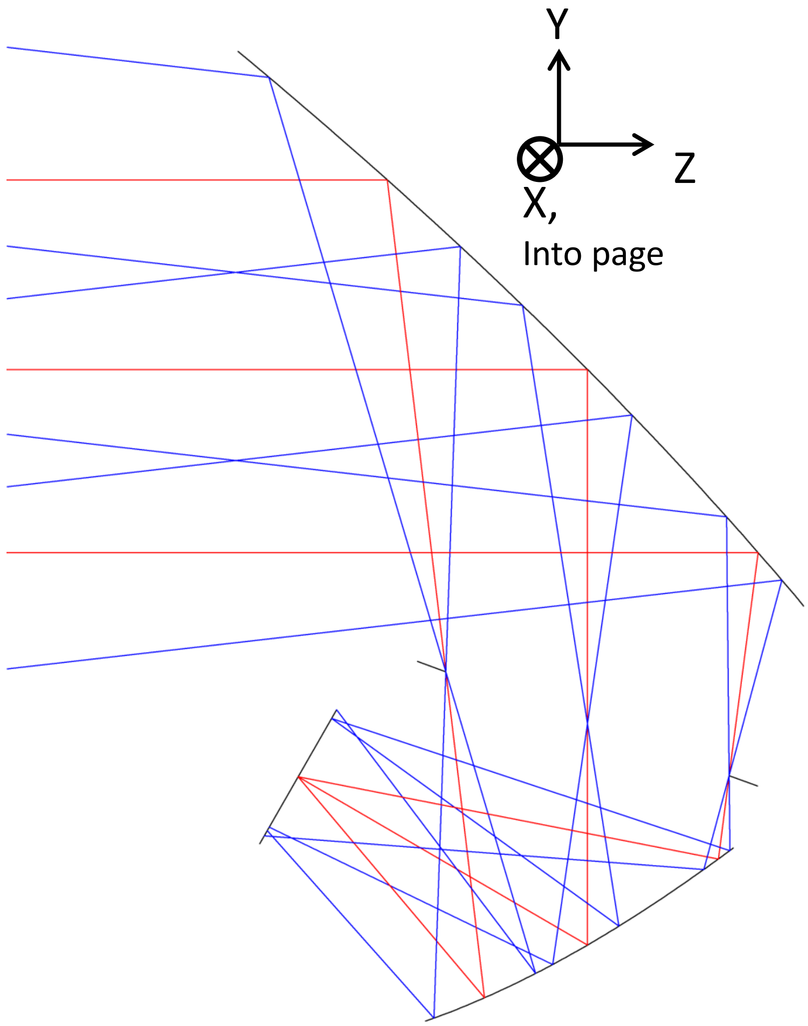
Focal plane temperature

- Comparing 50 mK, 100 mK, 150 mK focal plane
- Phonon noise scales as sqrt(T_1/T_2)
- Change is significant at low frequency where phonon noise is closest (~60%) to photon noise



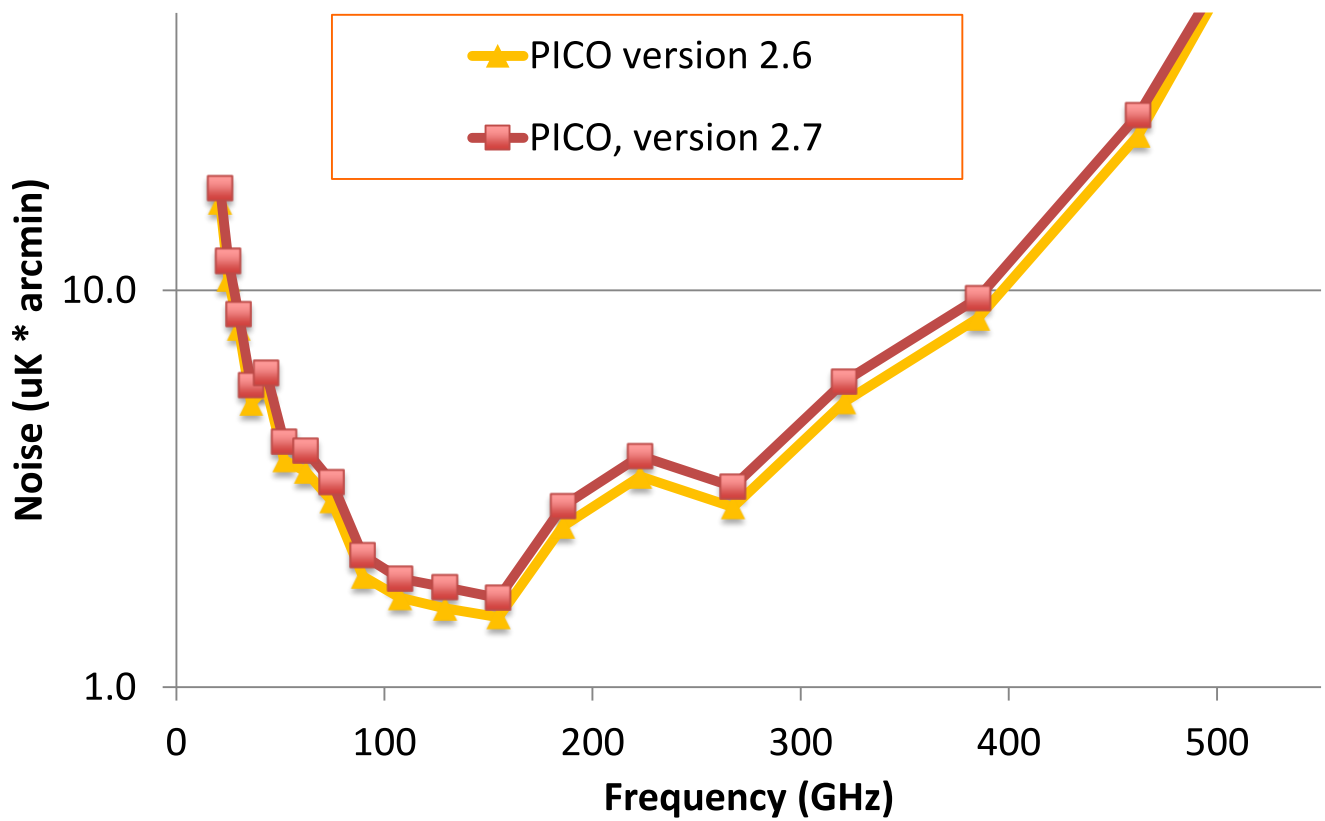
Alignment sensitivity

- Rough spot check using CodeV at 900 GHz
- Mirror offsets parallel to chief ray of 100 um give < 1% change in Strehl
  - Offsets of 1 mm give 3% change in strehl
- Alpha is rotation around X axis
- Beta is rotation around Y axis
- Mirror tilts, primary
  - Alpha tilts of 0.01 deg gives 3% change in strehl
    - 0.01 deg is 200 um shift at mirror edge
  - Beta tilts of 0.5 deg gives 3% change
- Mirror tilts, secondary
  - Alpha tilts of 0.01 deg gives 3% change
  - Beta tilts of 0.05 deg gives 3% change
- Focal plane tilts
  - Alpha or beta 0.5 gives 7% change in strehl



Version 2.7

- New sensitivity sheet on the imager wiki under "Frequency Bands and Noise: Specifications to Use"
  - Link: https://zzz.physics.umn.edu/ipsig/_media/banddefinitions_v2.7.xlsx
- 140 cm Open Dragone, 30 K primary, 4 K secondary
- Margin added so total CMB sensitivity is 0.75 uK arcmin
  - Number of detectors is reduced.
- 12060 detectors



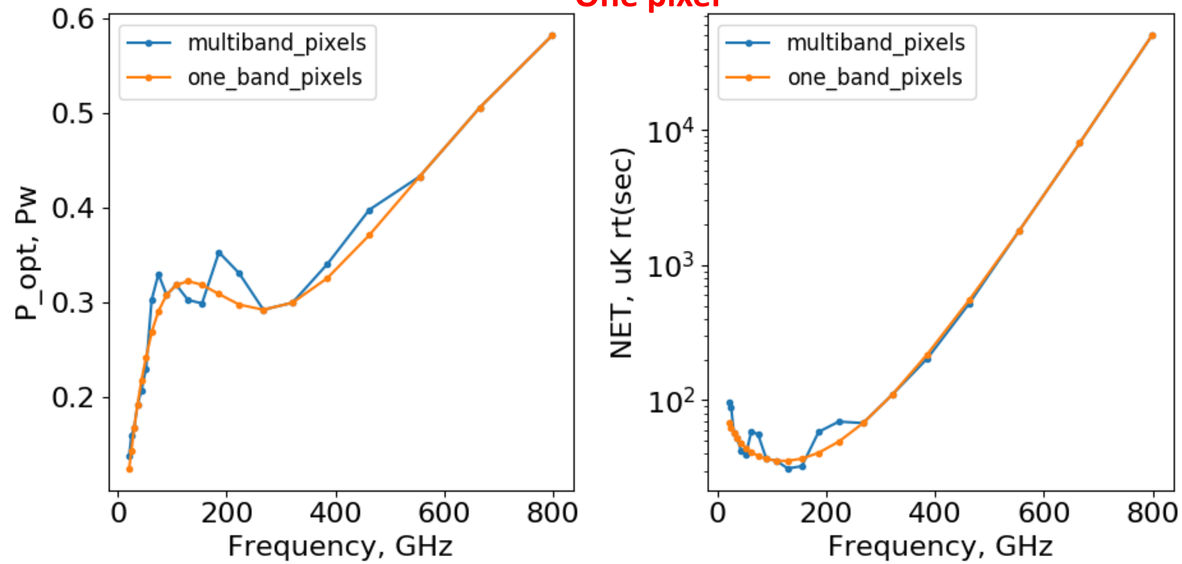
Miscellaneous items

- Difference when using all single band pixels
- Sensitivity of the 120 cm Crossed Dragone at 4 K

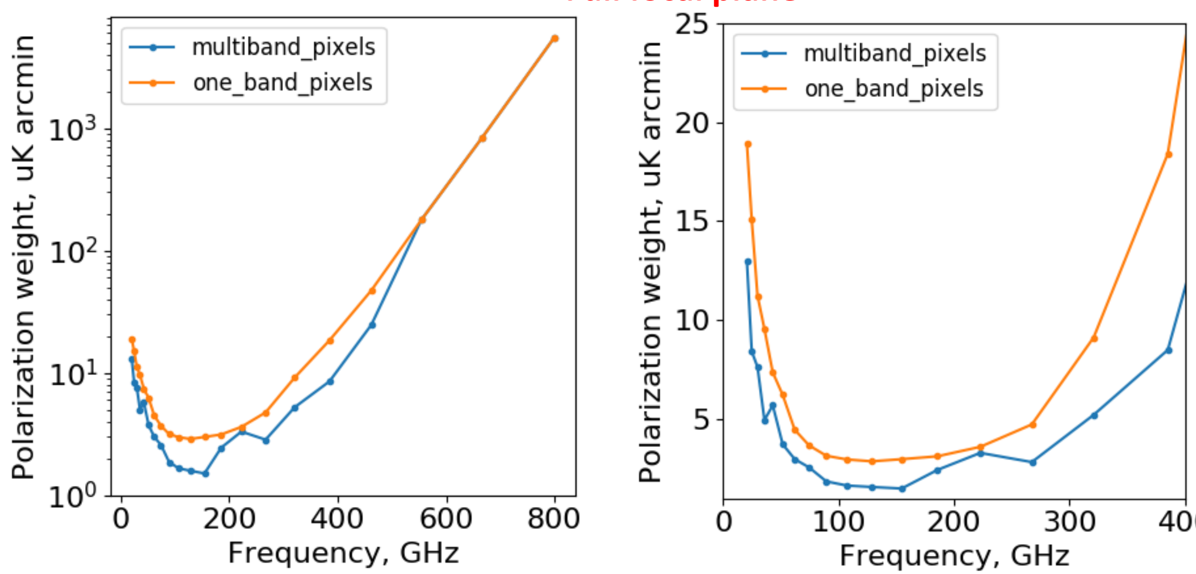
Single band pixels

- 21 single band pixles compared to 21 bands in 6 trichroics and 3 single frequency pixels
- Smoother NET per pixel, illumination is 10 dB edge taper for all bands
- Worse total sensitivity because fewer detectors
- No change to 565, 665, 800 GHz since already single band
- Total CMB weight is
  - 0.67 uK arcmin, multiband v2.6
  - 1.08 uK arcmin, singleband

One pixel



Full focal plane



4 K, 120 cm crossed Dragone

- Assuming all mirrors and stop are 4 K
- Comparing to 15,000 detector 140 cm open
- Both have pixel size set by middle band of pixel
- 140 cm: 15,030 detectors
- 120 cm: 12,840 detectors