Lenslet-Coupled Sinuous Antenna TES Bolometer Arrays for the LiteBIRD Low- and Mid-Frequency Focal Planes

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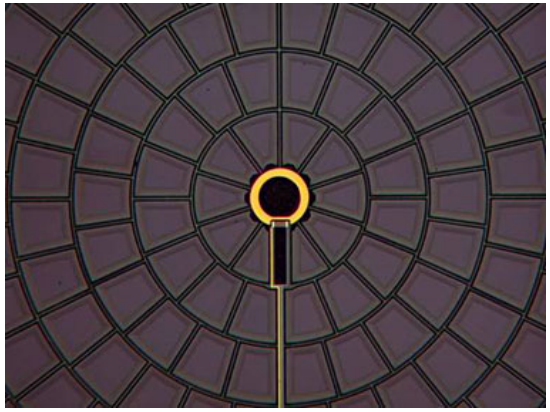
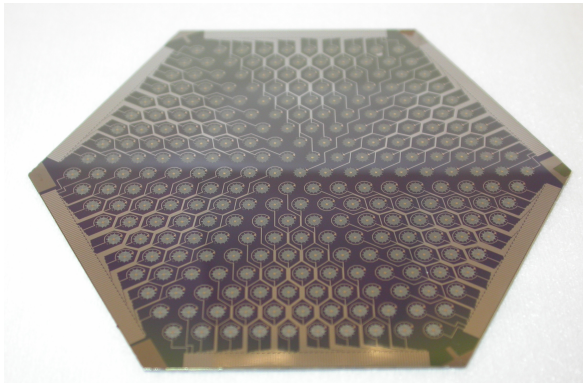
Overview

- Review of sinuous antenna pixels
  - Why is this a candidate technology for LiteBIRD?
- Achieving LiteBIRD specifications
  - Tailoring for a space environment
  - Accurately tuning bands
- Current status of LiteBIRD prototype detectors

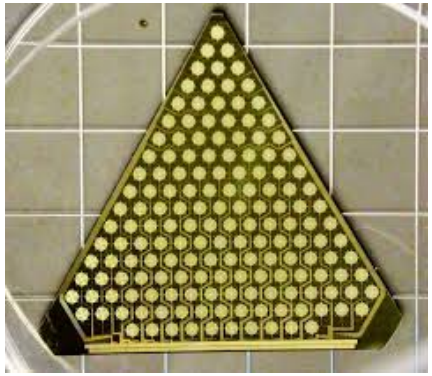
UC Berkeley: Fabrication Heritage



APEX-SZ



ASTE



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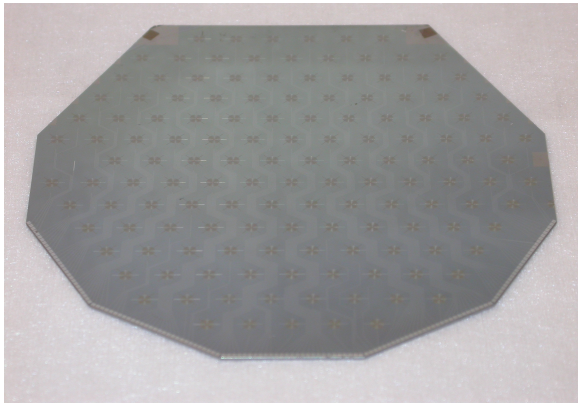
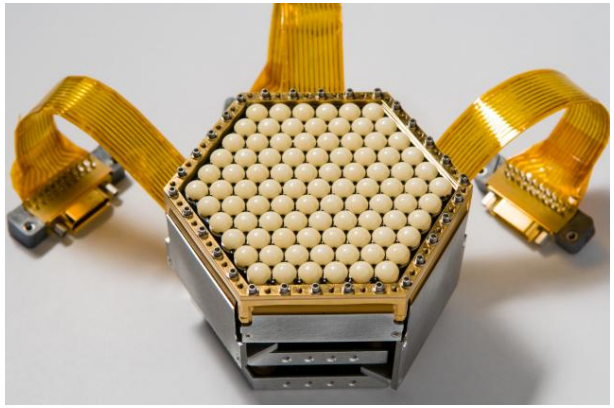
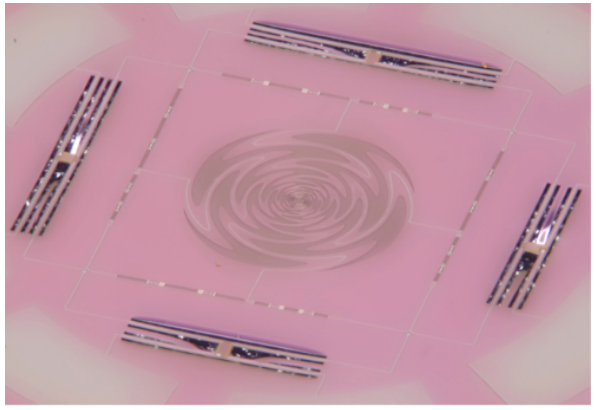


EBEX

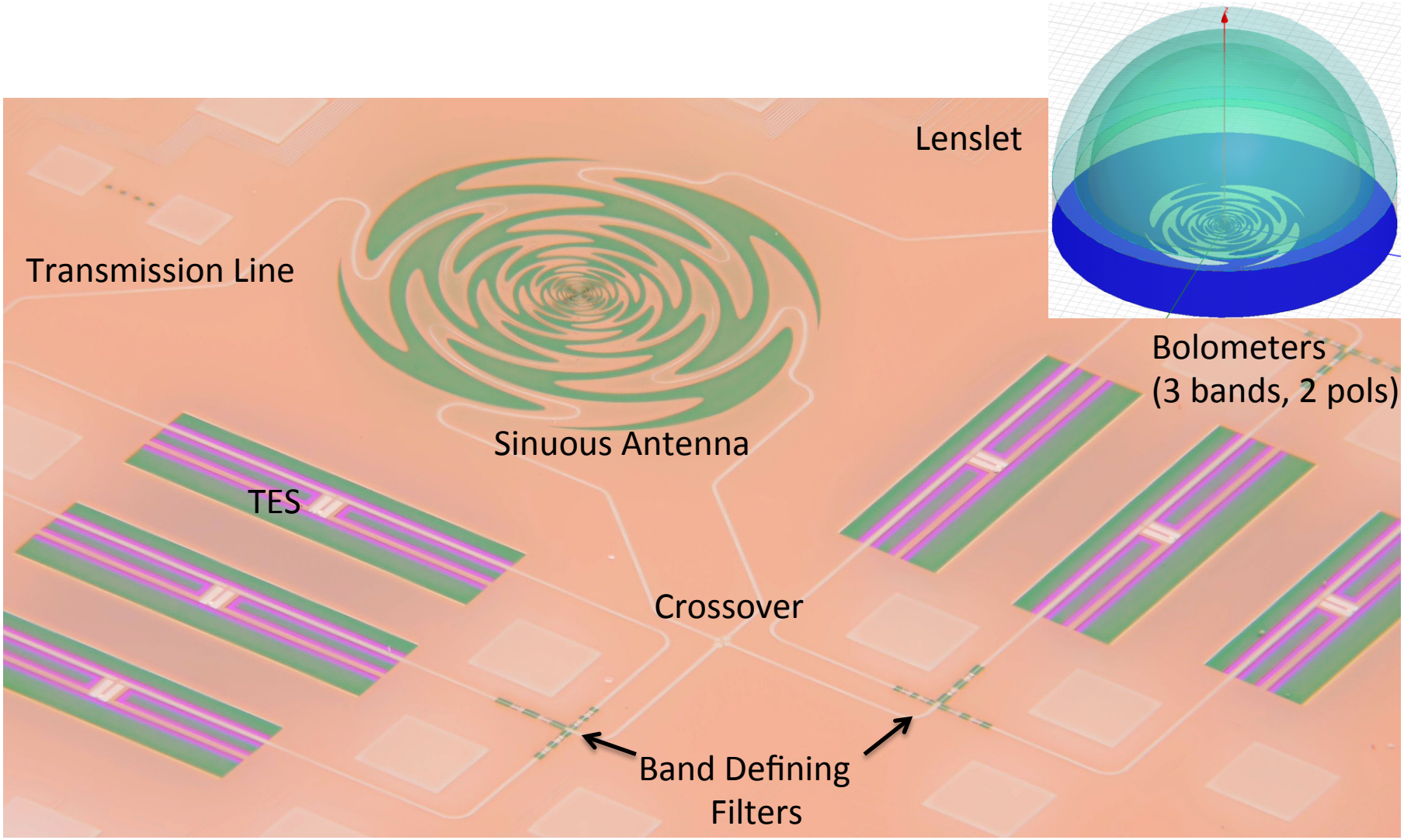


POLARBEAR-1



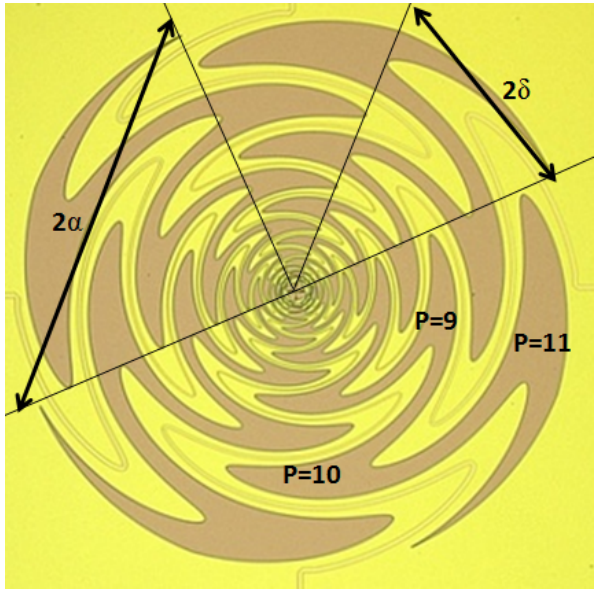
POLARBEAR-2

Lenslet Coupled, Sinuous Antenna, Multi-choric, TES Bolometers



Technology Overview

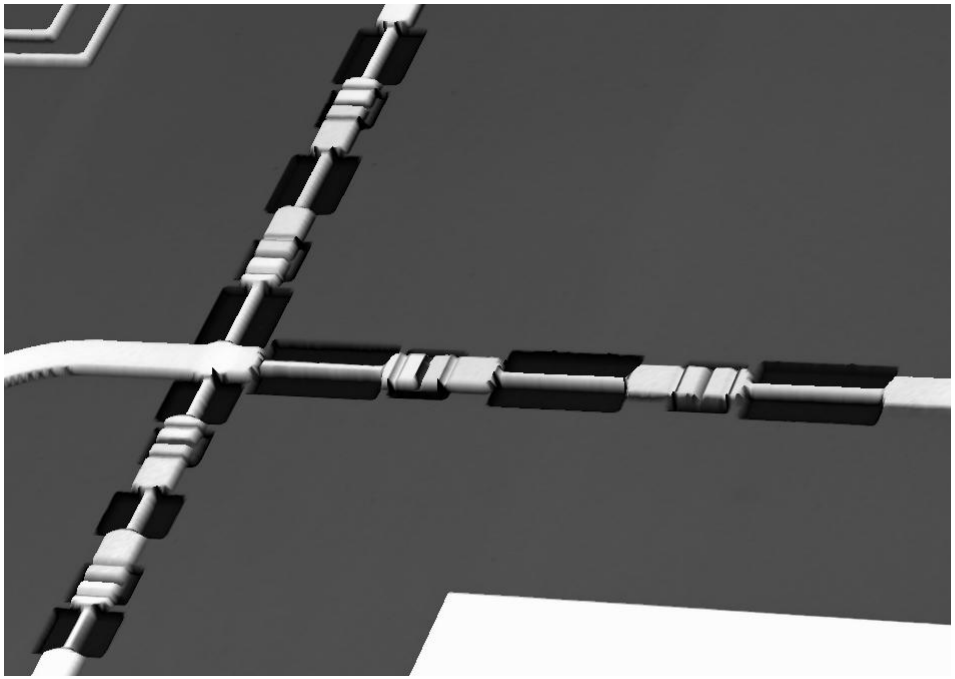
- Sinuous Antenna
  - Self-complimentary, dual polarization, **broadband** slot antenna design

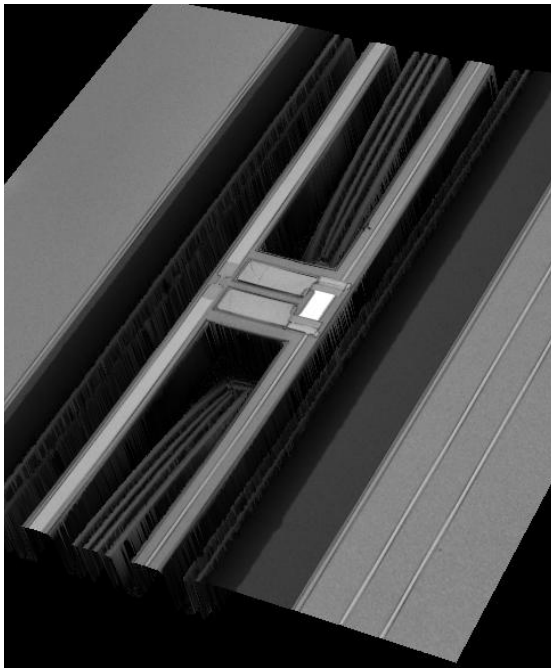


$$\phi(r) = (-1)^p \alpha_p \sin[\pi \frac{\ln(r / R_p)}{\ln(\tau_p)}] \pm \delta_p$$

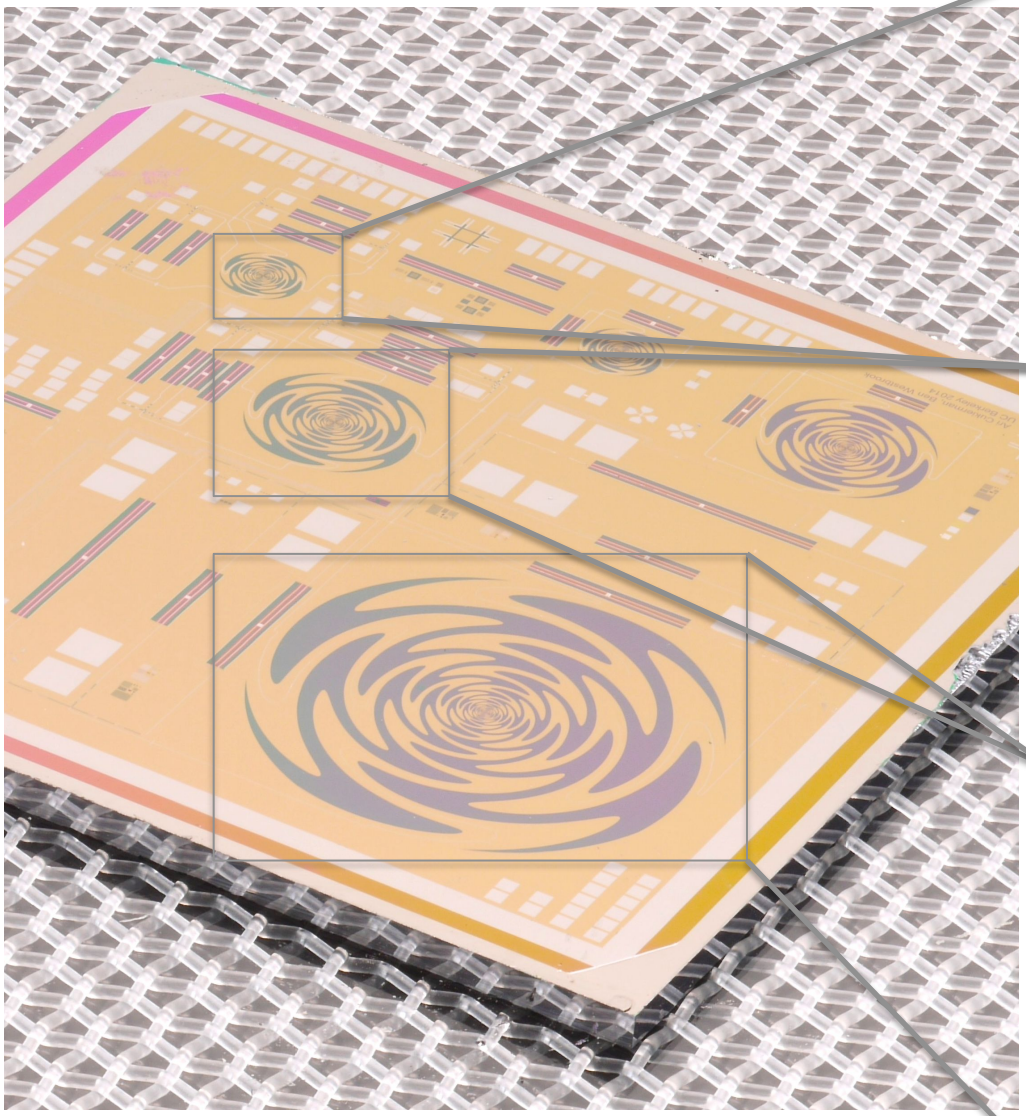
Technology Overview

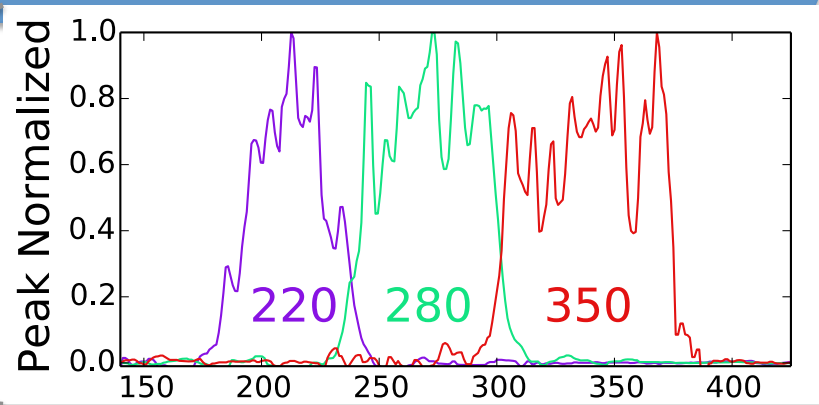
- RF Filters and Bolometers
  - **Tunable** Chebyshev RF filters (band center/bandwidth)
  - **Tunable** TES bolometers (power per band per pol)

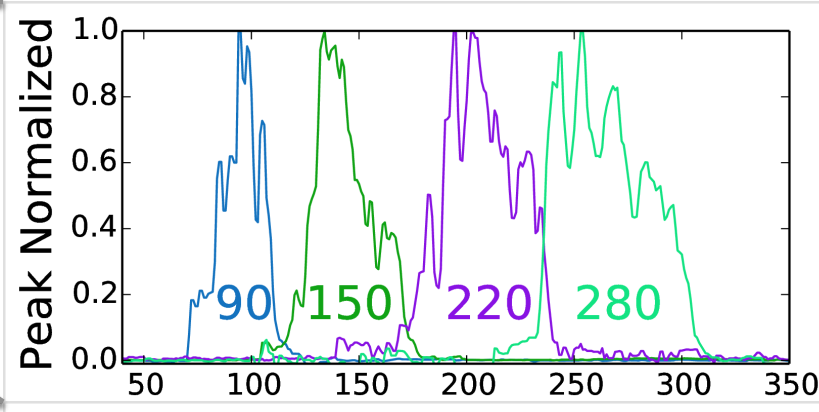


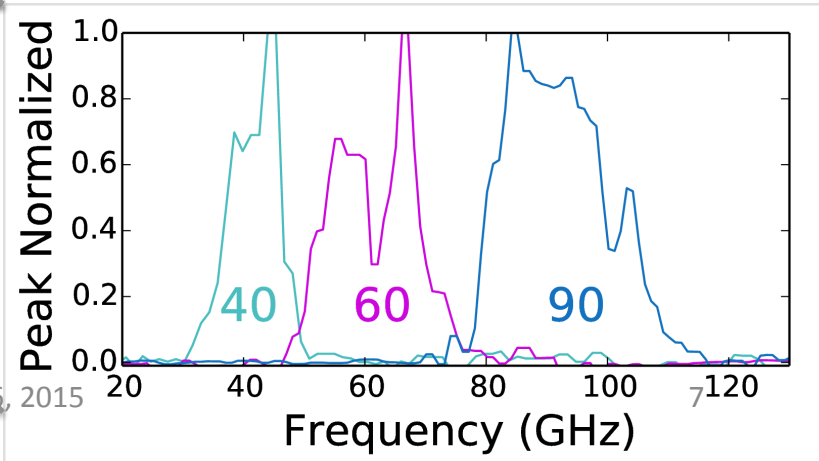


Result: Frequency Tunable Devices

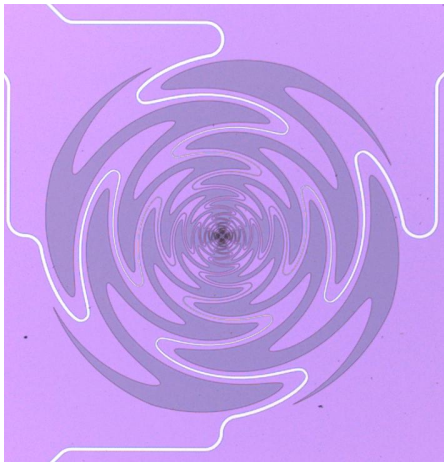


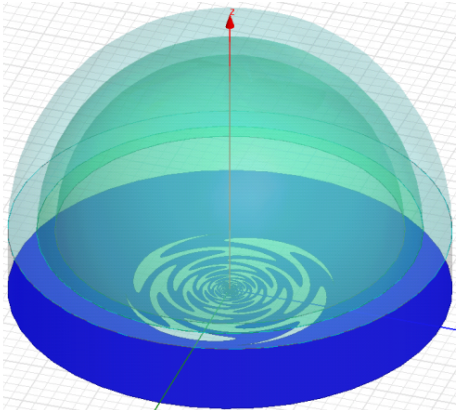






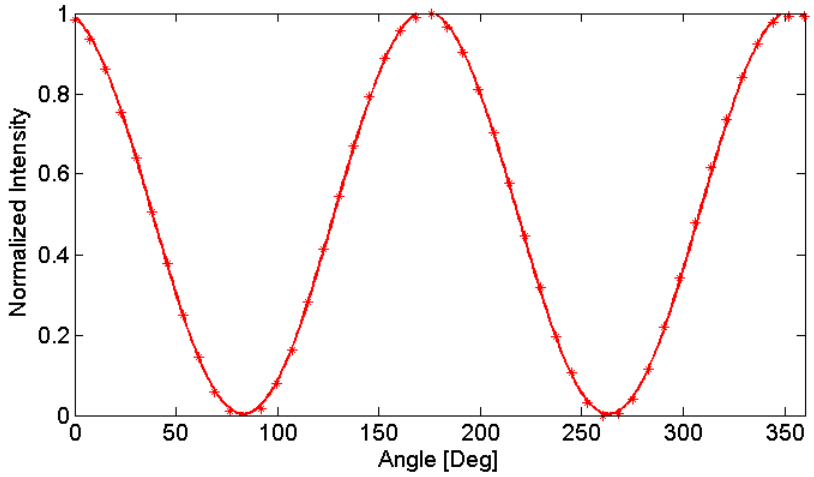
Optical Performance: LB Pixel

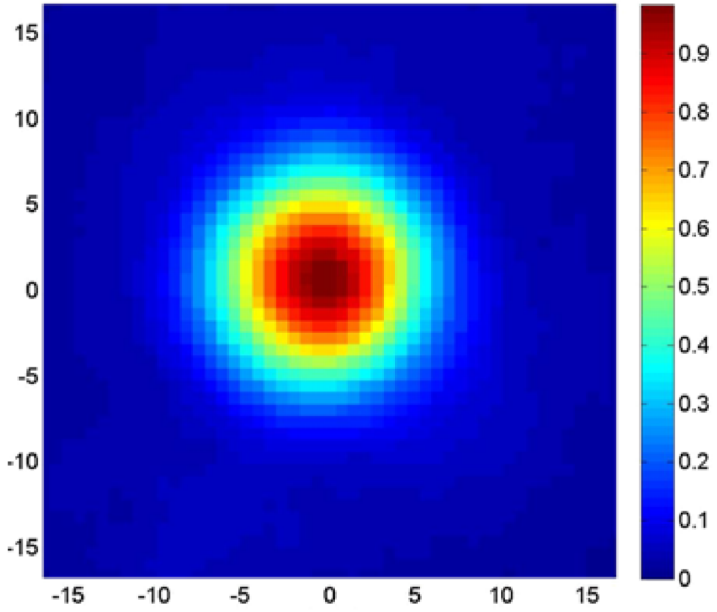




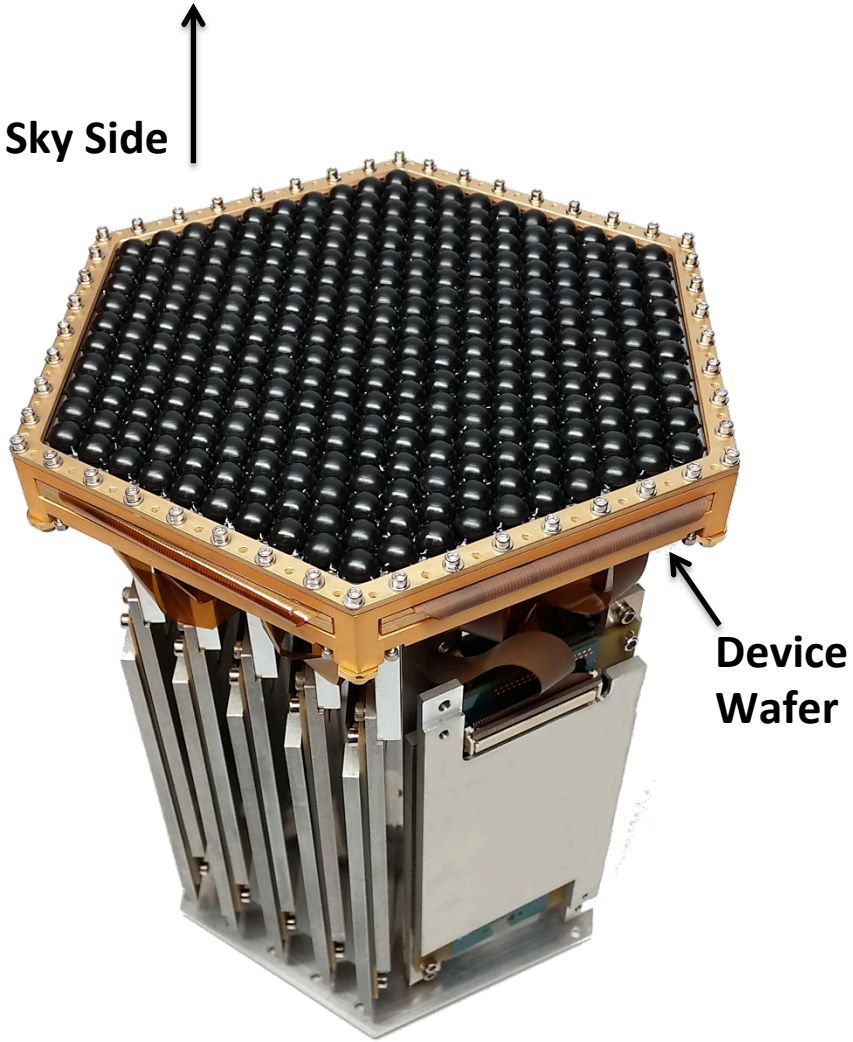
Low Ellipticity Beams (< 1%)

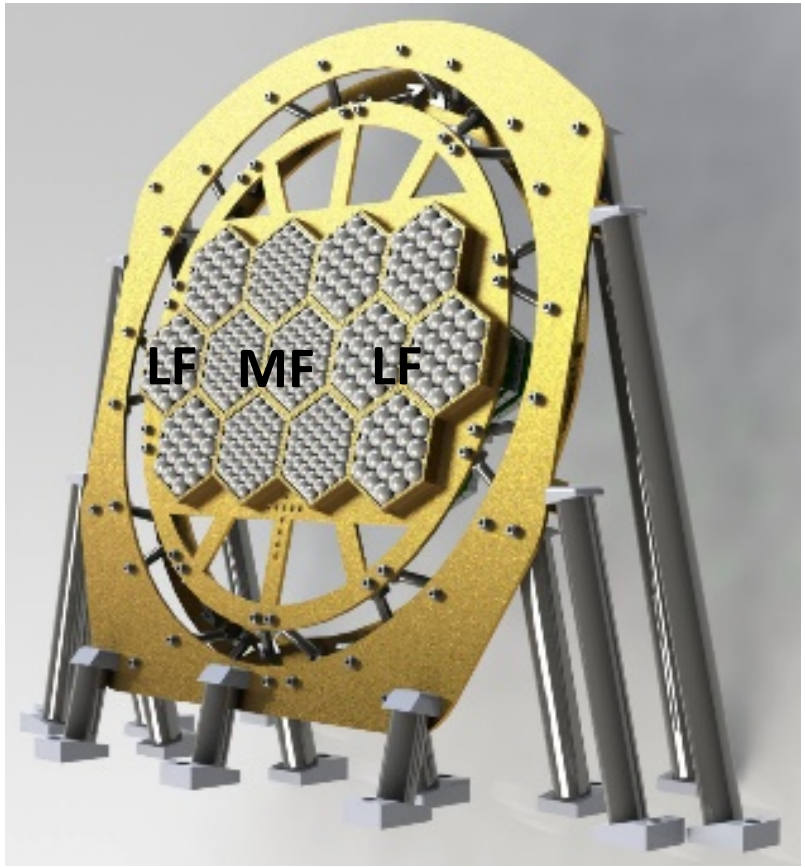
Excellent Pol Efficiency in Both Pols (>99%)



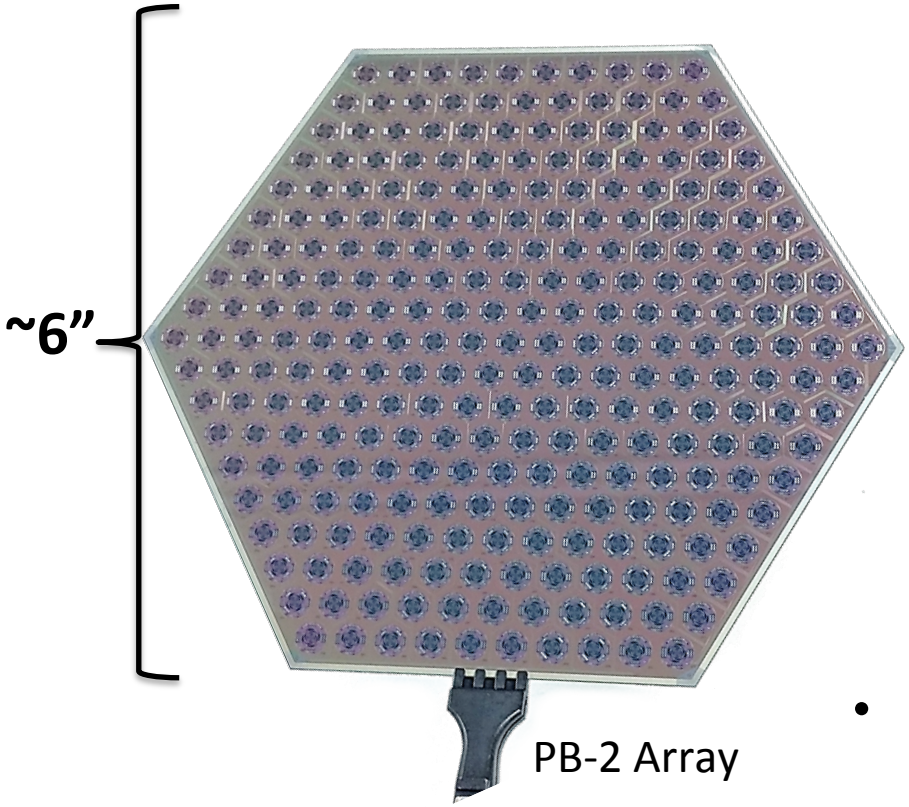


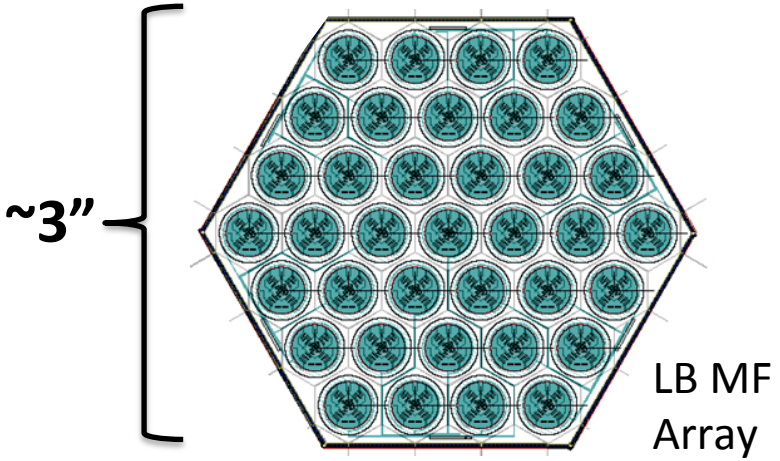
Integration into Low Frequency Telescope





LB Arrays vs Ground Arrays





- PB-2 Arrays 271 Pixels compared with 37 (MF) and 19 (LF) arrays
- Ground based work has already laid the ground work for LB
- Small arrays benefit in many ways from a fabrication perspective

Achieving the LiteBIRD Specs

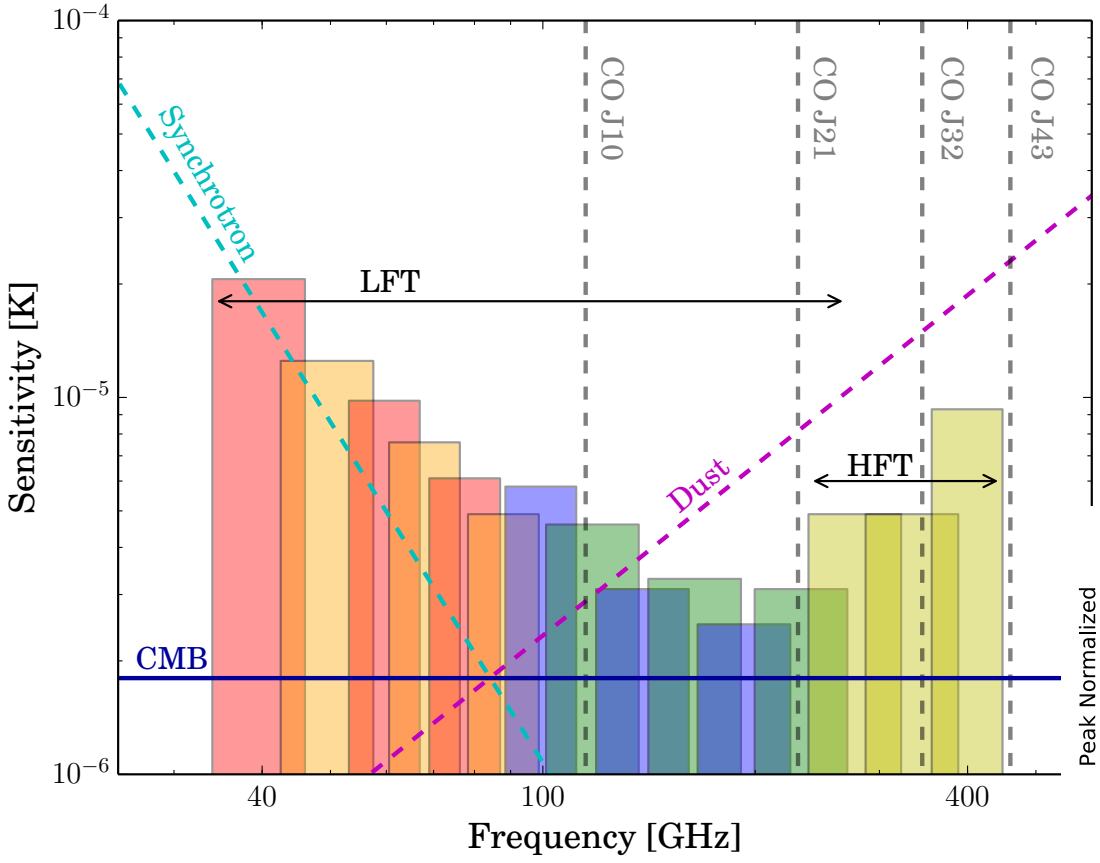
- Robust, high-yield, high-uniformity fabrication
- Fabrication tolerance directly impacts instrument sensitivity

Achieving LiteBIRD Specifications

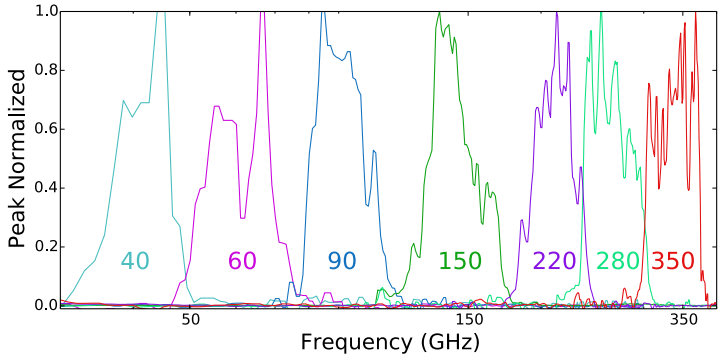
- Frequency Bands
- Sensitivity and Fabrication Requirements
  - Thermal tuning
  - Yield/Optical efficiency
  - Intra-pixel uniformity (e.g. crossovers, filters)
  - Pixel-Pixel and Wafer-Wafer uniformity (e.g. bandwith, efficiency)

LiteBIRD Frequency Bands

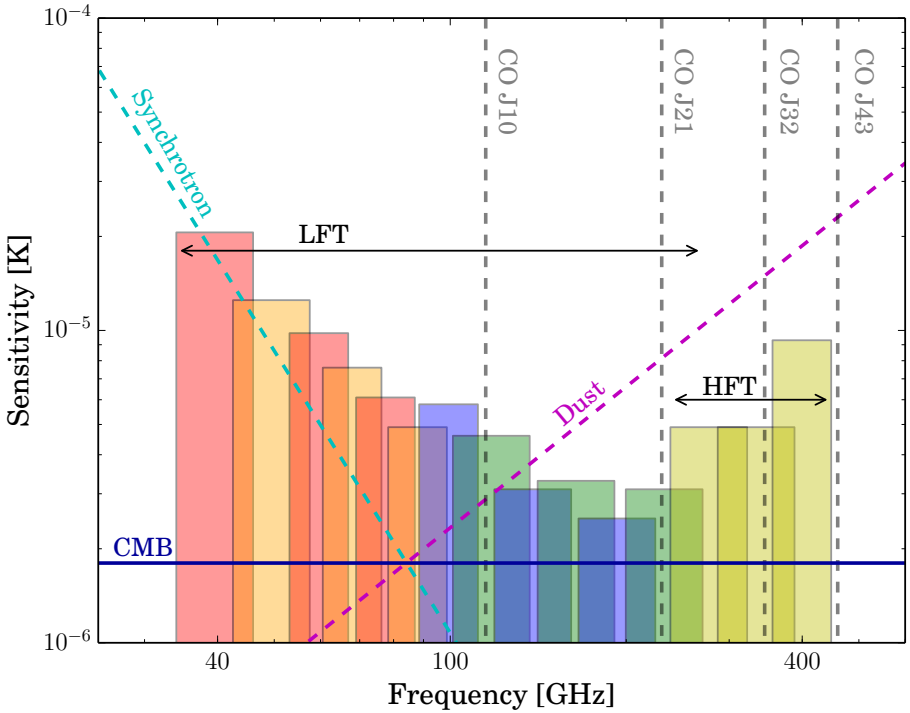
- Tuning the bands of the LF and MF focal planes

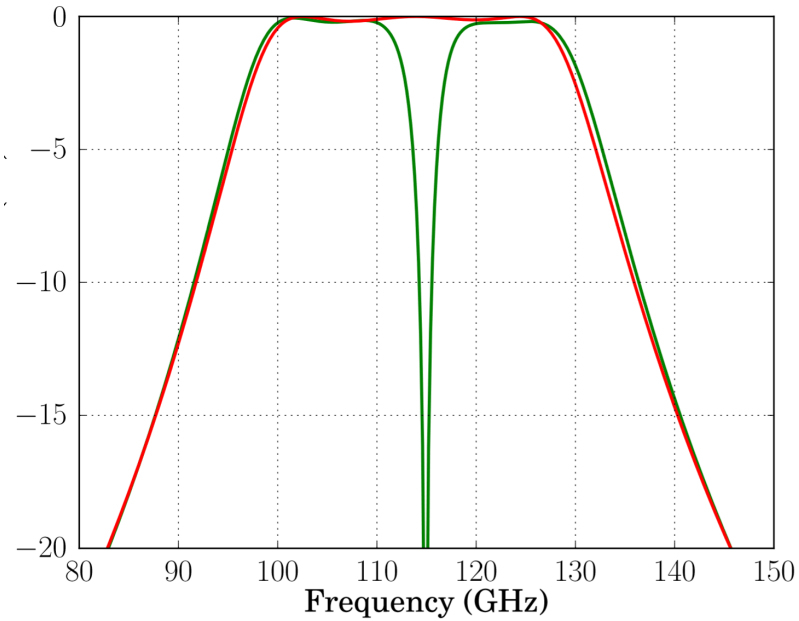


- 12 bands in 4 pixel types
- CO J10, J21



LiteBIRD Frequency Bands: CO Notch Filters





- CO lines with LB bands
- Notch filter(s) to take CO line(s) out
- Only 2 bands in MF/LF baseline configuration for LB have CO lines

- Response of designed notch filter (Ari Cukierman)

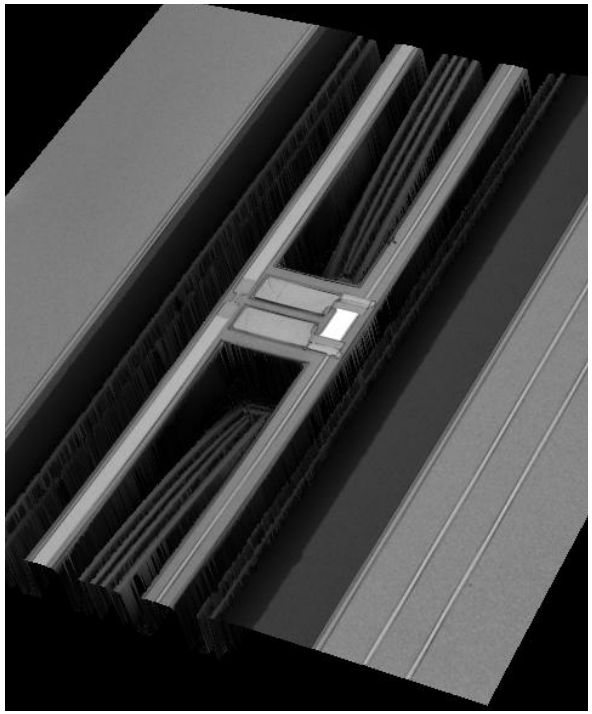
Sensitivity: Saturation Power (NEP)

- Expected Optical Loading
- LB spec is ~0.7 pW at 140 Ghz
- By comparison the Psat spec for PB-2 is ~10 pW @ 145 GHz

Sensitivity: Saturation Power (NEP)

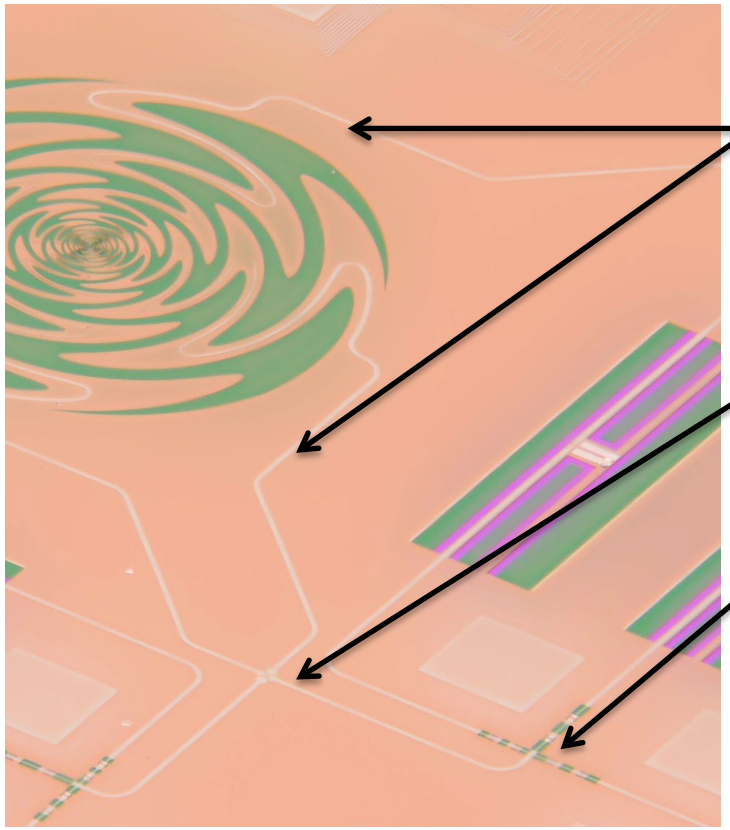
- Optical loading sets saturation power of detectors
- We have 3 knobs to turn
  - **Materials**, **Geometry,** and ***Tc***
- Assuming PB-2 Geometry

and Materials and a Tc of 180 mK we get Psat with the specs of LB (~0.7pW)

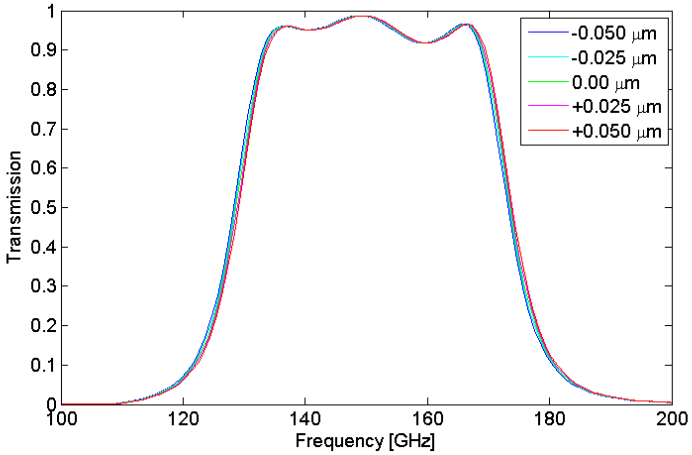


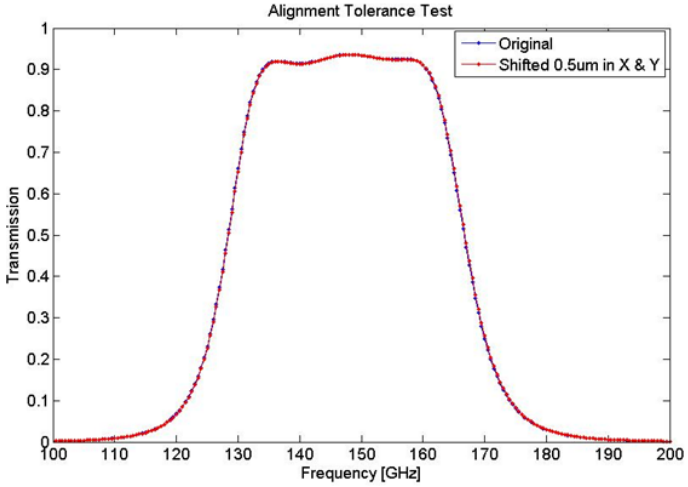
Systematics: Pair Differencing

- Both polarization channels must be balanced



- Symmetric microstrips (~0.05um typical)
- Symmetric crossovers
- Layer to layer alignment (~0.1um typical)





Current Status of Development

- Co-fabbing a 180 mK T_c demonstration bolo w/ NIST
  - Wafer mid-way through fab
- Previously characterized test chips irradiated at HIMAC in Japan
  - Will be re-characterized to study effects of radiation on pixel performance
- Work to begin soon on single LB pixel fab
  - Start with 100, 145, 190 GHz triplexer in early 2016

Conclusions

- Lenslet coupled, sinuous antenna, TES bolometers are excellent candidates for the Low and Mid Frequency focal planes
- We've demonstrated these pixels for the frequency bands of LiteBIRD
  - Work will leverage the strong heritage at UC Berkeley, NIST, and Stanford
- Prototype development for LiteBIRD is ongoing