Planar Antennas for CMB Polarimetry

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Jet Propulsion Laboratory

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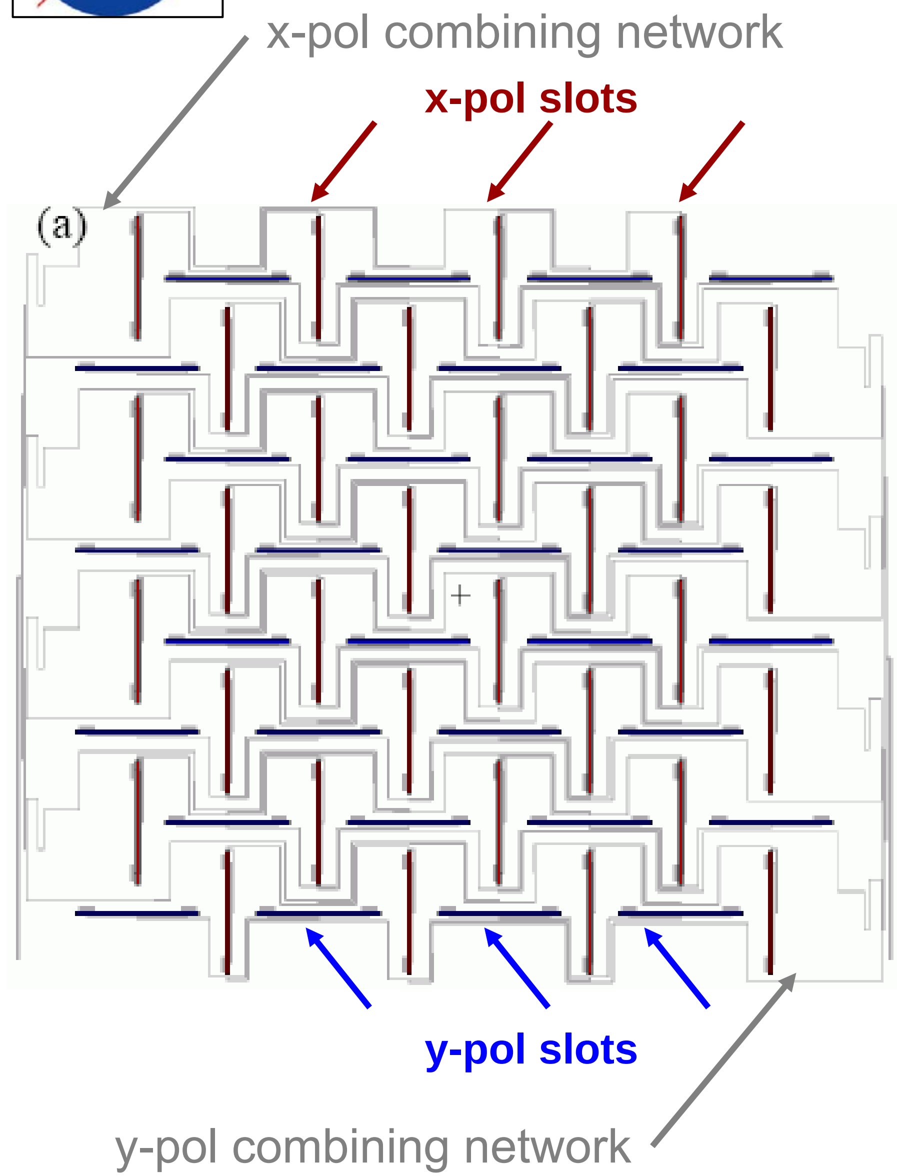
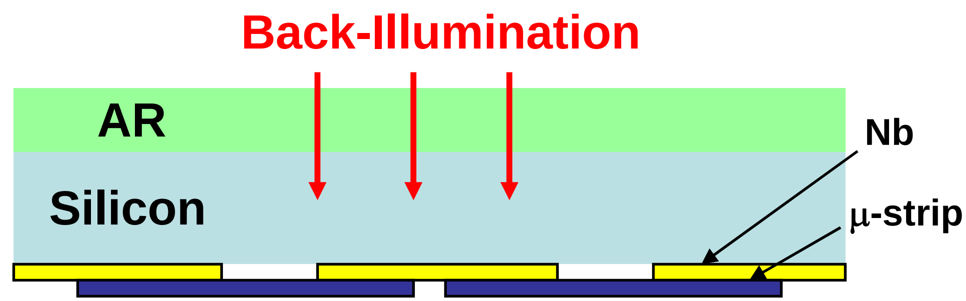
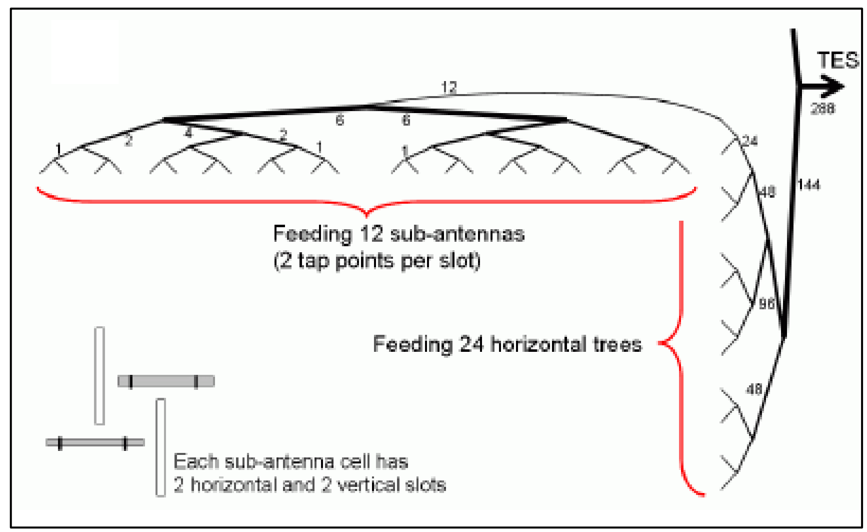
Principle of Operation





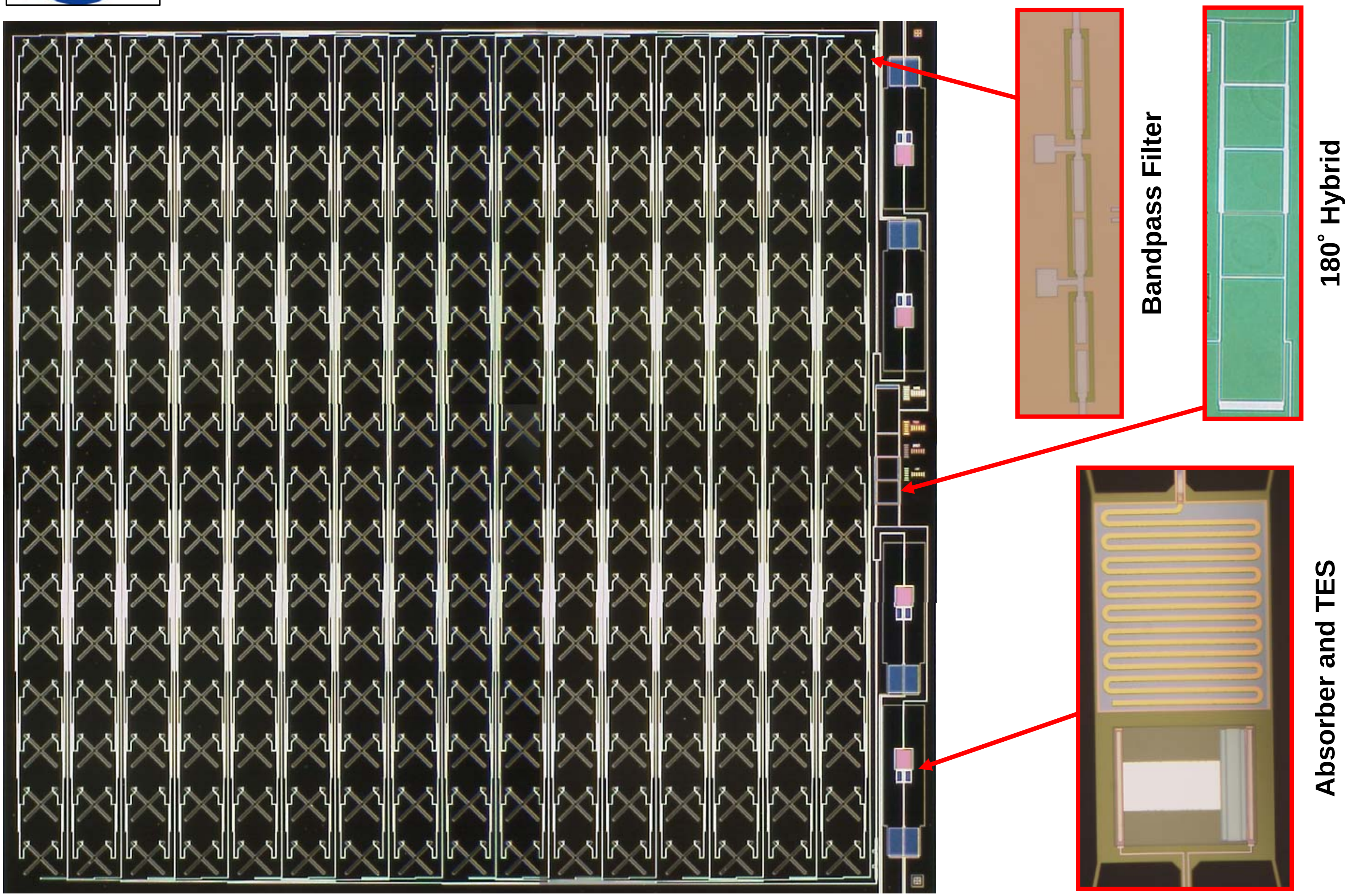
Combiner network



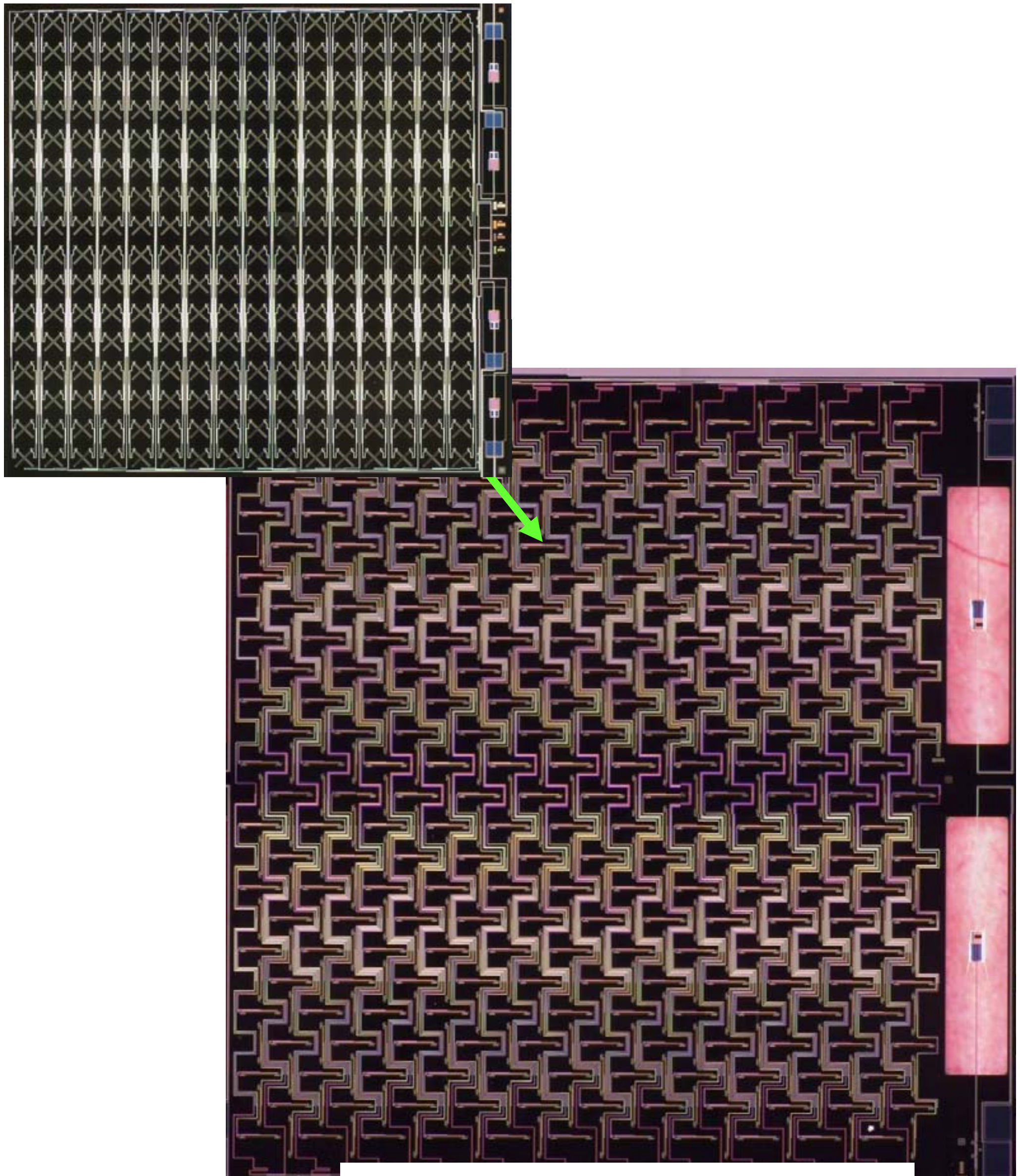
Planar Antenna

- Combine sub-slots coherently
- Higher forward gain than single slot
- E-field distribution defines beamshape

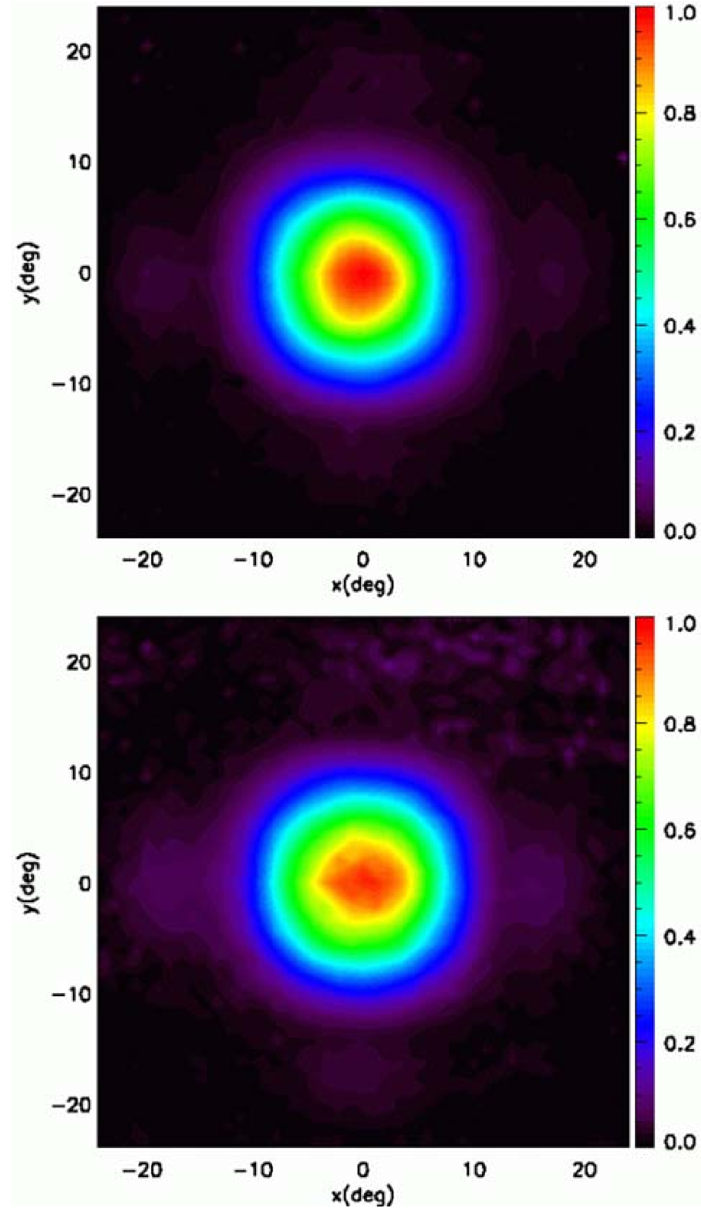
Implementation in a 150 GHz Device



Measured Antenna Performance

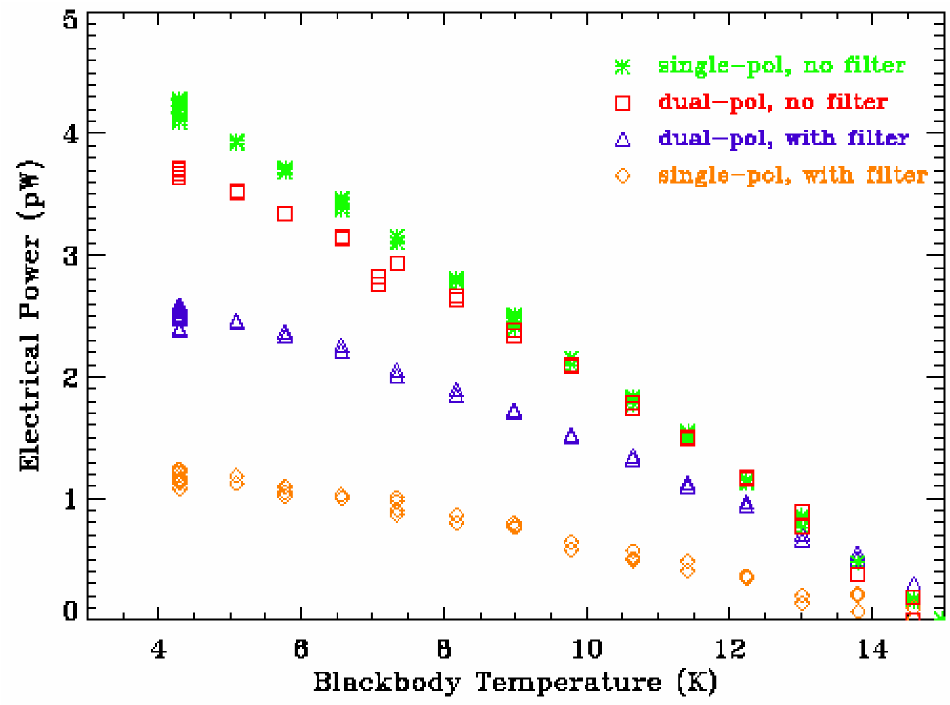


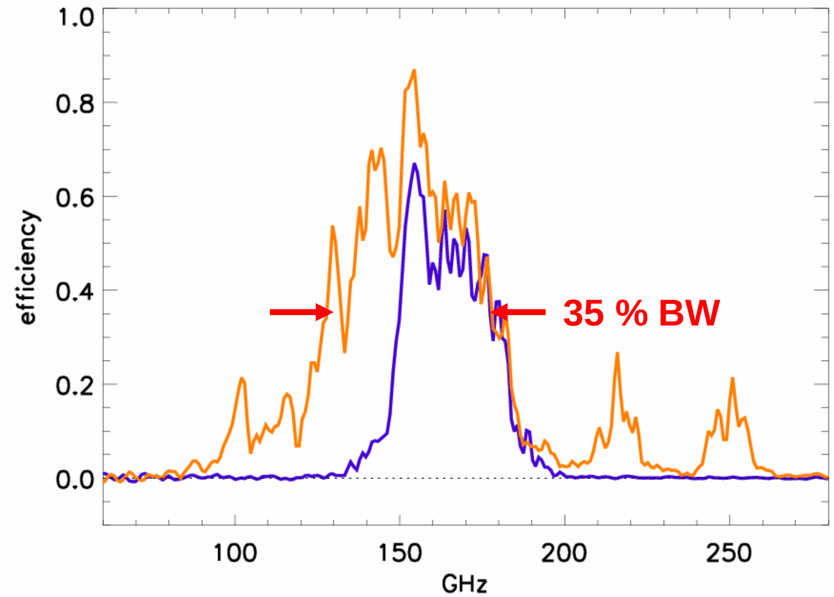
New broad band design

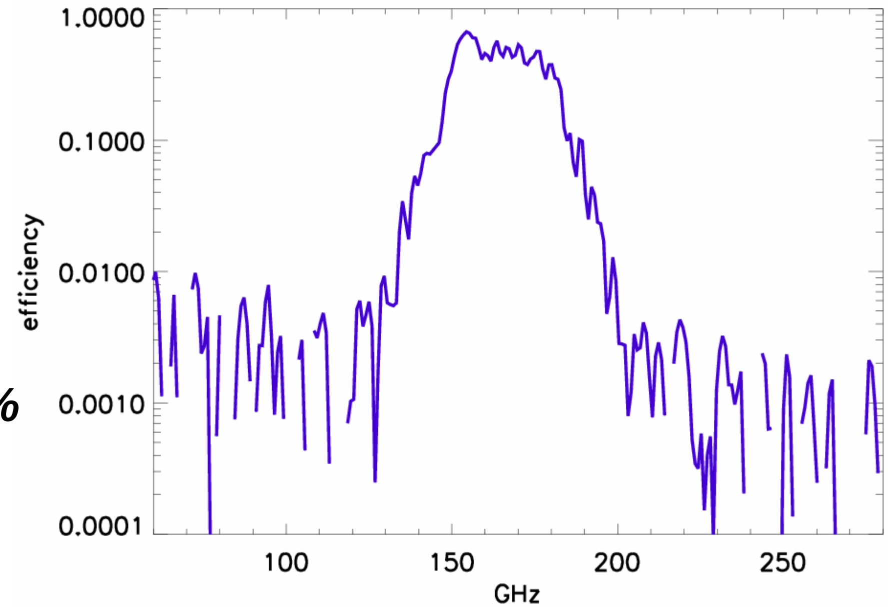


Measured cross-polar response < 3 %

Spectral Response and Optical Efficiency



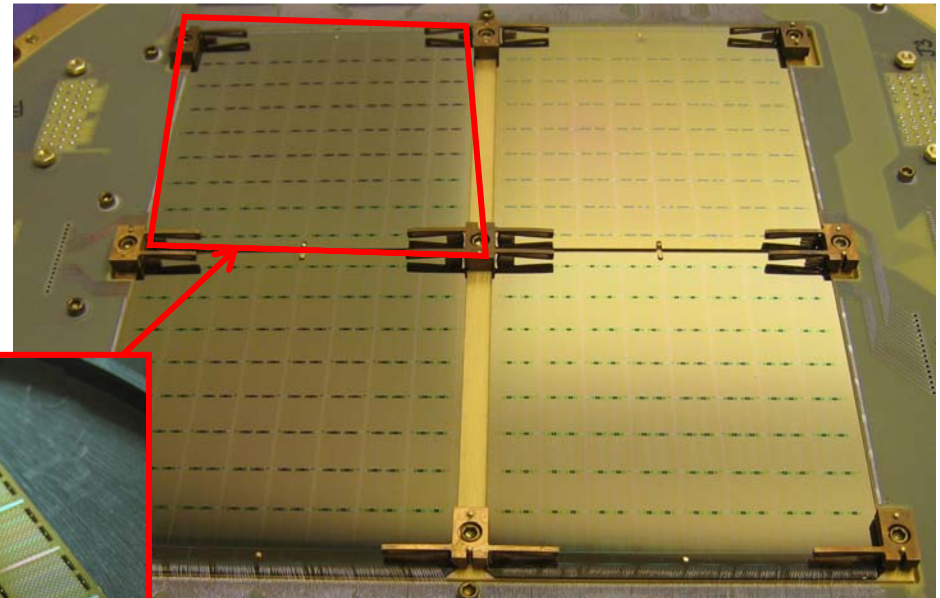




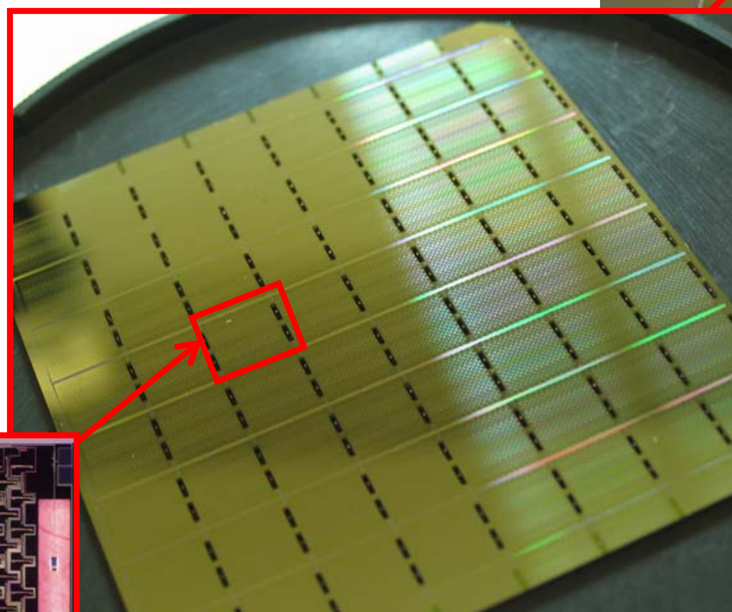
Measured efficiencies range from 50 – 80 %

Results now for 100 GHz devices as well

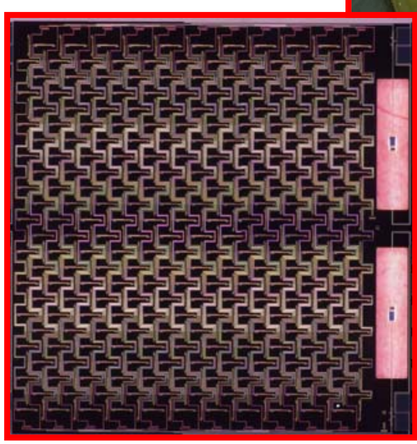
Implementation in Focal Plane Arrays



512 Bolometer Focal Plane

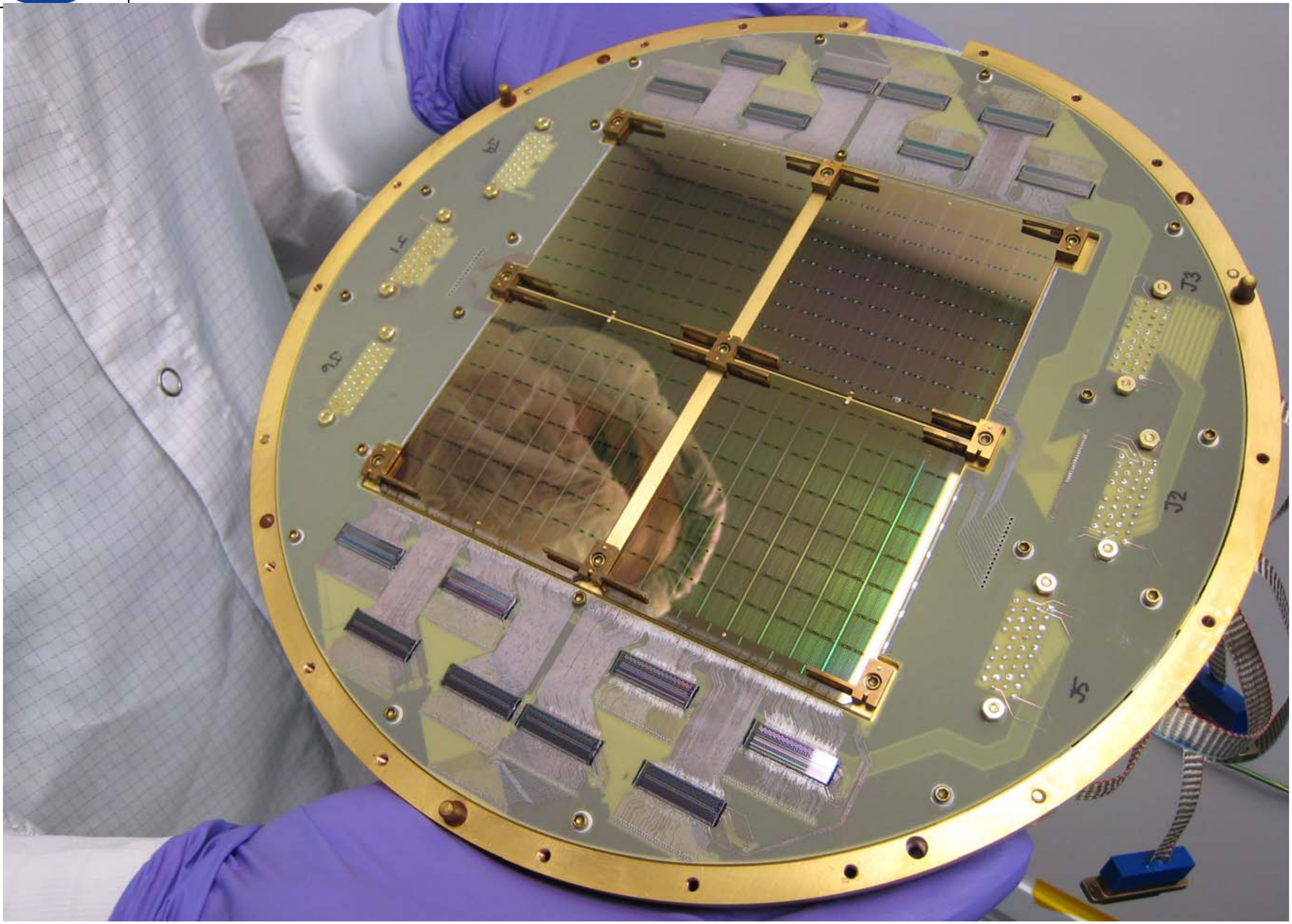


8x8x2 Focal Plane Tile



Dual-Pol 150 GHz Pixel

Implementation in Focal Plane Arrays



A Very Flexible Technology

Extended Frequency Range

Scale slot array and reroute combiner network
No problems seen for low frequencies
Space gets tight for ν > 250 GHz

Highly Tapered Beams

Make d/fλ larger
Change combiner network to taper field amplitude
Account for (known) slot-slot impedance matrix

Non-Telecentric Beams

Change combiner network to produce phase lag

Simultaneous Stokes I, Q & U

Add hybrid and use 4 detectors per pixel, balanced hybrids for band matching

Multiple Bands per Antenna

Demonstrated with diplexer in one polarization
Keeping diffraction limit requires beam sharing

Overlapping Antennas

It is possible to recover perfect mapping speed (factor ~3 at 2fλ)
Antennas must be large to use entire aperture

Advantages & Disadvantages

Advantages

- AR Coating is Very Simple
- Coupling is Lithographic
- Minimizes Focal Plane Mass
- High Optical Efficiency
- Polarized Beam Matching
- Beam Control
- Flexibility

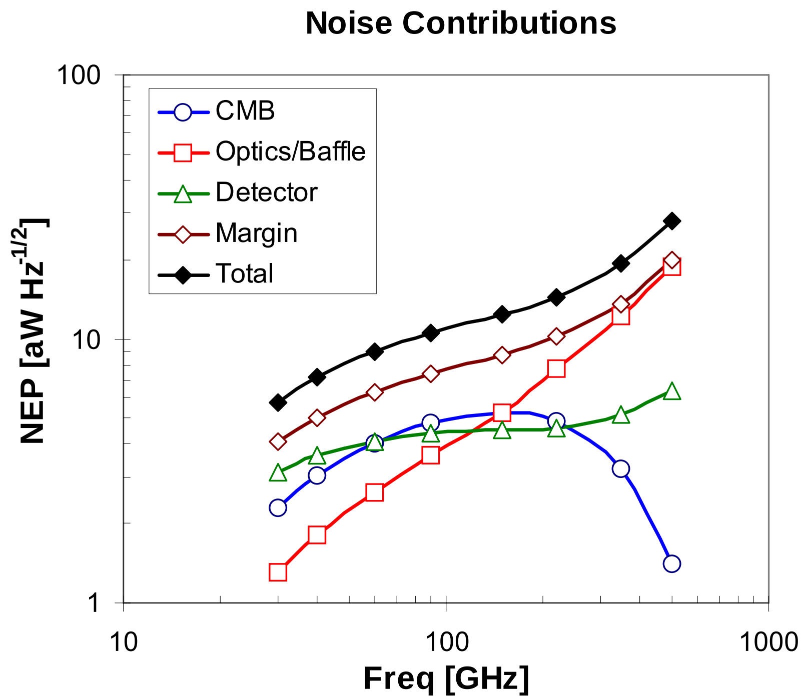
Disadvantages

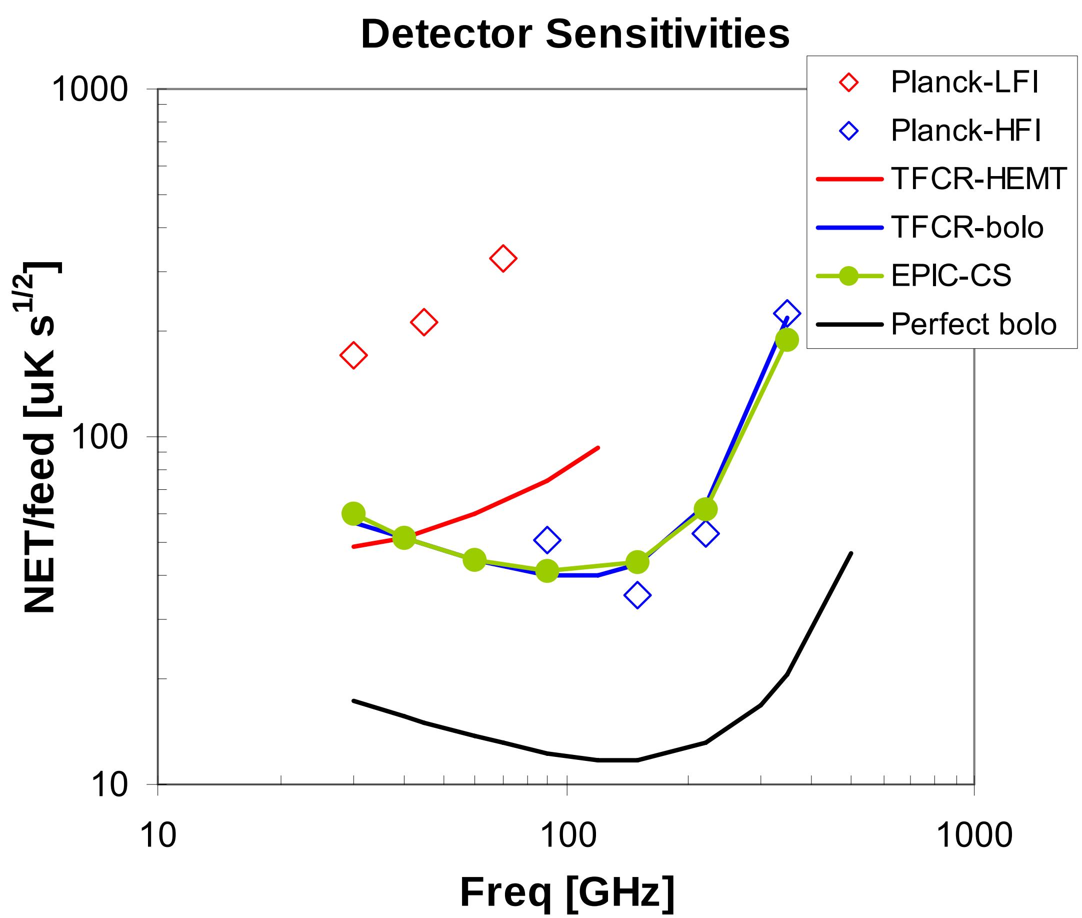
- Need Space for Detectors
- Need Better Control of Defects

Technology Readiness and Milestones

Capability	Advantage for CMBPOL	Technical Challenges	Milestone	TRL?
		Attributes Necessary for CMBPOL		
Optical coupling	Beam formation, polarization analysis, band definition	Antenna and filter design, RF properties and losses	Pixel demonstration (completed at 100 and 150 GHz)	**5**
Focal plane arrays	System sensitivity	Process uniformity and reliability	Field focal plane arrays in a CMB receiver	**4**
Frequency coverage	Foreground removal	Antenna and filter design	Pixel demonstrations at ≤ 30 and ≥ 300 GHz	**4**
		Attributes Necessary for Some CMBPOL Mission Designs		
Highly tapered beams	Sidelobe control for optics without a cold stop	Antenna and combining network design	Pixel demonstration in a single band	**2**
Simultaneous Stokes I, Q and U	Systematics control, depends on scan strategy	Hybrid design and spectral band matching	Pixel demonstration in a single band	**2**
		Attributes Advantageous for CMBPOL		
Directed beams	Use in non-telecentric optical designs	Antenna and combining network design	Pixel demonstration in a single band	**2**
Multiple frequency bands per antenna	System sensitivity	Diplexer design done Dual-polarization design	Pixel demonstration in multiple bands	**4**
Overlapping antennas	System sensitivity	Antenna and combining network design, transmission line density and crossovers	Focal plane array demonstration in a single band	**1**
Polarization modulation	Noise stability	Active device to switch polarization states, RF design	Field focal plane arrays in CMB receiver	**2**

Focal Plane Sensitivity Budget





EPIC Sensitivity Assumptions

Focal plane temperature	T_0	0.1 K	Optical efficiency	η_{opt}	40 %
Lens temperature	T_{lens}	4 K	Fractional bandwidth	$\Delta\nu/\nu$	30 %
Mirror temperature	T_{opt}	60 K	Noise margin		1.414
Mirror emissivity at 1 mm	ε	1.0 %	Mission lifetime	T_{life}	4 years
Bolometer pitch	$d/f\lambda$	2	TES safety factor	P_{sat}/Q	5

T_0 = 250 mK for the Inflation Probe?

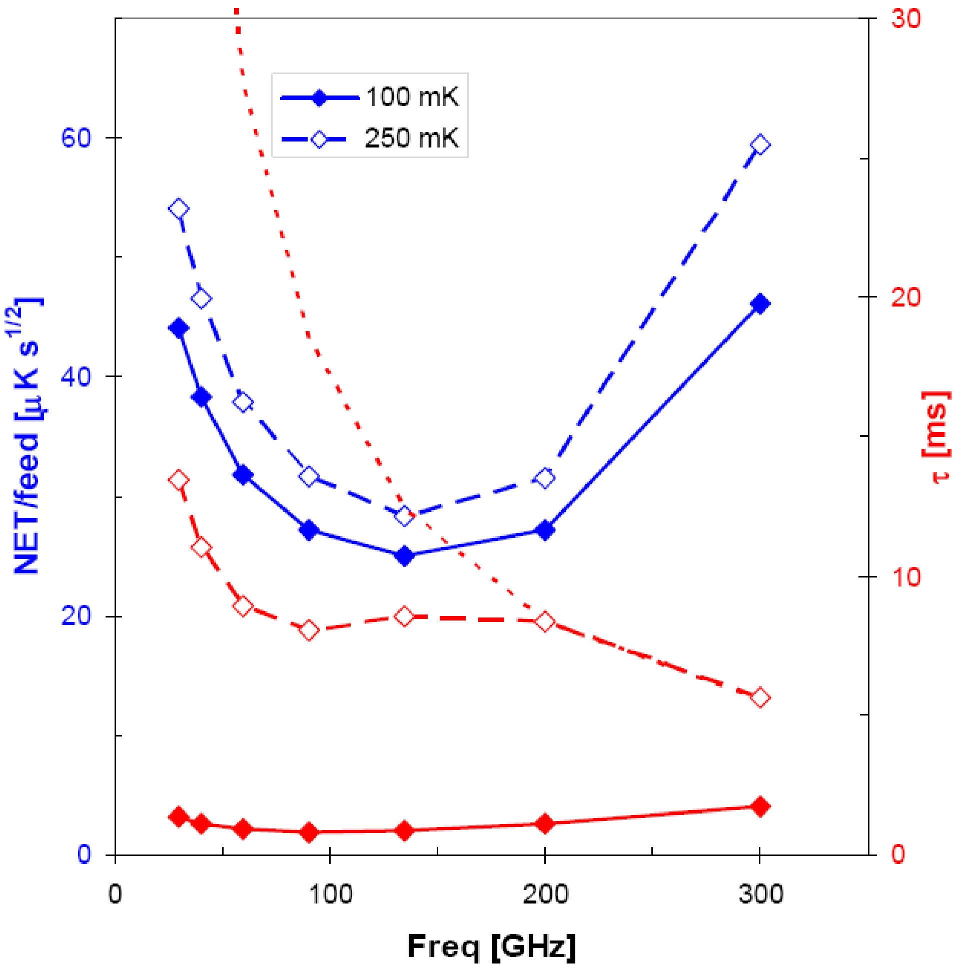


Table 4. TES Bolometer Parameters

Quantity	Value		Units
T_0	100	250	mK
Psat/Q	5	3*	
G_0 (min)	0.7	3.2	pW/K
β	1.5	2.5	
C_0	0.2	0.4	pJ/K
α	100	100	
Rop	10	30	mΩ
NEP √τ	1	4	e-19 J
Spin rate	3	1.5	rpm
1/f knee	50	25	mHz

Note: All other detector parameters from Table 2.

*200 and 300 GHz bands have higher P_{sat}/Q to meet required τ.