BICEP-3

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for the
BICEP-3 Collaboration

Stanford/KIPAC
Univ. Minnesota
Univ. British Columbia
NIST
Caltech/JPL
Harvard
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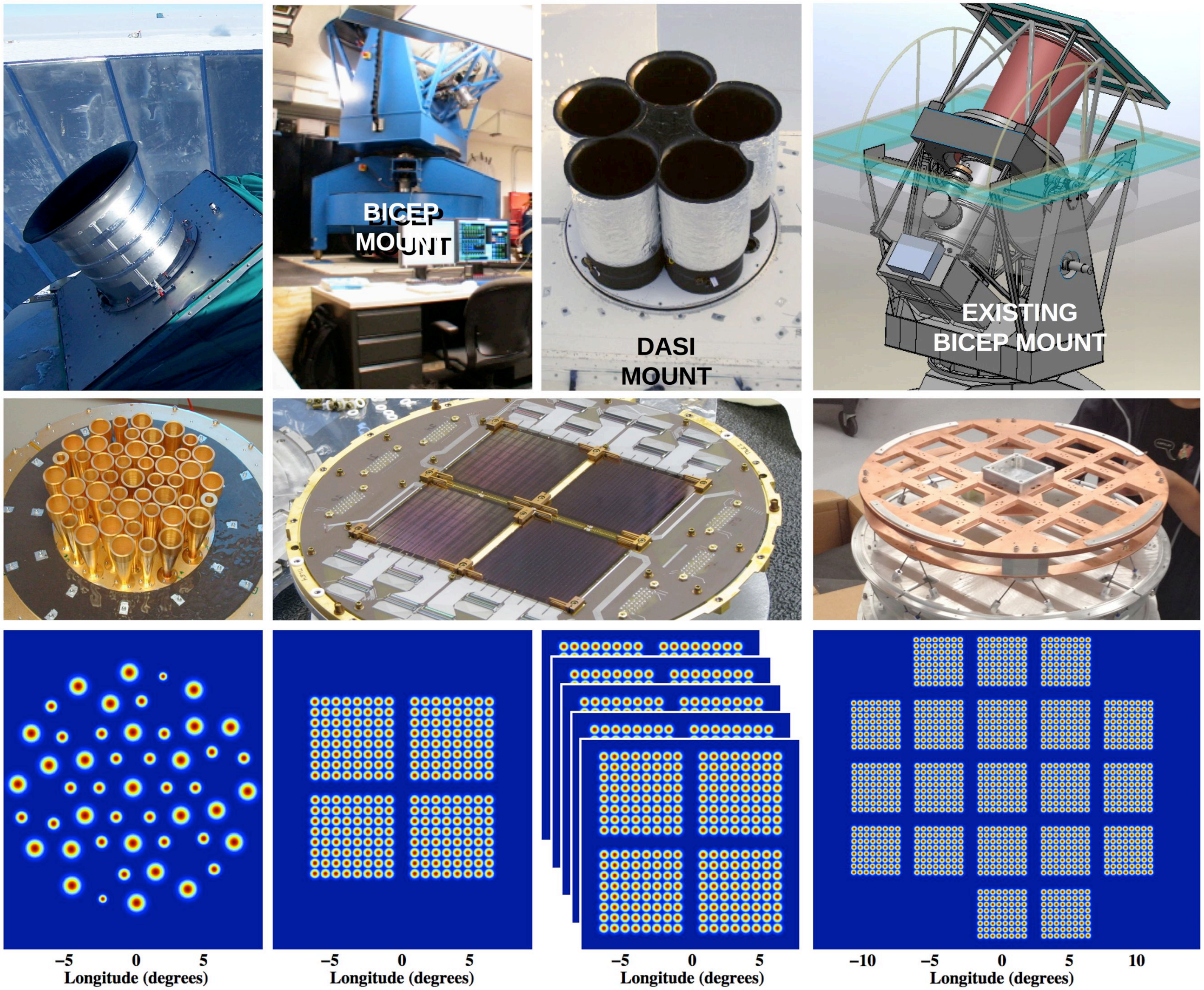
BICEP-3 Polarization Experiment:

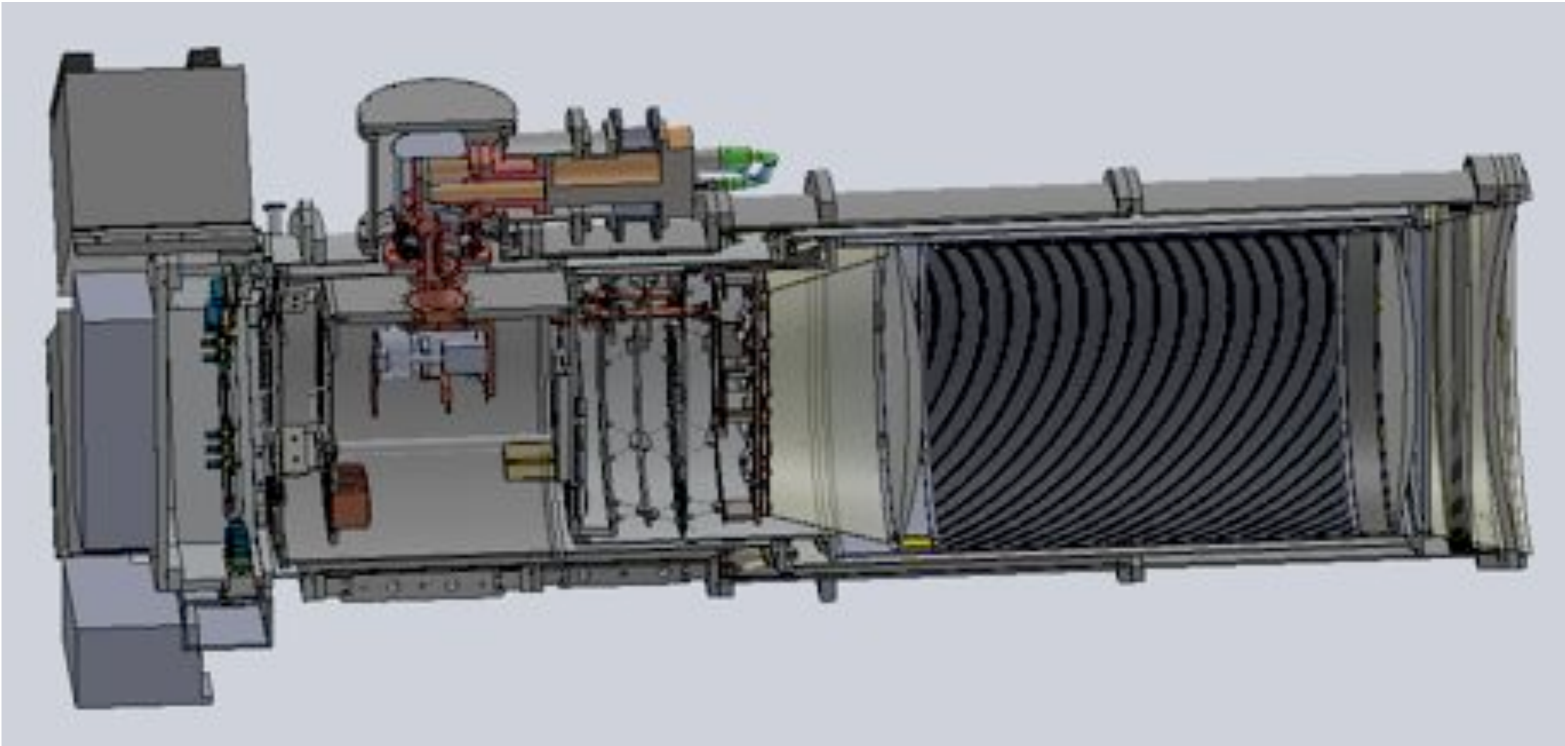
- What we need: higher mapping speed
- How?
  - Fast f-ratio
  - large aperture
  - large focal plane
  - re-use of as much hardware as possible
- New developments in 3 key areas:
  - Detectors
  - Lens material
  - IR filtering

BICEP 2006–08	BICEP2 2010–12	Keck/SPUD 2011–	BICEP3 2014-



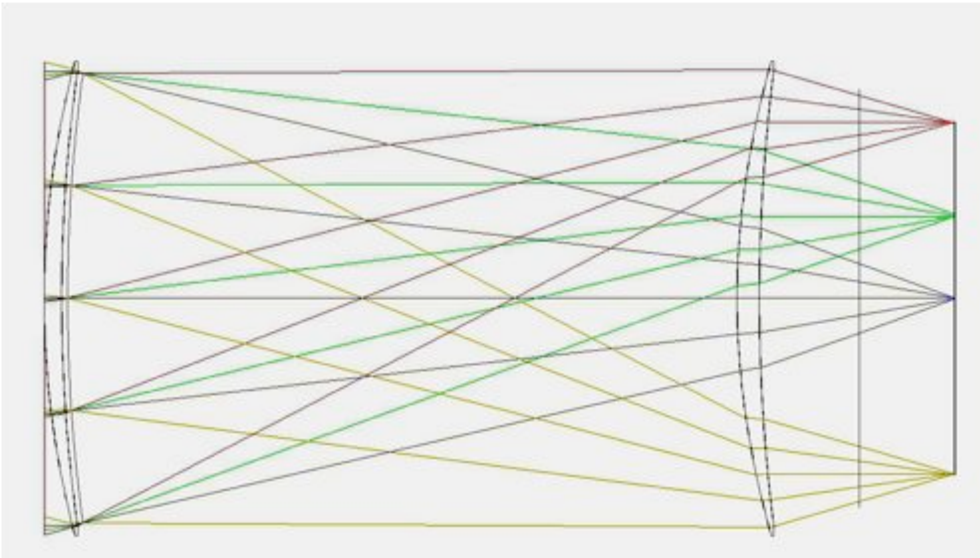
98 NTDs (95/150 GHz)	512 TESs (150 GHz)	2560 TESs (150 GHz)	**2560 TESs (95 GHz)**
0.93°/0.60° FWHM	0.52° FWHM		**0.37° FWHM**
18° FOV	17° FOV		**26° FOV**
44 m^2 deg^2 AΩ	44 m^2 deg^2 AΩ	222 m^2 deg^2 AΩ	**502 m^2 deg^2 AΩ optical throughput**

BICEP-3 Design Scheme



- linear polarization-sensitive detector tiles of the BICEP-2/Keck/SPIDER style
- Cryomech pulsetube cryocooler plus Chase 3-stage adsorption fridge
- lenses attached to 4K stage
- IR filters at ambient (film filters) and 50K (absorptive)
- alumina lenses
- detectors and SQUID preamplifiers all in Faraday cage and multi-layer magnetic shielding
- (not shown) co-moving forebaffle -- either absorptive or reflective (Winston)

Optics

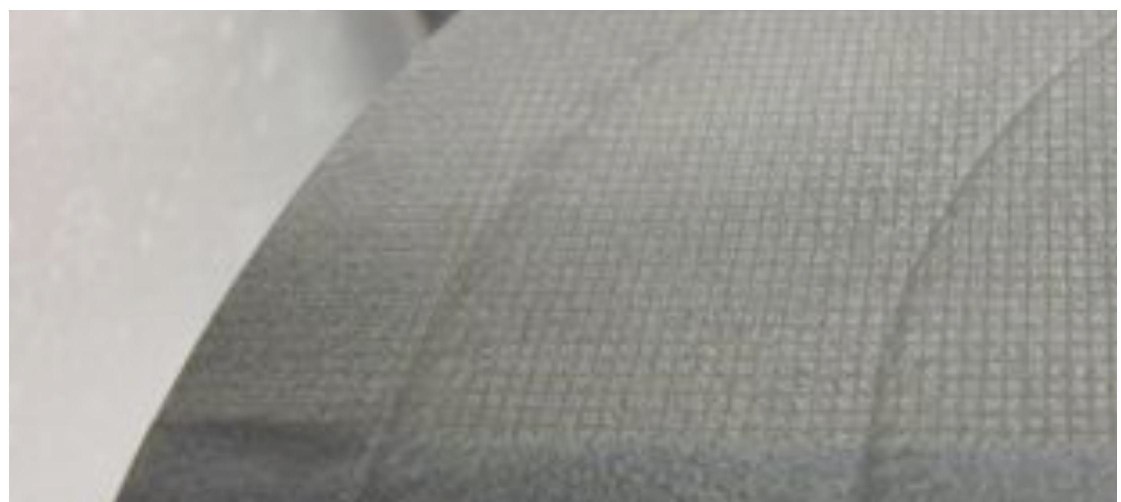


Design

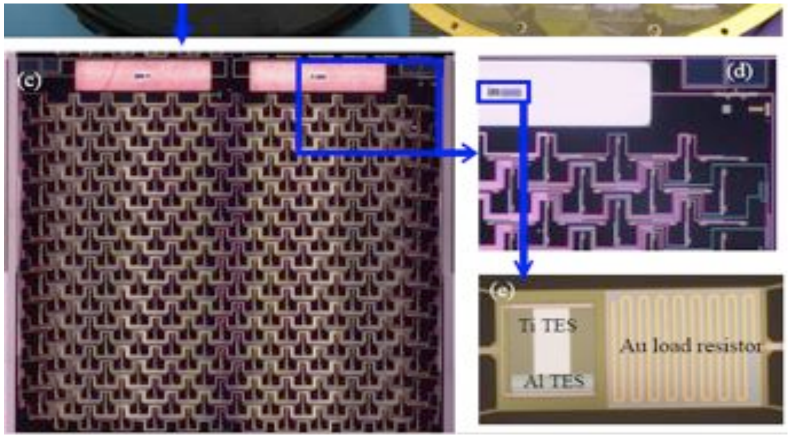
- f/1.6
- 14° half-angle, 215mm focal plane radius
- diffraction-limited
- lenses:
  - alumina, n=3.1
  - 58cm clear aperture
  - several materials tested at 300K and 90K, best chosen
  - being manufactured now
- back-up designs use HDPE, PTFE, but these lenses are very thick
- telescope tube absorbing walls
- external co-moving baffle to catch large-angle sidelobes (scattered radiation)

Anti-reflection coating

- epoxy mix to get n=sqrt(3.1) for λ/4 layer
- relative thermal contraction too large, must cut relief channels
- tests with UV laser cutting successful with ~30μm channels
- ongoing testing to determine best spacing to minimize scattering and diffractive losses



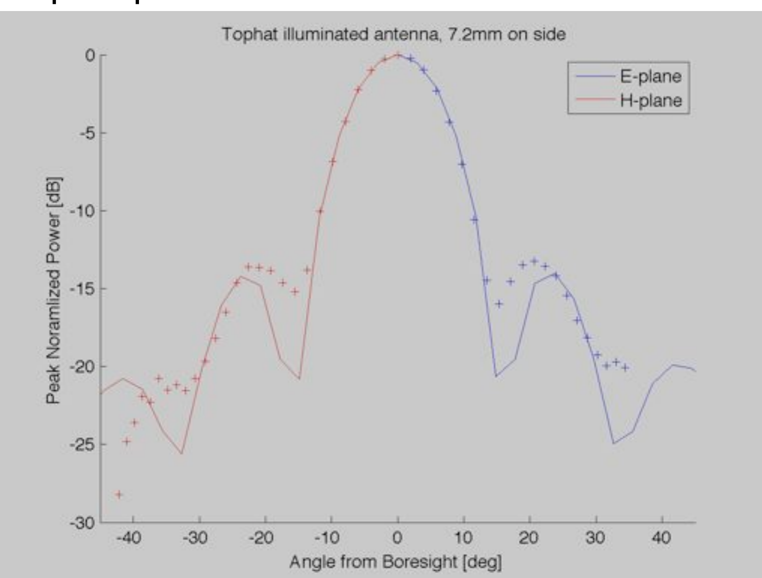
Detectors: tapered pixel response

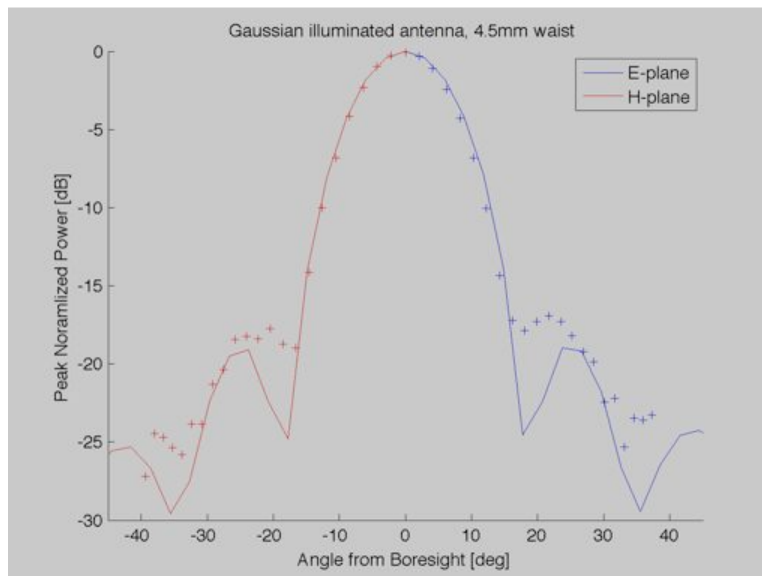


JPL pixel arrays

- each pixel an array of slot antennas on thin wafer of silicon
- BICEP-2/Keck version: all slots signals added with equal weight → “top-hat” profile
  - generates fairly large sidelobes that hit the inside of the telescope walls, at (nominally) 4K
- New version: slot signals added with profiled weights approximating truncated Gaussian
  - smaller sidelobes, lower contribution from the 4K telescope walls
  - cleaner beams
- BICEP-3 pixels: 95 GHz, same size as the 150s → wider beams for the fast optics

tophat pixel



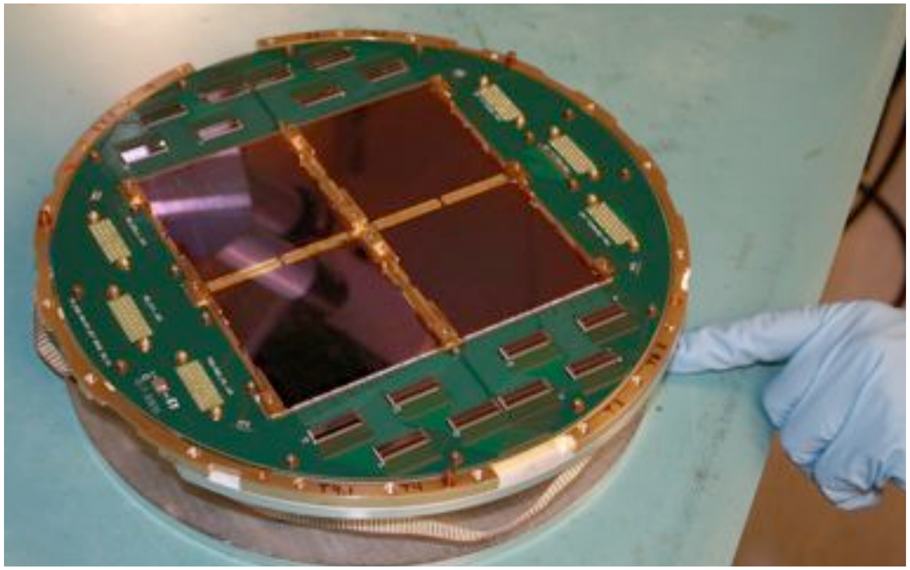


Other upgrades

- sensitivity recovered
- beam offsets reduced (absolute and differential)

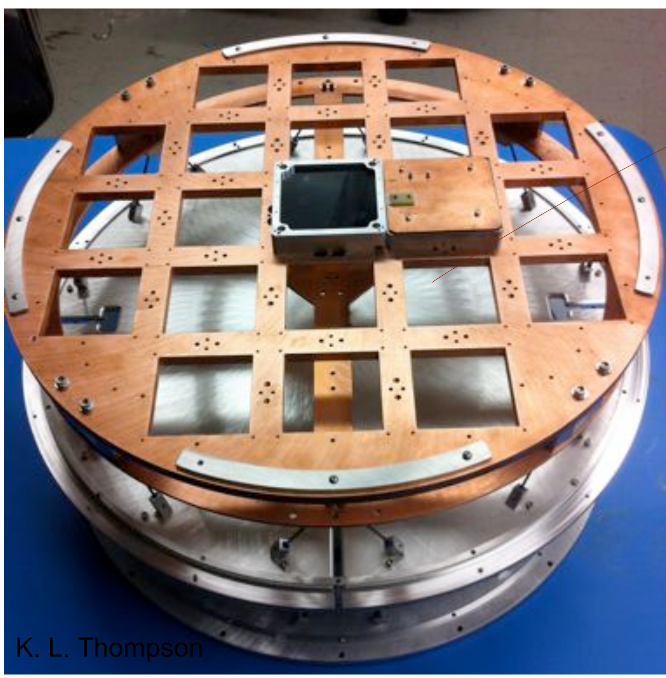
prototype 150 GHz tapered pixel (2012)

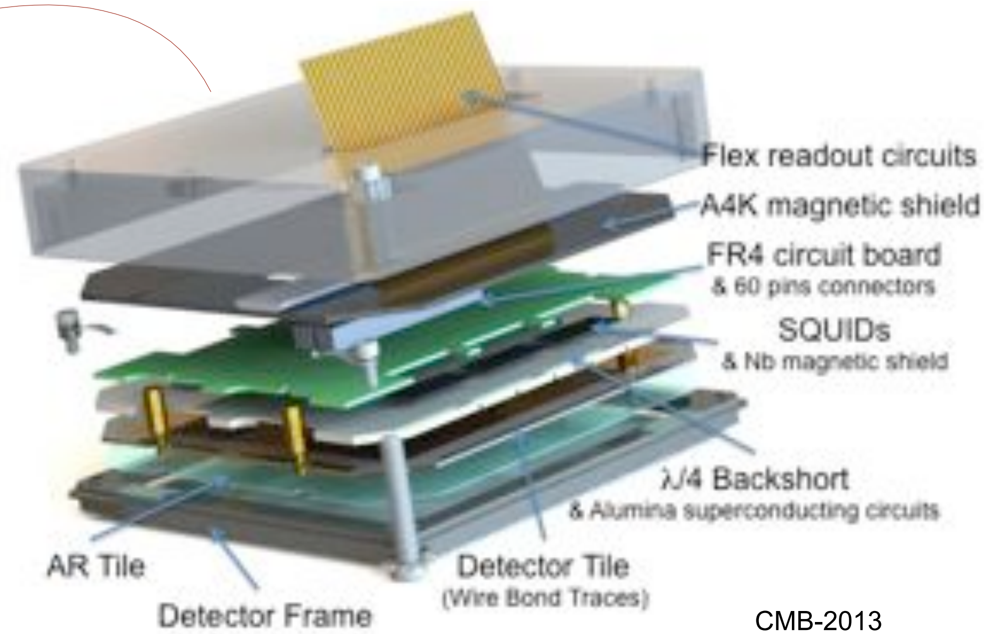
Detectors: single-tile modules



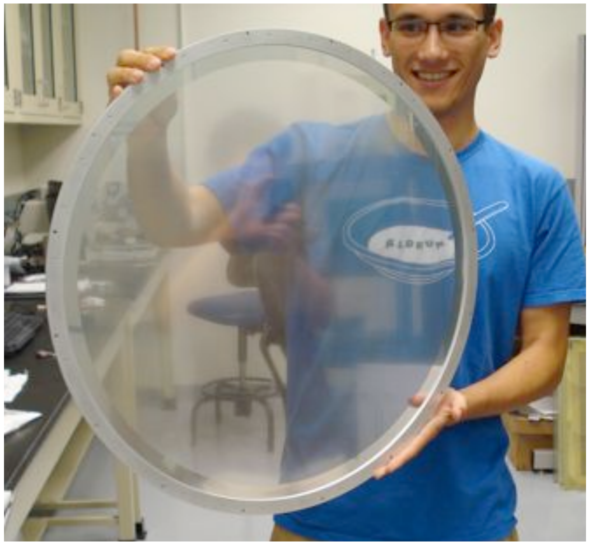
BICEP-2/Keck style:
- 4 tiles in one focal plane
- multiplexing on surrounding board
- wire bonds integrate the assembly
- swapping tiles requires many hours

BICEP-3 style:
- one tile per module
- wire bonds only to multiplexing board inside module
- 20 modules/tiles per focal plane
- swapping modules requires minutes
- geometry more flexible



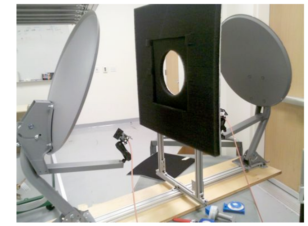


Infrared Filters



(grad student Jimmy Grayson with prototype, 2012)

Radiation Load: ~150 W incident on window
Pulsetube cryocooler (Cryomech PT-415): 1st stage ~40W
Need Reflective IR Filters

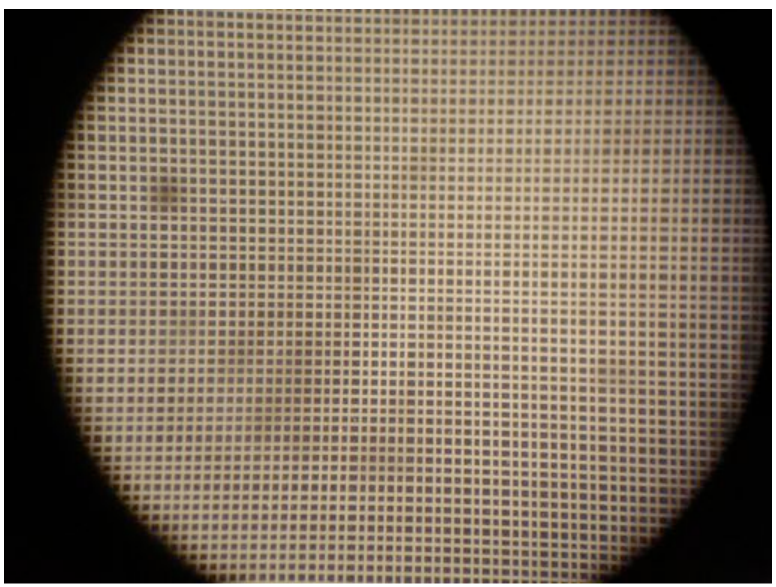


Final Scheme: thin Mylar with aluminized squares

Development:
- HFSS simulations
- scaled-up filters (500x, 1000x) tested with VNA and free-space optics at ~8-32 GHz

(postdoc Zeeshan Ahmed installing prototype filters in cryostat)

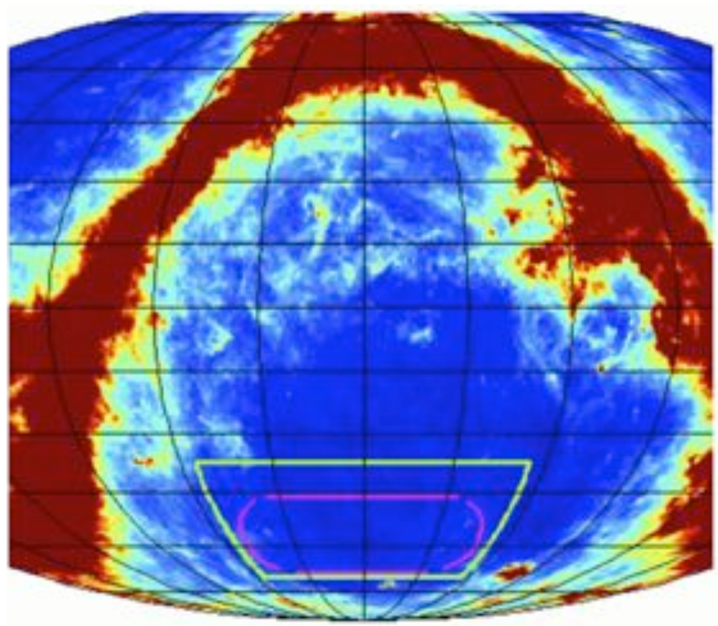
Testing:
- in-band transmission
- integrated BB transmission 0.5-40μm
- IR verification in cryostat: up to 7 layers, cuts down IR loading as expected

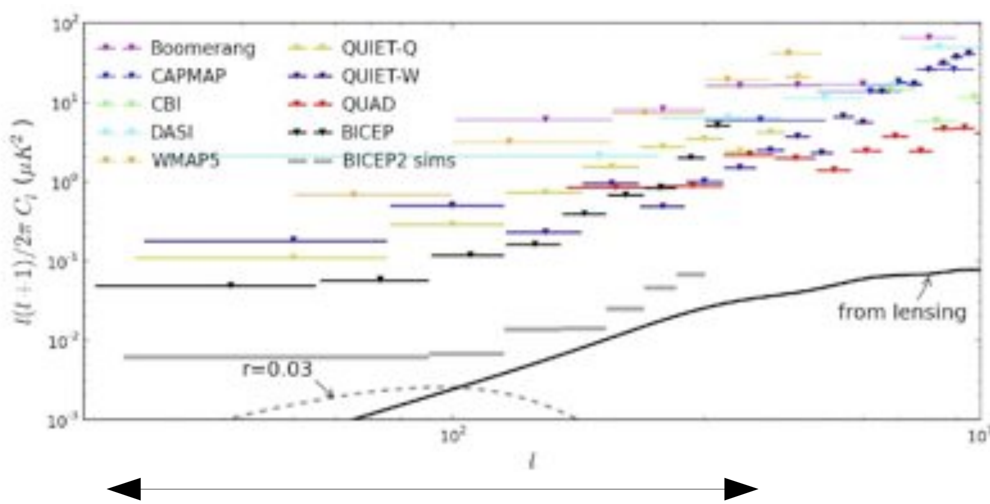


BICEP-3 configuration
- 6 layers, 3 different designs to spread resonant spectral features around
- 3.5μm Mylar, minimizes IR absorption of each layer
- aluminized Mylar roll is cut into sheets, attached to mounting rings, then laser ablated into pattern
- primary location: just behind window, 300K
- absorptive filter at 50K to catch remainder

BICEP-3 Field, Power

28° telescope field of view requires larger field on the sky: 2000 deg^2 vs. 800 for BICEP-2, Keck





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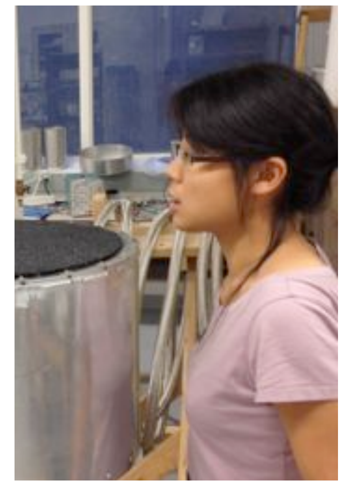

grad student Kimmy Wai Ling Wu

real power spectrum predictions someday

BICEP-3 Schedule

- receiver integration: summer 2013
- detector fab and screening: summer 2013 – spring 2014
  - first two module-style tiles in fab now
  - testing will allow design feedback this summer
- receiver testing at Stanford: summer/fall 2013
  - cryogenic tests
  - basic optical tests
- beam mapping at Harvard: winter – summer 2014
  - far field beams and scattering measurements
  - simultaneous mount integration, testing of mount mods
- deployment: fall/winter 2014
  - begin 2 years of observation