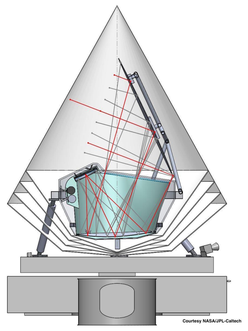
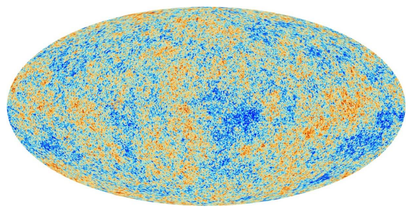


Optical Design of PICO, a Concept for a Space Mission to Probe Inflation and Cosmic Origins



K. Young[1†], M. Alverez[2], N. Battaglia[3], J. Bock[4], J. Borrill[5], D. Chuss[6], B. Crill[7], J. Delabrouille[8], M. Devlin[9], L. Fissel[10], R. Flauger[11], D. Green[12], K. Gorski[7], S. Hanany[1], R. Hills[13], J. Hubmayr[14], B. Johnson[15], B. Jones[3], L. Knox[16], A. Kogut[17], C. Lawrence[3], T. Matsumura[18], J. McGuire[7], J. McMahon[19], R. O'Brient[7], C. Pryke[1], X.Z. Tan[1], A. Trangsrud[7], Q. Wen[1], G. de Zotti[20]

[1]Univ. of Minnesota, [2]Univ. of California Berkeley, [3]Princeton Univ, [4]California Institute of Technology, [5]Lawrence Berkeley National Laboratory, [6]Villanova Univ., [7]Jet Propulsion Laboratory, [8]Astroparticule et Cosmologie, [9]Univ. of Pennsylvania, [10]National Radio Astronomy Observatory, [11]Univ. of California San Diego, [12]Univ. of Toronto, [13]Cavendish Laboratory, Univ. of Cambridge, [14]National Institute of Science and Technology, [15]Columbia Univ., [16]Univ. of California Davis, [17]Goddard Space Flight Center, [18]Kalvi IPMU, Univ. of Toyko, [19]Univ. of Michigan, [20]Osservatorio Astronomico di Padova

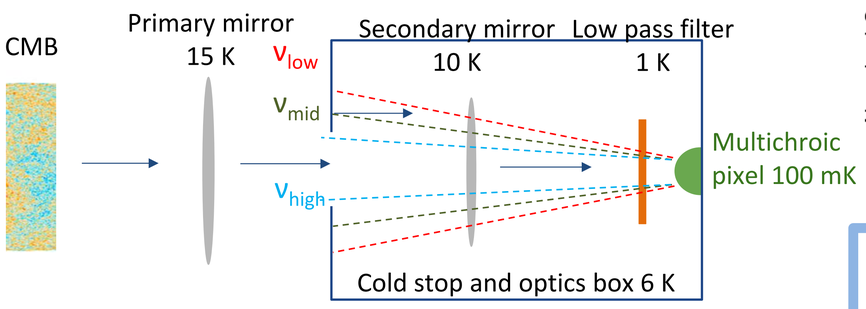
[†]Email: kyoung@astro.umn.edu

Scientific Observations

- Measure or set upper limits on primordial B-modes with $\sigma(r) \sim 10^{-5}$
- Determine the number of light relic particles, N_{eff}, to $\sigma(N_{eff}) = 0.03$
- Measure τ, the optical depth to reionization to cosmic variance limits, $\sigma(\tau) = 0.002$
  - Along with DESI-BAO observations measure Σm_ν, the sum of neutrino masses at $\geq 4\sigma$
- Map Galactic magnetic fields from Galactic scales to 0.05 pc in 10 nearby molecular clouds
- Discover 10,000s of protoclusters and clusters via the SZ effect
- Map the CIB and dusty infrared galaxies across the full sky

Satellite and Instrument

- 70 times the polarization sensitivity of *Planck*
- 21 bands from 20 GHz to 800 GHz
- 25 % fractional bandwidth
- 12,996 polarization sensitive TES bolometers
- 1' resolution at 800 GHz, 38' at 20 GHz
- Full-sky coverage
- TDM readout: 128 rows, 100 columns
- Launch vehicle is a Falcon 9, 4.6 meter fairing
- L2 orbit, precession and spin based scan strategy with precession angle 26° and boresight angle 69°

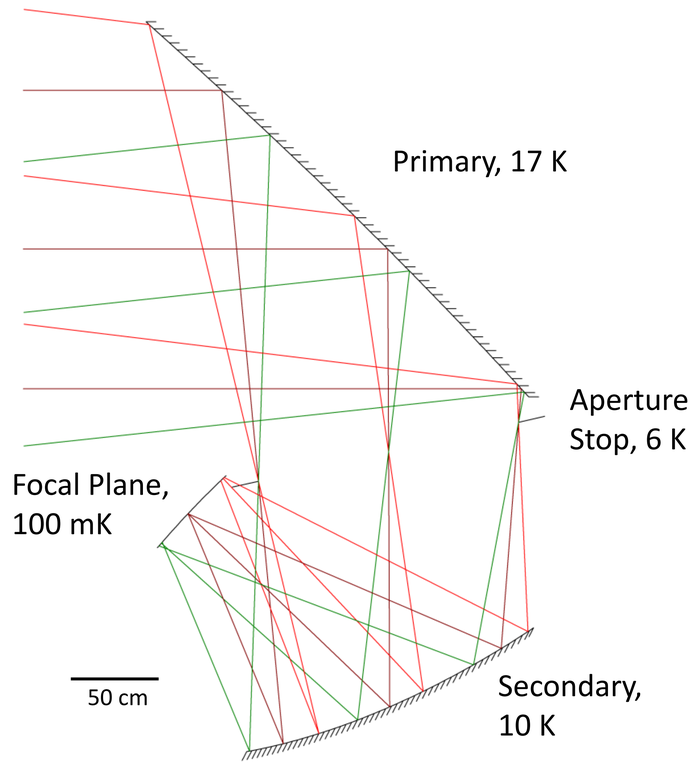


- Multichroic pixel make stop illumination dependent on band
- Edge tapers are 4.8, 10, 20.7 dB for low, mid, high
- Affects optical efficiency, optical load, and telescope beam size

Reference

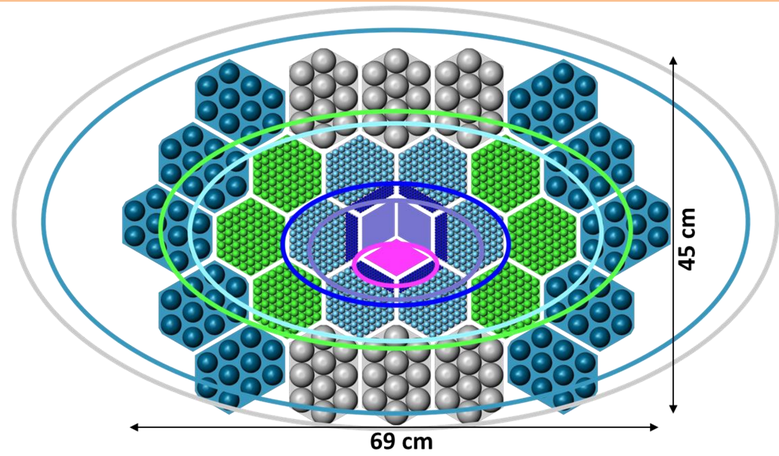
[1] C. Dragone, "First-order correction of aberrations in Cassegrainian and Gregorian antennas," in IEEE Transactions on Antennas and Propagation, vol. 31, September 1983.

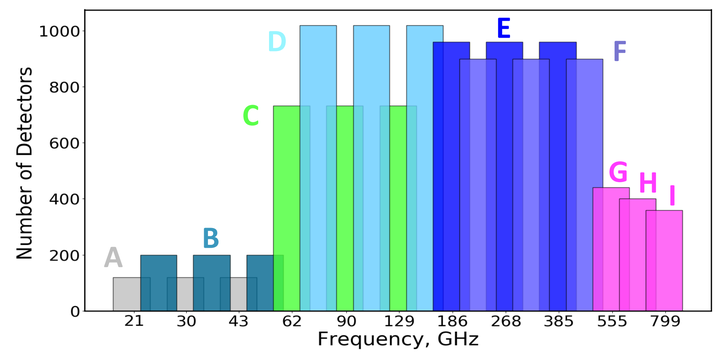
Optical Design



- 1.4 m Open Dragone, numerically optimized
- 19 x 13 degree field of view
- f/1.42 system gives compact focal plane
- Low far sidelobes, largest 70 dB below main beam
- Cold stop reduces detector load

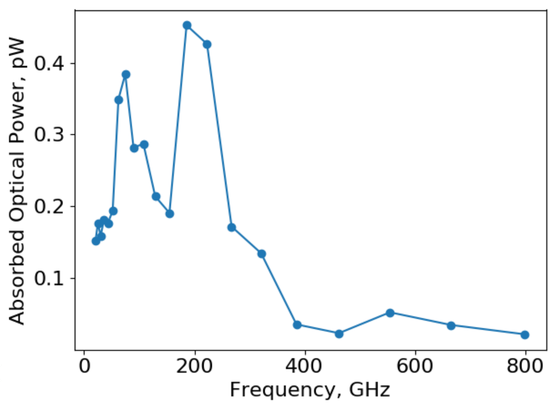
Focal Plane

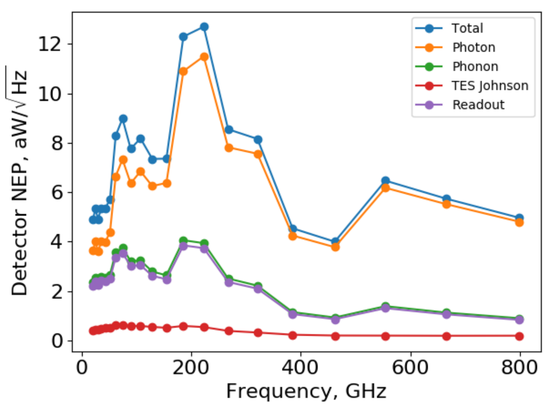


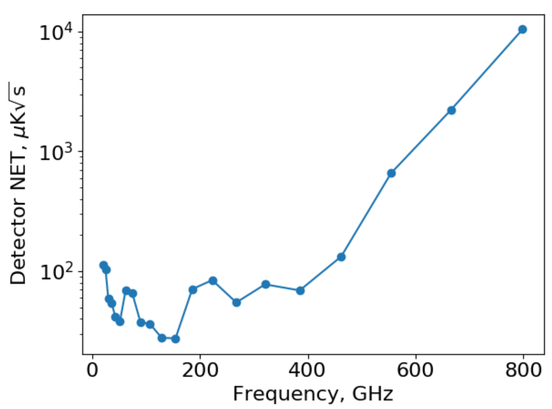


- Three color pixels, six polarization sensitive detectors per pixel

Detector Noise Predictions







Model

- White noise only
- Includes photon (dominates), phonon, readout, and TES Johnson noise terms
- 5 year mission at 95% observing efficiency
- Safety factor of 2, $P_{sat} = 2\ P_{opt}$
- 70 % bolometer effeciency
- 100 % yield

The PICO collaboration thanks NASA for supporting this study.

Results

- CMB and stop are the largest optical load in all bands
- Maximum load from stop is at 223 GHz and is 4.7 times the CMB load
- NEP_{phonon} / NEP_{photon} is 65% at 21 GHz and 19% at 800 GHz
- Bose / Poisson photon noise is 1.5 at 21 GHz and drops below 10% at 321 GHz.
- Full sky polarization map depth is 0.62 μK_{CMB}-arcmin