Virtual Research Presentation Conference

Antenna-Coupled TES Bolometer Arrays for CMB Polarimetry

Principal Investigator: James Bock (3268)
Co-Is: Krikor Megerian (389I), Hien Nguyen (3268), Roger O'Brient (389I), Anthony Turner (389I), Alexis Weber (389I)
Program: Strategic Initiative

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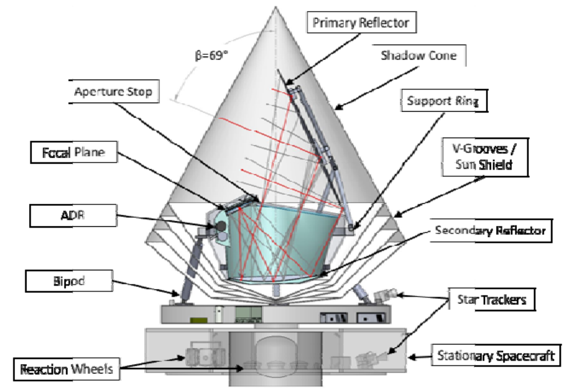
Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

We are developing arrays of antenna-coupled transition-edge superconducting bolometers for Cosmic Microwave Background polarimetry.

- Demonstrate technical readiness for the Einstein Inflation Probe, a potential future CMB satellite described in NASA's strategic plan for astrophysics.
- Facilitate JPL detectors for the planned CMB-S4 experiment, funded at the scale of a NASA facility mission.
- Demonstrate arrays on balloon-borne and ground-based experiments, which provide the closest environment to a space mission.
- Antenna-coupled arrays offer high sensitivity and dense formats, demonstrating frequencies (30 – 300 GHz) required for comprehensive foreground removal.

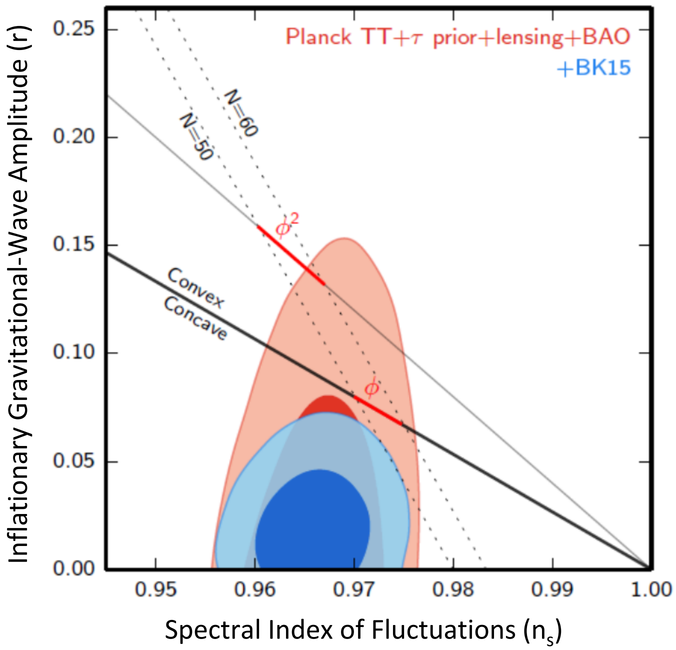


The PICO study for the NASA Inflation Probe mission concept (Hanany *et al.* 2018) is based on large arrays of antenna-coupled TES bolometers operating in multiple frequency bands.

CMB-S4, a ground-based CMB polarization experiment, operates large arrays of multi-frequency antenna-coupled TES bolometers. The program is approved through the DOE Decadal process with first light expected in the mid 2020s.

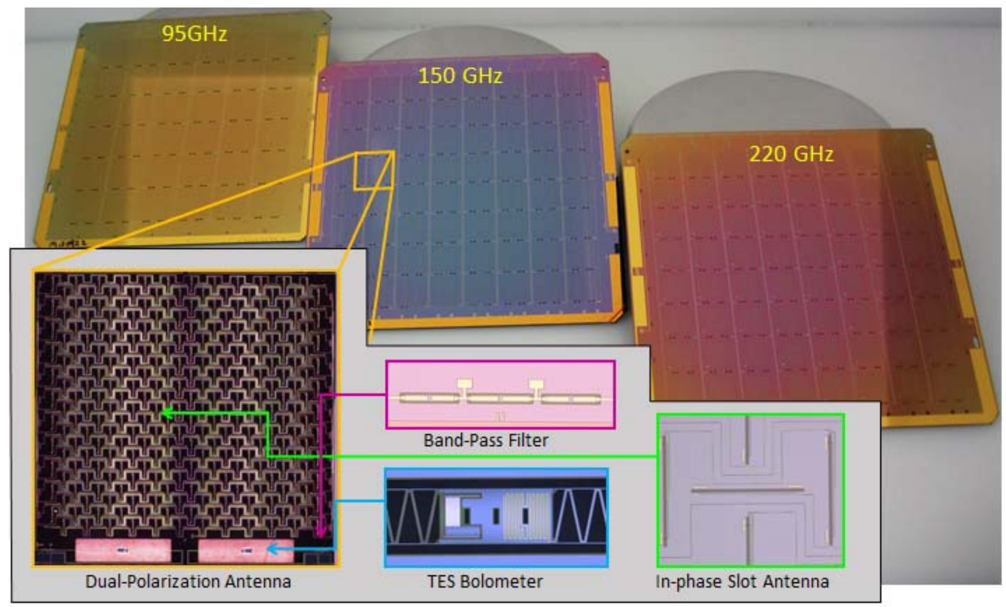
Problem Description

Current Constraints on Inflation



BK15 = BICEP2 and Keck Array Collaborations *et al*. 2018

Planar Antenna-Coupled TES Bolometer Arrays

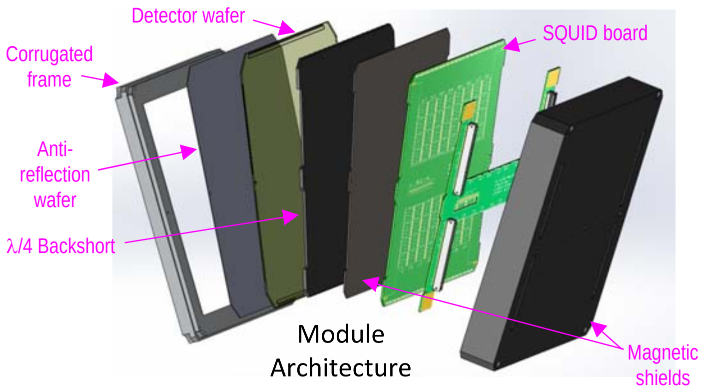


CMB polarization measurements allow us to probe the state of the early universe, most notably a possible polarization signal from a background of Inflationary gravitational waves. Realizing the necessary sensitivity and accuracy requires large arrays of background-limited detectors.

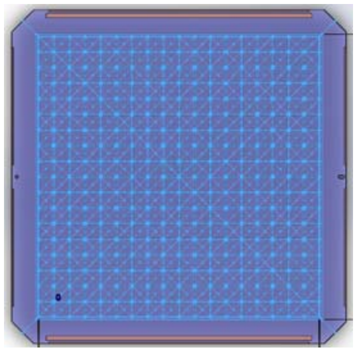
Our approach uses transition-edge superconducting (TES) bolometers coupled to planar antennas. The antennas couple to two polarizations using an array of slots combined with superconducting microstrip. The entirely lithographic process enables large-scale fabrication and operation in multiple frequency bands.

Methodology

Focal Plane Module for 150 GHz



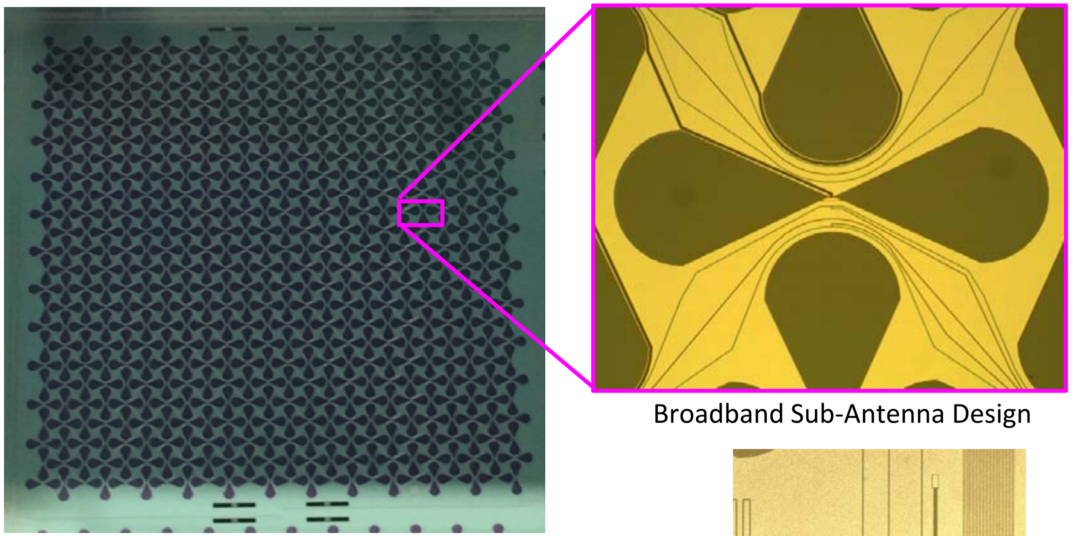
Module Architecture



150 GHz Wafer Layout

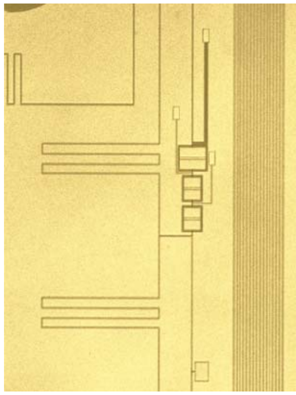
For FY20, we planned to deign a new array for 150 GHz with high detector count on a ϕ150 mm wafer. The wafer is packaged in a focal plane module that integrates the detector with multiplexed SQUID amplifiers, providing a optical and electrical interfaces and integral magnetic shielding.

Dual-Band 30/40 GHz Polarimeter Demonstration



30/40 Dual-Band Antenna Pixel

Broadband Sub-Antenna Design

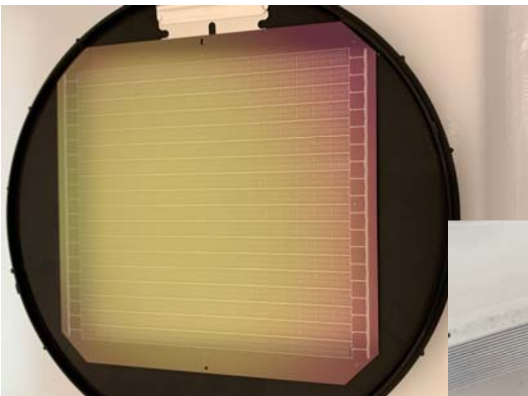


30/40 GHz Diplexer

We also planned to scientifically demonstrate 30 and 40 GHz arrays, the first use of this technology at these frequencies. The demonstration includes a new design, a dual-color antenna that measures polarization at 30 and 40 GHz simultaneously.

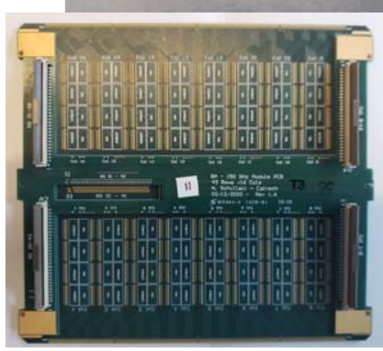
Results

Focal Plane Module for 150 GHz



First 150 GHz Wafer

Corrugated Frame

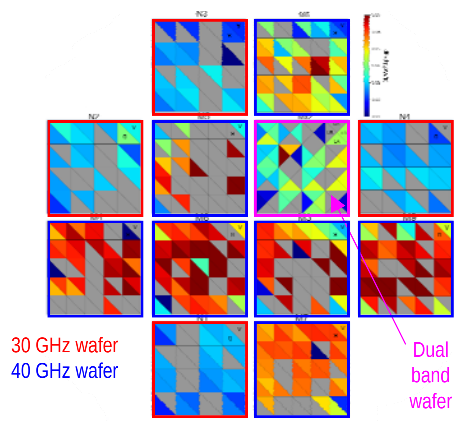


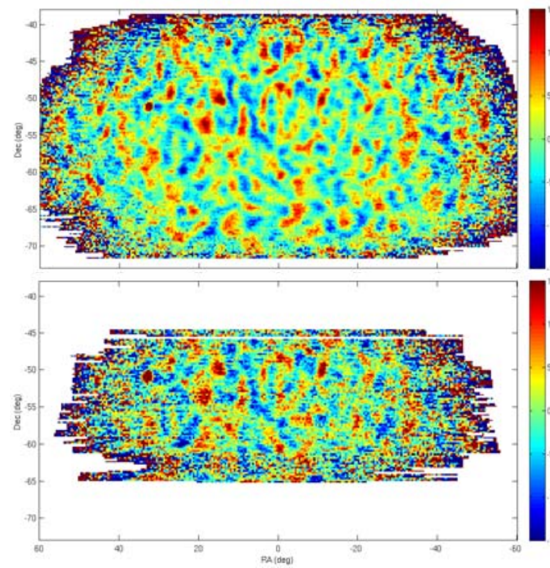
High-Density SQUID Board

We completed the design of the wafer and all of the module boards and parts. The challenging high-density SQUID board is ready for test in a prototype assembly. With MDL reopening, we have completed the first prototype 150 GHz wafer.

Dual-Band 30/40 GHz Polarimeter Demonstration

30/40 GHz Receiver at South Pole



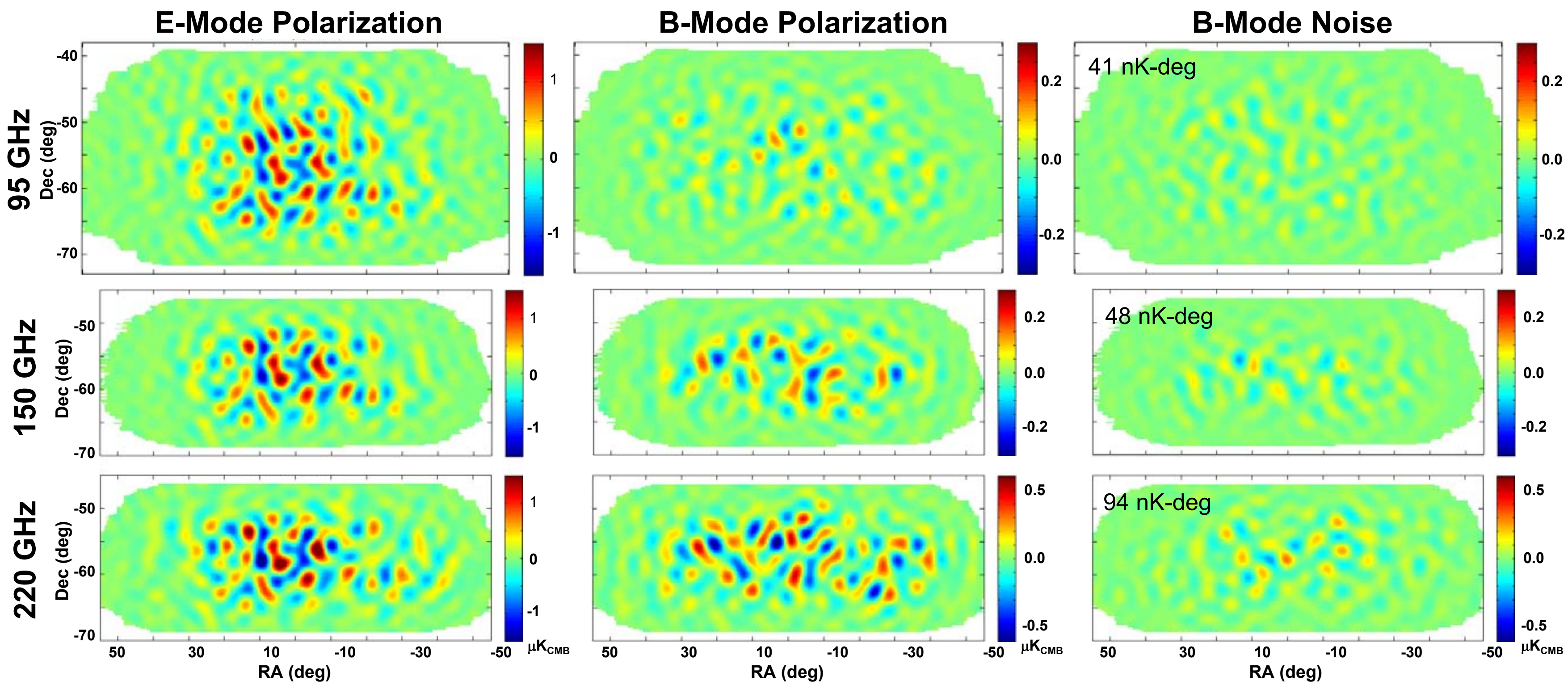


CMB Temperature Maps at 40 GHz (top) and 30 GHz (bottom, dual-band tile).

The 30/40 GHz receiver was deployed to the South Pole and has returned performance results. The focal plane included a dual-band tile, providing performance on spectral response and beam maps. A CMB map is shown from dual-band tile above at 30 GHz.

Results

CMB polarization measurements, produced in 3 bands in dedicated observations using this technology, lead the world in sensitivity and constraints on a B-mode polarization signal from a background of inflationary gravitational waves. The data shown significantly improve upon the leading constraints on inflation, published by our team in 2018.



Publications and References

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**Publication from this RTD program*