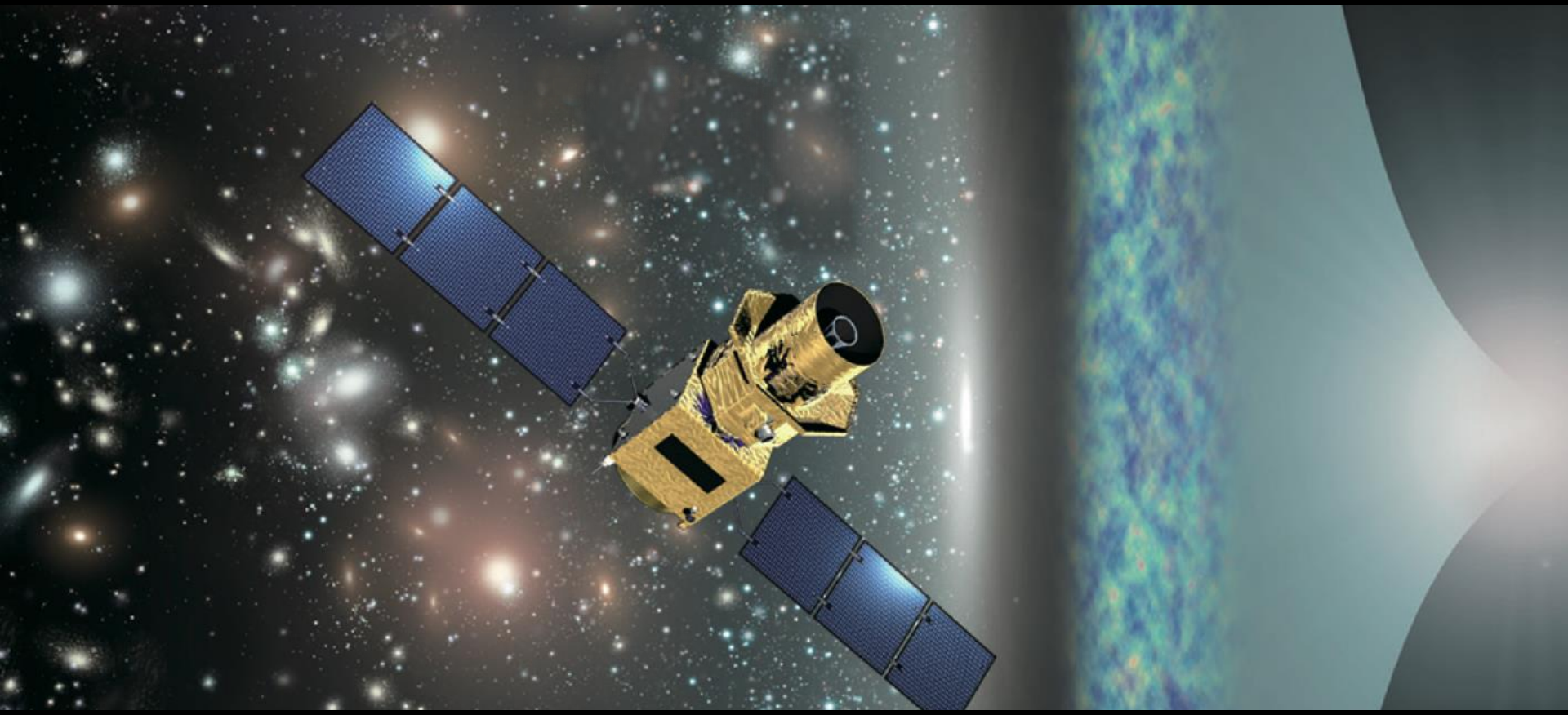
The LiteBIRD Space Mission
Sub-Kelvin Instrument

Lite(Light) satellite for the studies for ***B***-mode polarization and ***I***nflation from cosmic background ***R***adiation ***D***etection



Aritoki Suzuki on behalf of LiteBIRD Joint Study Group
Lawrence Berkeley National Laboratory
Low Temperature Detector Conference 17
2017-07-20

LiteBIRD working group

152 members, international and interdisciplinary (as of July 2017)

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E. Taylor
U. Seljak
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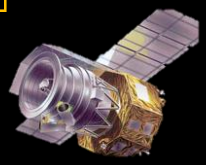
M. Willer
N. Whitehorn

Satellite

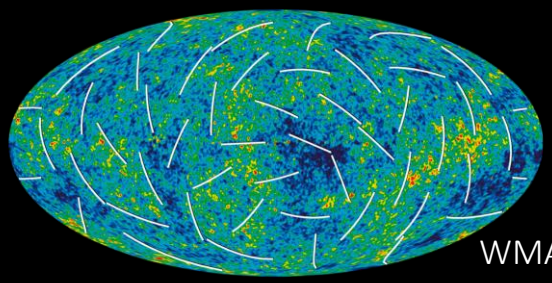
X-ray

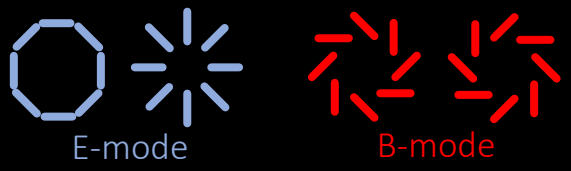


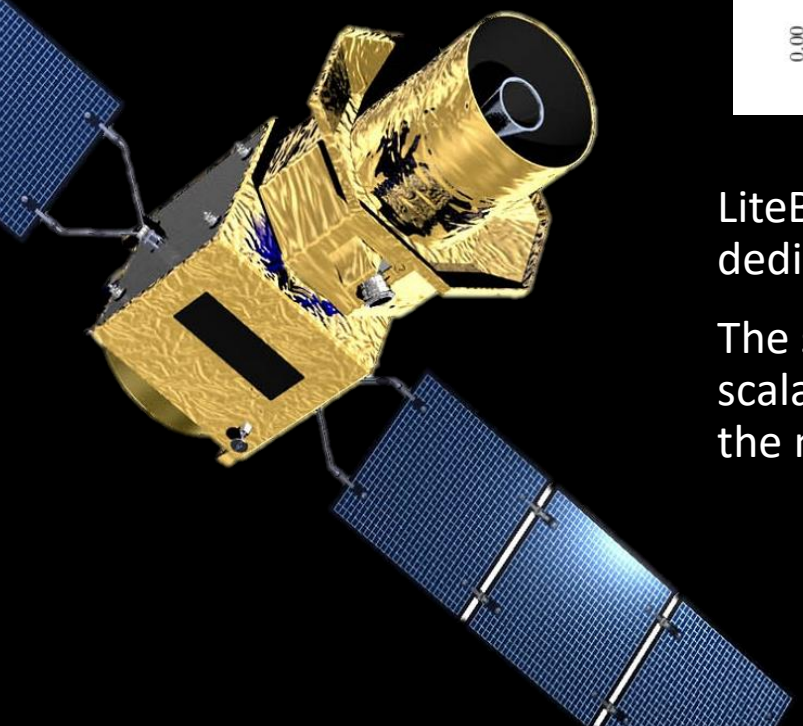
Infrared

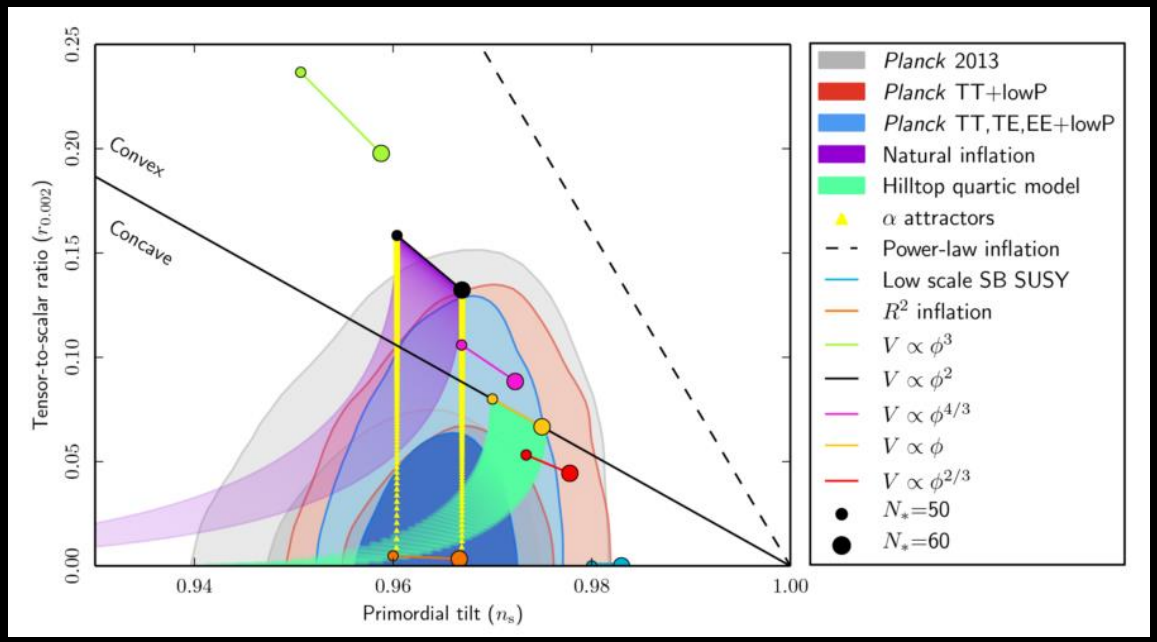
CMB

Science Target









LiteBIRD is a next generation CMB polarization satellite dedicated to probe the inflationary B-mode

The science goal of LiteBIRD is to measure the tensor-to-scalar ratio with the sensitivity of $\delta r < 0.001$ to explore the major large-single-field slow-roll inflation models

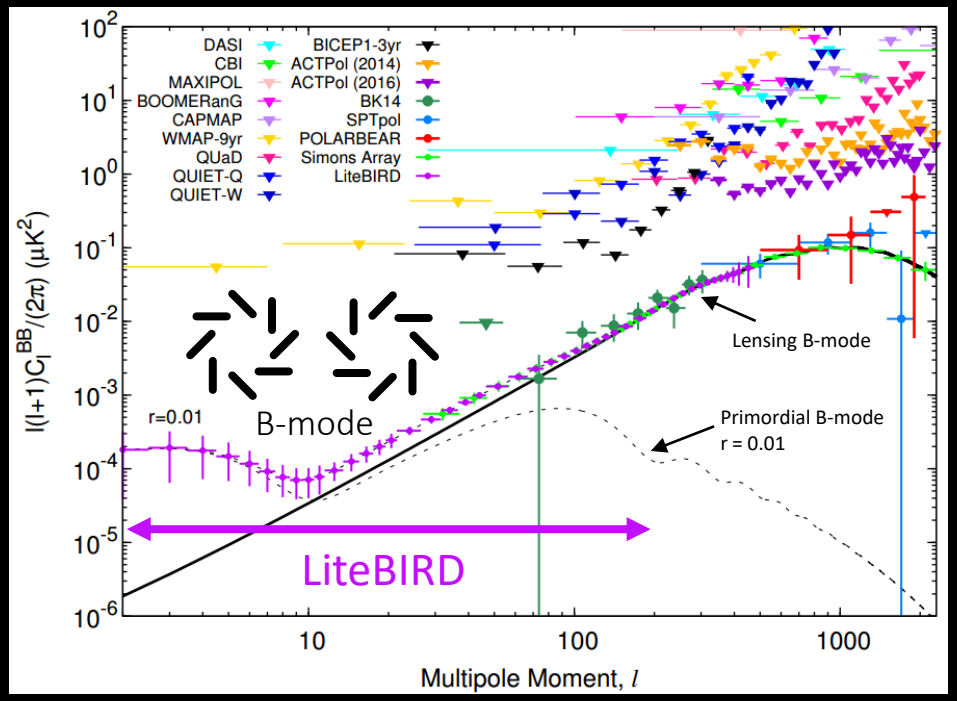
Mission Approach

Posters

(PE-7) Overview

(PD-3) Development of half-wave plate

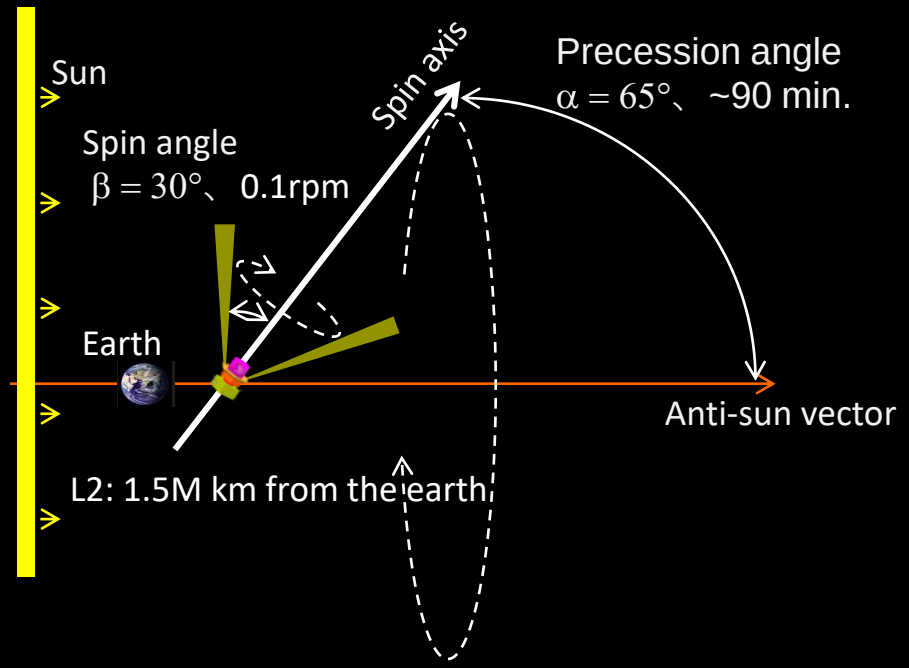
(PD-13) High frequency telescope



- Large angular scale
  - Full sky coverage from space
- High sensitivity
  - Efficient focal plane with multichroic pixel
  - Stringent control of systematics
- Foreground removal
  - Multi-frequency band observation

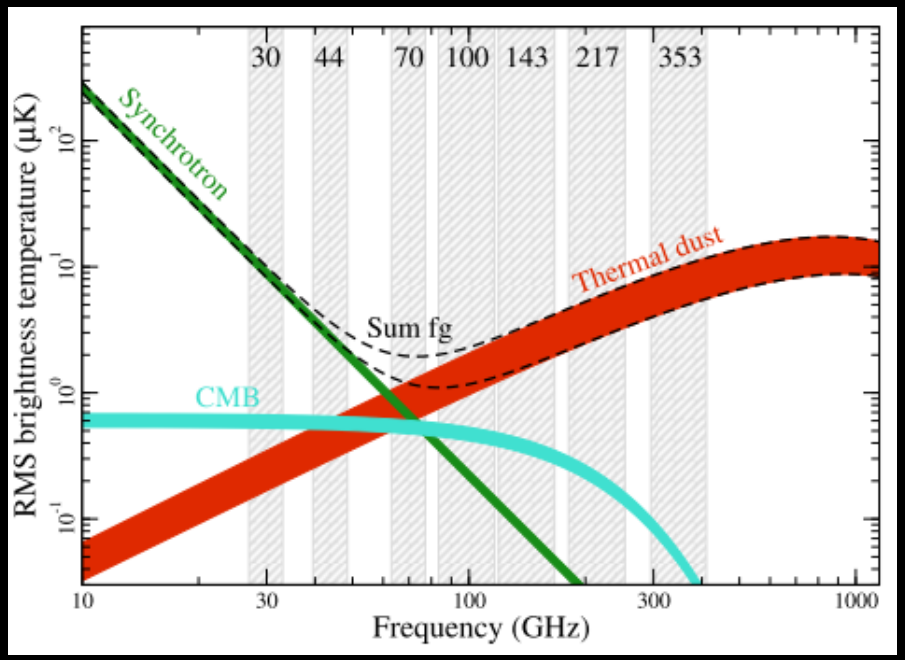
Observation Strategy

JAXA H3 Launch Vehicle (JAXA)

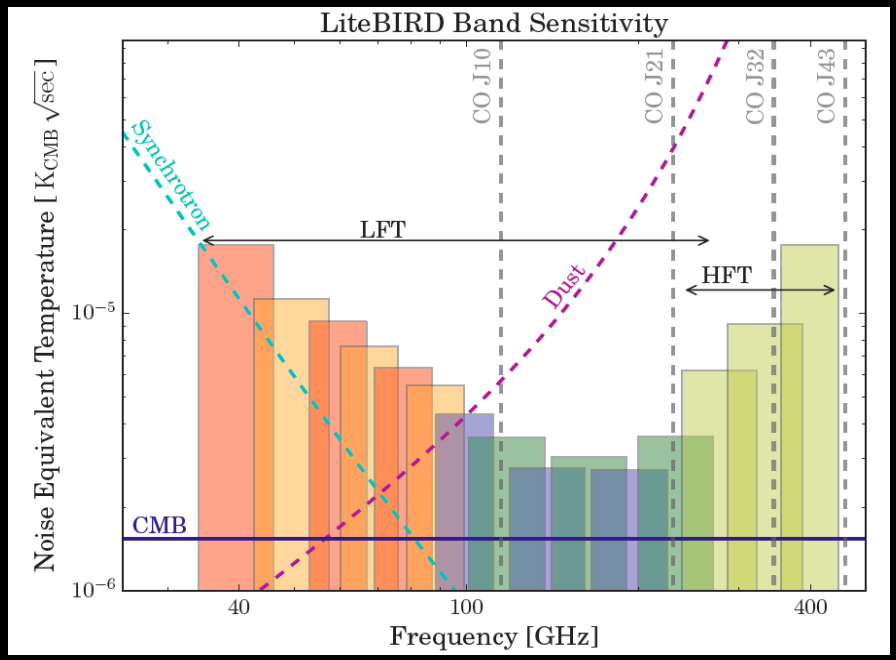


- Launch vehicle: JAXA H3
- Observation location: Second Lagrangian point (L2)
- Scan strategy: Spin and precession, full sky
- Observation duration: 3-years
- Proposed launch date: Mid 2020's

Foreground Removal



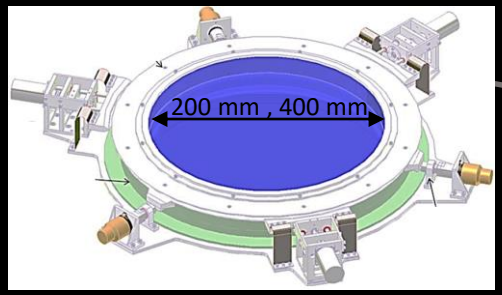
Polarized galactic emission (Planck X)



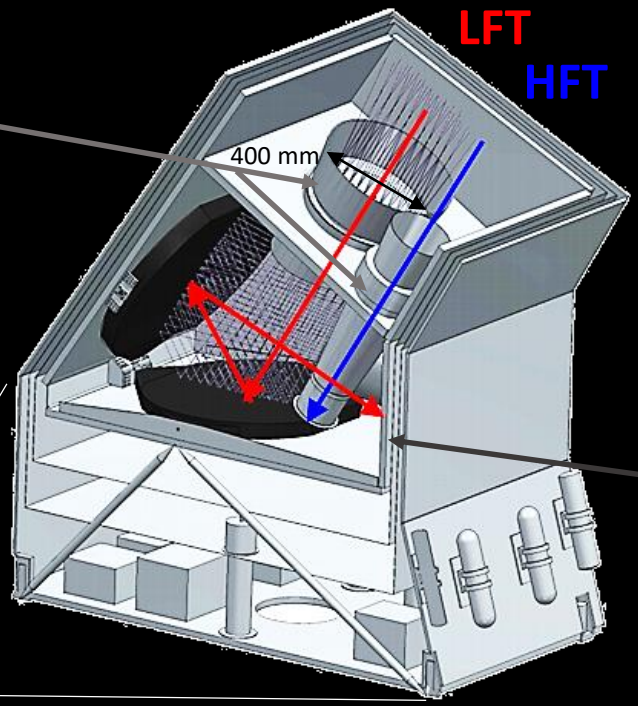
LiteBIRD: 15 frequency bands

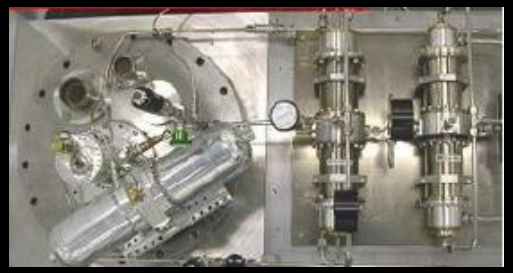
- Polarized foregrounds
  - Synchrotron radiation and thermal emission from inter-galactic dust
  - Characterize and remove foregrounds
- 15 frequency bands between 40 GHz - 400 GHz
  - Split between Low Frequency Telescope (LFT) and High Frequency Telescope (HFT)
  - LFT: 40 GHz – 235 GHz
  - HFT: 280 GHz – 400 GHz

Instrument Overview

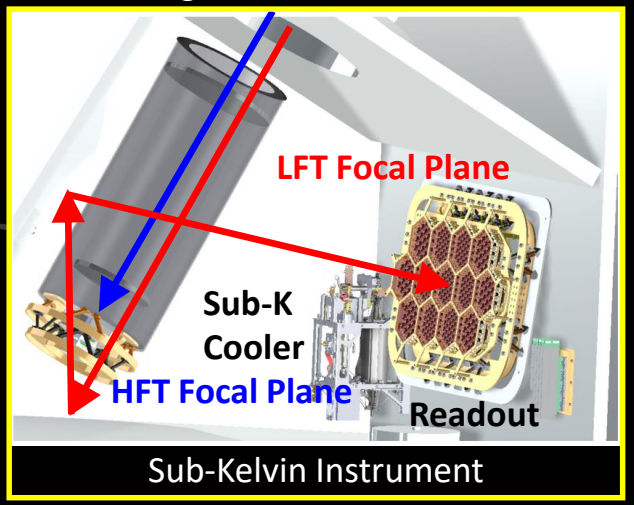


Half-wave plate

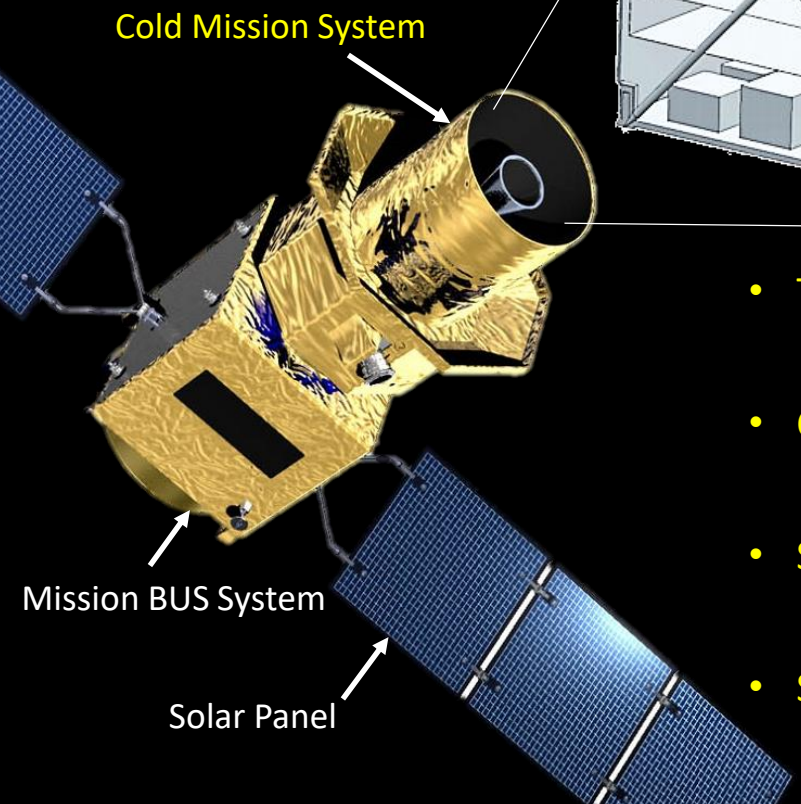




Stirling & Joule Thomson Coolers

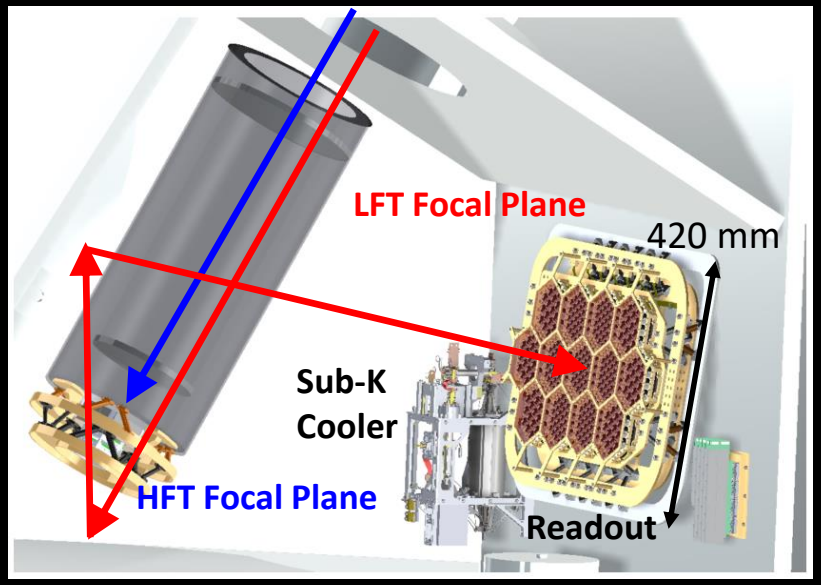


Sub-Kelvin Instrument



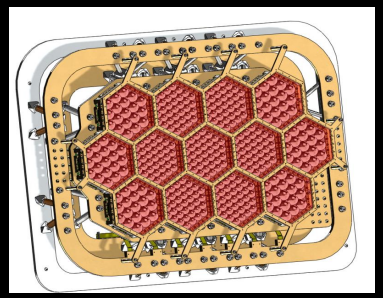
- Two telescopes
  - Crossed-Dragone (LFT) & on-axis refractor (HFT)
- Cryogenic rotating achromatic half-wave plate
  - Modulates polarization signal
- Stirling & Joule Thomson coolers
  - Provide cooling power above 2 Kelvin
- Sub-Kelvin Instrument
  - Detectors, readout electronics, and a sub-kelvin cooler

Sub-Kelvin Instrument

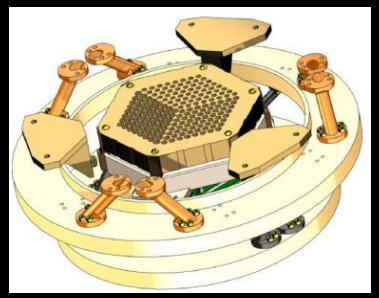


Key parameters

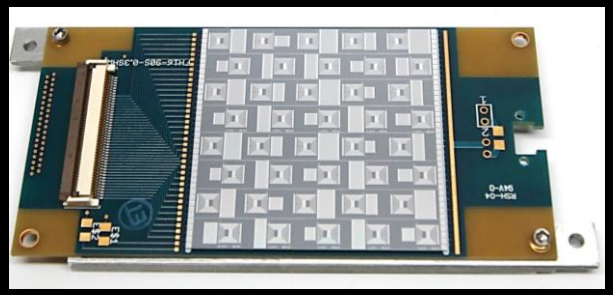
- Frequency coverage: 40 GHz – 400 GHz
- Bolometer count: 2,622
- Base temperature: 100 mK
- Beam FWHM (@140 GHz) 31 arc minute
- NET per det (@ 140 GHz) 38 $\mu K \cdot s^{1/2}$
- Sensitivity (@ 140 GHz) 4.1 μK arc minute



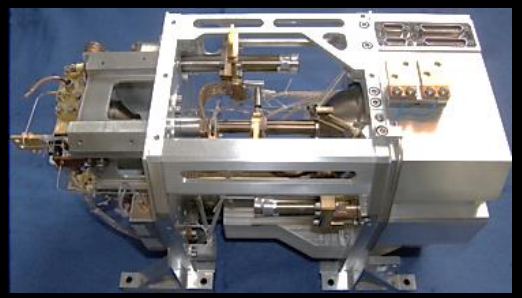
Low Frequency Focal Plane Unit



High Frequency Focal Plane Unit

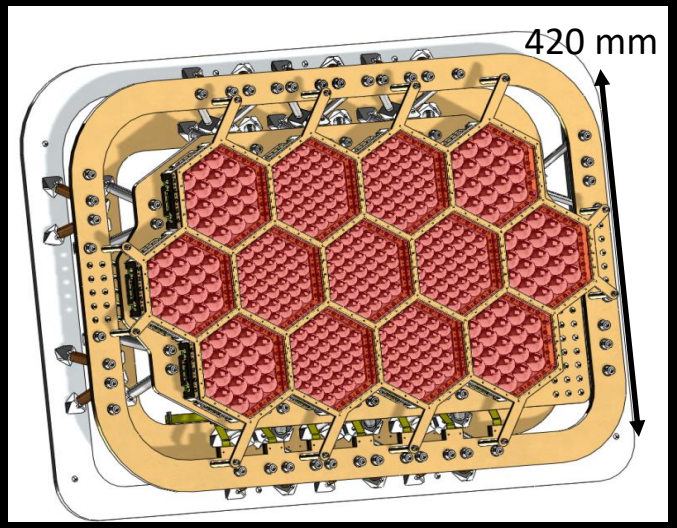


Cold Readout Electronics

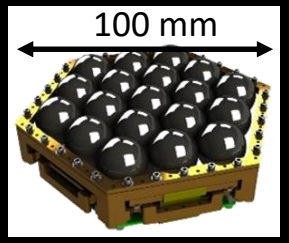


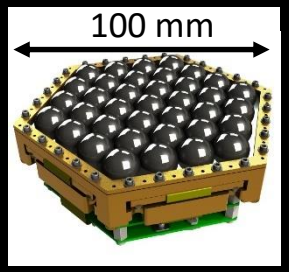
Sub-Kelvin Cooler

Low Frequency Focal Plane Unit

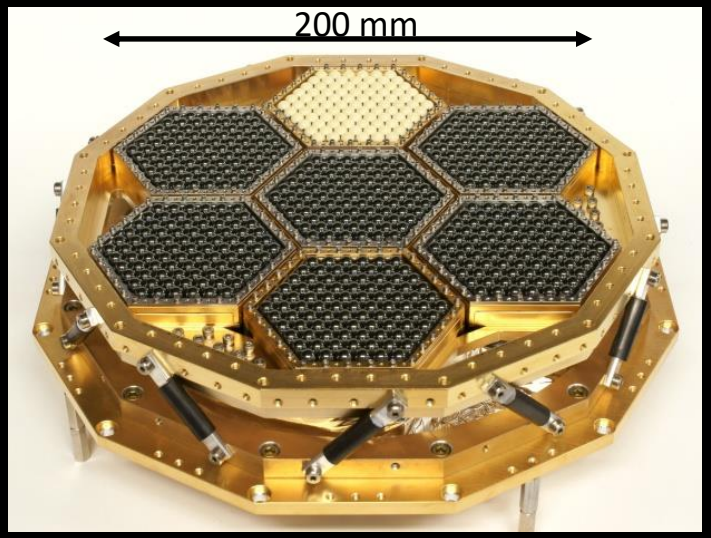


Low frequency focal plane unit





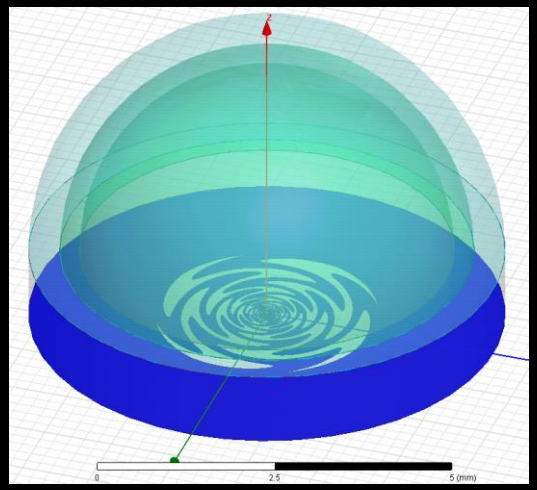
Low (top) and mid (bottom) frequency module



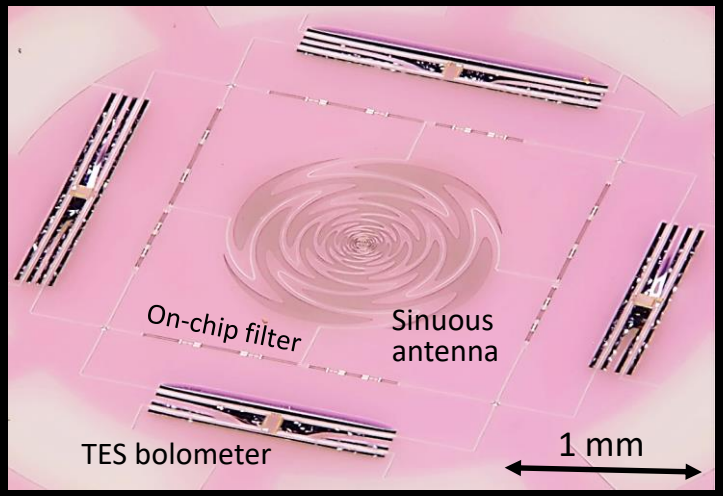
POLARBEAR-1 Focal Plane

- Technology
  - Lenslet coupled sinuous antenna detectors
  - Focal plane design is based on sub-orbital experiments
- Frequency Range
  - Low Frequency Module: 40 GHz – 90 GHz, Pixel size 18 mm
  - Mid Frequency Module: 100 GHz - 235 GHz, Pixel size 12 mm

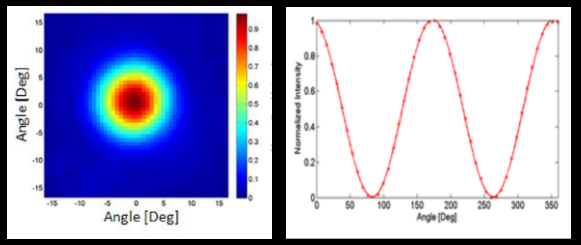
Lenslet Coupled Sinuous Antenna Detector



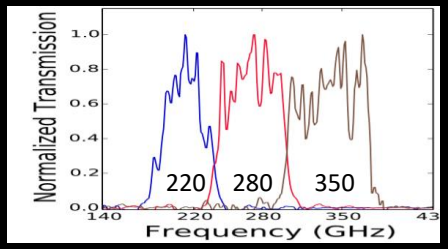
Lenslet coupled sinuous antenna



Sinuous antenna with TES bolometers



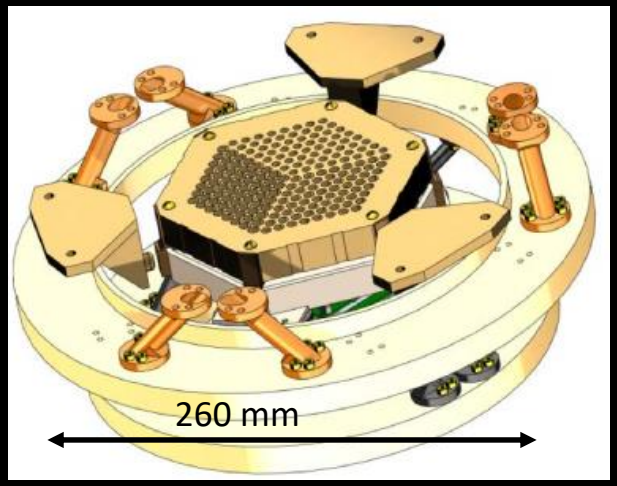
Beam and polarization



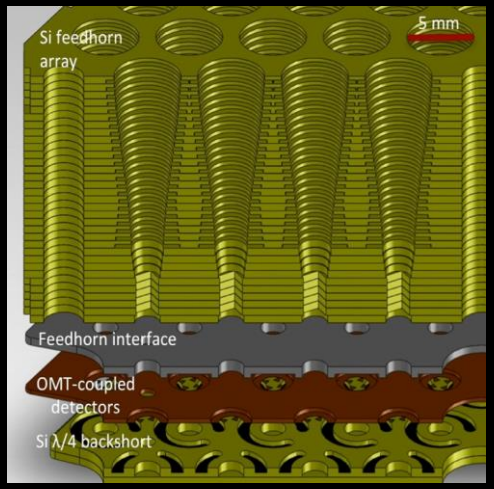
Spectra

- Lenslet coupled sinuous antenna detector
  - Sinuous antenna: Dual polarized broadband antenna
  - On-chip filter → 3 colors per pixel
  - TES bolometers: Aluminum-Manganese (Tc = 170 mK)
- Technology in sub-orbital experiments
  - POLARBEAR-2/Simons Array, SPT-3G, Simons Observatory, EBEX-IDS

High Frequency Focal Plane Unit



High frequency focal plane unit

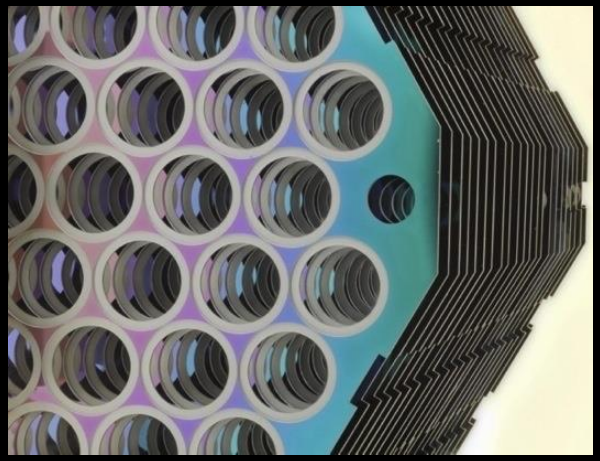


OMT coupled corrugated horn

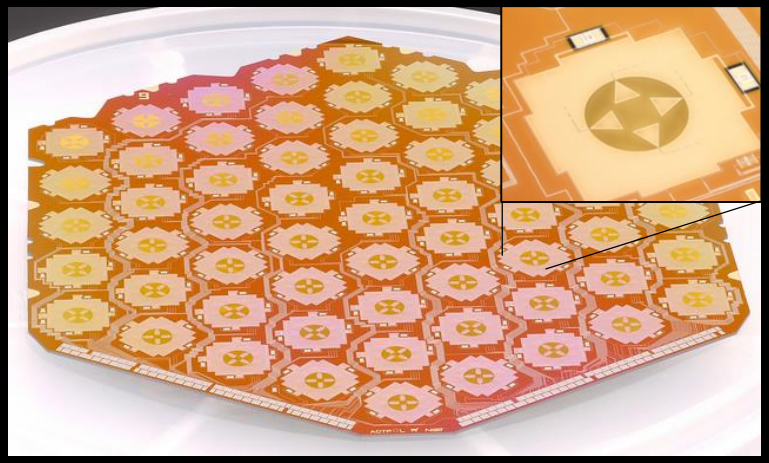
ACTPol Focal Plane

- Technology
  - OMT coupled corrugated horn detectors
  - Focal plane design is based on sub-orbital experiments
- Frequency Range
  - High Frequency Module: 280 GHz, 337 GHz, 402 GHz

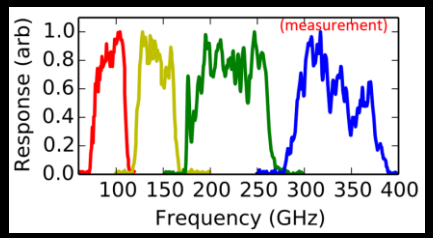
OMT Coupled Corrugated Horn Detector

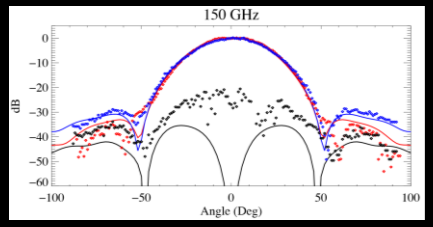


Silicon platelette array



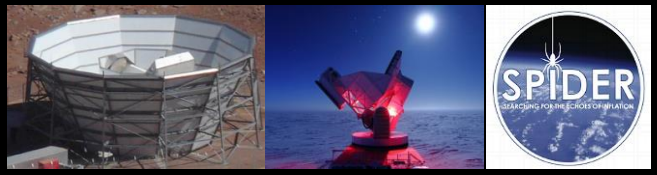
Detector wafer (OMT fin upper right)





Spectra and beam

- OMT Coupled Corrugated Horn Detector (Shannon Duff's Talk)
  - Corrugated horn: Gold plated silicon platelette stack
  - OMT coupling: Dual polarization
  - On-chip filter → 1 color per pixel
  - TES bolometers (Aluminum-Manganese, Tc = 170 mK)
- Sub-orbital experiments
  - ACT-Pol (150 GHz), SPT-Pol (150 GHz), SPIDER (285 GHz)



Detector Fabrication Facilities

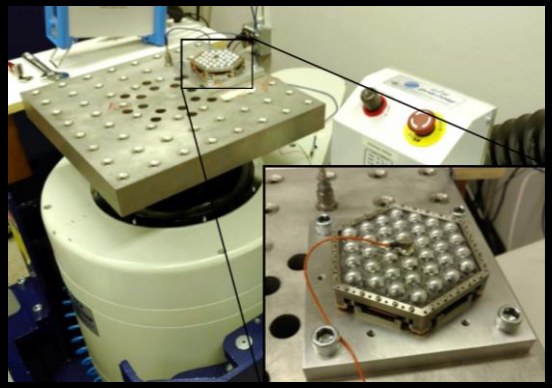
NIST Boulder Microfabrication Facilitry

U.C. Berkeley Marvell Nanofabrication Laboratory

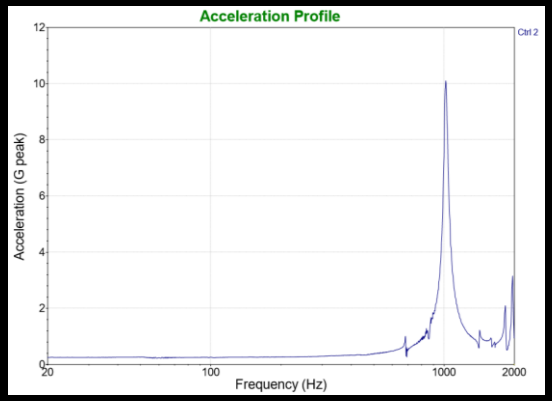
- NIST Boulder Microfabrication Facility
  - 18,000 square feet class 100 clean room
  - AdvACT, ACT-Pol, SPT-Pol, SPIDER, BLAST
- U.C. Berkeley Marvell Nanofabrication Laboratory
  - 15,000 square feet class 100 clean room
  - APEX-SZ, POLARBEAR-1, SPT-Pol, EBEX, POLARBEAR-2/ Simons Array

Detector Developments

Launch Survival Test

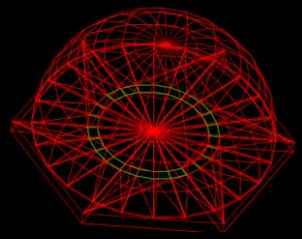


Shake table at Space Science Lab

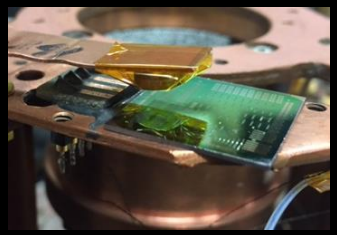


Surviving 15g rms shake test.
No known resonance below 1 k Hz

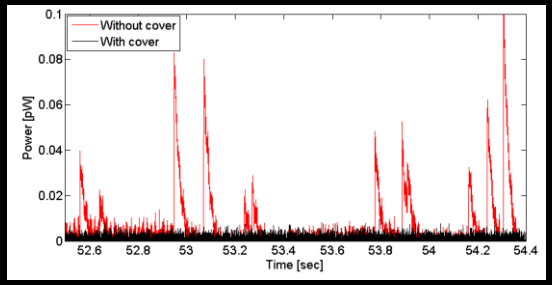
Cosmic Ray Event Study



GEANT4 simulation



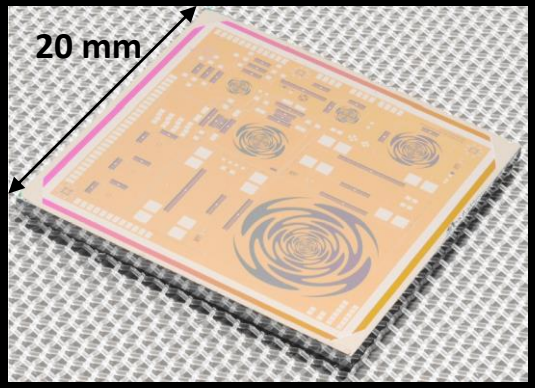
TES bolometer under radioactive source



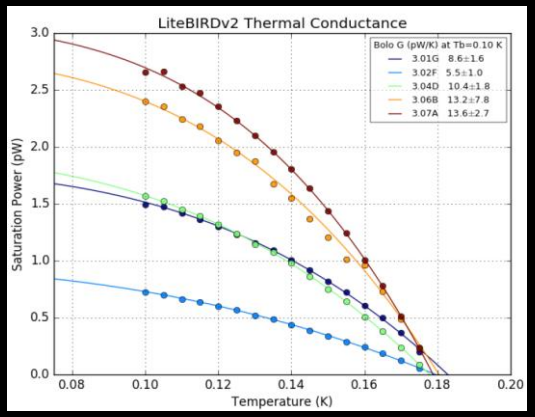
Measured glitch events with radioactive source

- Engineer phonon boundary

Space-optimized Bolometers

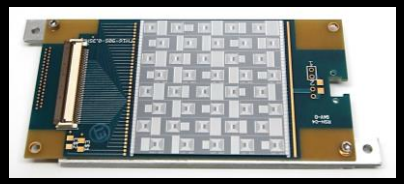


Test chip with various bands & bolometers

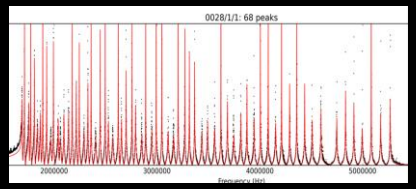


- Sub pico-watt bolometer fabrication and test

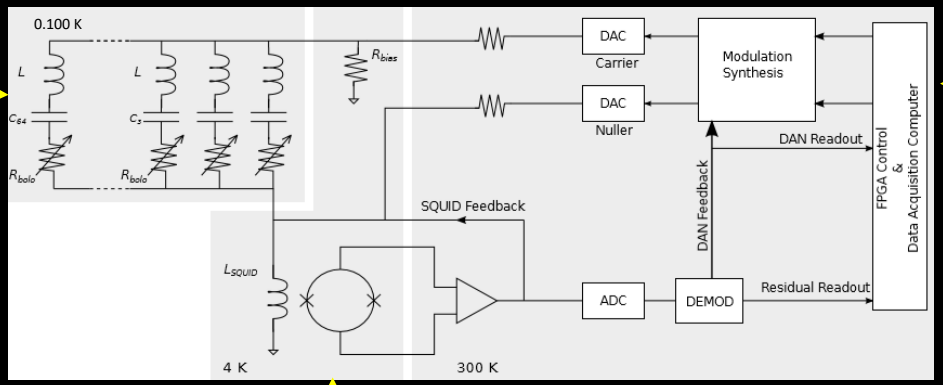
Readout Electronics



LC Resonators
(POLARBEAR-2)

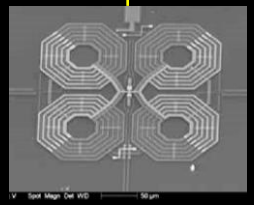


Network analysis for
x68 mux resonator
(SPT-3G)



DfMUX schematics

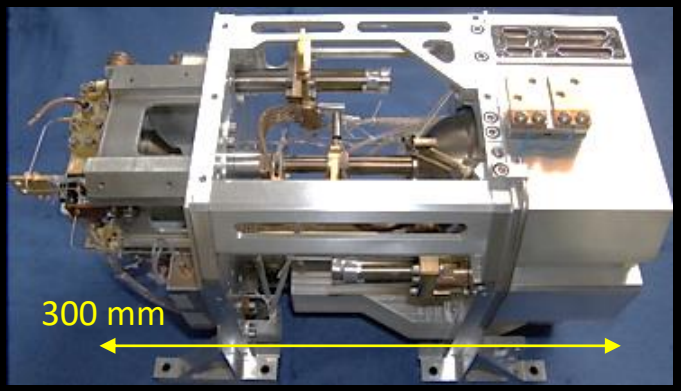
Digitizer/ synthesizer
circuit board



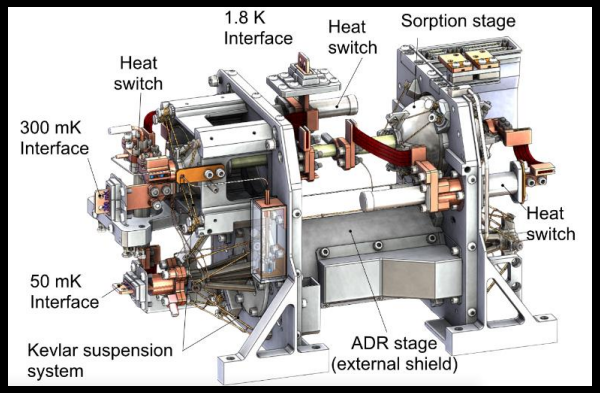
Gradiometric
SQUID

- Digital Frequency Multiplexing Readout
  - Superconducting resonator chip for frequency definition (x78 mux)
  - SQUID amplifier
  - FPGA based warm electronics
  - Sub-orbital experiments:
    - Simons Array (x40), SPT-3G (x68), EBEX-IDS (x105), Simons Observatory (TBD)

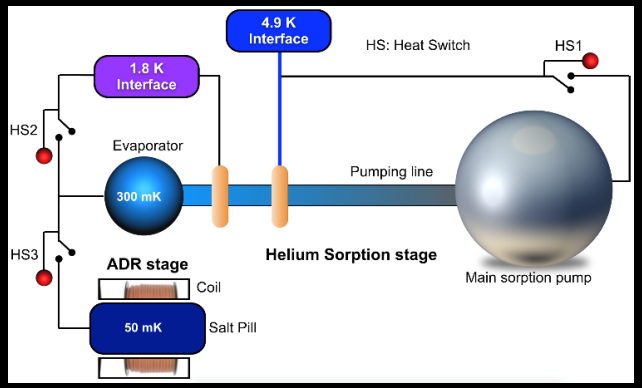
Sub-Kelvin Cooler



Sub-Kelvin Cooler without a cover



CAD drawing with parts call out



Schematic of the ADR

- CEA Sub-Kelvin Cooler
  - Experience from SPICA-SAFARI instrument
- Two temperature stages
  - 300 mK He-3 sorption stage
  - 100 mK ADR (CPA) stage
- 25 hour hold time, 89% duty cycle
- Vibration: 21g rms 120g static

Summary

- LiteBIRD is a next generation CMB satellite to probe the inflation with the uncertainty on tensor to scalar ratio $\delta r < 0.001$.
- LiteBIRD team in Japan is at Phase A1. The concept development study is in progress
- US LiteBIRD team is in technology development phase to raise Technology Readiness Level of key instruments
- Developments of low temperature devices are enabling next generation mission!