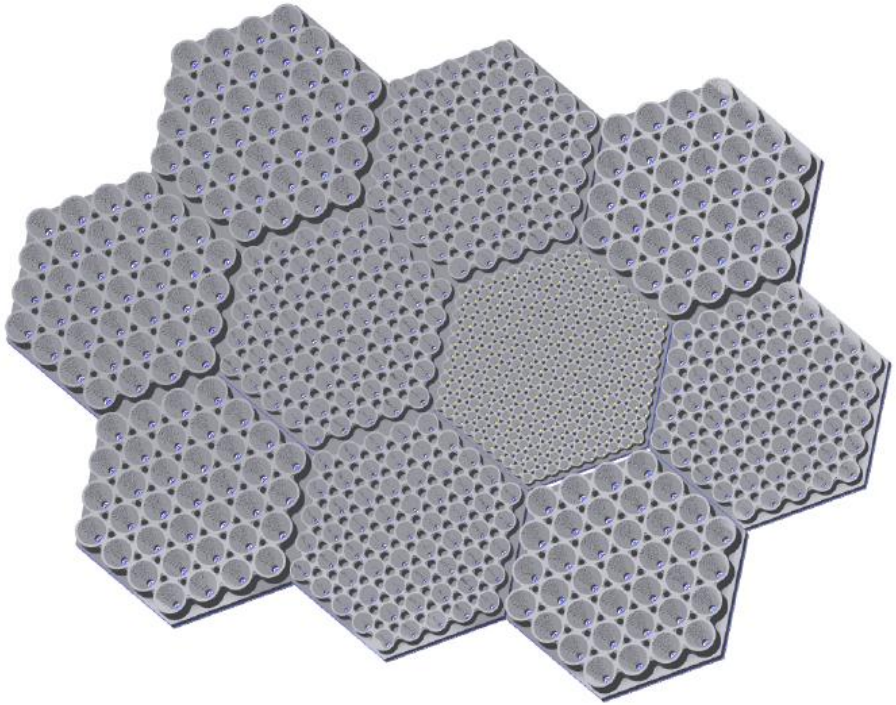
MKID feed and polarimeter



Shigeyuki Sekiguchi, Masahiro Sugimoto, Kenji Mitsui, Yoshiyuki Obuchi, Shibo Shu, Yutaro Sekimoto, Norio Okada, Kouichi Kubo, Toshikazu Takahashi, Masakazu Sekine, Tom Nitta, Kenichi Karatsu, Agnes Dominjon, Masato Naruse, Takashi Noguchi

THE UNIVERSITY OF TOKYO

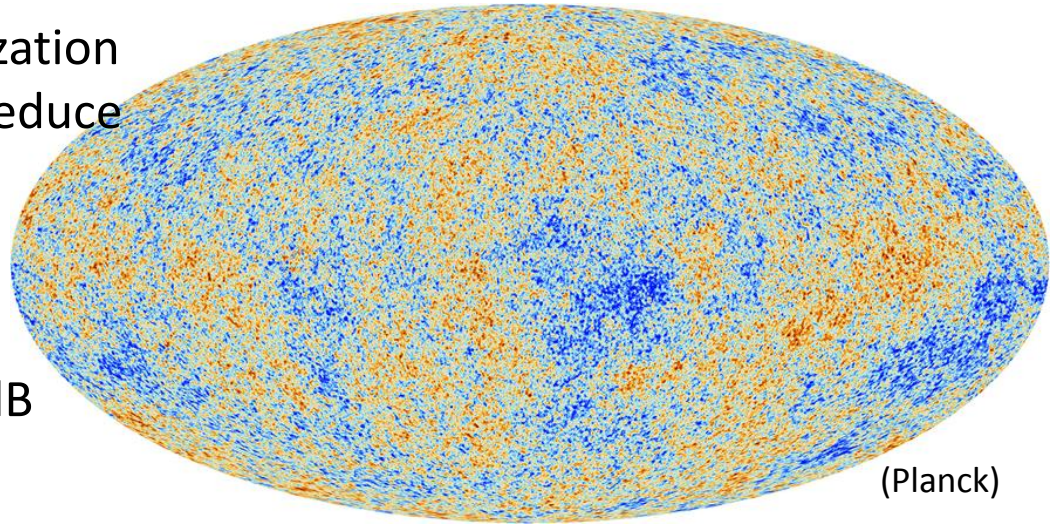
国立天文台 NAOJ National Astronomical Observatory of Japan

Outline

- Introduction
- Wide band corrugated horn (80 - 180 GHz)
- 4 pixel horn array camera
  - MKID coupled camera
  - 2 band (90, 150 GHz), 2 polarization
- Design of wide band corrugated horn array camera module for LiteBIRD

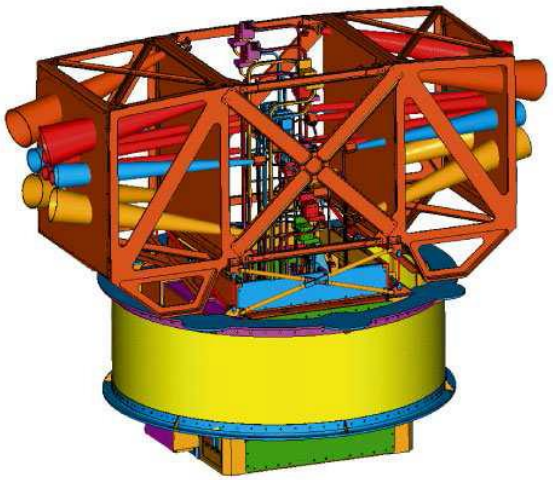
Corrugated feed horn for CMB

- Corrugated horn for B-mode polarization
- Good beam shape is necessary to reduce systematic error.
  - ✓ Symmetrical beam shape
  - ✓ Low side lobe : < -30 dB
  - ✓ Low cross-polarization : < -30 dB

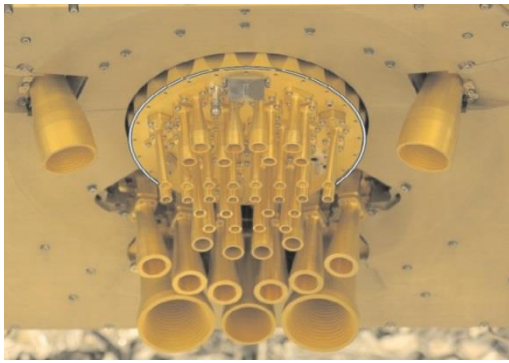


(Planck)

- Corrugated horn has been used in WMAP and Planck.
- One corrugated horn observes single band since horn BW ~ 40%
- Wide band corrugated horn, over 1 octave BW, is necessary for large frequency range observation.



(C. Barnes et al. 2003)



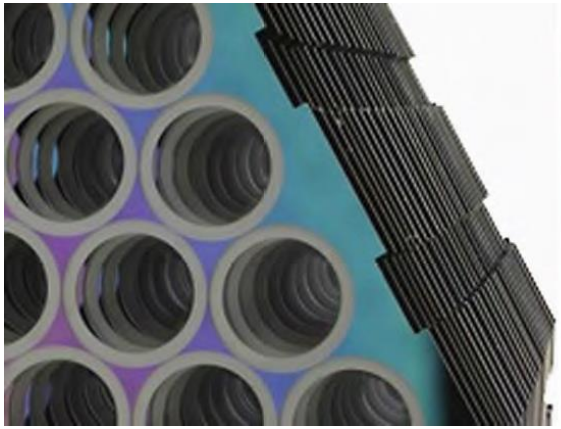
(J. A. Tauber et al. ESO 2010)

Horn fabrication

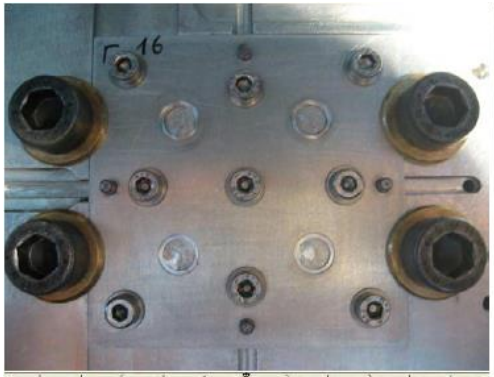
1. Electroforming

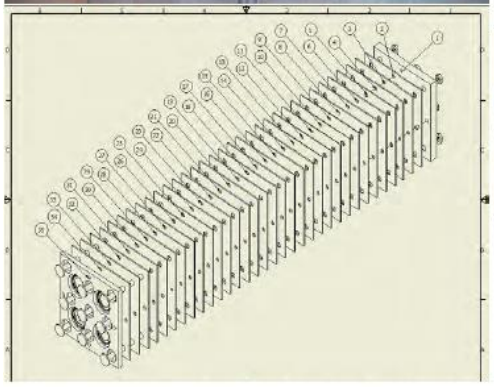
2. Platelet/Stacked
   1. Si plates
   2. Al plates

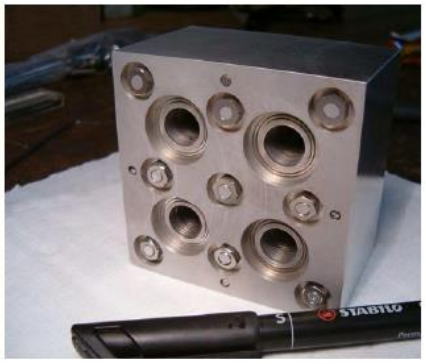
3. Direct machining
   1. 2 pieces (ALMA Band 4)
   2. Single piece



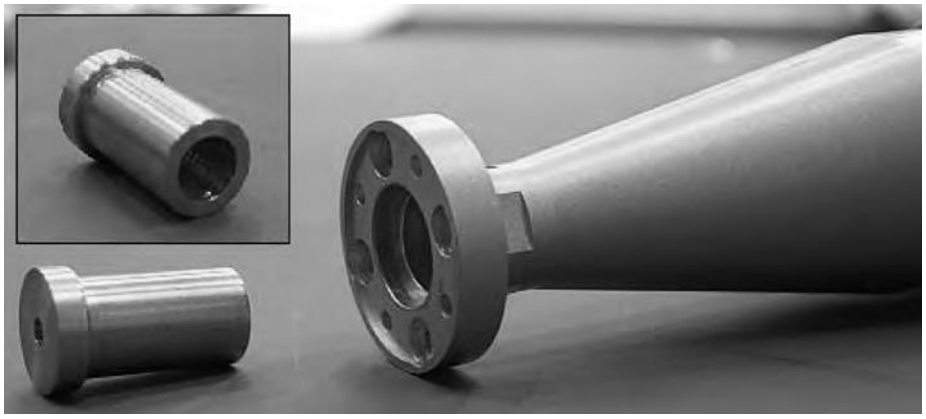
123 – 174 GHz (J.P.Nibarger et al., 2012, J Low Temp. Phys.)







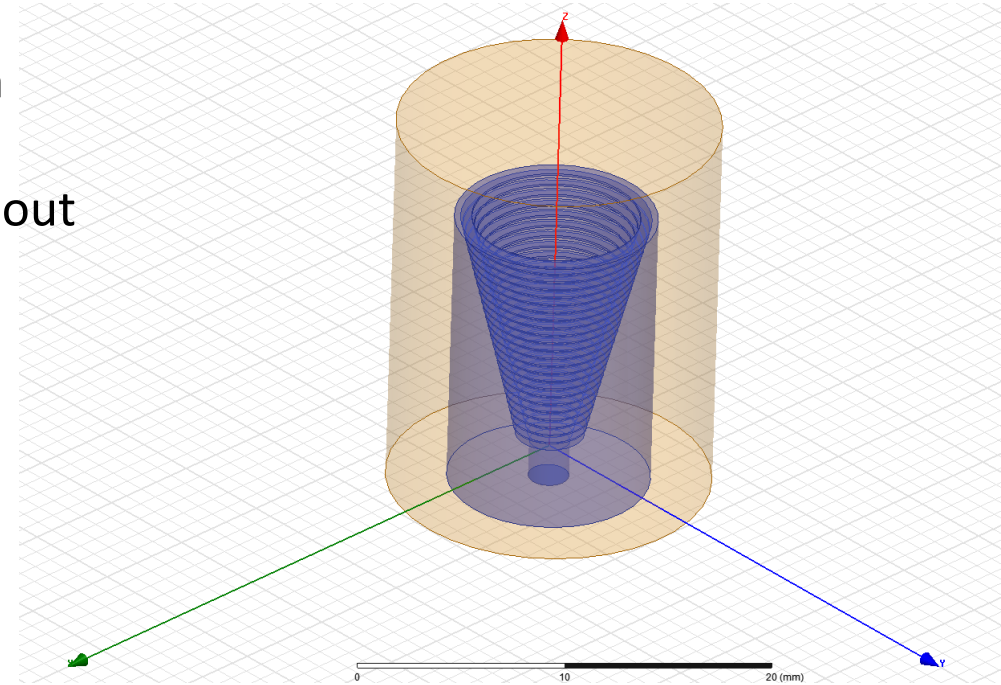
75 – 111 GHz (F.D.Torto et al., 2011, J Instrum.)



125 – 163 GHz
(K.Kimura et al., 2008, J Infrared Millim. Terahertz Waves)

Wide band corrugated horn

- Wide band corrugated horn with thin grooves and tooth structure
- Simple plane corrugation design without ring-roaded structure

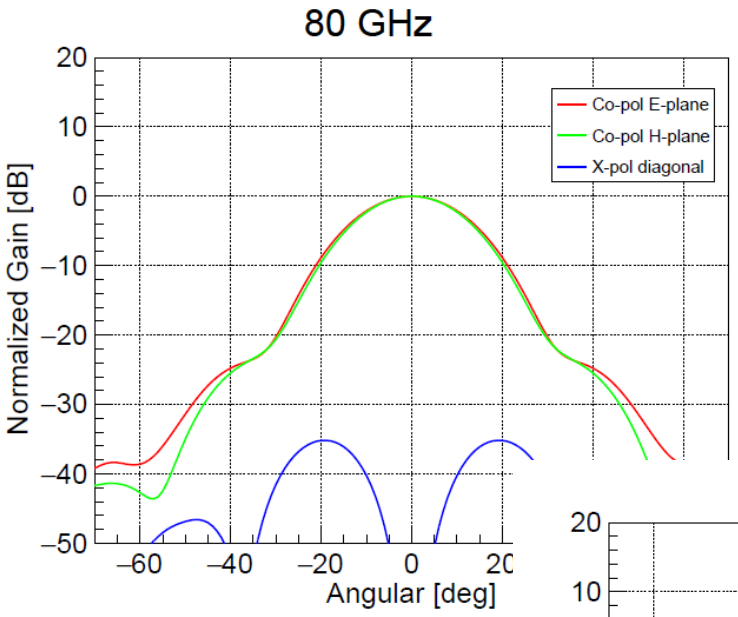


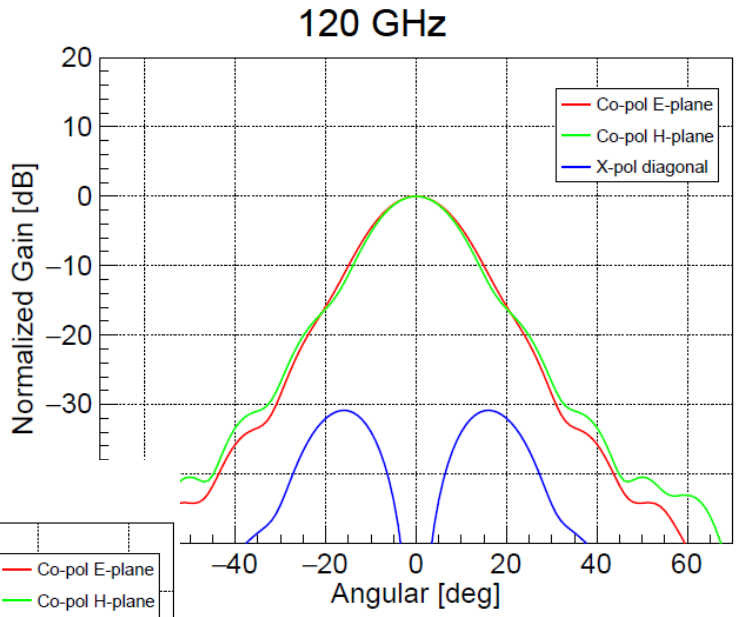
◎ Specification

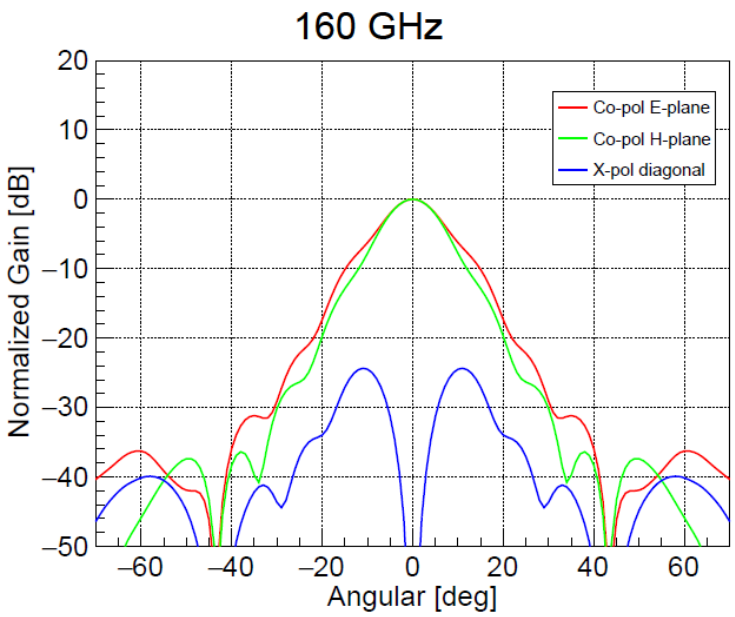
- BW ; 1 : 2.3 (80 – 180 GHz)
- Return loss ; < -10 dB
- Side lobe ; < -30 dB
- Cross – polarization ; < -25 dB

Analysis beam pattern using HFSS

- Beam pattern cut plane simulated by HFSS software







Horn fabrication and measurement

◎ 4 pixel horn array

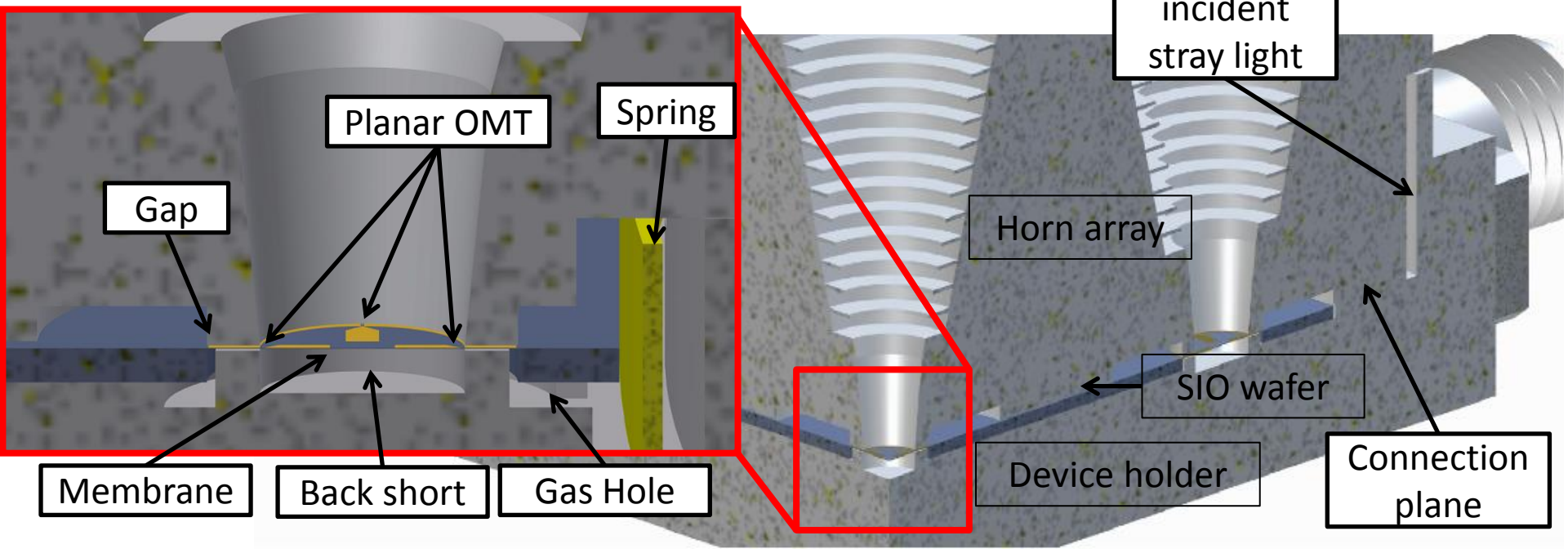
- Horn was made at NAOJ machine-shop.
- Single piece horn array
- Material : Aluminum
- Direct machining（Single piece）
- The unnecessary part was caved to reduce the standing wave and the weight.

◎ Measurement

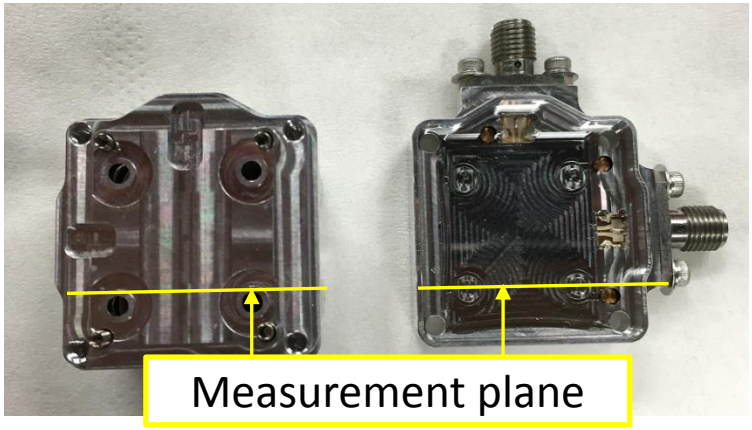
- Return loss and beam pattern
- Measurement temperature : 300 K
- good beam pattern and return loss corresponding to the simulation in each frequency.

4 pixel horn array camera

- Frequency ; 2 Band (80 – 115 GHz, 125 – 160 GHz)
- No. of MKID ; 16 = (4 horn)*(2 band)*(2 polarization)
- Total Size ; 30 mm * 30 mm * 26.7 mm
- Material ; Aluminum
- Mass ; ～50 g
- Planar OMT antenna is patterned on 5 μm membrane.
- Gas holes of back shorts prevent to be broken OMT.
- Device fixed by 3 alignment pins and 2 kinds of springs.

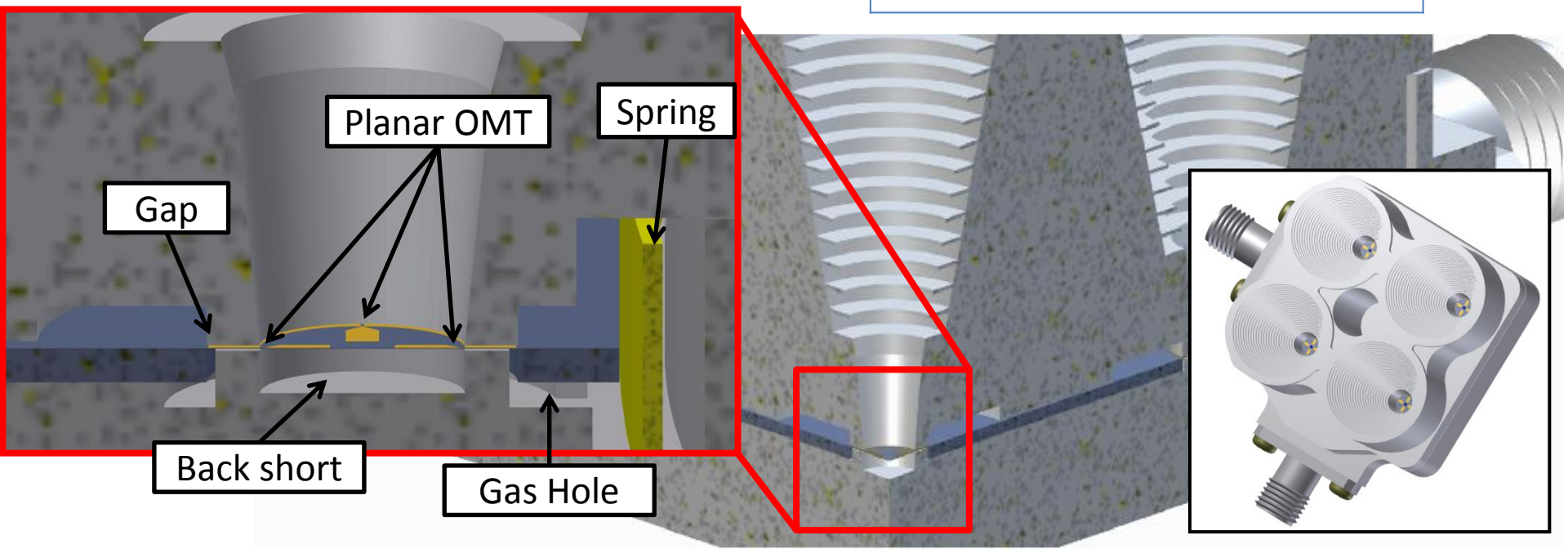


- Measurement of horn array and device holder dimension
- Non-contact surface measurement using NH-3SP



- Average dimension of horn and holder

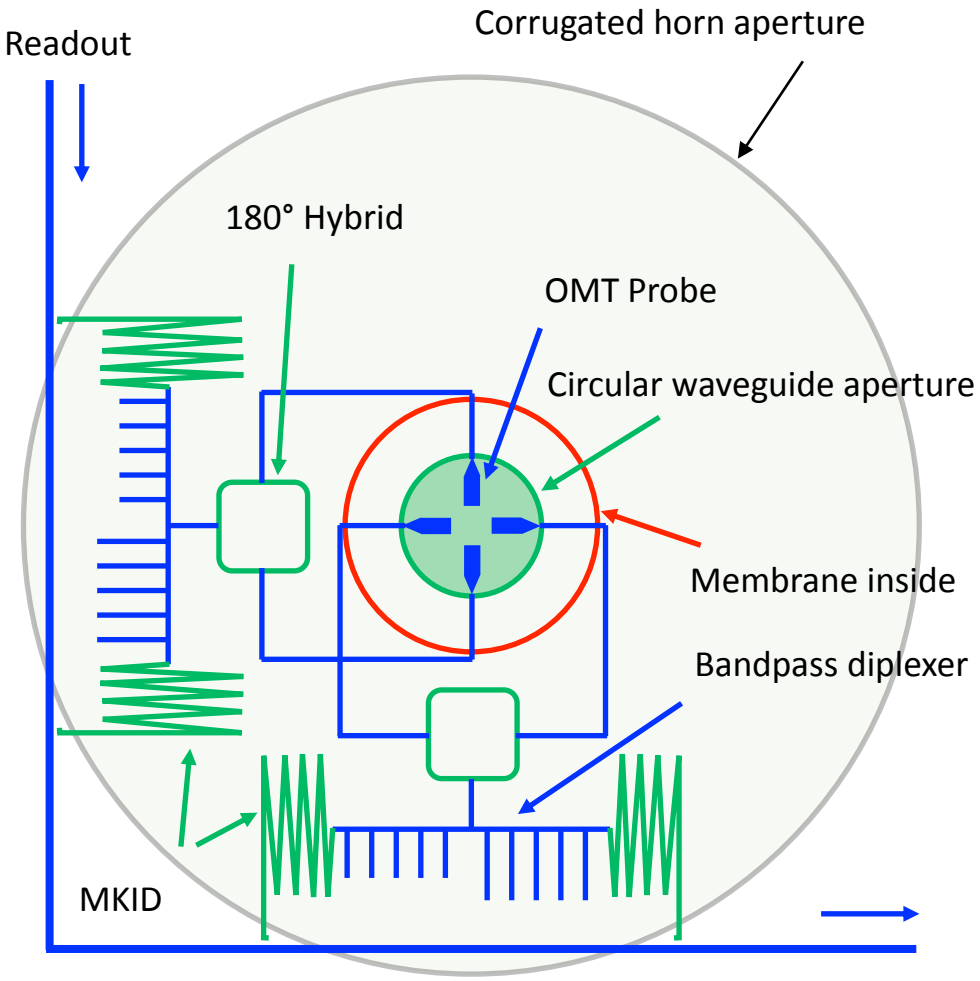
Part name	Length (μm)	
	measure	Design
Back short gap	70	60
Back short to device bottom	377	377
Horn bottom to device bottom	495	487
ID of back short	2370	2400
OD of back short	3421	3436



Device design

S. Shu et al. (presented in poster P15)

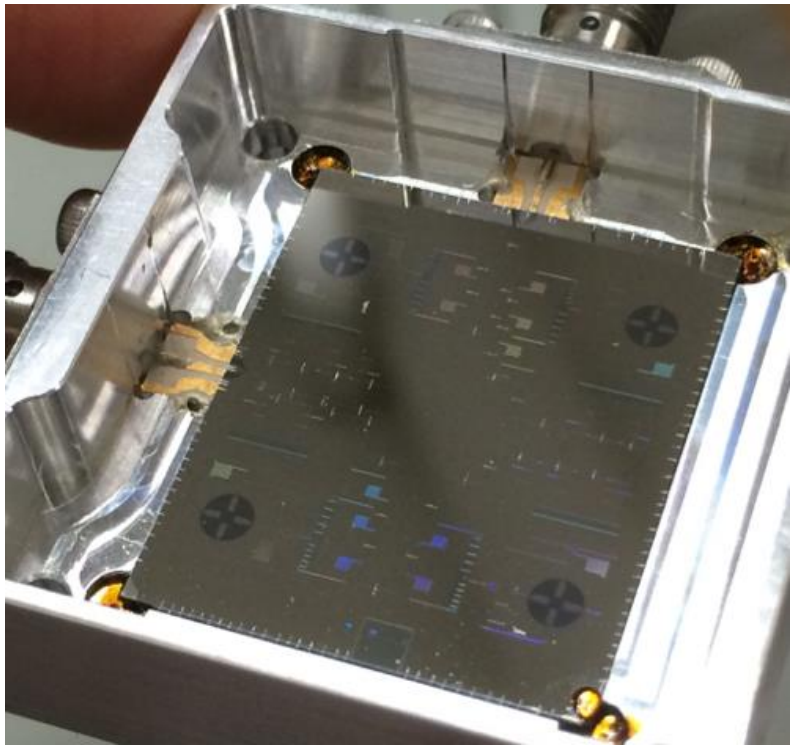
- Planar OMT antenna
  - Frequency ; 80 - 160 GHz
  - Division the orthogonal polarization
  - Circular wave guide -> CPW line
- 180 – hybrid
  - Frequency ; 80 - 160 GHz
  - Fundamental mode can be pass
  - Higher mode is absorbed and rejected.
- Bandpass diplexer
  - Frequency ; 2 band
    (80 – 115 GHz, 125 – 160 GHz)
  - Micro strip line



MKID fabrication

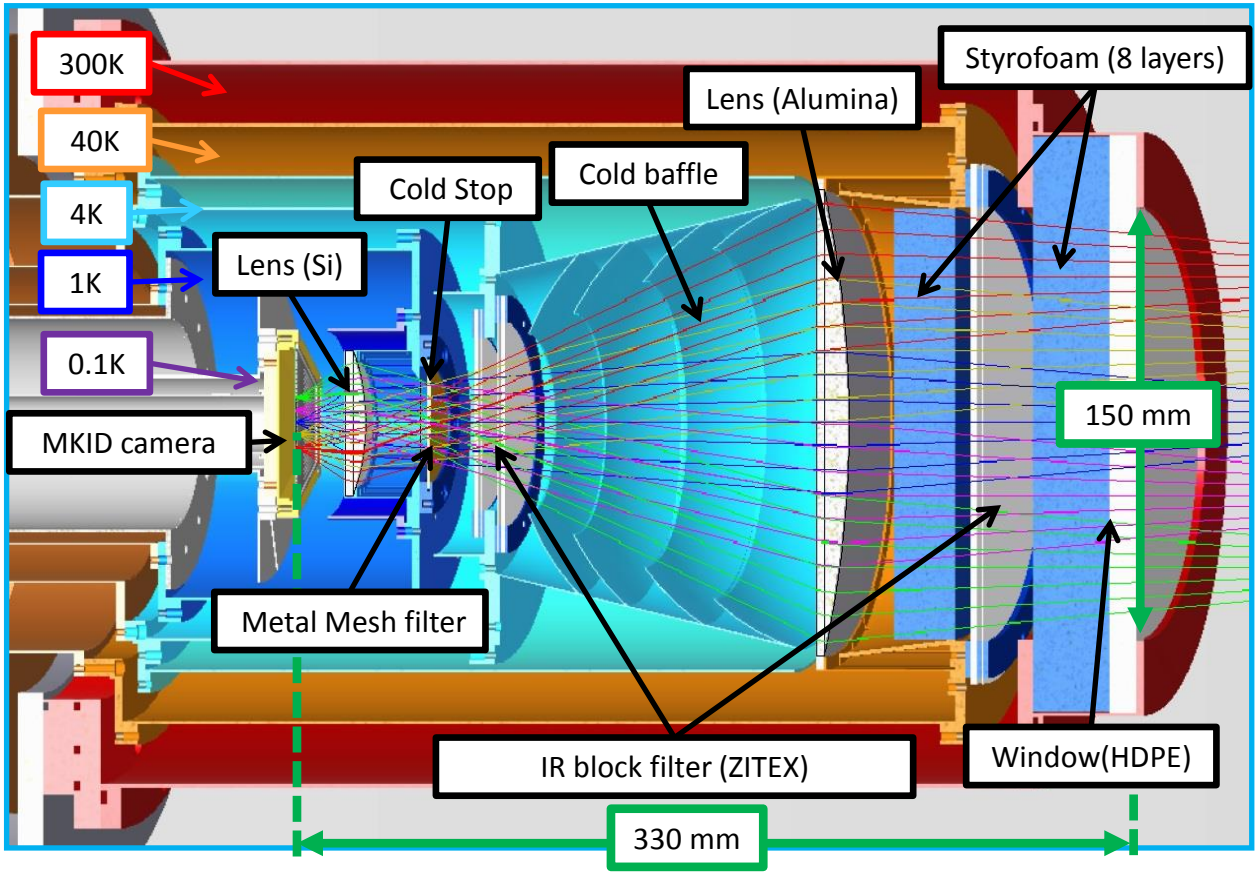
M. Sekine et al.

- Fabrication of back short
  - Alignment from the back side
  - Deep Reactive Ion Etching 400µm Si wafer
  - Membrane wafer has Only 6µm Si and 1µm SiO2 3.4mm diameter
- MKID measurement
  - OMT MKID device has been measured with dark cooling system (100mK)



Optical test system for MKID camera

S. Sekiguchi et. al. 2015 IEEE



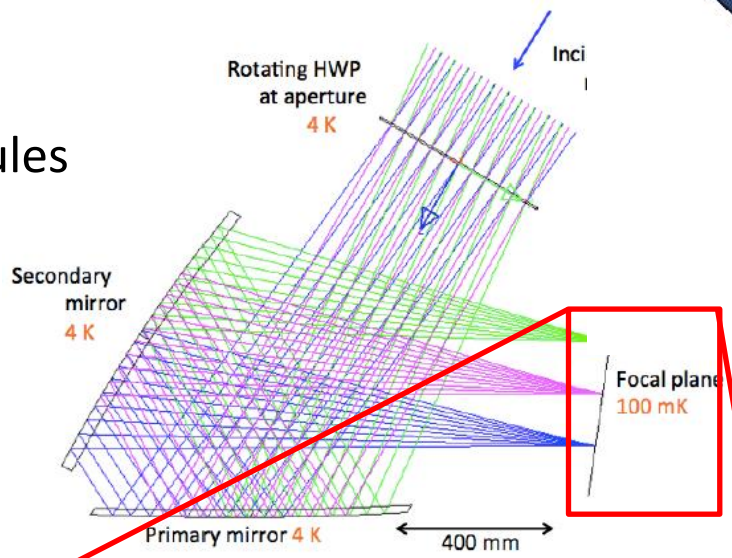
- Compact cold optics for measurement of MKID camera beam pattern and optical property.
- Cold stage is cooled at 100 mK using dilution refrigerator. (20 μW cooling power @ 100 mK)
- 2 high reflective index lenses and 3 kinds of IR blocking filter are used.
- Cold baffle is designed to reflect stray light to outside of window.
- We are measuring optical property of horn array camera.

For LiteBIRD MKID focal plane

- MKID horn array camera modules
- 3 kinds of horn array modules
- ϕ160 mm / module
- Frequency ;
  - Low ; 55 – 108 GHz
  - Mid. ; 80 – 160 GHz
  - High ; 165 – 330 GHz

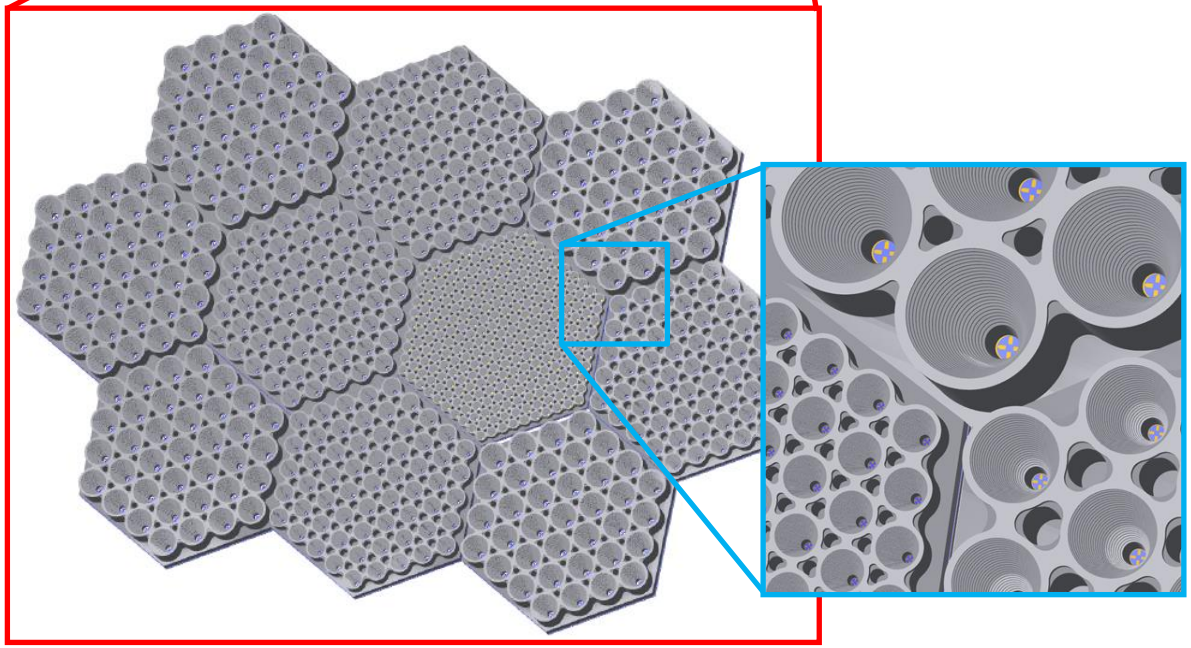
- Total pixel ; 700 pixel
  - Low ; 185 pixel
  - Mid. ; 244 pixel
  - High ; 271 pixel

- Total weight ; ~ 8 kg
  (including device weight)



M. Hazumi et al. 2012 SPIE

T. Matsumura et al. 2015 LTD



Summary

- 4 pixel wide band corrugated horn array coupled MKID camera
  - 4 pixel horn array
    - Direct machining fabrication
    - 80 - 180 GHz
    - Good beam shape
    - Low side lobe < -30 dB
    - Low cross-polarization < -25 dB
    - All horn beam pattern is corresponded.
  - Device
    - Planar OMT antenna, 180-hybrid, bandpass diplexer
    - Aluminum (center line) and Niobium (GND plane) hybrid MKID

- LiteBIRD MKID focal plane
  - 3 kinds of horn array modules
  - 55 – 330 GHz frequency range is covered
  - Total camera weight is ~ 8 kg.