Developments of Millimeter-wave MKID Camera

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MKID (Microwave Kinetic Inductance Detector) group of Advanced Technology Center is developing superconductive camera in millimeter and terahertz wavelengths for Antarctica terahertz telescope/Nobeyama 45 m telescope which observes distant galaxies with wide field-of-view and for CMB B-mode polarization in collaboration with University of Tsukuba, Saitama University, ISAS/JAXA, KEK, and Riken. Four papers related to millimeter/submillimeter MKID instruments were published in 2016 fiscal year.

1. Broadband corrugated horn array [1]

We are developing a broadband corrugated horn array to observe millimeter-wave polarization with high sensitivity and high accuracy. An 80–180 GHz horn array exceeding the octave band has been fabricated as shown in Fig. 1 and characterized with millimeter waves. The geometry of corrugations is so simple that the horn array can be directly machined from a bulk of aluminum with an end-mill.The cross-polarization and near side-lobe levels are less than -20 dB and -30 dB, respectively.The return loss is less than -15 dB in most design frequency bands, and the beam pattern is symmetric.The beam pattern and the return loss are measured in the 120–170 GHz range at room temperature.They are in good agreement with the simulation. It is possible to reduce reflection at the aperture surface and to reduce the weight by carving the unnecessary part.This design provides an octave bandwidth of the corrugated horn array at reasonable machining time.

Figure 1: A broadband corrugated horn array [1].

2. Broadband anti-reflective structures for silicon [2]

A broadband antireflective sub-wavelength structure was developed for large diameter silicon lenses used in the optical systems of superconducting cameras. In this study, a broadband antireflective sub-wavelength structure that can be easily fabricated with a dicing blade was designed. Pyramid structure (depth 550 μm) and straight section (depth 150 μm) have been fabricated with a special V-shaped dicing blade and a normal blade, respectively (Fig. 2). The structure was fabricated on a flat surface, and transmittance at cryogenic temperatures was measured using a Fourier transform spectrometer. The measured average transmittance between 186 and 346 GHz was approximately 95 %, and the experimental result is in good agreement with the simulation results.

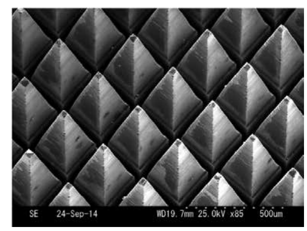

Figure 2: Broadband anti-reflective structure for Silicon [2].

3. Octave-band OMT with MKID [3]

We demonstrate a design of octave-band circular waveguide coupled planar ortho-mode transducer (OMT) with MKIDs. In our 4-pixel prototype design, each single pixel is sensitive to two frequency bands (90 GHz and 150 GHz) corresponding to atmospheric window. Silicon on insulator (SOI) has been used for the OMT backshort structure and a broadband coplanar waveguide (CPW) 180-degree hybrid is designed to cancel higher modes of a circular waveguide and add two signals from the fundamental mode together. After a microstrip bandpass diplexer, a microstrip line to coplanar waveguide transition structure couples signals to an MKID. MKIDs are designed with Nb ground plane and Al/Ti bilayer center strip line to achieve low frequency response and high sensitivity.

4. LiteBIRD MKID focal plane design [4]

Observations of large scale B-mode polarization of cosmic microwave background radiation (CMB) explore the inflation theory (K. Sato 1981), which explains the hot big-bang. This paper shows a focal plane design with corrugated horn coupled OMT-MKID for LiteBIRD, which observes CMB B-mode polarization from the cosmological gravitational wave.

References

[1] Sekiguchi S., et al.: 2017, *IEEE TST*, **7**, 36.
[2] Nitta, T., et al.: 2017, *IEEE TST*, **7**, 295.
[3] Shu, S., et al.: 2016, *SPIE proceedings*, 99142C.
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