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 45m telescope which observes distant galaxies with wide field-of-view and for LiteBIRD which detects CMB B-mode polarization in collaboration with University of Tsukuba, Saitama University, ISAS/JAXA, KEK, and Riken. Five papers related to millimeter/submillimeter MKID instruments were published in 2015 fiscal year.

1. Nb/Cu bilayer MKID

MKID is a Cooper pair breaking detector, in which superconducting resonators sense variations of the surface impedance caused by quasi-particles, which are generated by higher frequency photons than the gap frequency. A gap frequency is proportional to the critical temperature (T_c) of a superconductor film. For aluminum, $T_c = 1.1$ K corresponds to the gap frequency of 90 GHz. If the gap frequency (or T_c) can be adjusted, it makes easier to use MKID for millimeter and submillimeter observations.

Dominjon et al. [1] have developed Nb/Cu bilayer MKID. The T_c of the bilayer can be *settled* by the thickness of Nb and Cu. Fig. 1 shows the evoluation of T_c as a function of the Nb layer thickness.

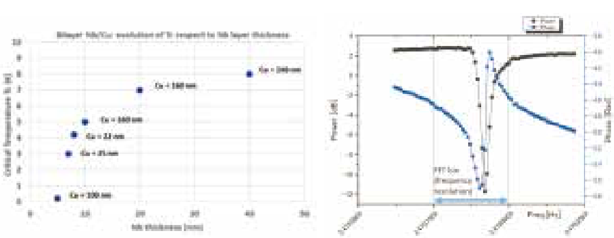

Figure 1: (Left) Evoluation of the critical temperature T_c of the Nb/Cu bilayer respect to the Nb layer thickness [1]. (Right) A resonance of MKID taken by a frequency sweeping FFT readout system [2].

2. Frequency sweeping readout

MKID is capable of frequency multiplexing with high Q superconducting resonators. To utilize this advantage, we are developing multi-channel FFT readout system. A frequency sweeping readout with synchronizing the FFT interval has been proposed and demonstrated [2]. This enables us to read multi-channel MKIDs with a large dynamic range (Fig. 1).

3. Dual polarization MKID camera

A combination of Si lens array and double slot antenna connected to MKID has been developed (eg. Nitta et al., 2014). This paper demonstrates single-layer dual polarization capability of the lens and double slot antenna with MKID (Fig. 2), which improves the sensitivity of millimeter observations [3].

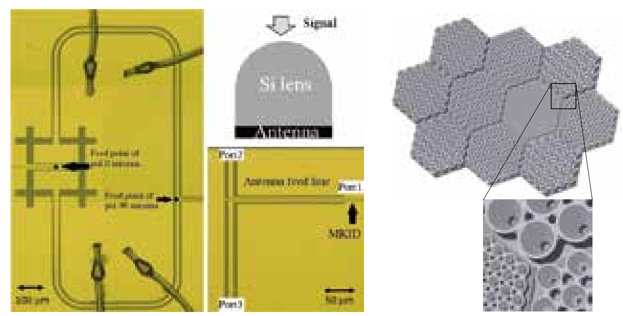

Figure 2: (Left) A picture of the dual polarization antenna coupled to an MKID. (Right) Corrugated-horn coupled OMT-MKID focal plane of LiteBIRD.

4. LiteBIRD focal plane design

Observations of B-mode polarization of cosmic microwave background radiation (CMB) sense 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 of LiteBIRD (Fig. 2), which observes CMB B-mode polarization from the gravitational wave.

5. Radiation tolerance of MKID

Radiation tolerance of Al-MKID has been investigated. NEP of MKD has been measured at the level of $2 \times 10^{-18}\,\mathrm{W}/\sqrt{\mathrm{Hz}}$ before and after the total dose of 10 k rad, which corresponds 5 years absorption at the Lagrange point [5].

References

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