MKID 102 Pixel Millimeter-Wave Camera Development

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A 1000 pixel millimeter and terahertz camera with superconducting MKID (Microwave Kinetic Inductance Detector) is being developed for LiteBIRD which detects CMB B-mode polarization and for Antarctica Dome Fuji telescope which observes distant galaxies with wide field of view, in collaboration with KEK, Riken, Tsukuba University, Saitama University, and Okayama University [1]. We developed 220 and 440 GHz imaging array in 2012 fiscal year.

The MKID was invented by Caltech/JPL group (P. Day et al. 2003). Superconducting resonators in MKID senses surface impedance determined by a number of quasi-particles which incoming photons generate by destroying cooper pairs. It has larger dynamic range than TES (transition-edge sensors). The resonant frequencies among 2–12 GHz are sensed by frequency comb generated by DAC (Fig. 3). MKID has a simple structure named CPW (co-planar waveguide), so a higher yield is expected.

To detect submillimeter-waves efficiently, the camera combined lens array with superconducting planar antenna. Although silicon is an ideal material for millimeter-wave lens in the aspects of low loss and large refractive index, it was not available for this lens, because it was difficult to fabricate millimeter-wave lens array. Recently, ATC ME shop succeeded in fabricating millimeter-wave Si lens array by a sealing process with a high-speed spindle and small diameter end-mills.

We have demonstrated symmetrical and low side-lobe beam pattern of this camera with the Si lens array (Fig. 2) [2]. Although it is necessary to apply anti-reflection coating on the lens surface due to a large refractive index of Si, the anti-reflection coating was not applied at the measurement.

T. Noguchi et al. have been developing high quality superconducting film to reduce imaginary part of the gap energy and to decreases the noise and the loss [3]. For this purpose, an MBE instrument has been introduced. Al (111) epitaxial film was fabricated on Si (111) substrate [4]. This Al MKID achieved an extremely low noise of electrical NEP 6×10^{-18} W Hz$^{-1/2}$ (Fig. 2) [4,5].

A test system for noise and beam measurements has been developed with 0.1 K dilution refrigerator (Fig. 3) [6]. A readout circuit with a complex FFT has been also developed for frequency multiplexed MKIDs (Fig. 3). It has been demonstrated to read the 100 pixel Al-MKIDs simultaneously [1].

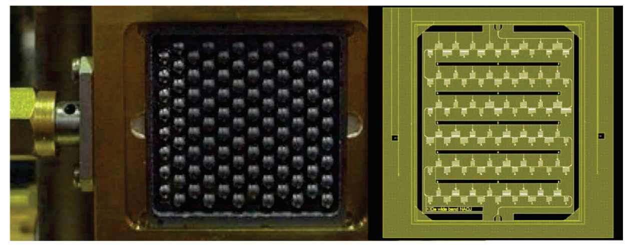

Figure 1: Antenna coupled Al-MKID 102 pixel camera [2]. (left) 102 pixel Si lens array fabricated by ATC ME shop. (right) Al CPW pattern of 102 pixel camera. The size of the camera is 24×22 mm^2.

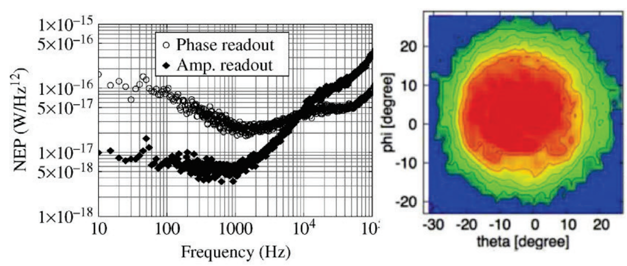

Figure 2: (left) Dark NEP of Al MKID [5]. Amplitude noise of NEP was 6×10^{-18} W Hz$^{-1/2}$. Phase noise was larger by an order of magnitude. (right) Beam pattern of a pixel of Al-MKID camera was measured at 220 GHz [2].

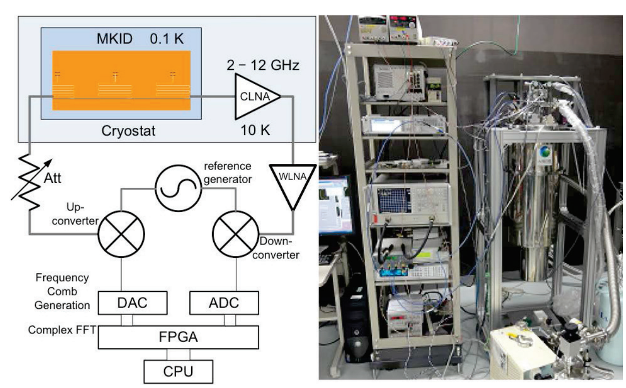

Figure 3: (left) Schematic drawing of MKID and its readout electronics. (right) Al-MKID camera and 0.1 K cryogenic system [6] .

References

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