600 Pixels MKID Superconductive Millimeter-wave Camera

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MKID (Microwave Kinetic Inductance Detector) group at Advanced Technology Center is developing superconductive camera in millimeter and submillimeter wavelengthes for LiteBIRD which detects CMB B-mode polarization and for Antarctica Dome Fuji telescope which observes distant galaxies with a wide field of view, in collaboration with KEK, Riken, Tsukuba University, Saitama University, and Okayama University. We developed 220 GHz 600 pixels imaging array in 2013 fiscal year [1,2].

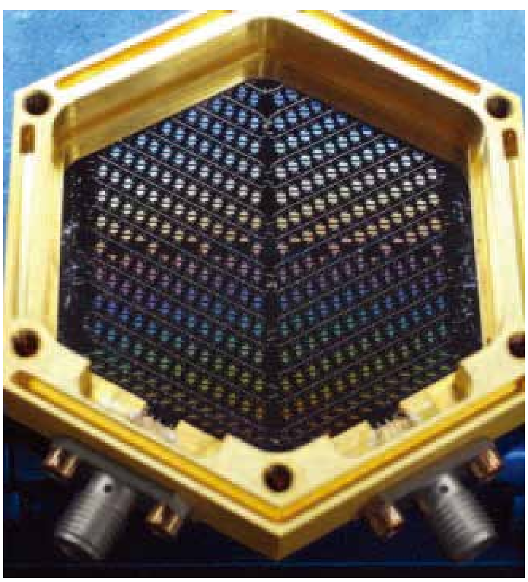

Figure 1: MKID 220 GHz - 600 pixels camera [1]. The size is around 6 cm.

MKID camera which is a new technology (P. Day et al. 2003) is a Cooper pair breaking detector. Superconducting resonators in MKID sense surface impedance variations owing to quasi-particles generate by incoming photons. The resonant frequencies distributed among 2–12 GHz are measured through a pair of coaxial cables with frequency comb generated by a DAC. The MKID is composed of a simple structure named CPW (co-planar waveguide), so a higher yield is expected.

To detect submillimeter-waves efficiently, the camera combined a 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,

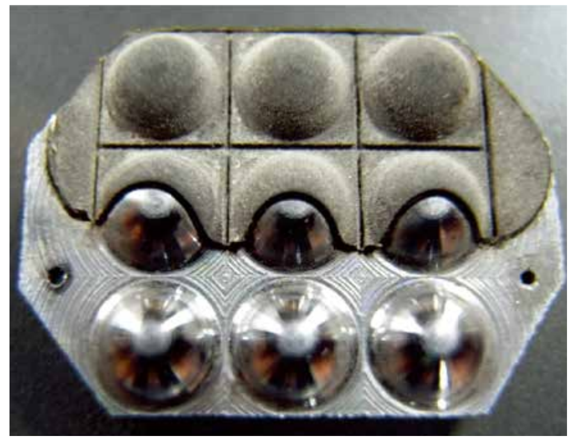

Figure 2: Si lens array and mixed epoxy anti-reflection layer (upper half). Slits reduce thermal stress of the Si and the AR [3].

because it was technically difficult to fabricate such Si lens array. ATC ME shop succeeded in fabricating millimeter-wave Si lens array by a milling process with a high-speed spindle and small diameter end-mills. We demonstrated symmetrical and low side-lobe beam pattern of this camera with the Si lens array . Two kinds of cryogenic epoxies were mixed to match the refractive index for Si and Alumina (Fig. 2) [3]. The AR thickness was controlled by machining with the same fabrication process as the Si lens array.

We also developed another AR of alumina using sub-wavelength structure (SWS). It is difficult to fabricate the SWS on small lens array, however, it is possible for the large lenses of the re-imaging optics. Among a few merits of SWS, this structure plays an important role as a low pass filter or an IR block filter.

T. Noguchi et al. studied excess noise of MKID generated by sub-gap states of superconducting [4]. A readout circuit with a complex FFT board has been also developed for 100 pixels MKID. The readout noise was evaluated to be as low as that of a single-channel readout system using an IQ mixer [5]. We are investigating a wide field optics for MKID camera.

References

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[4] Noguchi, T., et al.: 2013, *IEEE AS*, **23**, 1501404.
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