Design of On-chip Broadband Band Selection Filter for Multi-chroic mm/submm Camera.

Kah Wuy Chin[1,2], Tai Ohshima[2], Satoshi Ono[3], Takeshi Sakai[3], Tatsuya Takekoshi[1], Satoru Mima[4], Ryohei Kawabe[2], Masato Naruse[5], Keisuke Yoshioka[2,3], and Shinsuke Uno[1].

Astronomical observation of the broadband submillimeter continuum emission is an important approach to investigate evolution history of the large-scale structure in the universe. The Sunyaev-Zel'dovich effect (SZE), distortion of cosmic microwave background (CMB) spectrum shown between 10—1000 GHz caused by Compton scattering of CMB photons by high energy electrons in galaxy clusters[1], is an important probe of evolution history of galaxy clusters. To promote observational studies of SZE, we are developing a multichroic continuum camera system that has 2 focal planes separated at ~300 GHz by a dichroic filter[2]. We plan to realize 6-color simultaneous observations (150/220/270 GHz and 350/450/670 GHz for low and high pass focal planes, respectively) by implementation of 3 RF bandpass filters (BPFs) for each spatial pixel on detector wafers of each focal plane.

Here we report the on-chip RF filter design for the low pass band detector array. The on-chip filters for 150/220/270 GHz detectors are required to meet following requirements: (1) center frequencies are 150, 220, and 270GHz, (2) bandwidth is more than 40 GHz, (3) physical sizes of the filters are smaller than 1.0 mm x 0.5 mm. Because of the limited space, we adopted compact lumped element filters. We promoted designs of the BPFs by following steps. First, we designed the circuits of the bandpass filters (BPF) whose center frequency are 150, 220, and 270 GHz by equivalent circuit models using inductors and capacitors. Next, we designed a 150 GHz BPF as a 3rd order Chebyshev filter, and 270 GHz and 220 GHz BPFs as 5th order Chebyshev filters in order to avoid crosstalk between the filters. Then, we designed planar capacitors and inductors on a Si wafer. Finally, we integrated designed planar capacitors and inductors as same as the designed circuits of BPFs to make the on-chip filter designs. In Fig. 1, we show the on-chip 150 GHz BPF design. Its physical size was 80 µm x 414 µm. Physical sizes of 220 and 270 GHz BPFs were 96 µm x 634 µm, and 80 µm x 528 µm, respectively.

To evaluate our designs by considering the stray capacitance made by physical structure of BPFs, we calculated the S-parameters of the on-chip BPFs using electromagnetic simulation, Sonnet. As a result of calculation, 150, 220, and 270 GHz BPFs show the bandwidths of 50, 60, and 80 GHz respectively. On the other hand, we found large ripples up to 5 dB in the passband of the on-chip BPFs. We expect that these ripples can be suppressed by modification of the planar structure of the on-chip BPFs. We also plan to modify the first planar capacitor structure because the bandwidth of the 270 GHz BPF is too wide to use the 220 and 270 GHz BPFs at the same time.

In conclusion, our BPF designs are small enough to fit a spatial pixel on the focal plane wafer. We are going to fabricate our BPFs combined with MKIDs and measure the frequency response. We are also going to design on-chip BPFs for higher frequency bands (350/450/670 GHz).

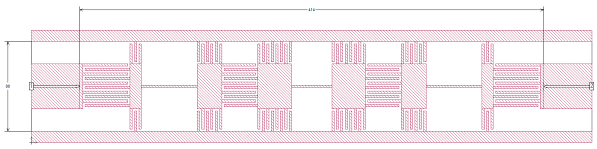

Fig. 1. Design of the 150 GHz BPF. The physical size of the BPF is 80 µm width and 414 µm length. From the Sonnet simulation result, the bandwidth was estimated to be 50 GHz.

REFERENCES

[1] Sunyaev, R. A. and Zel'dovich, Y. B.: 1980, Annual Review of Astronomy and Astrophysics 18(1), 537

[2] Oshima, T., Ohtawara, K., Takekoshi, T., Ishii, S., Izumi, N., Izumi, T., Yamaguchi, M., Suzuki, S.,Muraoka, K., Hirota, A., Saito, F., Nakatsubo, S., Kouchi, A., Ito, T., Uemizu, K., Fujii, Y., Tamura,Y., Kohno, K., and Kawabe, R.: 2018,Journal of Low Temperature Physics193

1 The Univ. of Tokyo, Tokyo 113-0033, Japan
2 National Astronomical Observatory of Japan, Tokyo 181-8588, Japan
3 The University of Electro-Communications, Tokyo 182-8585, Japan
4 RIKEN, Saitama 351-0198, Japan
5 Saitama University, Saitama 338-8570, Japan

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