



Contribution ID: 118

Type: Poster

## Microwave Multiplexing Based on SQUIDs Directly Coupled to Resonators with a View to Simultaneous Readout of 80 TES X-ray Microcalorimeters

Thursday, 25 July 2019 18:45 (15 minutes)

We have been developing a microwave superconducting quantum interference device (SQUID) multiplexing (MW-Mux) for the future X-ray astronomical observatory with large field of view and high-resolution imaging spectrometer such as super DIOS (T. Ohashi et al., 2018). MW-Mux consists of a number of superconducting resonators coupled to each dissipationless radio-frequency (RF) SQUID detecting signals from TES X-ray microcalorimeter. Yoon et al., 2018 reported simultaneous readout of 28 pixels, and it is promising that a readout of 100-1000 signals by a pair of coaxial cables.

So far we have been developing MW-Mux with an RF-SQUID coupled directly to a resonator, in contrast to the conventional magnetically coupling regime. The advantage of our directly coupled MW-Mux is a simple chip design based on identical SQUIDs except for the position of grounding via even when all channels are required to have the same gain in the whole readout band, typically 4–8 GHz. Also, we have demonstrated the readout of single-pixel TES X-ray microcalorimeter and the MW-Mux with readout noise lower than  $20 \text{ pA}/\sqrt{\text{Hz}}$  which is below the typical noise level of our TES X-ray microcalorimeter.

In the next stage, we are working on it to increase the multiplexing number. Up to the present, we have designed and fabricated the two chips consisting of 40 resonators in  $5 \times 20 \text{ mm}^2$  rectangles, and verified that the 80 resonators and SQUIDs have worked well at 4 K. We have been improving the chip fabrication and microwave circuitry, yielding the enhancement of the unloaded quality factor four times better than before.

Using multi-chip assembly, we are preparing the simultaneous readout of 80 TES X-ray microcalorimeters with our directly coupled microwave SQUID multiplexer.

In this paper, we will report the current status and the latest results of the development of the directly coupled MW-Mux.

### Less than 5 years of experience since completion of Ph.D

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### Student (Ph.D., M.Sc. or B.Sc.)

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**Session Classification:** Poster session

**Track Classification:** Detector readout, signal processing, and related technologies