AIST SRON THE UNIVERSITY OF TOKYO Poster ID: 152-118 **Microwave Multiplexing Based on SQUIDs Directly Coupled to Resonators** with a View to Simultaneous Readout of 80 TES X-ray Microcalorimeters

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Summary

We have been developing a microwave SQUID multiplexer (MW-MUX) for the future X-ray astronomical observatory with a large field of view and highresolution imaging spectrometer such as super DIOS (T. Ohashi et al., 2018). Yoon et al., 2018 reported simultaneous readout of 28-pixel TES microcalorimeters, and it is promising that a read out of 100-1000 signals by a pair of coaxial cables.

In the present status of our MW-MUX development, we are working on increasing the multiplexing number. Up to the present, we have designed and fabricated two chips embedding 40 resonators with different resonance bands in 5x20 mm² rectangles. We have also developed low-temperature systems to readout 80ch MW-MUX, i.e., a sample holder module and a PCB with low dissipation factor for the GHz signals.

Here, we show a preliminary result that we have successfully detected X-ray signals from 40-pixel TES microcalorimeters fabricated by SRON with our 40ch MW-MUX systems.

Motivation

Future Japanese X-ray Satellite Mission

· S-DIOS (Super Diffuse Intergalactic Oxygen Surveyor) is proposed to launch around 2030 S. Yamada+ 2018

• The goal is to measure large structure formation through WHIM (Warm-Hot Intergalactic Medium) mapping and to visualize the effect of dark energy

Requirements for Microcalorimeter detector

- Energy resolution: better than 2 eV@0.3–2 keV, 5 eV@-10 keV
- Field of view: 30×30 arcmin²
- Spacial resolution: at least 15 arcsec
- \rightarrow > 15,000 pixels
- → Microwave SQUID Multiplexing

Microwave SQUID Multiplexing (MW-MUX)



Microwave SQUID Multiplexer Chip



20 mm

- 40 Nb CPW resonators on 5×20 mm² chip
- Resonance spacing: ~ 16 MHz
- Resonance bandwidth: ~ 3 MHz
- Input mutual inductance, M_{in} : ~ 210 pH
- Fabricated by CRAVITY in AIST
- Please follow Y. Nakashima+2017, 2018, 2019

TES Bias Chip



kilo-pixel Uniform Array (SRON)

Note: See the poster 132 for more details

· Developed by SRON for the Athena X-ray mission

· 256 pixels are accessible from the wirebond pads

 \cdot 120x40 μ m² TiAu TES with T_c ~107 mK and $R_{\rm n} \sim 95 \,{\rm m}\Omega$



Room-temperature Electronics



• ADC/DAC: 14-bit, 1 GSPS / Bandwidths supported up to 800 MHz • Up to 50 tones can be simultaneously generated in the case of 16 MHz resonance spacing • Using two system of the circuit, 80ch MUX can be readout at the same time

Ch21

Ch22

Ch1

Importance of CPW Air-bridge







• Undesirable resonances (UR) caused by an odd propagation mode (e.g. Slot mode) can distort MW-MUX resonances

• Right figure shows that air-bridge works well and makes S₂₁ flatten among 4—8 GHz band

Preliminary Result on MW-MUX of 40-pixel TES Microcalorimeters

RF-SQUID

GND via

Resonator

Josephson junction

with $Ic \sim 10 \mu A$

Directly coupled

o a resonator



 \cdot 80 resonances have been verified, and internal quality factors, Qi ~ 44000.

- The first half of the resonances have been used to MUX TES microcalorimeters.
- · Injection power launched to the input feed line \sim -71.5 dBm.
- Flux-ramp frequency / amplitude: 500 kHz / $2.0\Phi_0$
- Using $1.7\Phi_0/2.0\Phi_0$ flux-ramp phase information for flux-ramp demodulation
- Pulses have been detected at 60 mK.

These 40 resonances have been activated for multiplexing TES microcalorimeters

Measured Readout Noise of 40ch MW-MUX





• We successfully detected X-ray signals from 40-pixel TES microcalorimeters with 40ch MW-MUX

• Readout noise level: 18—44 pA/√Hz

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