Toward large FOV-high-resolution X-ray imaging spectrometer:
microwave multiplexed readout of 32 TES microcalorimeters

Abstract
We performed a small-scale demonstration at GSFC of high-resolution x-ray TES microcalorimeters read out using a microwave SQUID multiplexer. This work is part of our effort to develop detector and readout technologies for future space based x-ray instruments such as the microcalorimeter spectrometer envisaged for Lynx, a large mission concept under development for the Astro 2020 Decadal Survey. In this paper we describe our experiment, including details of a recently designed, microwave-optimized low-temperature setup that is thermally anchored to the 50 mK stage of our laboratory ADR. Using a ROACH2 FPGA as room temperature interface, we simultaneously read out 32 pixels of a GSFC-built detector array via a 512-channel multiplexer chip with No coplanar waveguide resonators coupled to 40 SQUIDs. The resonators are spaced 6 μm apart (at ~5.9 GHz) and have quality factors of ~5.000. Using flux ramp modulations frequencies of 160 kHz we have achieved spectral resolutions of ~0.5 eV FWHM on each pixel at 6 K. We will present the measured system-level noise and maximum slew rates, and briefly describe the implications for future detector and readout design.

Microwave SQUID multiplexing

- Fabricated by NIST
- 33 Nb microwave resonators
- Resonance freq.: 9.7-6.0 GHz
- 300 kHz bandwidth
- Frequency spacing: ~6 MHz
- Quality factor: ~15,000
- Coupling constant: ~8.73

Lynx
A large mission concept under development by NASA for the Astro 2020 Decadal Survey

- Microcalorimeter detector array for Lynx
  - Energy resolution: better than 3 eV FWHM at 0.2 – 10 keV
  - Number of readout channel > 56,000

Promising initial results: microwave multiplexing of 5 TESs

Ongoing work: microwave multiplexing of 32 TES microcalorimeters

- Changed TES detector chip with the goals:
  1. Improved energy resolution—expect non-multiplexed \( dE_{\text{FWHM}} \) of 1.6 eV based on measurements of similar chip
  2. 32-channel multiplexing—bond pad layout compatible with \( \mu \text{MUX} \) chip layout

Measured system noise and slew rate

- Noise of readout circuit is the measured noise without TES connection
- Microwave readout noise on 300 μV/Hz
- TES noise level: 150 μV/Hz
- Readout noise: 30 μV/Hz
- Slew rate: 0.33 A/s

8 X 8 TES microcalorimeter, NASA/GSFC

- T ≈ 50 mK
- 120 μm² TES
- 2.5 μm backside Cu
- Absorber: Au/Bi
- 0.5 μm SiN membrane

Low temperature \( \mu \text{MUX} \) setup

- ROACH 2 with MKID-ADC/DAC board
- ADC/DAC sampling rate: 512 Msps
- Number of channels: 32
- Bin select: 8 MHz sampling per channel
- Signal bandwidth: 1 MHz

Room temperature electronics

- ROACH 2 with MKID-ADC/DAC board
- ADC/DAC sampling rate: 512 Msps
- Number of channels: 32
- Bin select: 8 MHz sampling per channel
- Signal bandwidth: 1 MHz

Sensor: Transiion-edge sensor (TES) or magnetically coupled calorimeter (MCC)
Number of readout channel > 56,000

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Future work: microwave readout of "Hydra" pixels for Lynx (see Bander, Smith)