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


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Abstract
We performed a small-scale demonstration at GSFC of high-resolution x-ray TES microcalorimeter readout using a microwave SQUID multiplexer. This work is part of our effort to develop detector and readout technologies for future space based x-ray observatories 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 at room temperature, we simultaneously read out 32 pixels of a GSFC-built detector array via a uMUX-multiplexer chip with Nb coplanar waveguide resonators coupled to RF SQUIDs. The resonators are spaced 6 MHz apart (at ~5.9 GHz) and have quality factors of ~15,000. Using flux ramp modulation frequencies of 160 kHz we have achieved spectral resolutions of ~5.5 eV FWHM on each pixel at 8 keV. 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

- A few GHz of bandwidth per amplifier channel
- TESs couple to unique microwave resonator
- RF SQUIDs built into microwave resonator
- Inductance modulates resonance frequency
- Linear circuit output without feedback (common modulation)
- Single-microwave feed-line can read out hundreds of pixels

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
  - Many of pixel = 150,000 with hydroxide
  - Various angular resolution, energy resolution and count rates
  - Sensor: Transition-edge sensor (TES) or magnetically coupled calorimeter (MCC)
  - Initial approach: Use position-sensitive TES microcalorimeter, "Hydra". These have multiple absorbers attached to each sensor
  - See also

Promising initial results: microwave multiplexing of 5 TESs

- 8x8 TES microcalorimeter, NASA/GSFC
  - 7, ~ 89 mK
  - 120 μm2 TESs
  - 2.5 μm backside Cu
  - Absorber: Au/Bi
  - 0.5 μm SiN membrane

Low temperature uMUX setup

- uMUX chip
  - ROACH2 with MKID ADC/DAC board
  - ADC/DAC sampling rate: 512 Mbps
  - Number of channels: 32
  - Bin select: 8 MHz sampling per channel
  - Signal bandwidth: 1 MHz

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- Response of the uMUX read out
  - 33 resonators
  - Center frequency: ~5.87 GHz, 6 MHz spacing
  - Q = 13500
  - Q=13,000 ⇒ Q=13.5×2π

- Measured system noise and slew rate
  - Noise of readout circuit is the measured noise without TES connection: ~50 pA/√Hz
  - TES noise level: ~150 pA/√Hz
  - uMUX readout noise is a factor of ~5 below the TES noise level

In progress: fixed wiring, replaced damaged Nyquist chip (4/2017), required new uMUX chip due to subsequent damage during handling, uMUX screening underway (4/7/2017)

Future work: microwave readout of ‘Hydra’ pixels for Lynx (see Bandler, Smith)