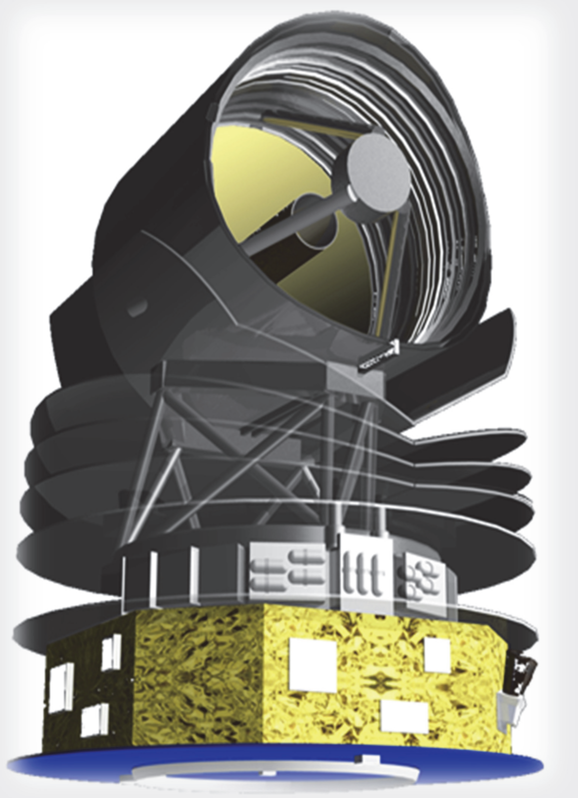
FDM Readout of TES Bolometers for the SAFARI Far-Infrared Spectrometer

Damian Audley, Amin Aminaei, Richard Hijmering, Pourya Khosropanah, Jan van der Kuur, Gert de Lange, Ton van der Linden, Marcel Ridder, Emanuele Taralli, Qian Wang

SAFARI

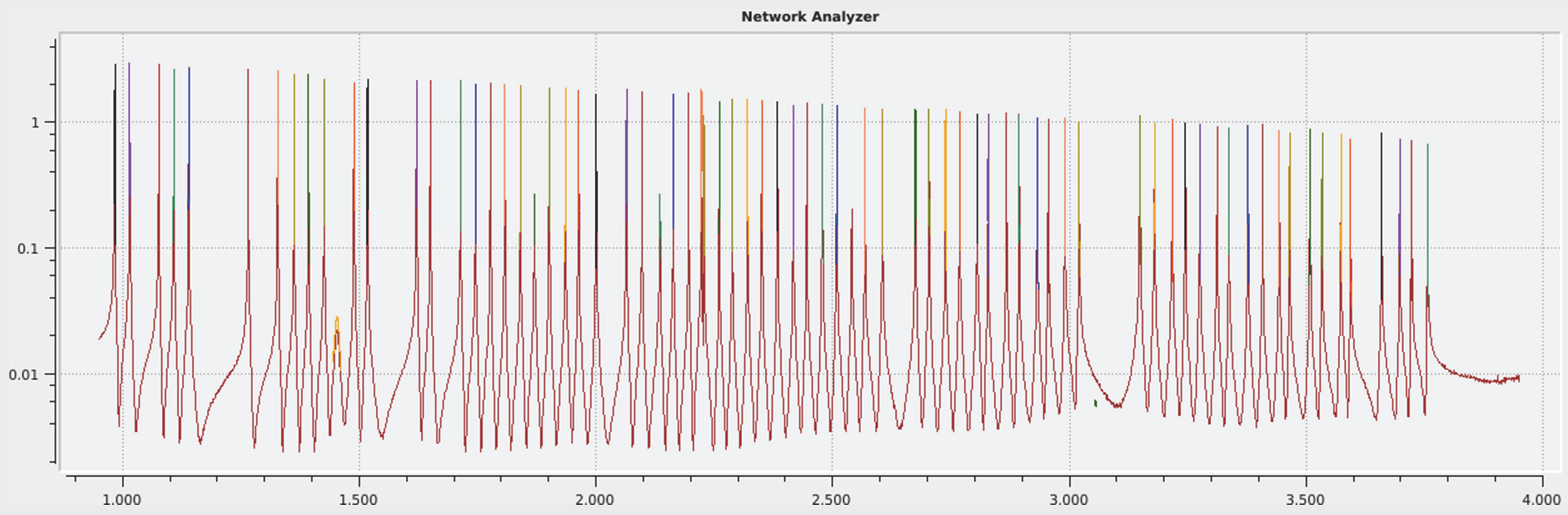
Introduction

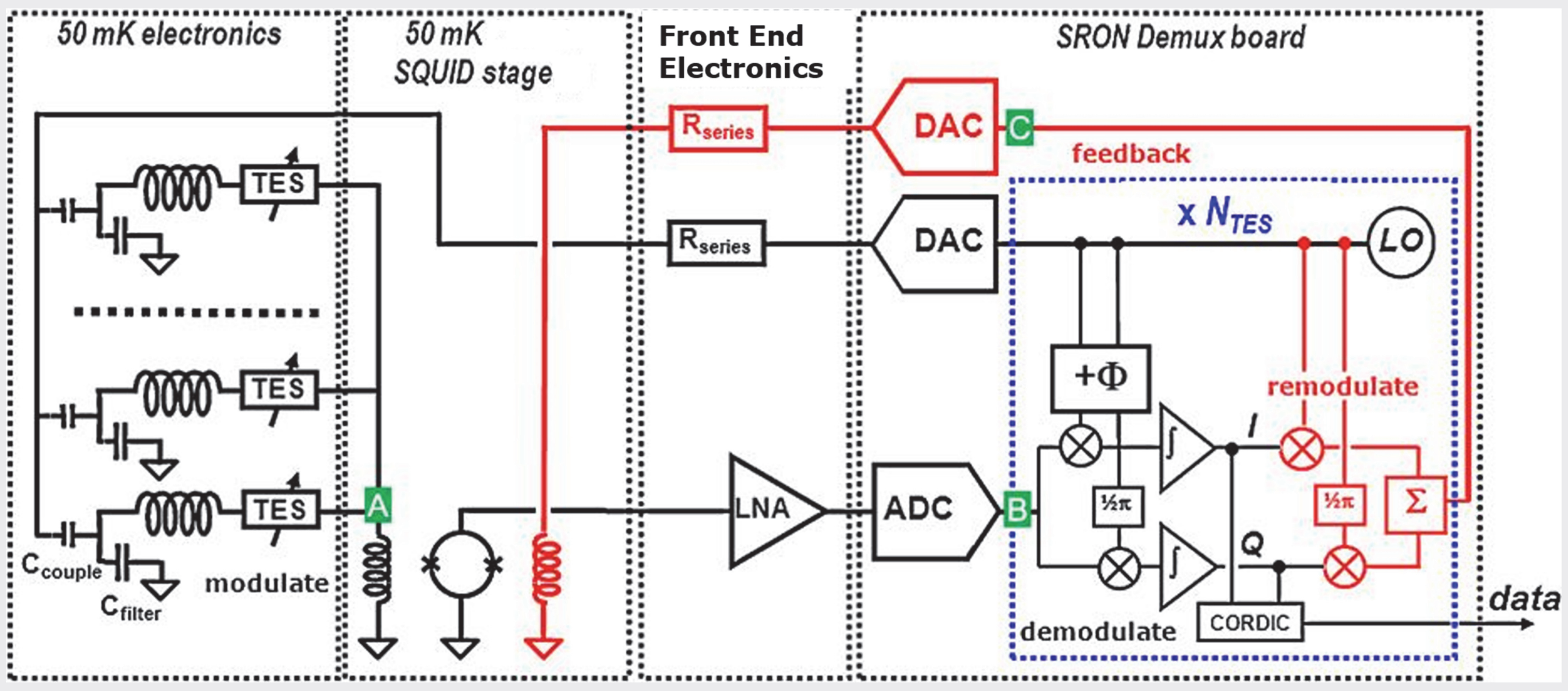
SAFARI is a far-infrared grating spectrometer for the proposed Japanese SPace Infrared telescope for Cosmology and Astrophysics (SPICA). SAFARI will cover the wavelength range 34—230 µm with a spectral resolution R~300 using four diffraction-grating modules populated with ultra-sensitive TES bolometers. These require a dark NEP≤2×10^{-19} W/√Hz to take advantage of SPICA's cold (<8 K) telescope. At SRON we have already fabricated TES bolometers that are twice as sensitive as required. We are developing the frequency domain multiplexing (FDM) readout for SAFARI's ~3600 TES bolometers. SAFARI will have 160 pixels per SQUID channel. Here we report on some of our recent measurements of the noise properties of a 176-pixel FDM demonstrator.



Frequency Domain Multiplexing with Baseband Feedback:

Each TES has its own LC filter with unique resonance frequency. We generate tones at each of these frequencies to AC-bias the individual TESs

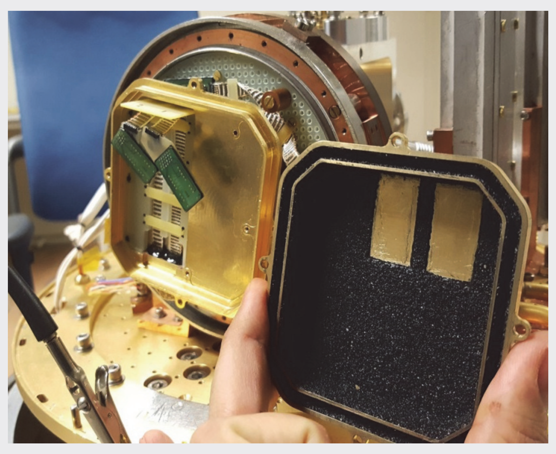




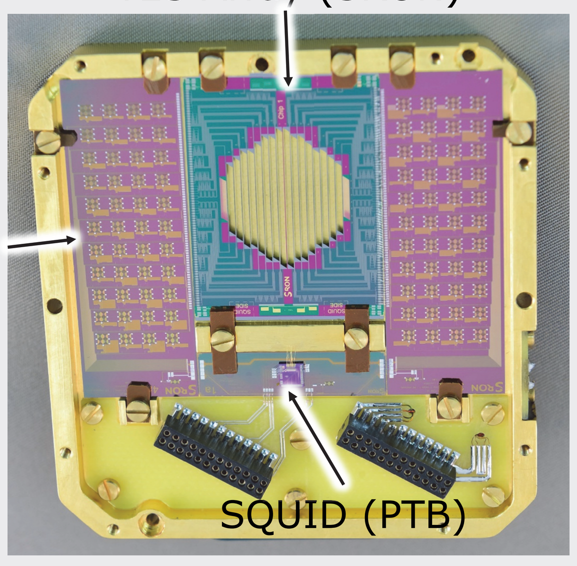
The TES currents are added at the input coil of the SQUID (summing point A). Each tone appears at the SQUID output (B) phase-shifted and amplitude-modulated. We generate a feedback signal at C to cancel the output signal (B). The amplitude of the feedback that we apply at each frequency is proportional to the power falling on the corresponding TES.

Baseband feedback: The output signal at B is deterministic (essentially an amplitude-modulated version of the AC bias), so the DEMUX board just needs to generate an amplitude-modulated and phase-shifted version of the AC-bias signal, i.e. the feedback is carried out on the amplitude of the generated tones. This amplitude varies no faster than the bandwidth of the TES (~40 Hz for SAFARI), not at the ~MHz frequencies of the AC bias.

176-pixel FDM Demonstrator:



Mounted in light-tight box in cryogen-free ADR

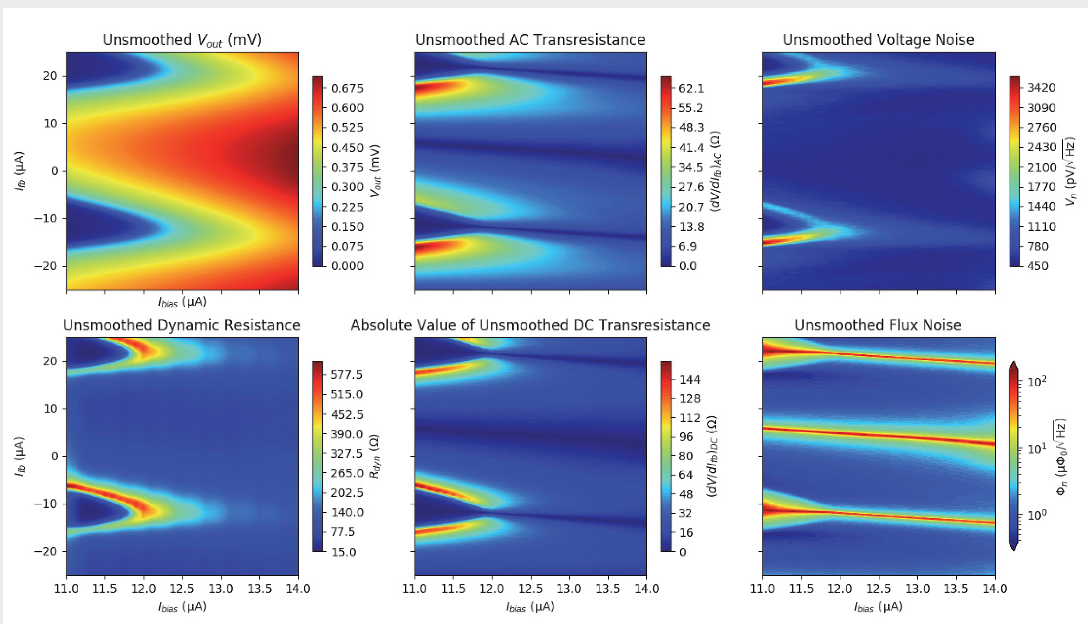


Two 88-channel LC filter chips with alternating frequencies
168 TES + 8 resistors

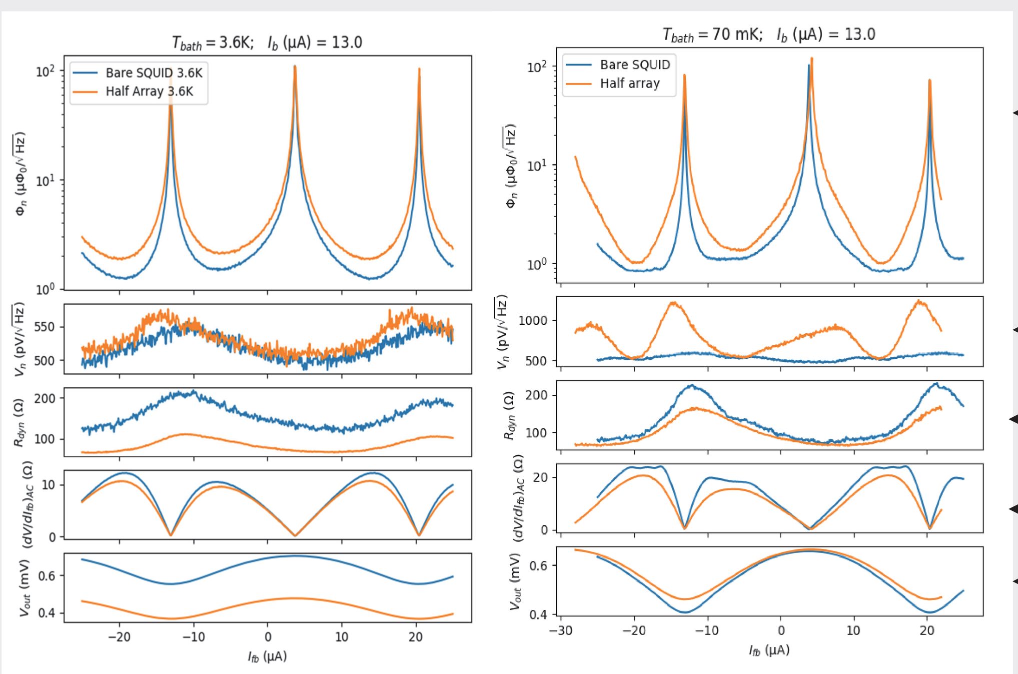
L :	3 µH
f_0 :	1-3.8 MHz
Δf :	16 kHz
T_c :	107±3 mK
P_{sat} :	20 fW @ 65 mK
NEP :	7×10^{-19} W/√Hz

Noise Measurements

We have characterized the intrinsic noise of the Front End Electronics in detail: **see Poster 106-265**. We measured noise for different SQUID bias and feedback. We used a tone of amplitude $0.01\Phi_0$ to calibrate the flux noise and measure the AC transfer.

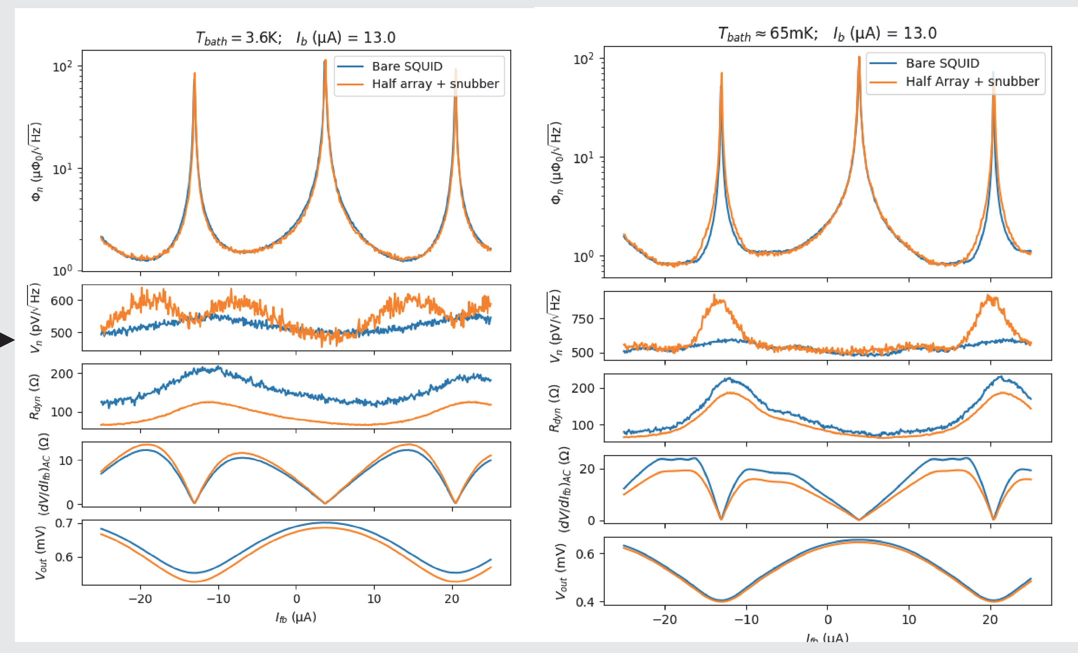


To investigate the effects of out-of-band resonances at the summing point at the SQUID input coil, we first disconnected the SQUID from the LC filters, then reconnected one of the LC filter chips (88 resonators). Reconnecting the half-array degrades both the flux noise and the AC transfer. The effect is smaller at 3.6 K than at 70 mK because the Al wirebonds are normal, reducing the quality factor of the resonators.

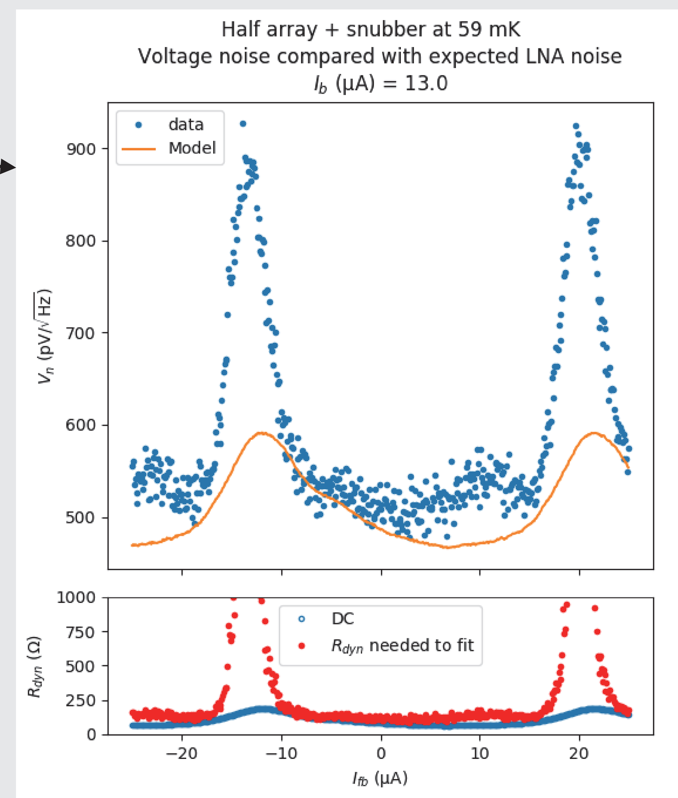


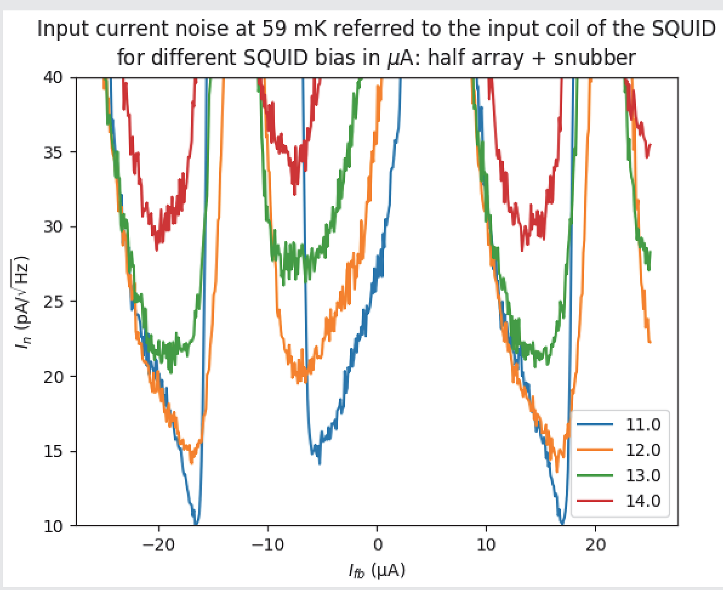
Effect of Snubber:

We added an RC snubber, i.e. a low-pass RC filter (2 Ω, 10 nF), across the summing point at the SQUID input coil. The snubber blocks the out-of-band resonances so that the flux noise is the same as for the bare SQUID, even when the TESs are superconducting and the quality factor of the resonators is high. With the snubber in place the readout noise is low enough that we can see the TES noise.



We expect the LNA noise to dominate the intrinsic noise of this SQUID. At right (top panel) we show the measured voltage noise compared with what we would expect from the known current and voltage noise of the LNA and the wiring resistance. Away from the troughs of the V-Φ curve, the measured voltage noise can be accounted for by the LNA noise, as long as the AC dynamic resistance is slightly larger than the measured DC dynamic resistance.





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