Superconducting transition detectors as power amplifiers for cryomultiplexing

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For large scale multiplexing of high-resolution astrophysical radiation detectors, power gain is needed. The power gain is normally provided by the readout amplifier, but especially in the case of time division multiplexing, power gain by the detector is beneficial. In this paper, we characterise the achievable power gain, dynamic range, noise and stability of resistively biased transition detectors.

Superconducting transition detectors such as X-ray calorimeters or THz bolometers are usually operated in voltage biased mode at voltages much below the minimum of the detector I - V curve.[1] Such biasing provides high current responsivity, low Johnson noise, high stability and good linearity due to the strong negative electrothermal feedback (ETF). However, there is no power gain in the detector. This calls for a very low noise readout amplifier, typically SQUID, in the case of cryomultiplexing.

Recently, it was shown that by voltage biasing the detector at the I - V curve minimum, a room temperature amplifier can read out the signal of transition detectors operated even in the mK range.[2] This is due to the effective power gain in the detector near the minimum current bias point: the output noise power $r_d i_n^2$ of the detector diverges as the differential resistance of the detector $r_d \to \infty$.[3] Unfortunately, at high frequencies, r_d is reduced, making the method not optimal for high bandwidth cryomultiplexing.

Here we demonstrate that by biasing the detector through a bias resistor, power gain G is obtained, the maximum of which is equal to the ETF loop gain L_0. The available power gain is limited by stability: the dynamic resistance of the system has to be positive at all frequencies. In first experiments we have measured power gains of up to 10-20. In an optimized system, we expect to achieve maximum power gain up to 50-100, allowing multiplexing of up to 100 detectors in the scheme described in Ref [4].

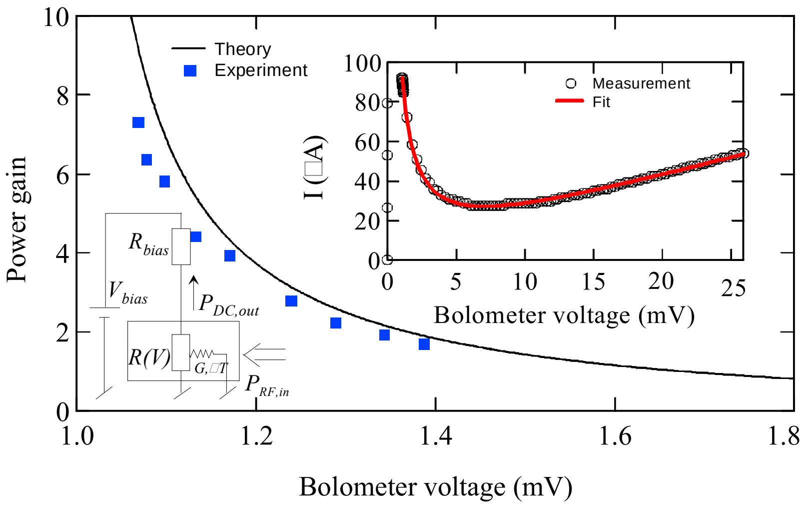

Figure 1: Power gain of a superconducting transition bolometer as a function of voltage. Squares – experiment, solid line – theory. Insets: Left: simplified circuit diagram. Right: bolometer I-V curve. $R_{\rm bias}$ = 9.9 Ω, bolometer normal state resistance $R_{\rm N}$ = 520 Ω.

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[2] JS Penttilä, H Sipola, P Helistö and H Seppä, Supercond. Sci. Technol. **19** (2006) 319–322.
[3] P Helistö, JS Penttilä, H Sipola, L Grönberg, F Maibaum, A Luukanen and Heikki Seppä, IEEE Trans. Appl. Supercond. **17** (2007) 310 – 313.
[4] A Luukanen et al, this conference.