Characterization of Transition Edge Sensors for Simons Observatory

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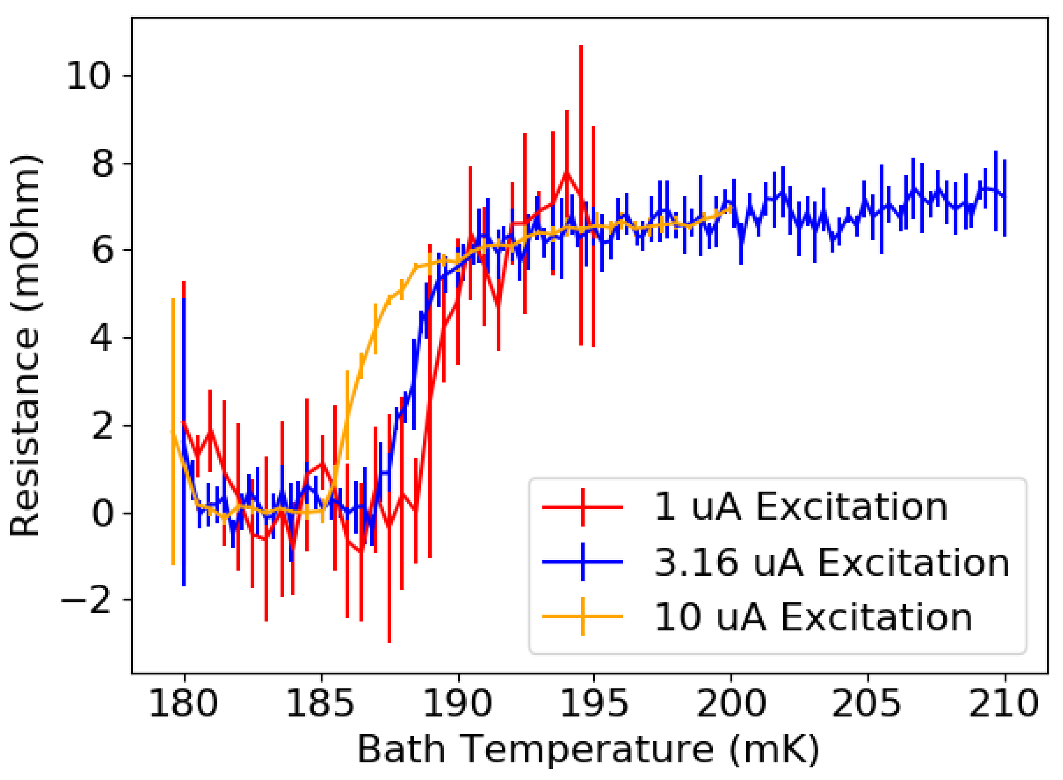
INTRODUCTION

The Simons Observatory is building both small and large aperture telescopes to observe the cosmic microwave background (CMB) from Chile. These telescopes will use over 60,000 transition edge sensor (TES) bolometers in total to observe frequencies spanning 27 to 280 GHz. These sensors operate at sub Kelvin temperatures and take advantage of the rapid change in resistance that occurs over a superconducting transition. TES bolometers are being iteratively designed and fabricated for SO at NIST, Berkeley, and commercially by HYPRES corporation, based on results of detector testing at Cornell University. We present some results of these ongoing tests.

FOUR LEAD MEASUREMENTS

We use cryogenic four lead resistance measurements of the TES bolometers to determine their critical temperature and normal resistance.



Here is an example four lead measurement of a NIST fabricated UHF (220 GHz) TES at multiple excitations.

While these parameters can also be obtained from the IV analysis, the four lead measurements are simpler to perform and provide complementary information to the IV curves [3].

REFERENCES

1. Irwin K., Hilton G. () Transition-Edge Sensors. In: Enss C. (eds) Cryogenic Particle Detection. Topics in Applied Physics, vol 99. Springer, Berlin, Heidelberg

2. Nicholas Galitzki, et al. "The Simons Observatory: instrument overview," Proc. SPIE 10708, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX, 1070804 (31 July 2018)

3. E. M. Vavagiakis, "Magnetic Sensitivity of AlMn TESes and Shielding Considerations for Next-Generation CMB Surveys" https://arxiv.org/abs/1710.08456

ACKNOWLEDGEMENTS

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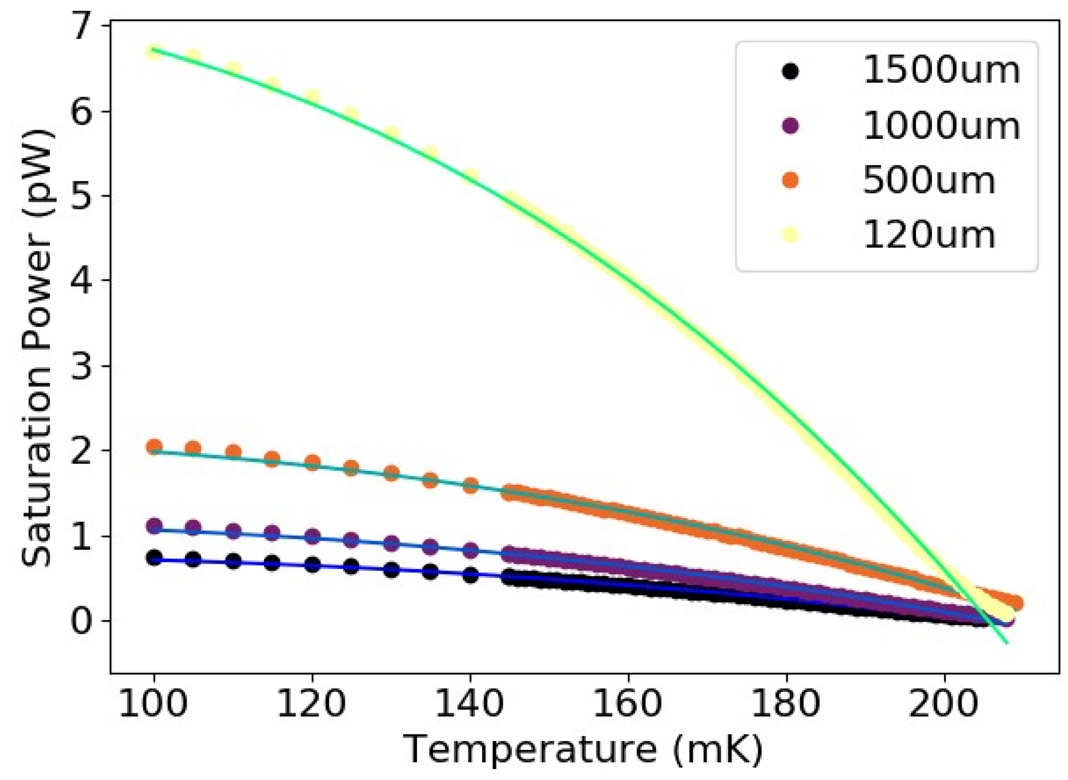
IV MEASUREMENTS

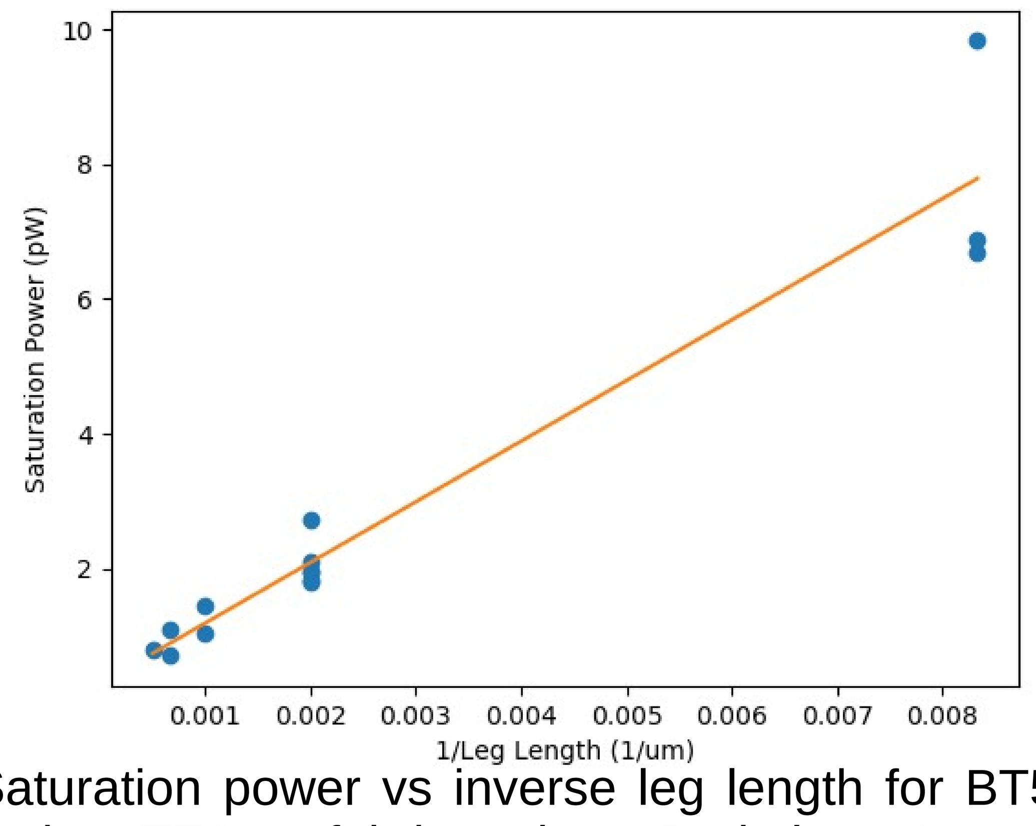
By plotting the TES current vs voltage (I-V) through the transition, we can determine the saturation power (P_{sat}) required to drive the TES normal. Measuring P_{SAT} at multiple temperatures allows us to fit the model

$$P_{sat} = k(T_c^n - T_{bath}^n)$$

Which relates the saturation power to the bath temperature and allows us to determine the superconducting critical temperature T_c and the thermal conductivity $G = nkT^{n-1}$.



This is an example fit to the equation above for a set of Berkeley fabricated BT5-01 TES detectors with various leg lengths. These are appropriate saturation powers for LF and MF detectors.



Saturation power vs inverse leg length for BT5-01 series TESes fabricated at Berkeley. Saturation power is inversely proportional to TES leg length and fits such as this one allow tuning of the saturation power.

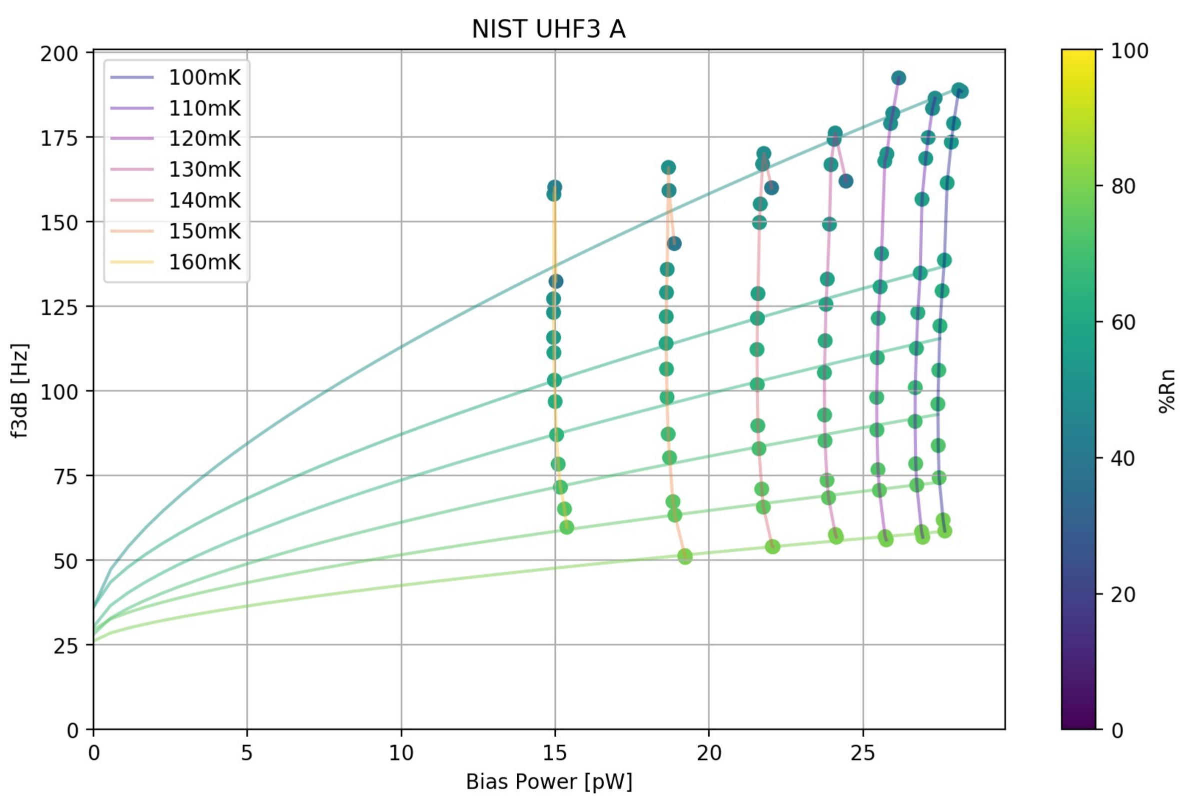
Parameter	Target	Measured
T_c	160 mK	186 mK
P_{sat} (220GHz)	11.6-19.4 pW	26 pW
P_{sat} (280GHz)	18.3-30.5 pW	30 pW
R_N (220GHz)	8 mOhm	7.1 mOhm
R_N (280GHz)	8 mOhm	7.6 mOhm

Target vs average measured values for various significant TES parameters for NIST UHF detectors obtained from the IV analysis. P_{sat} listed at 100mK.

With this information, the next step with NIST detectors is full wafer fabrication for 90/150 GHz and 220/270 GHz detector wafers.

BIAS STEP MEASUREMENTS

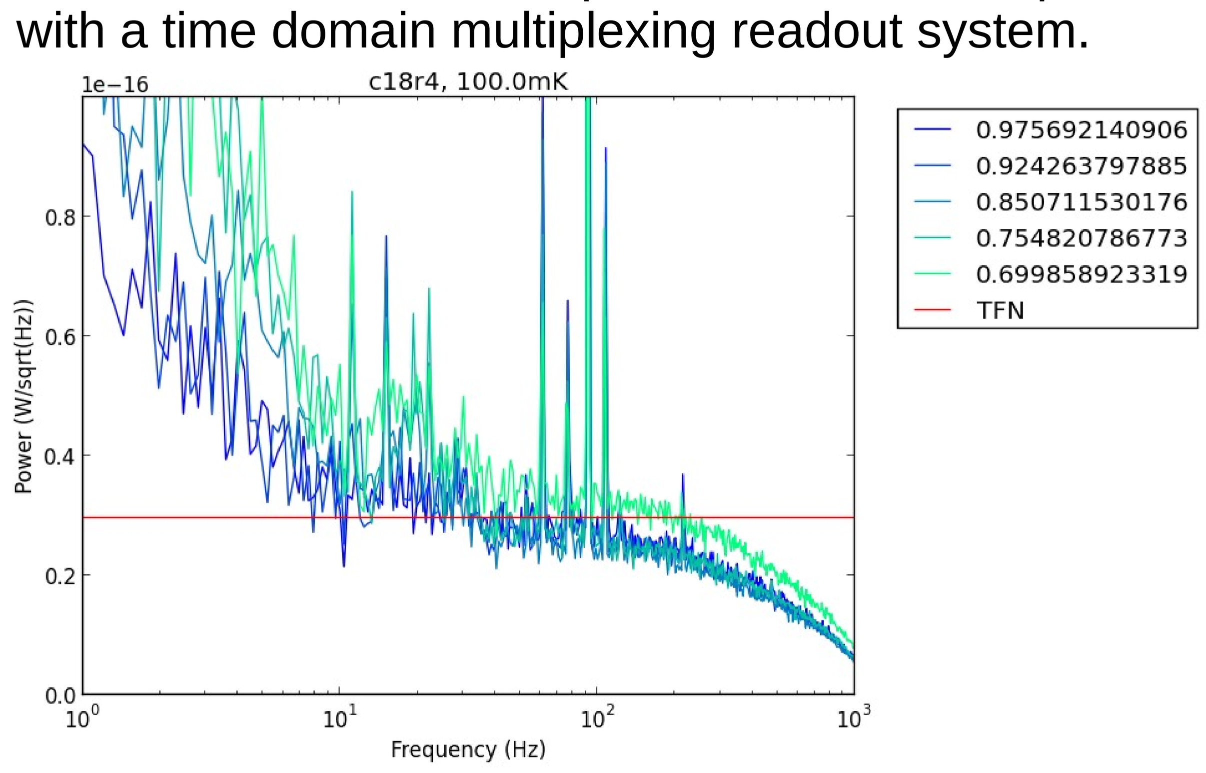
The time constant of the detector, which is the exponential decay rate that the TES will decay to a constant steady state with, can be measured by inputting a square wave into the TES bias line and measuring the current response.



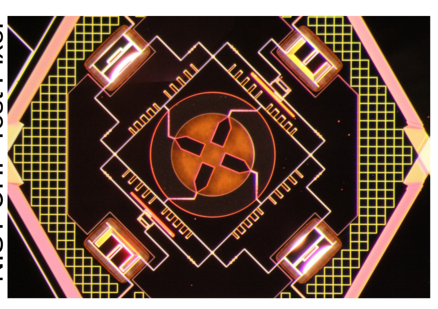
Example bias step measurements for a 280GHz NIST UHF detector at various temperatures and bias points. NIST 280GHz TESes are the best measured measured thus far, tests of other detector types are ongoing.

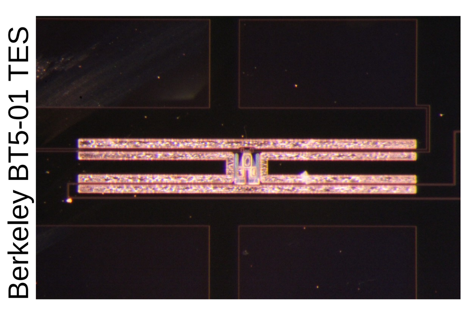
NOISE MEASUREMENTS

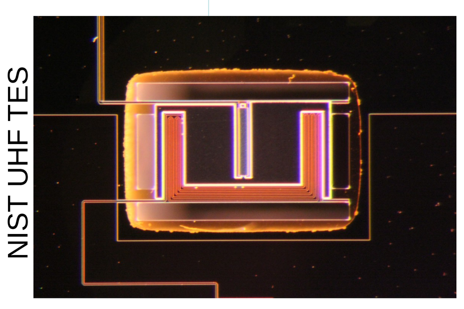
Noise spectra are obtained by measuring TES current at constant temperature and bias power with a time domain multiplexing readout system.

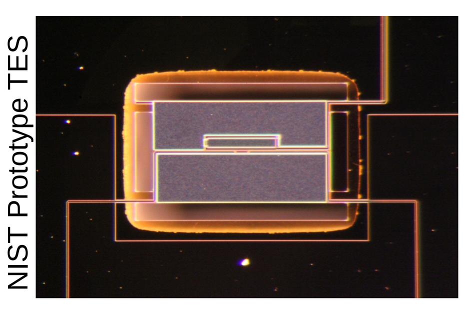


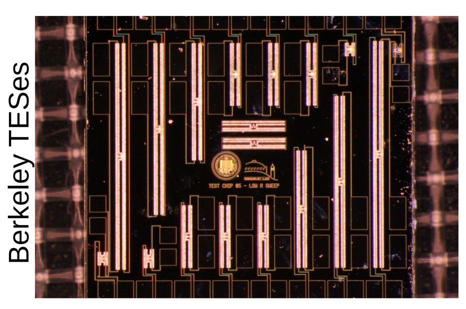
A sample noise power spectrum from a NIST UHF 280GHz TES. Also plotted is a DC approximation of the thermal fluctuation noise, equal to $(4k_bT^2GF_{link})^{1/2}$. G is obtained from the IV measurements, and Flink is assumed to be 1. The different curves correspond to different fractions of normal resistance. We are continuing to diagnose noise lines and 1/f variability in our testbed.


NIST UHF Test Pixel


Berkeley BT5-01 TES


NIST UHF TES


NIST Prototype TES


Berkeley TESes