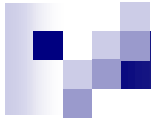


# Parameter Comparison for Low-Noise Mo/Au TES Bolometers

Dominic Benford  
Harvey Moseley  
Johannes Staguhn  
Christine Allen

Jay Chervenak  
Thomas Stevenson  
Wen-Ting Hsieh

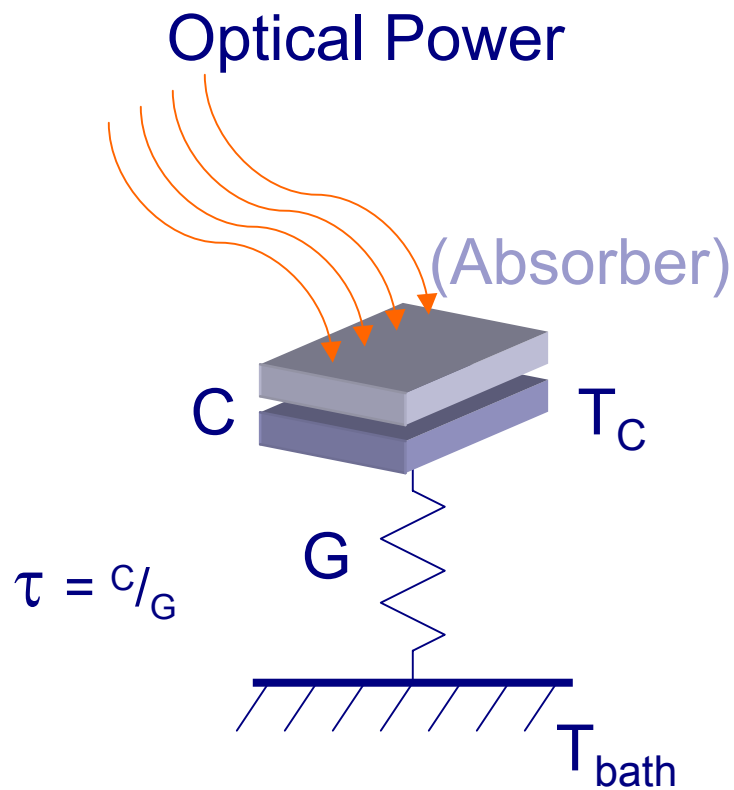
NASA / Goddard Space Flight Center



# Context

- Developing bolometers for far-IR astronomy
- Building arrays of SQUID-multiplexed bolometers for SOFIA/SAFIRE, ASTRO/SPIFI, GBT/3mmCam
- Related presentations:
  - Staguhn et al.            Detector noise analysis talk            R05
  - Chervenak et al.        Detector fabrication description        Y18
  - Allen et al.             Detector fabrication description        Y24
  - Dicker et al.            GBT/3mmCam instrument talk            W03
  - Moseley et al.          2D (semiconducting) array talk         Y06

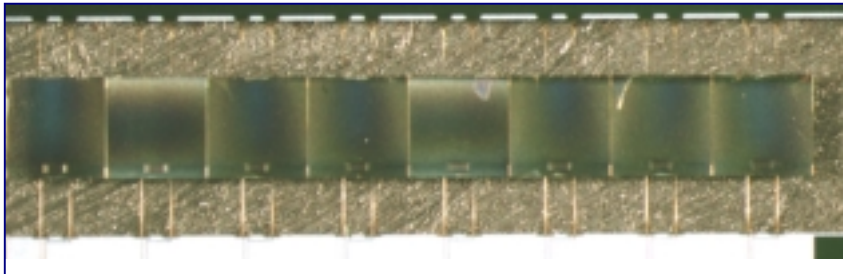
# Bolometer Requirements



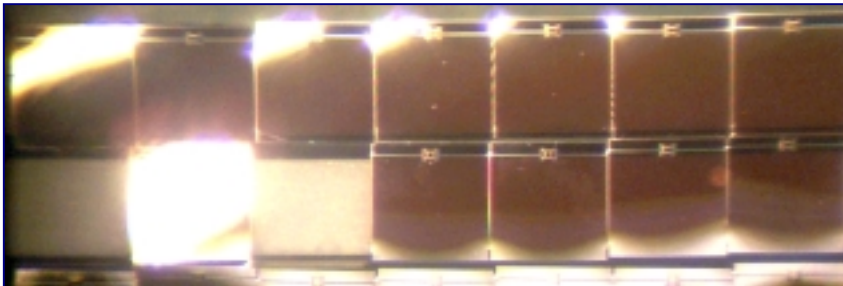
## ■ Parameters:

- $T_{\text{bath}} \sim 300\text{mK} (\pm 20\%)$
- Power  $\sim 1\text{pW} (\pm 3x)$
- NEP  $\sim 10^{-17} \text{ W}/\sqrt{\text{Hz}}$
- $\tau \leq 10\text{ms}$
- Absorbs at  $\sim 100\mu\text{m}-1\text{mm}$
  
- $T_C \sim 450\text{mK} (\pm 10\%)$
- $R_N \sim 400\text{m}\Omega (\pm 20\%)$
- $G(T_C) \sim \text{few } \times 10^{-11} \text{ W/K} (\pm 3x)$

# Mechanical Implementation



- 1x8 linear arrays of Pop-Up Bolometers



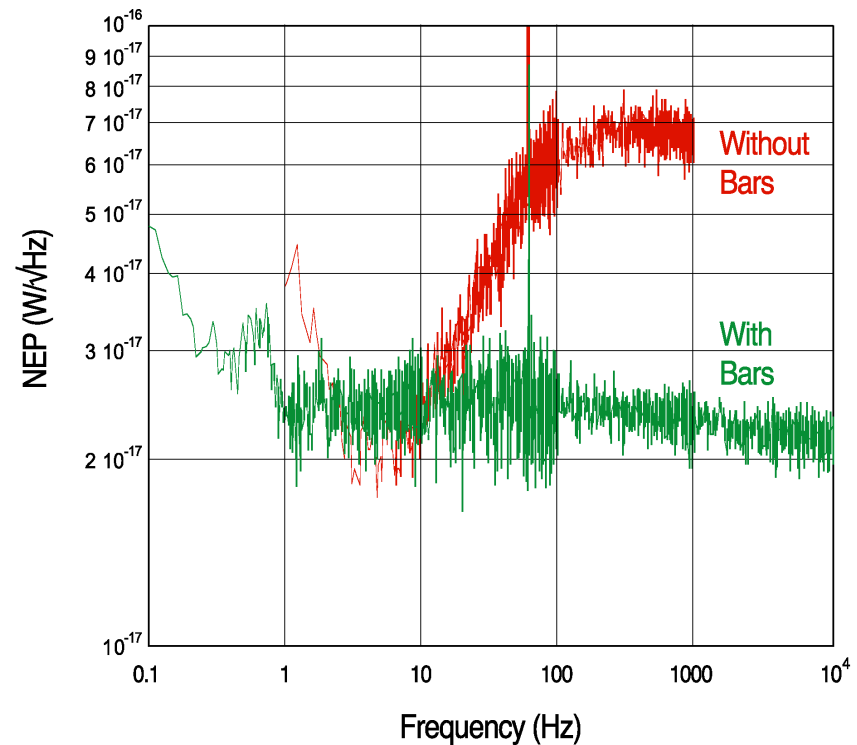
- Folding allows arrays to be close-packed
- Thermal isolation high, since flexure hinges are thin



- SHARC-II (12x32=384 pixel) semiconducting Pop-Up array (Moseley et al.)

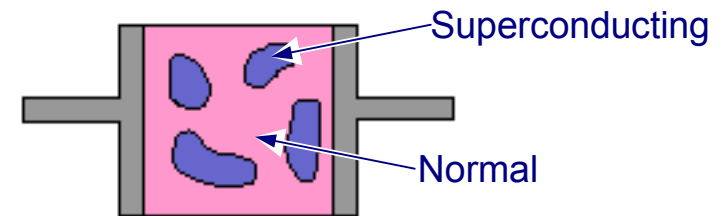
# History of our TES bilayers

- Both Mo/Au and Mo/Cu fabricated
- Good performance demonstrated, but not sufficiently repeatable
- Always some excess noise, often out-of-band, sometimes 5x-10x thermal noise limit



# Approach: Boundary Conditions

- Current flowing in TES can take many possible paths
- Initial trials indicated that normal metal bars on sides could help constrain possible paths, leading to more orderly current flow
- Other constraints may be more likely to prevent moving “chunks” of superconducting regions

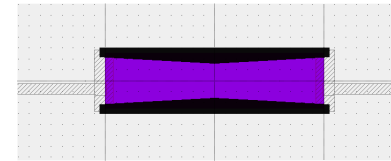


Lindeman et al. model

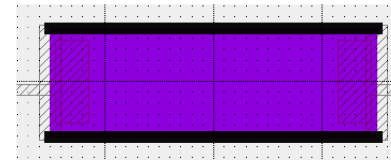


# Trial #1: Longitudinal Bars

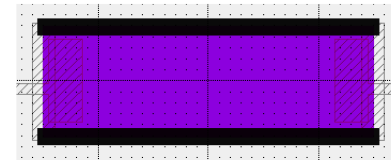
- In order to better understand the effect of boundary condition geometry on detector performance, we produced several nearly identical bolometers with different normal metal bars.
- Several designs of longitudinal bars produced
- Some designs are wedged to remove isotropy



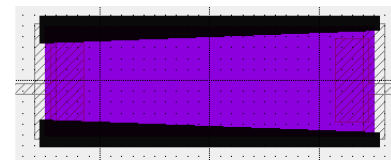
#0



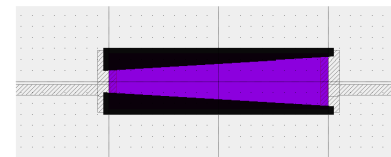
#1



#2



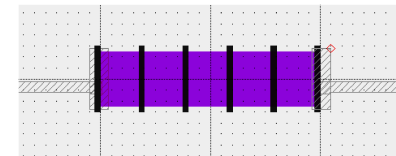
#3



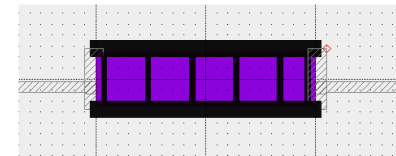
#4

# Trial #2: Transverse Bars

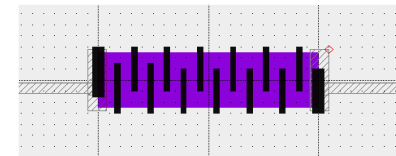
- Several designs of transverse bars produced
- Some designs are interdigitated; others are continuous



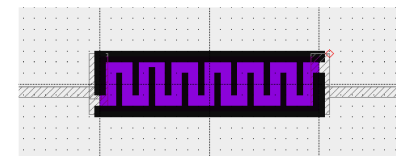
#0



#1



#2

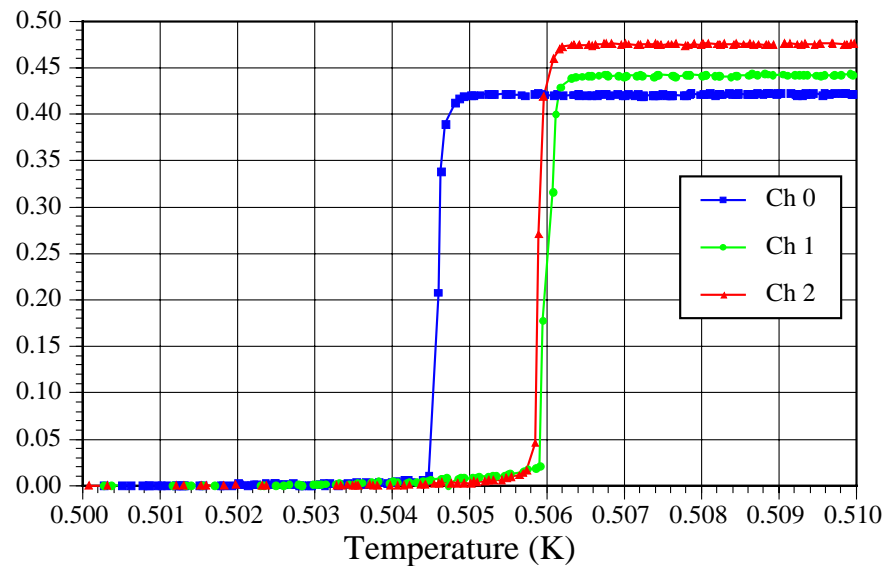


#3

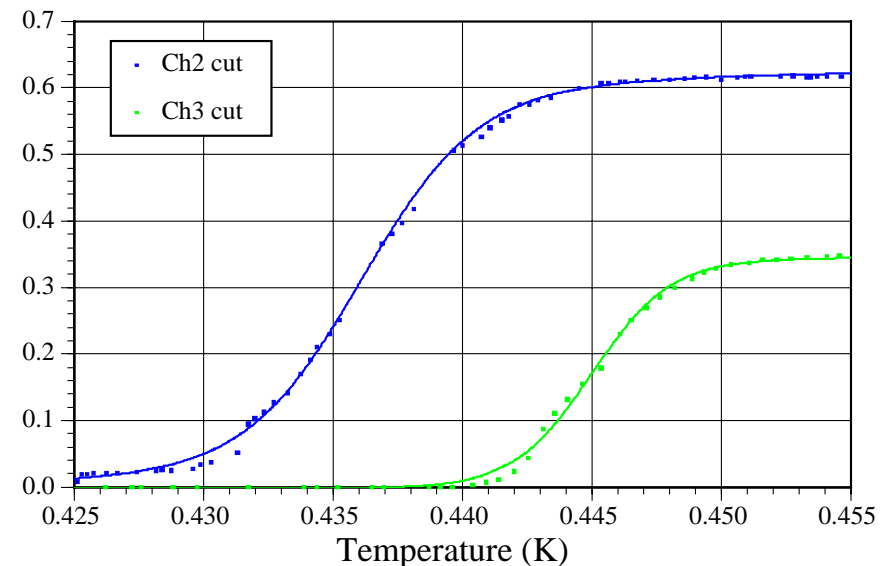


# Transition Measurements

- 4-wire measurements of resistance vs. temperature, with several bias currents to estimate self-heating and critical currents.
- Addition of transverse bars does cause sharpness to degrade, but still achieve  $\alpha \approx 100$



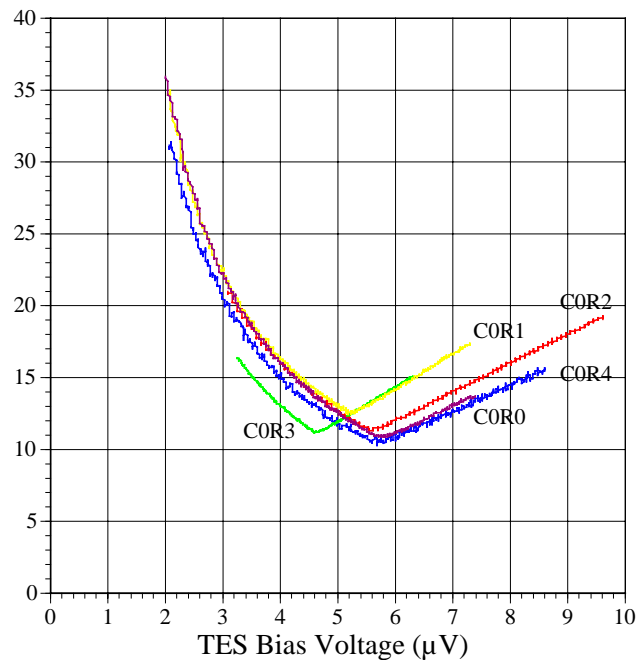
Longitudinal bars



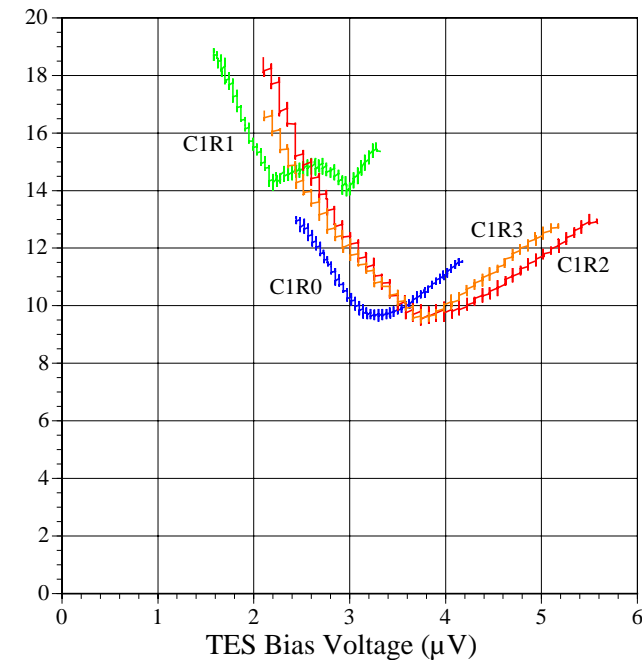
Transverse bars

# Behavior on Bias (I)

- I(V) curves taken on all devices; calibrated to determine resistance and power as a function of base temperature.
- Some calibration uncertainties remain.



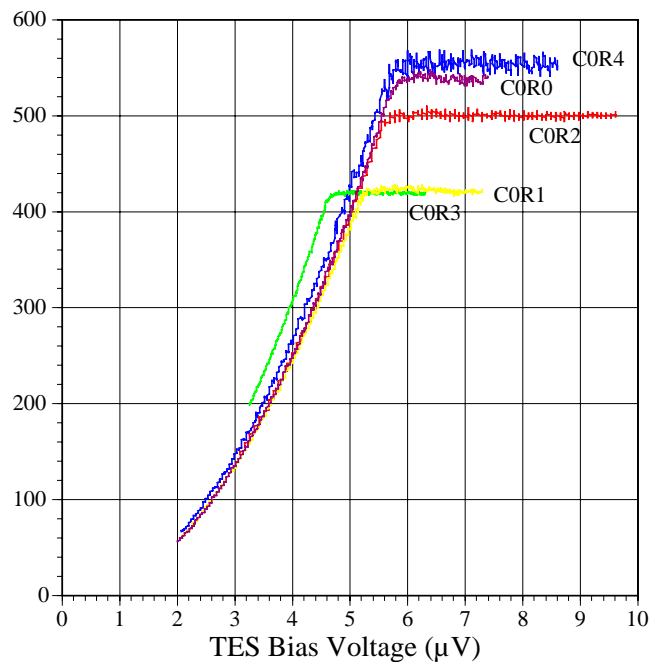
Longitudinal bars



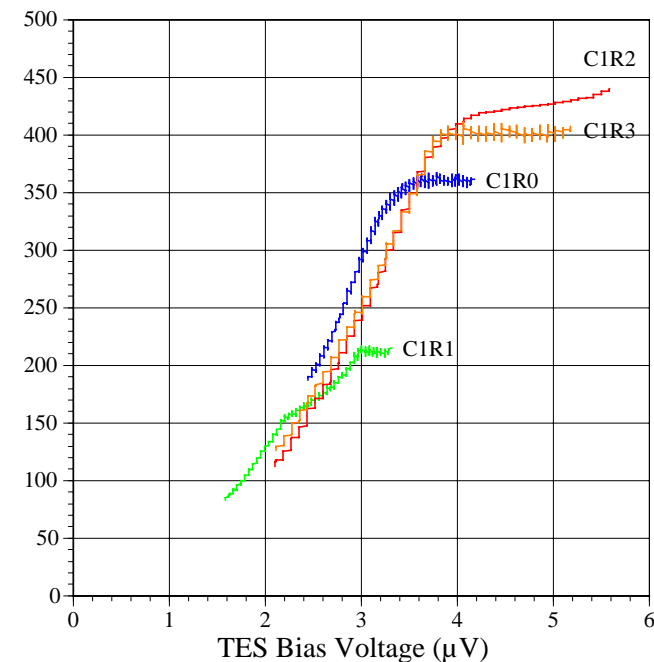
Transverse bars

# Behavior on Bias (II)

- Resistance vs. bias yields close to expected values.
- Some calibration uncertainties remain.



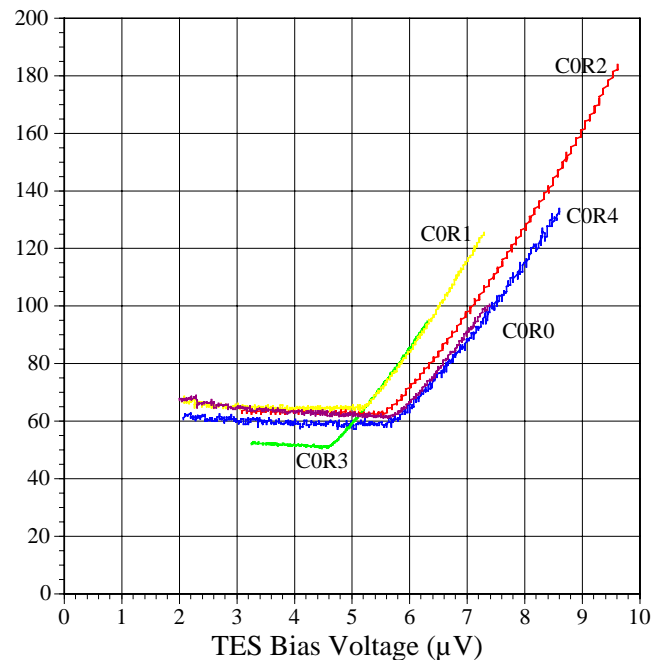
Longitudinal bars



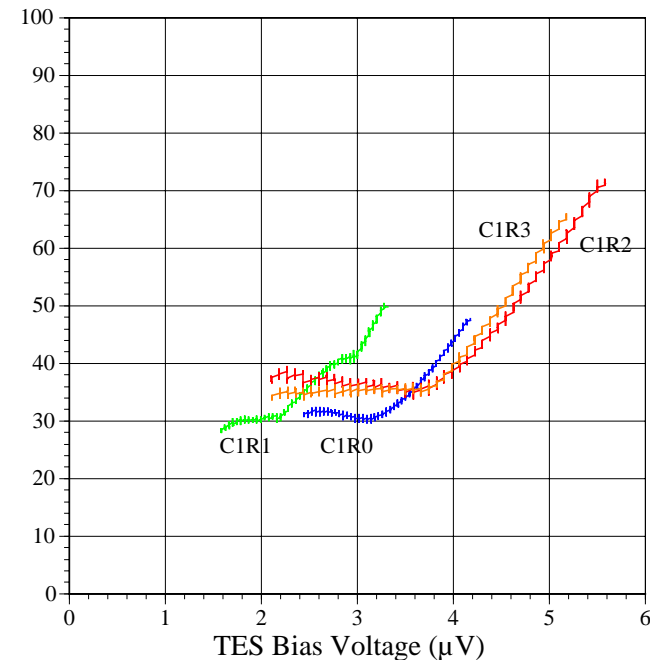
Transverse bars

# Behavior on Bias (III)

- Power vs. bias yields similar value for all pixels (as should be the case).
- Power on transition quite constant (as should be the case).
- Some calibration uncertainties remain.

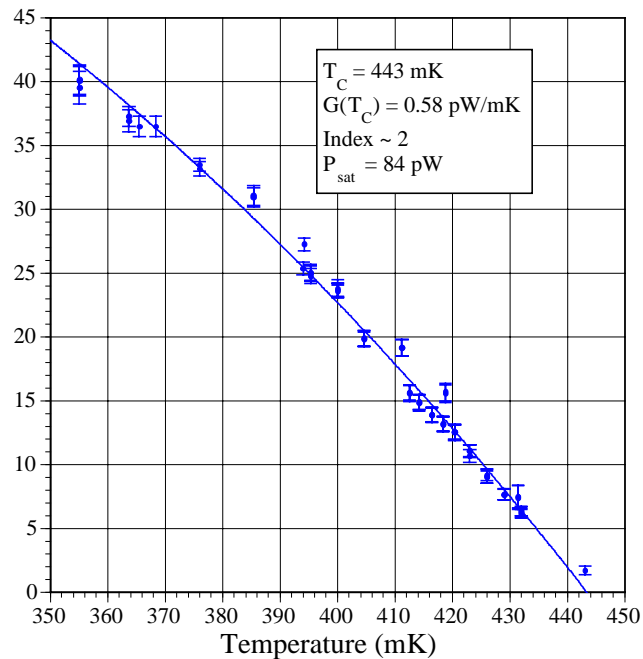


Longitudinal bars



Transverse bars

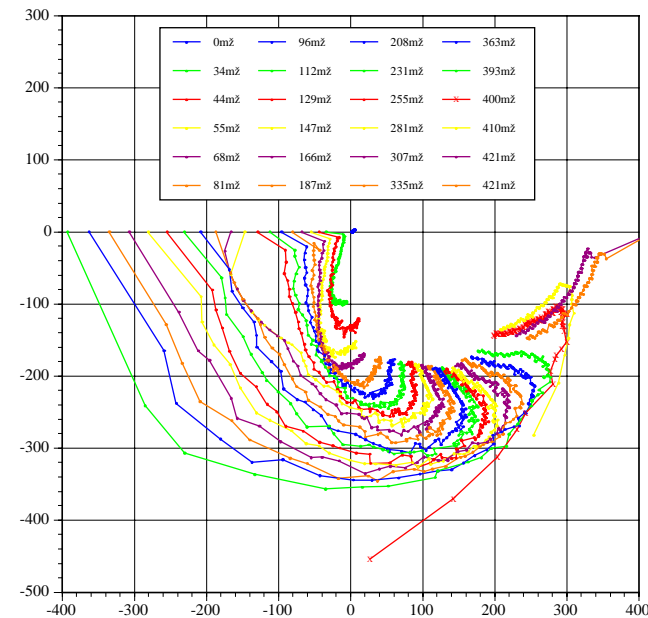
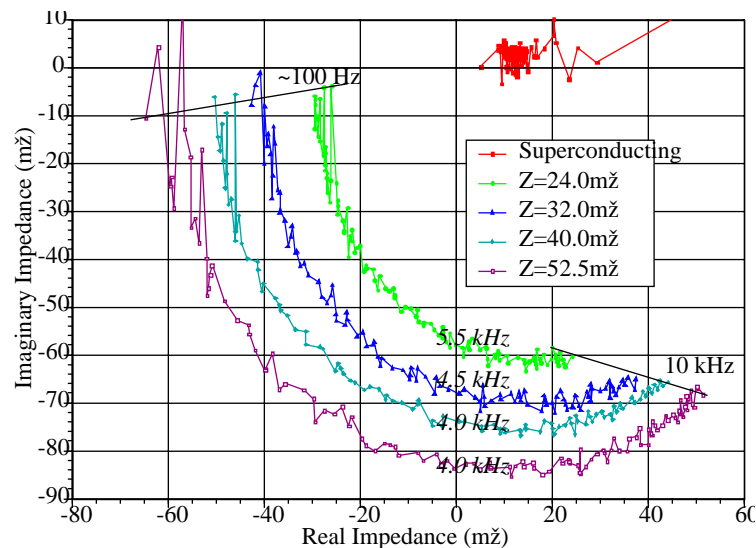
# Pixel Thermal Conductance



- Thermal conductance measured by average power on transition for many bath temperatures
- Power law fit:
  - $T_C = 443 \text{ mK}$
  - $G(T_C) = 6 \cdot 10^{-10} \text{ W/K}$  (higher than desired)
  - Index  $G = G_0 T^N$ ,  $N \sim 2$  (though not tightly constrained)
  - $P_{\text{sat}} = 84 \text{ pW}$  (with  $T_{\text{bath}} = 0$ ).
  - Phonon noise:  $6 \cdot 10^{-17} \text{ W}/\sqrt{\text{Hz}}$
- Next device mask will reduce leg width, to reduce  $P_{\text{sat}}$  and  $G(T_C)$  by  $\sim 10x$ .

# Dynamic Measurements

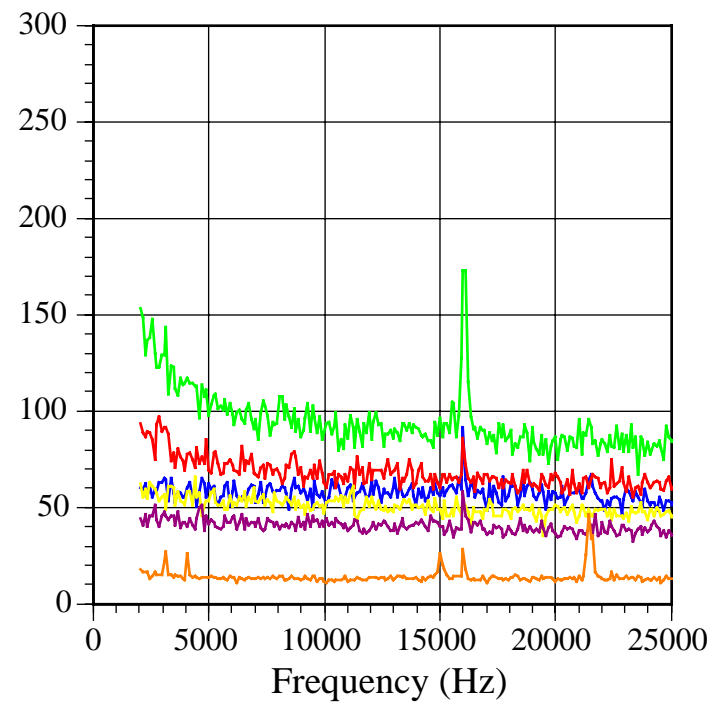
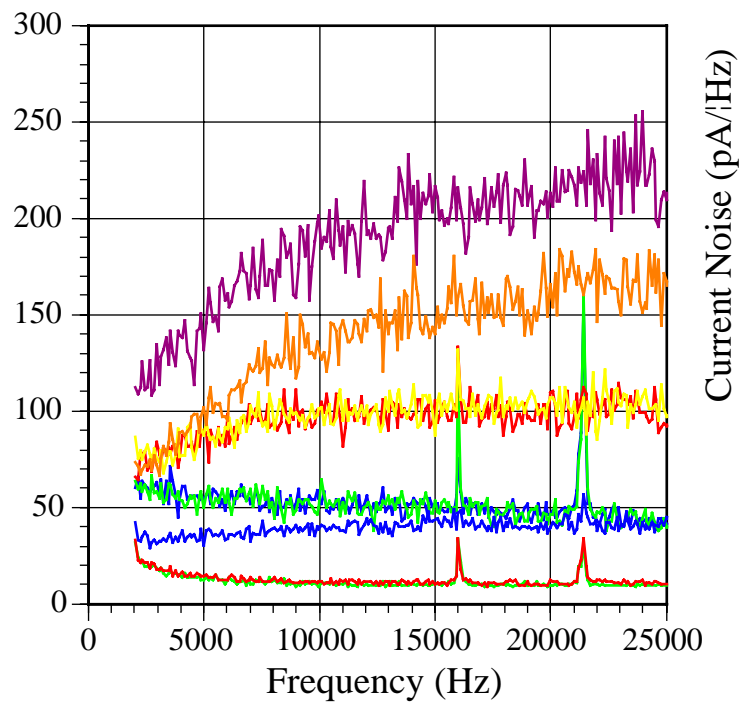
- Measured complex impedance  $Z(\omega)$  for bolometers, as per Lindeman et al.
- Results prove tricky to interpret; devices too fast for reliable high frequency impedance measurements
- Time constants of  $1/\tau_e \sim 5\text{kHz}$ .

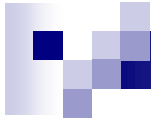


# Noise Measurements

- The subject of Johannes Staguhn's talk; in order not to spoil the surprise:

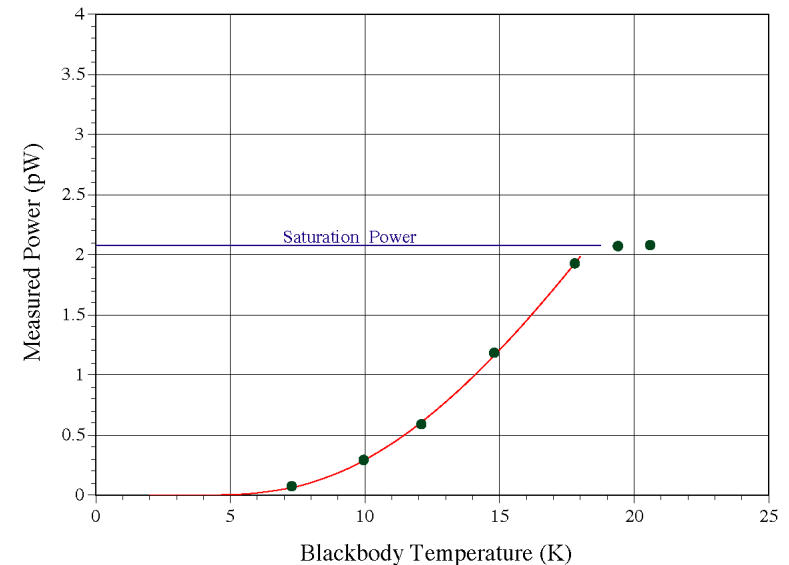
The geometry of the bars does affect the noise.





# Optical Measurements

- Bismuth absorbing film deposited on bolometers to impedance match to free space.
- Dark tests after deposition show same result as tests prior to deposition.
- Optically functioning bolometers are demonstrated in the dark; prior tests have verified optical performance.



Optical measurement of a blackbody calibrator from an earlier, similar bolometer.





# Summary

- Several nearly identical bolometers produced, with different normal metal bars. Bolometers are optically active detectors.
- Tests of quasi-DC parameters ( $T_C$ ,  $R_N$ ,  $\alpha$ ,  $P_{\text{sat}}$ , etc.) show good consistency.
- Noise performance can be improved by changing bar geometry.
- Measurements & analysis ongoing to quantify improvements and differences. Time constant (impedance) analysis to be refined.