Mapping Transition-edge Sensor Temperature Sensitivity and Current Sensitivity Surface as a Function of Current, Magnetic Field and Temperature with IV curve and Complex Impedance Measurement

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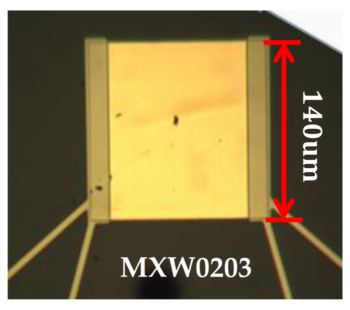
Motivation

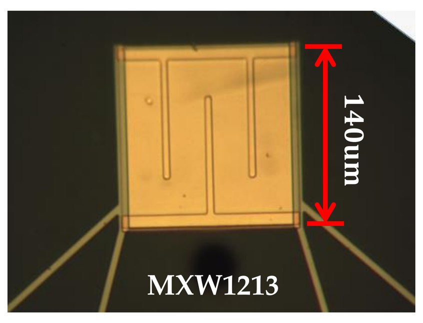
1. To resolve the spectra of the astronomical diffuse X-ray background in the 0.1-0.5 keV energy range, we need large area pixels (~1mm^2) with excellent energy resolution (1-2 eV).
2. For TES pixels with large absorbers that have a relatively high heat capacity, high α and low β are needed to achieve the required energy resolution.
3. Most work in the field has found high α to be correlated with high β and also with excess noise. The cause of this correlation remains to be understood[6].

TES devices – overview[5]

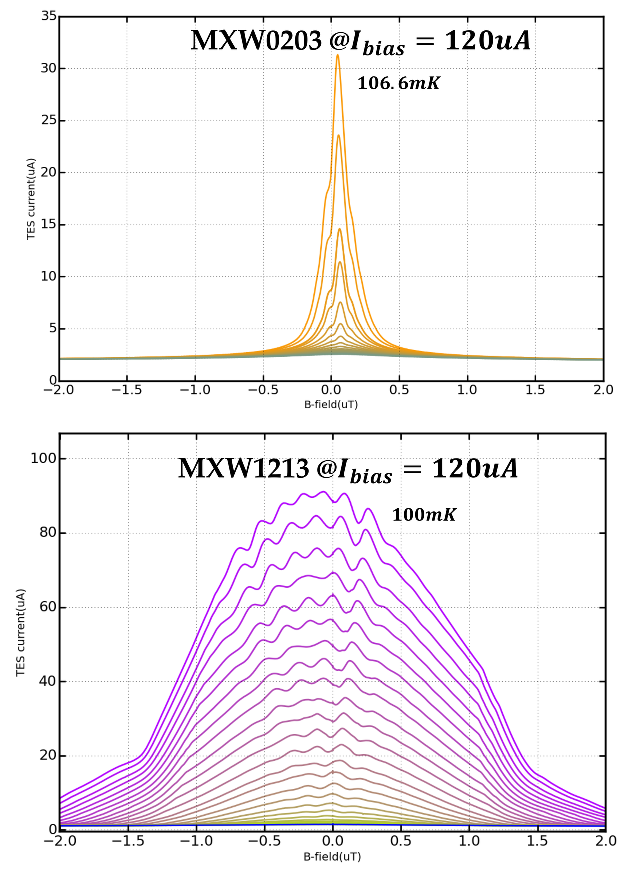
- Mo-Au bilayer
- No membrane/absorber



No zebra strips or banks



3 strips with banks

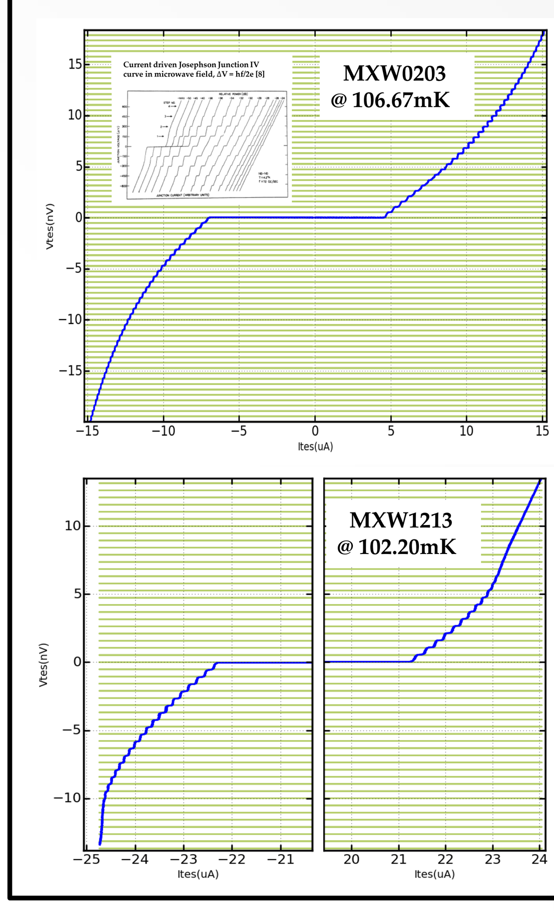


These two Mo-Au bilayer TESs are diagnosis chips with no membrane or absorber design.
MXW0203 Tc ~ 108mK;
MXW1213 Tc ~ 104mK.
Here we take *I_{TES} vs. B_{ext} for two devices at different temperature.*

MXW0203:
Ibias = 120uA
Bath Temperature ranging from 106.6mK to 109.6mK, in steps of 0.2mK

MXW1213:
Ibias = 120uA
Bath Temperature ranging from 100.0mK to 105.4mK, in steps of 0.2mK

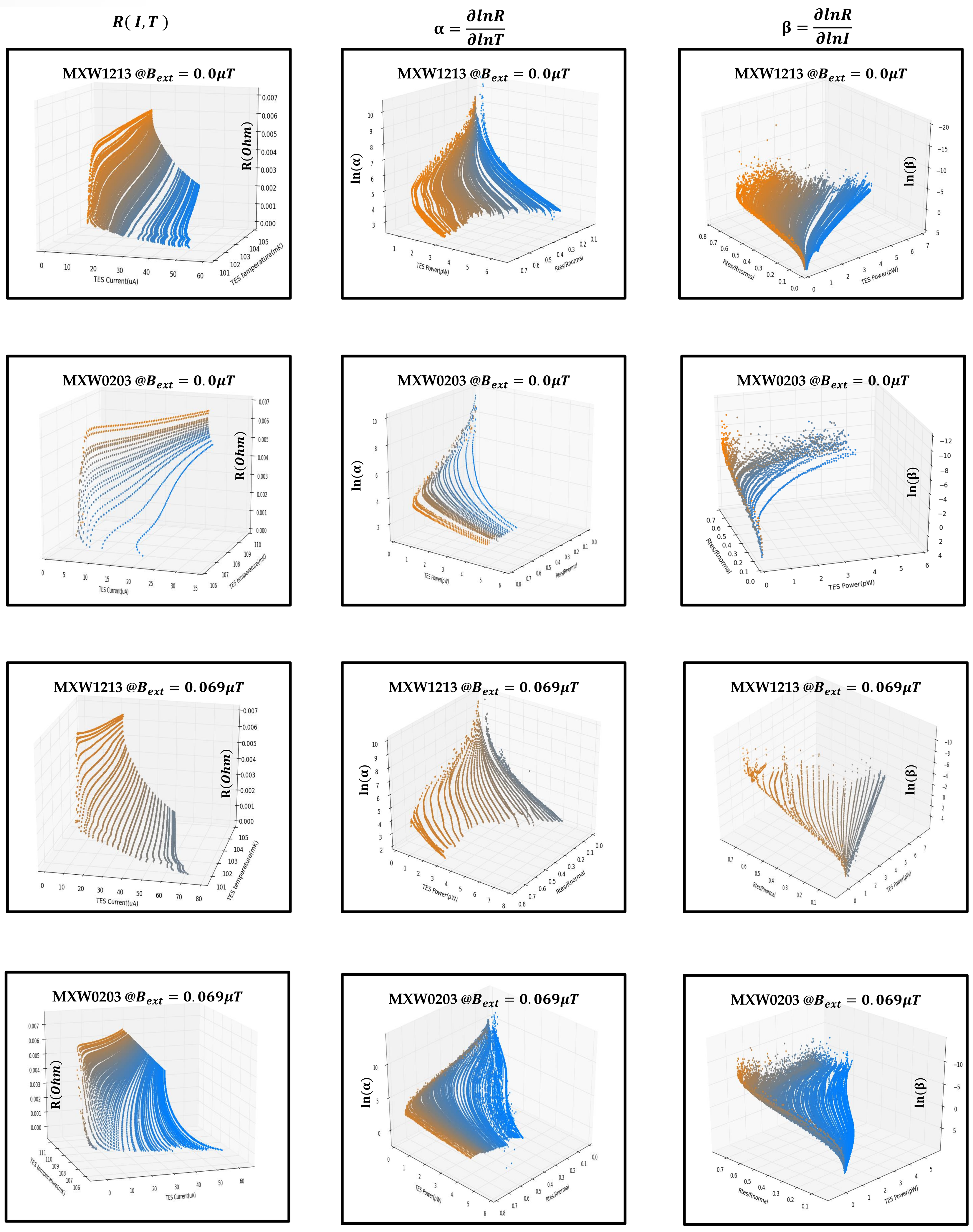
TES behaves like a Josephson Junction (Shapiro Steps)[7]



MXW0203– IV curve taken at 106.67mK. An external alternating B-field is applied to the device. Frequency =254.296kHz

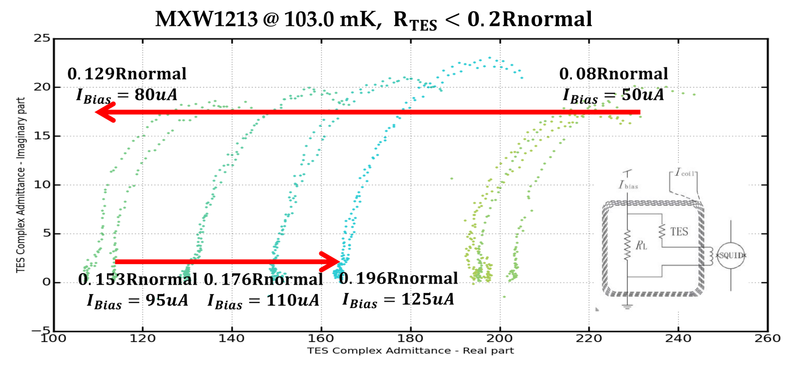
MXW1213– IV curve taken at 102.20mK. An external alternating B-field is applied to the device. Frequency =254.296kHz

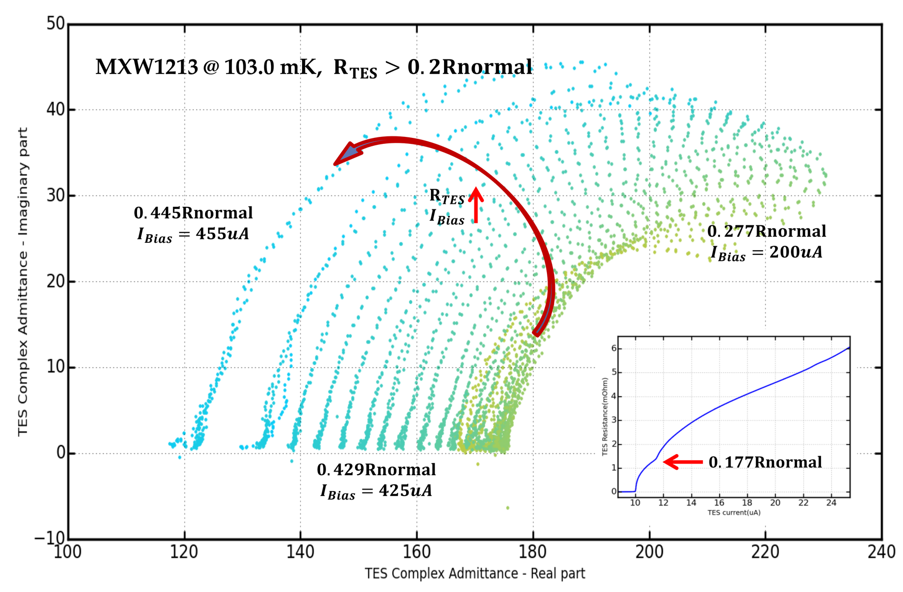
With $\Delta V_{TES} = \frac{hf}{2e}$ we were able to calibrate the shunt resistance to a precision of 1 μΩ..



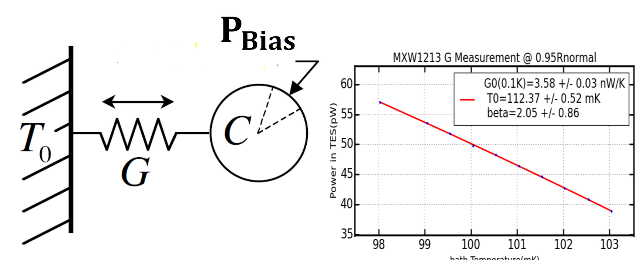
Complex Admittance Evolution

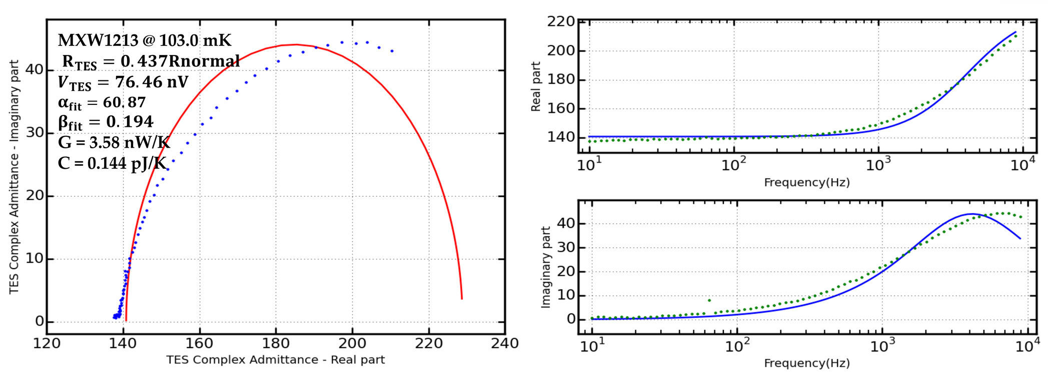
At 103.0mK base temperature the TES complex admittance calculated using an empirical Thevenin equivalent circuit for the bias and SQUID network [3] is driven by the bias current.
Starting from the right side, the admittance jumps to the very left side and then moves toward the right while its size roughly stays constant when $R_{TES} < 0.2Rnormal$. After R_{TES} is beyond $0.2Rnormal$, it starts to grow larger and move to the left.



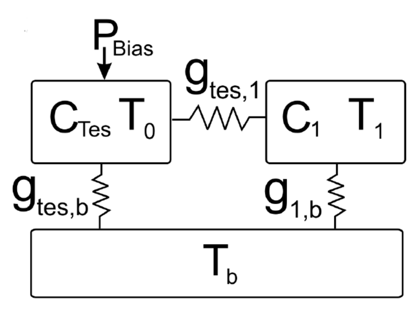


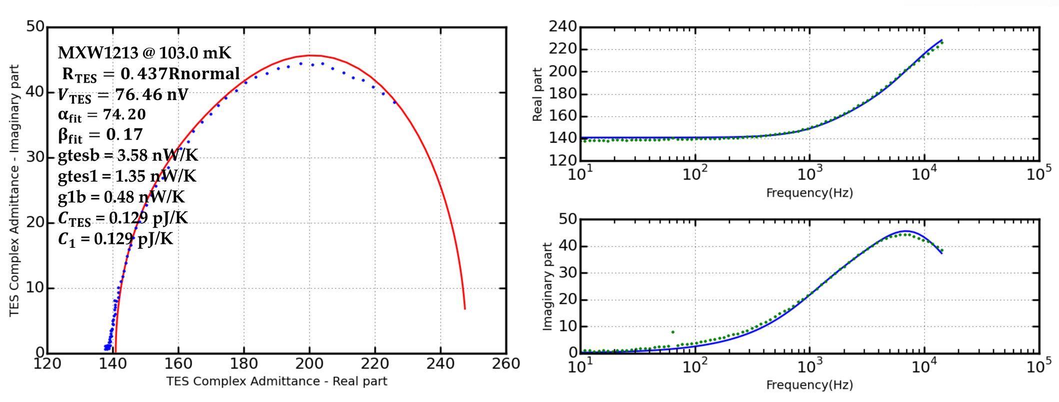
Thermal model 1[1]



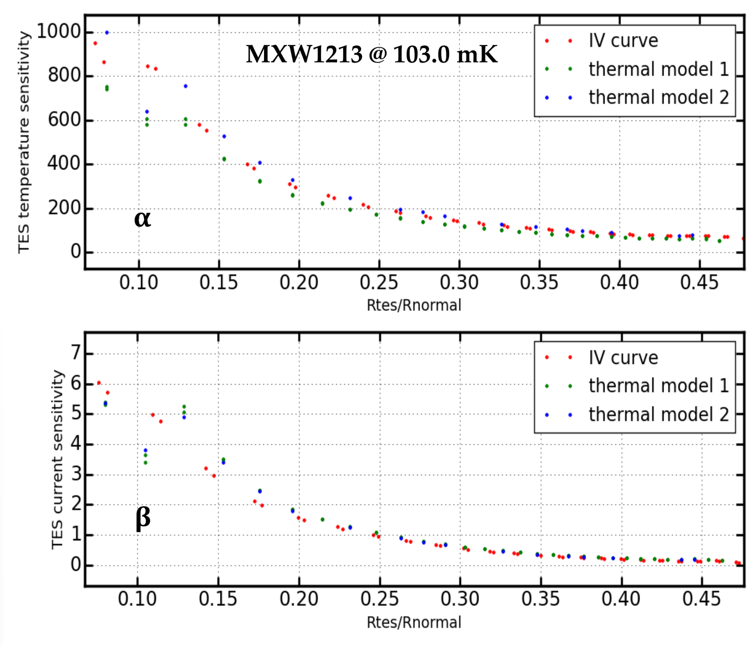


Thermal model 2[2]

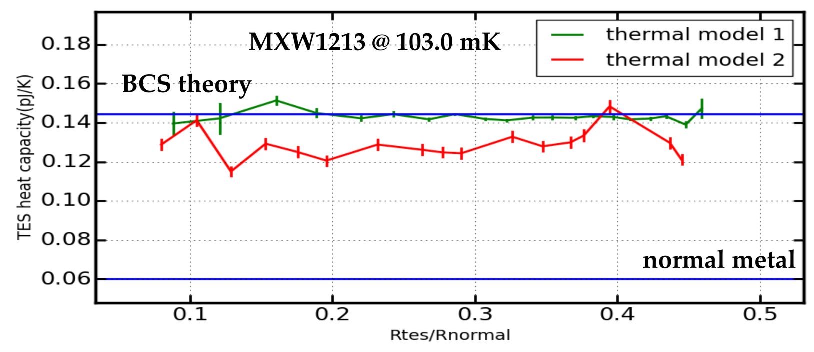




Compare α & β from IV curve with complex admittance fitting result



Heat capacity through transition



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Summary

1. We characterized two TES devices and compared them. The TES with no finger or bank structures is more sensitive to the magnetic field than the three finger TES, while the period of the fringes on the BI curve is about the same for both devices.

2.The IV curves of both devices show Shapiro steps when a high frequency external field is applied. More Shapiro steps are visible on the zero finger TES IV curve than the three finger TES.

3.The simple thermal model with only one time constant can't fit the complex admittance very well. The fitting results give smaller α compared with IV curve. The two block thermal model yields a better fit.