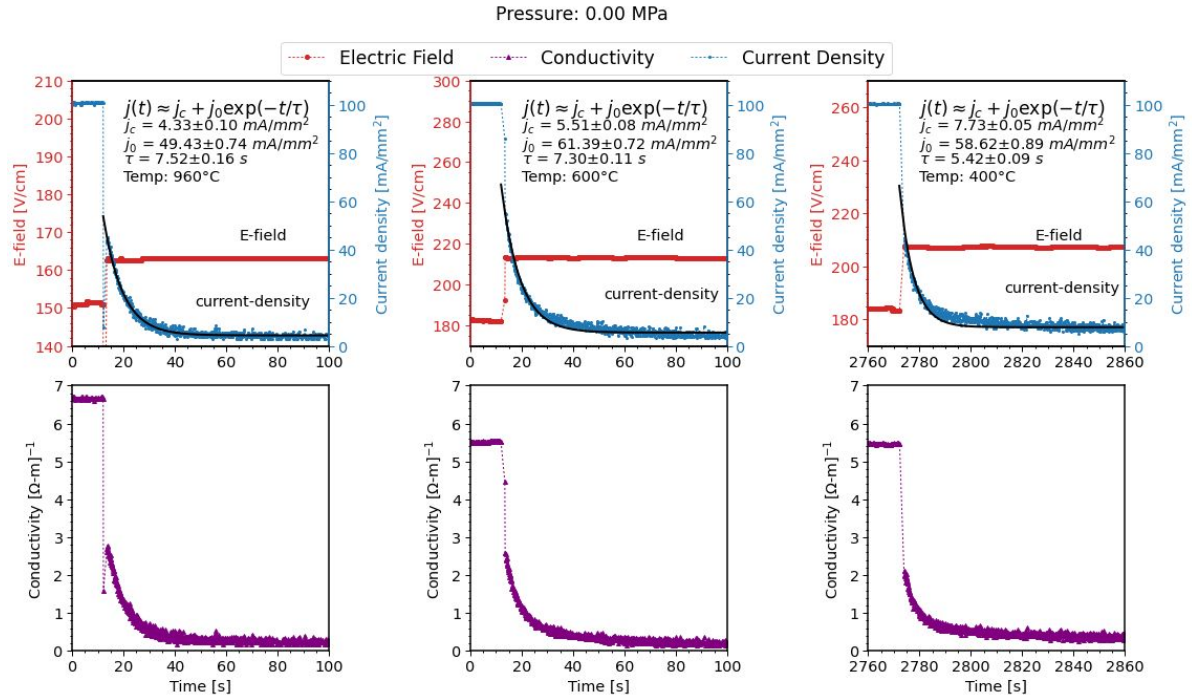


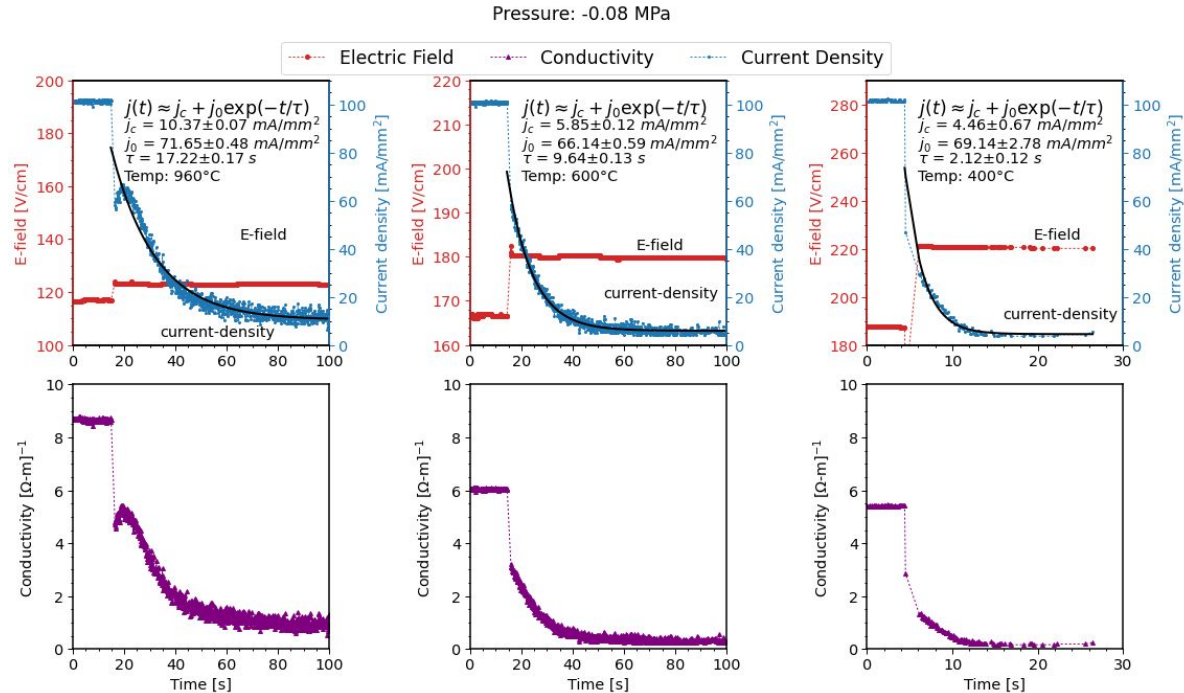
# Flash Relaxation of $\text{TiO}_2$ in Air

Figure 1: From this figure we can see the fitted data for current density and conductivity. Differing from the previous data set we see 960°C as decaying the slowest and 400°C decays the fastest. The time frame for the decay based on the fit varies by about 1 or 2 seconds for 600°C and 400°C while the time frame for 960°C varies by about 4 seconds.



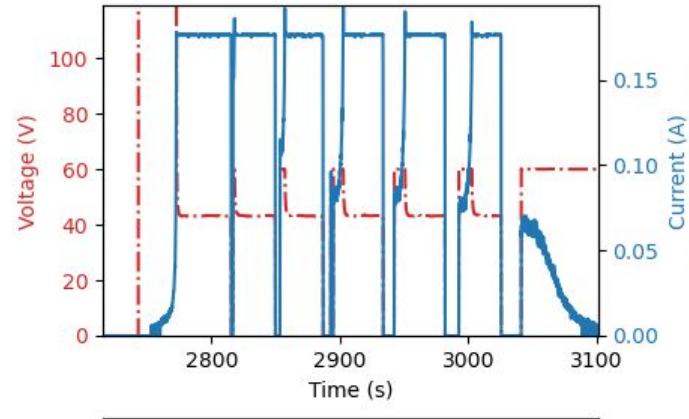
# Flash Relaxation of $\text{TiO}_2$ in vacuum

Figure 2: From this figure we can see the decay times for the fitted data while the crystals were under a vacuum pressure of -0.08MPa. The data agrees pretty well with the data from the previous set again with small variation in decay times but with a similar trend that 960°C takes much longer to decay in vacuum than in air and 400°C is much faster in vacuum than in air. With 600°C be pretty similar in decay times in vacuum and in air, with a deviation of about 2 seconds.



## Flash Restart at 900°C

Figure 3: This figure shows Flash being restarted at a constant electric field after different intervals of time at 900°C. The shown excerpt varies the time that the crystal is allowed to decay out from being in a flash state from 1 second to 15 seconds and then an electric field 1.4x the constant field it settles into once it reaches 100mA/mm<sup>2</sup>. The constant field is 168.25 V/cm. The crystal restarts after 1,3,5,10, and 12 seconds when a field of 235.5V/cm is applied. After 15 seconds it no longer restarts and just begins to decay to 0. This field is a little less than half the 500V/cm required to restart the flash after a long period of time.





## Possible things we learned about Flash

The results from this trial agree pretty similarly to the previous trial where we see the decay time in air to be pretty similar for all trials with small changes from the previous trial. When it comes to comparing the data in air versus the data in vacuum we can see the same trends. The decay time at high temperature, 960°C, is much slower in vacuum than in air and the decay time at low temperature, 400°C, is faster in vacuum than in air. With the decay time at 600°C still being longer in vacuum than in air but not much longer. When it comes to the electric field required to restart flash after 1 second, I can confidently say that it is much less than the required field to restart flash after a long stretch of time. After a 1 second delay in 900°C in air I was able to restart the flash with a field of 210.3 V/cm. Under these same conditions I let the crystal sit after I turned the power supply off for 5 minutes and then slowly turned the field back on. When I did this the crystal began to flash once it reached an electric field of 475V/cm. This is more than double the required field to turn the flash back on after a 1 second delay.

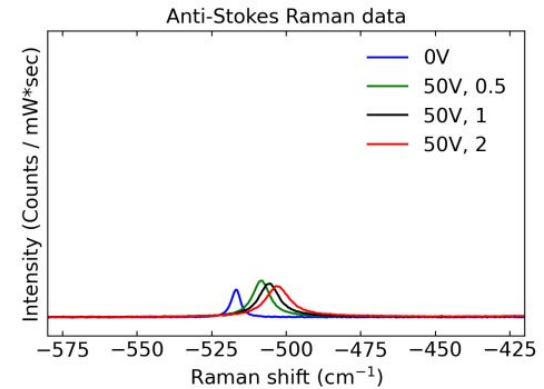
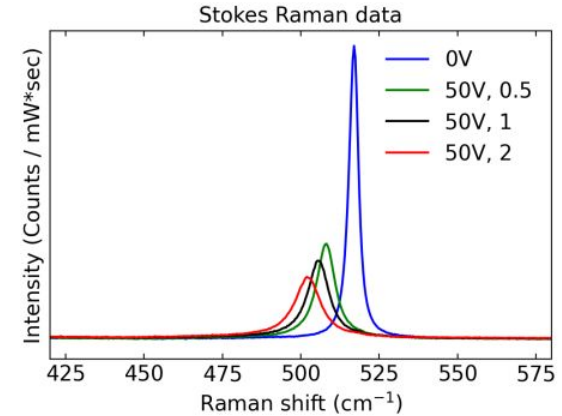


## Raman Analysis “Flashing” Si

From performing a Raman analysis on a sample of flashing Si we were able to learn that, at least in Si, the current flowing through the crystal does not affect the phonon in Si. Instead it just heats the sample up which is the change we see in the Raman spectra.

## Stokes and Anti stokes

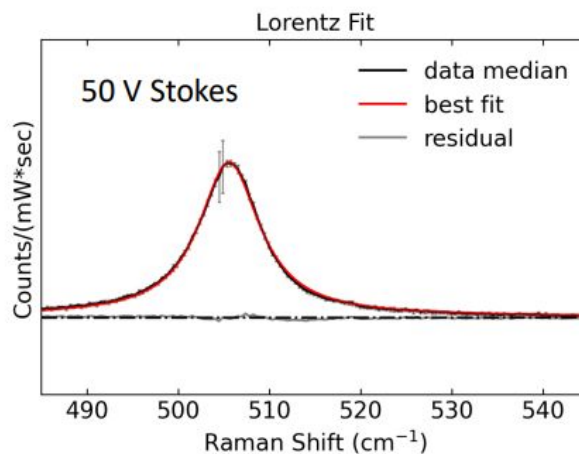
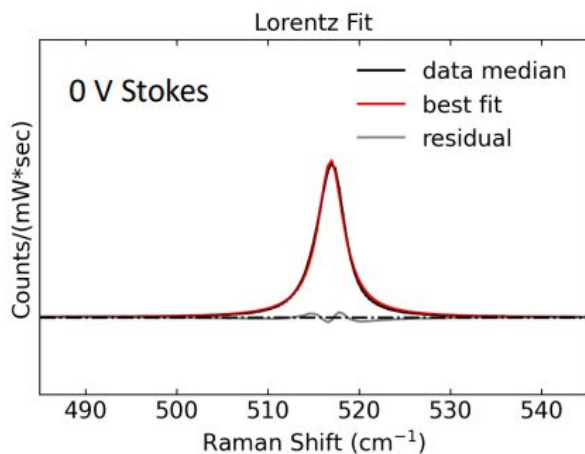
From the graph of the stokes and anti-stokes we can see a clear change in the spectra when the current density is changed ( $1 = 100 \text{ mA/mm}^2$ ,  $2 = 200 \text{ mA/mm}^2$ ,  $0.5 = 50 \text{ mA/mm}^2$ ). There is a clear trend that can be seen as the current density decreases the Raman shift increases in the Stokes data and the opposite is true in the Anti-Stokes data.



Energy gain

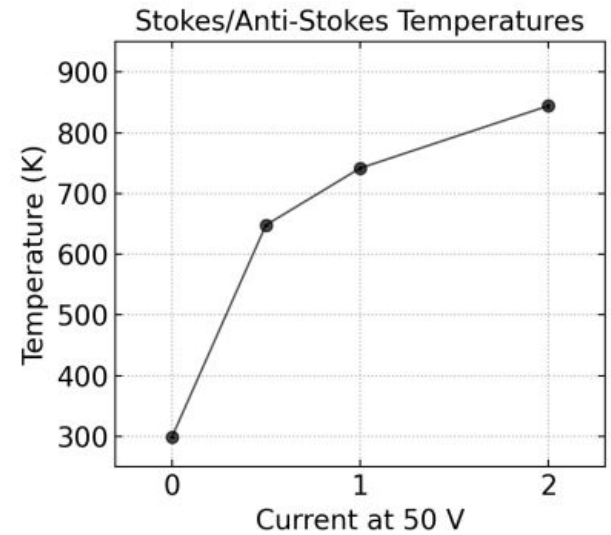
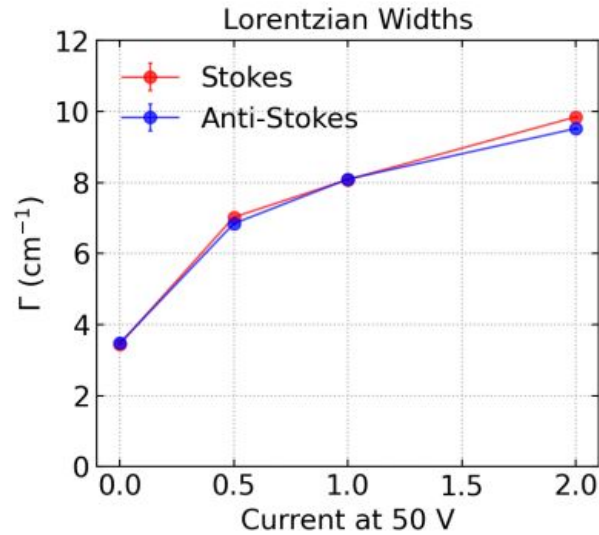
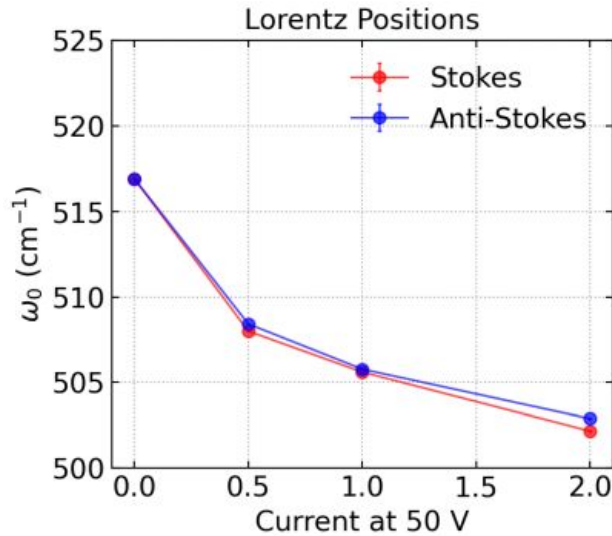
# Lorentz Fits

Lorentz fits



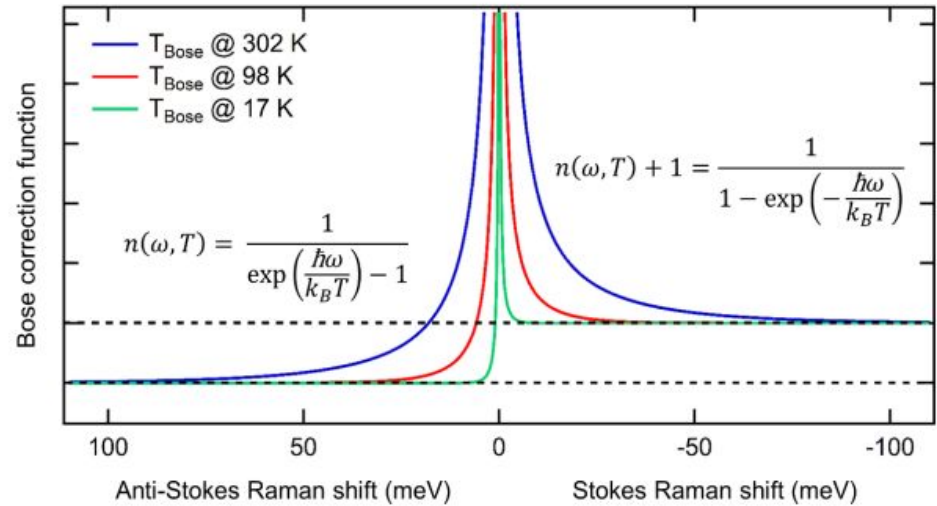
$$\frac{A_m \omega \Gamma_m^{Pho}}{(\omega^2 - \omega_{0,m}^2)^2 + \Gamma_m^2 \omega^2}$$

## Positions Widths and Temps compared to current





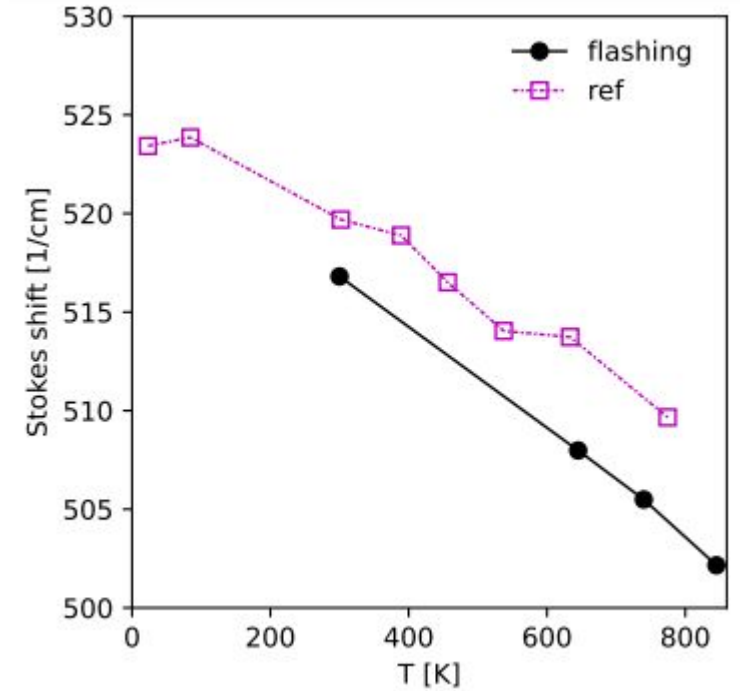
# Bose Functions



$$\frac{I_{\text{AS}}(\Delta E)}{I_{\text{S}}(\Delta E)} = \left(\frac{E_l + \Delta E}{E_l - \Delta E}\right)^4 \exp\left(-\frac{\Delta E}{k_B T}\right)$$

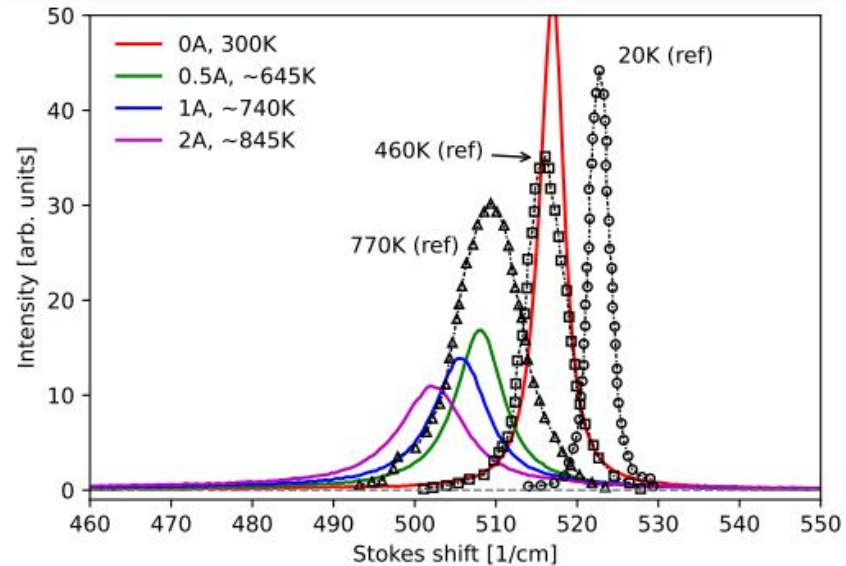
## Comparison of position vs Temp with PBR Paper

When comparing with the PBR [paper](#) on the temperature dependence on Raman Scattering in Si we see that the results agree pretty well. The linear nature and the slope of the line is the same but there is some dampening of the shift from our data compared to the reference data, this may have to do with some of the effects from flash.

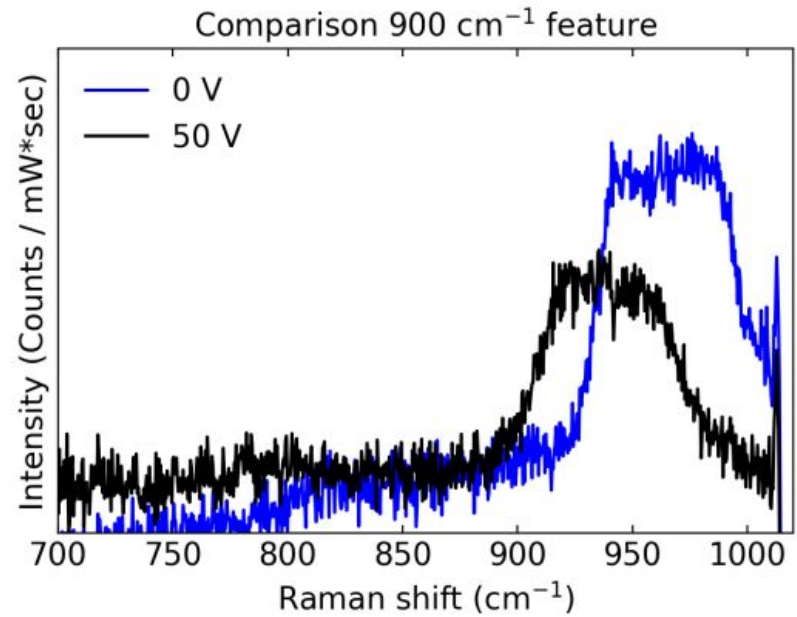
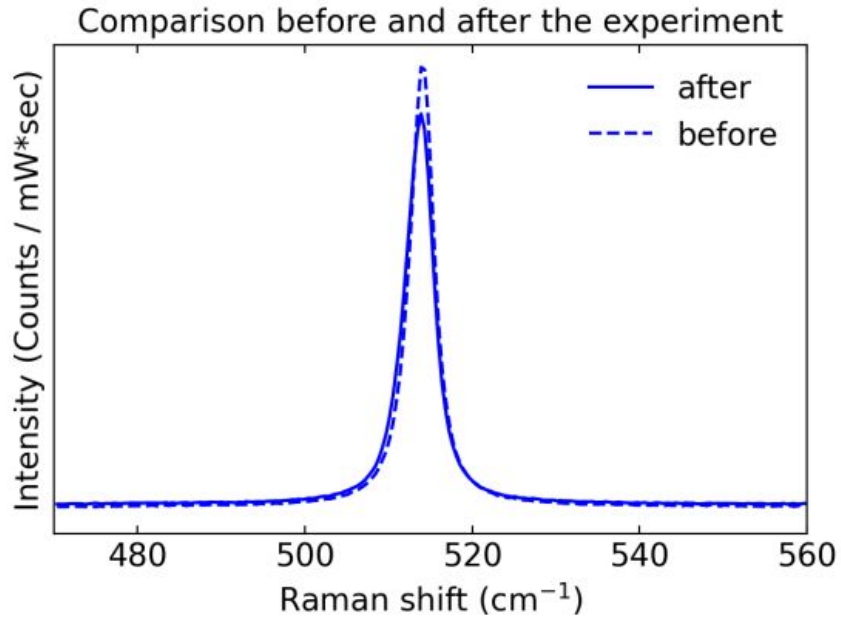


## Comparing peaks to the reference

In this comparison between the peaks we can also see the slight damping and shift that may be caused by the flash effects.

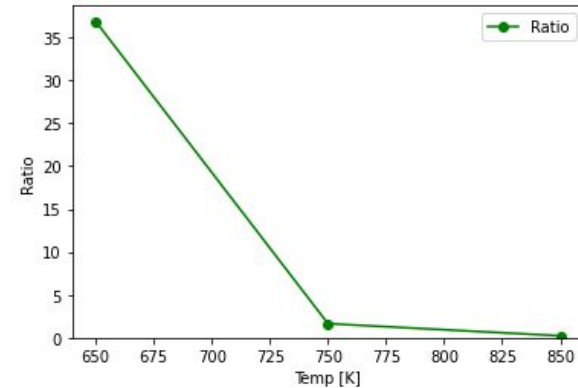
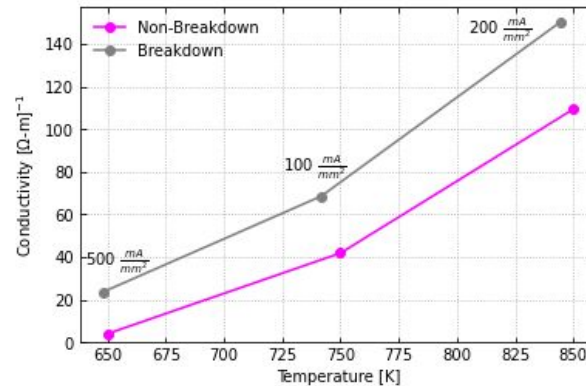


## Position of Phonon before and after



# Conductivity Vs Temp in a flashing sample and non flashing sample

We are weaning off using the term flash as we think this is just avalanche breakdown. The sample that was flashing had a higher conductivity at the same temperature than the samples that were not flashing or hadn't reached breakdown yet. The samples were at the same temperature as one another the difference is just that one was going through avalanche breakdown and had a larger current density while the other was not allowed to reach the breakdown threshold.



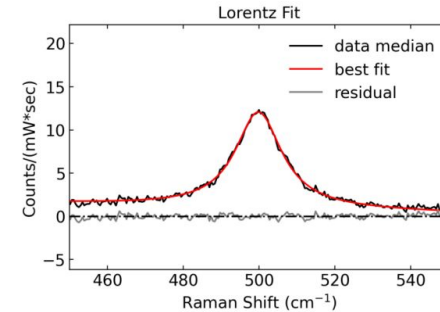
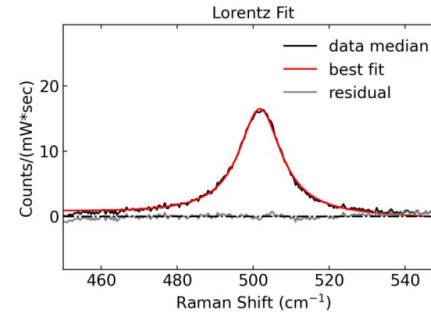
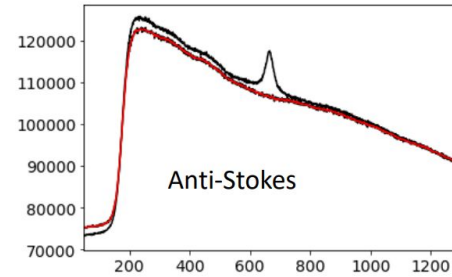
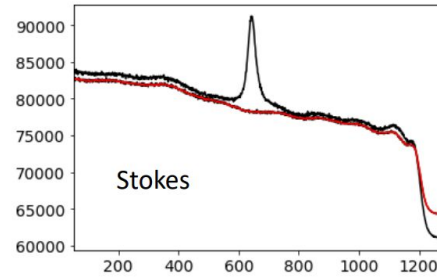


## What we did with this information

With this we decided to glue a piece of Si onto a larger piece of  $\text{TiO}_2$  in order to figure out what the temperature of the Flashing  $\text{TiO}_2$  is.

## Si on TiO2 Temp analysis

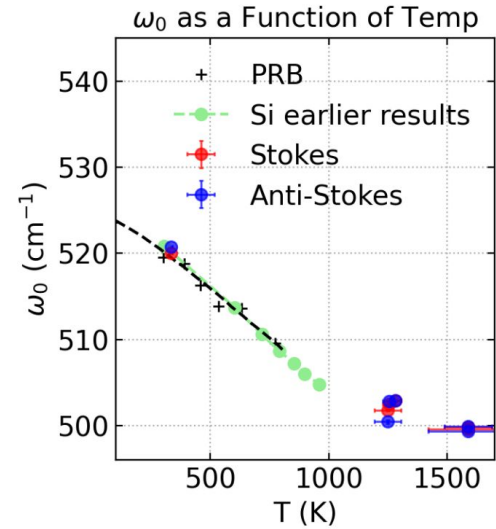
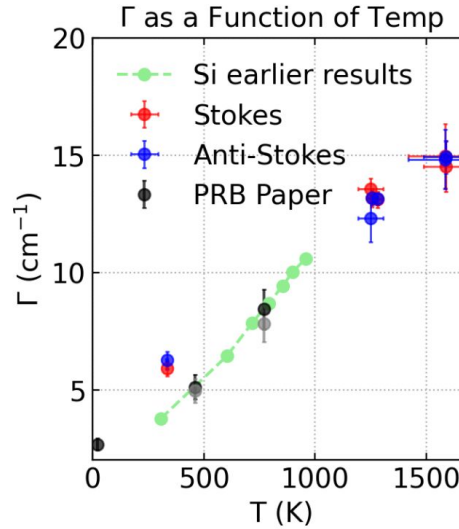
There was strong background noise due to the glow of the TiO2 but once subtracted we can see the phonon pretty well



$$-\text{Im}(D^0(\omega)) = -\text{Im}\left(\frac{\omega_0}{\omega^2\omega_0^2 + i\Gamma\omega_0}\right) \Rightarrow A \cdot \frac{\Gamma\omega}{(\omega^2 - \omega_0^2)^2 + \Gamma^2\omega^2}$$

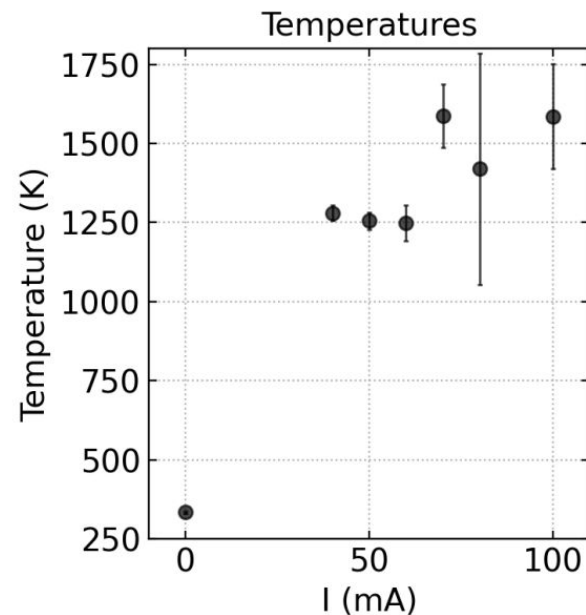
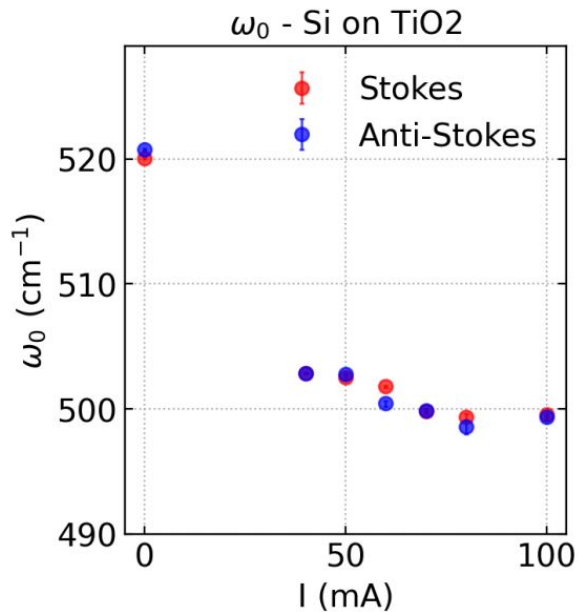
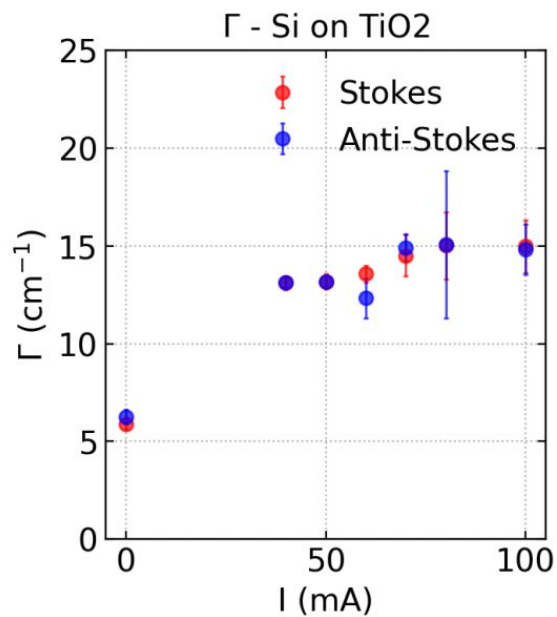
## Stokes Anti-Stokes and Temp data compared to paper

We generally follow along the trend that we saw in the paper and in our previous trials with just Si





## Temp and Current Graphs





Temp Data Raw

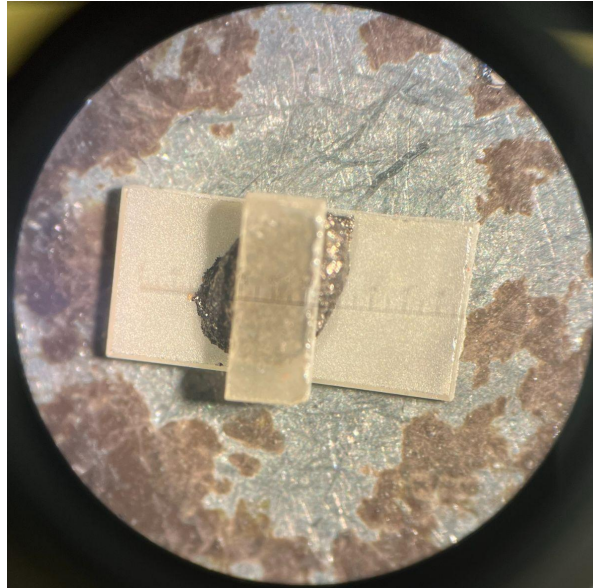
Temperature results:

0 mA	$333.97 \pm 1.49$ K
40 mA	$1280.37 \pm 7.89$ K
50 mA	$1255.22 \pm 8.76$ K
60 mA	$1248.58 \pm 18.87$ K
70 mA	$1588.00 \pm 33.24$ K
80 mA	$1419.47 \pm 121.72$ K
100 mA	$1586.08 \pm 55.47$ K

## TiO<sub>2</sub> Glued on Flashing TiO<sub>2</sub> Vacuum

### Pristine Sample

The pristine sample starts off in a semi-transparent and an off white color

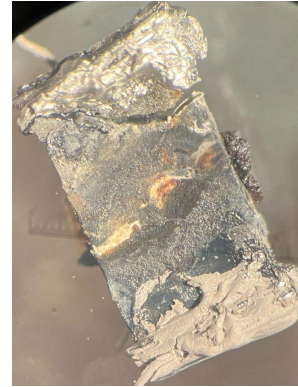
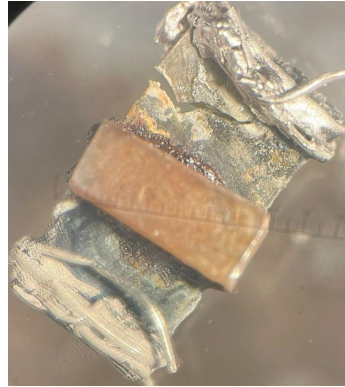


## After Flash and cool in Vacuum

I flashed the sample with a voltage of 100 V at 600 C under a vacuum of -0.08 MPa. Once the flash initiated I turned off the heat in the furnace and allowed the sample to cool with the furnace under vacuum while it was still flashing.

The base of the sample when cooled turned a dark blue and is no longer translucent at all while the top sample turned a rust red color and maintained its translucence

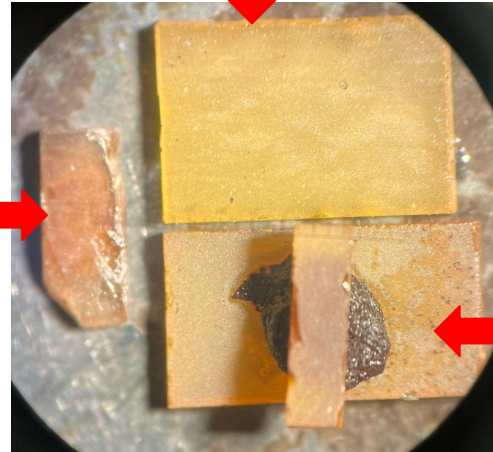
We can say with confidence that the base and the top were at the same temperature through the entire process showing that the structural changes in the  $\text{TiO}_2$  are due to the presence of both an electrical current and heat.



## Pure heating of $\text{TiO}_2$ in Furnace Under Vacuum

I heated 2 samples at 1250 K under vacuum. One sample was an untampered cut of  $\text{TiO}_2$ , and one sample had a smaller piece of  $\text{TiO}_2$  glued on top of it to see if that affected the color of the sample after heating.

Top Sample  
from  
Flashed  
trial



No Glue no top sample

Glue and Top  
Sample