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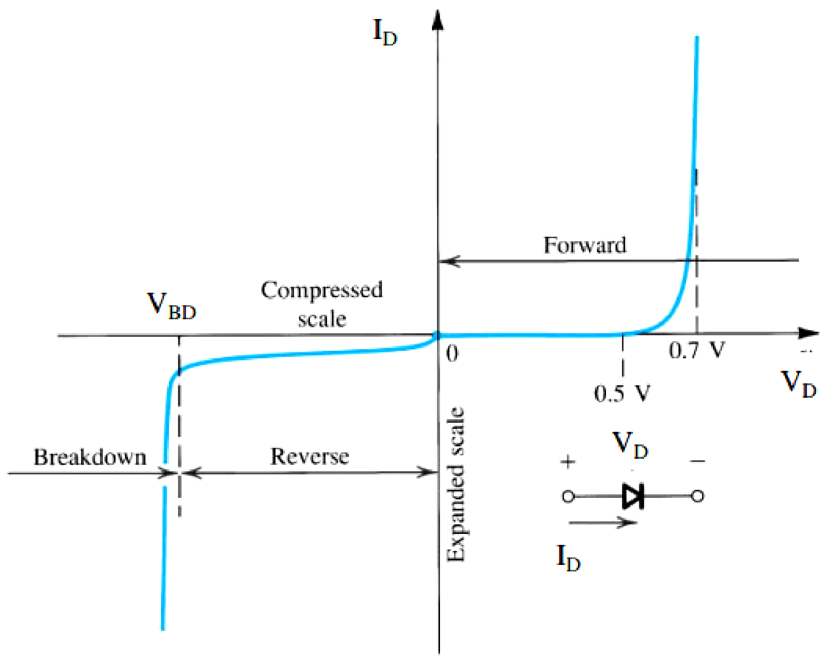
Lab 10

Figure 1. I-V characteristic of a diode.

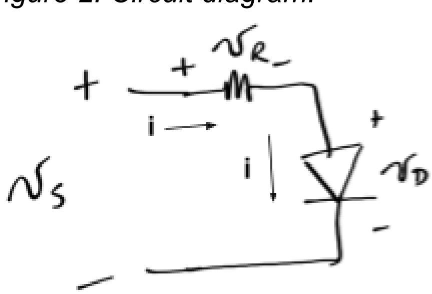


Given the graph above, it does make sense that for applied voltages between -5V and 5V, a) when the diode sees a voltage that is (-) or below the threshold, there is no current flowing and the diode acts like an open circuit; and b) if it sees a voltage at or above the threshold, there is almost no resistance, and it acts like a short circuit.

On the graph, when V_D is negative or below the diode's threshold voltage, the resistance in the diode is very high. The applied voltage isn't enough to create adequate electron-hole pairs which would increase the diode's conductivity and allow current to flow through it, so there is basically no current flowing through the diode.

When V_D is at or above the diode's threshold voltage, the applied voltage is enough to create lots of electron-hole pairs, so the diode becomes extremely conductive. It has very little resistance, so current can flow through it extremely easily.

Figure 2. Circuit diagram.



V_S = 5sin(500*2*pi*t)

R = 330 Ohms

Figure 3. Built circuit.

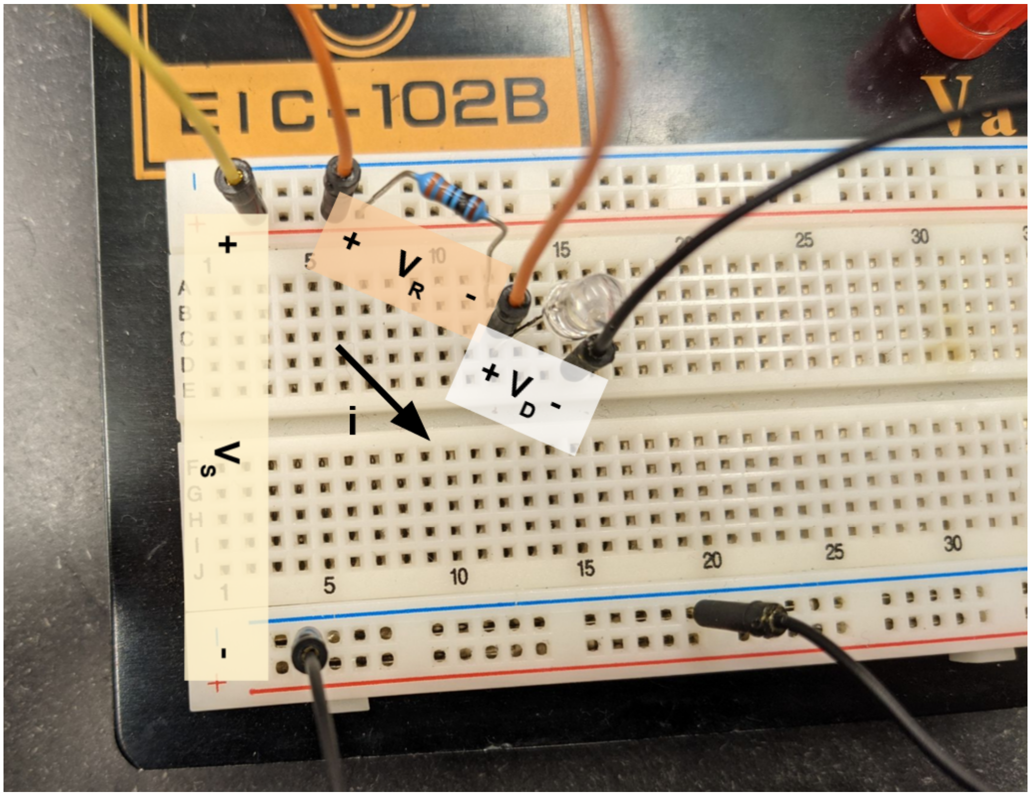
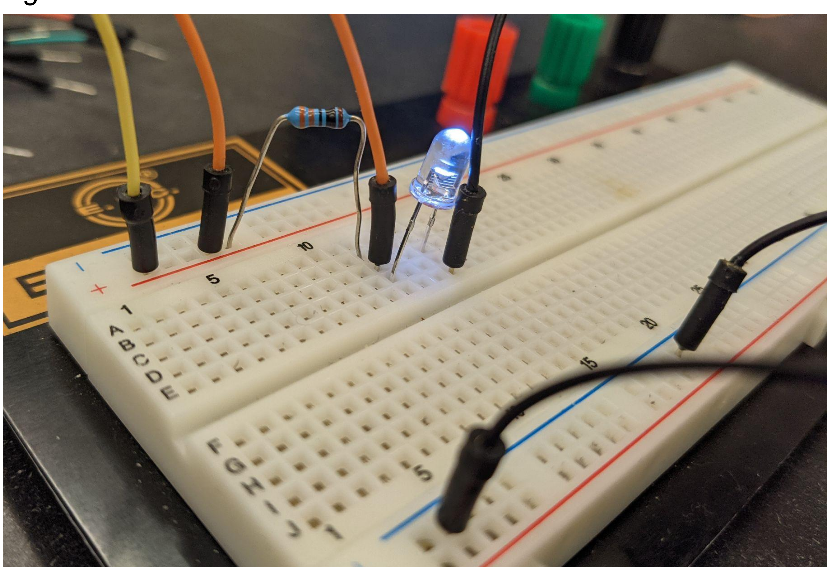
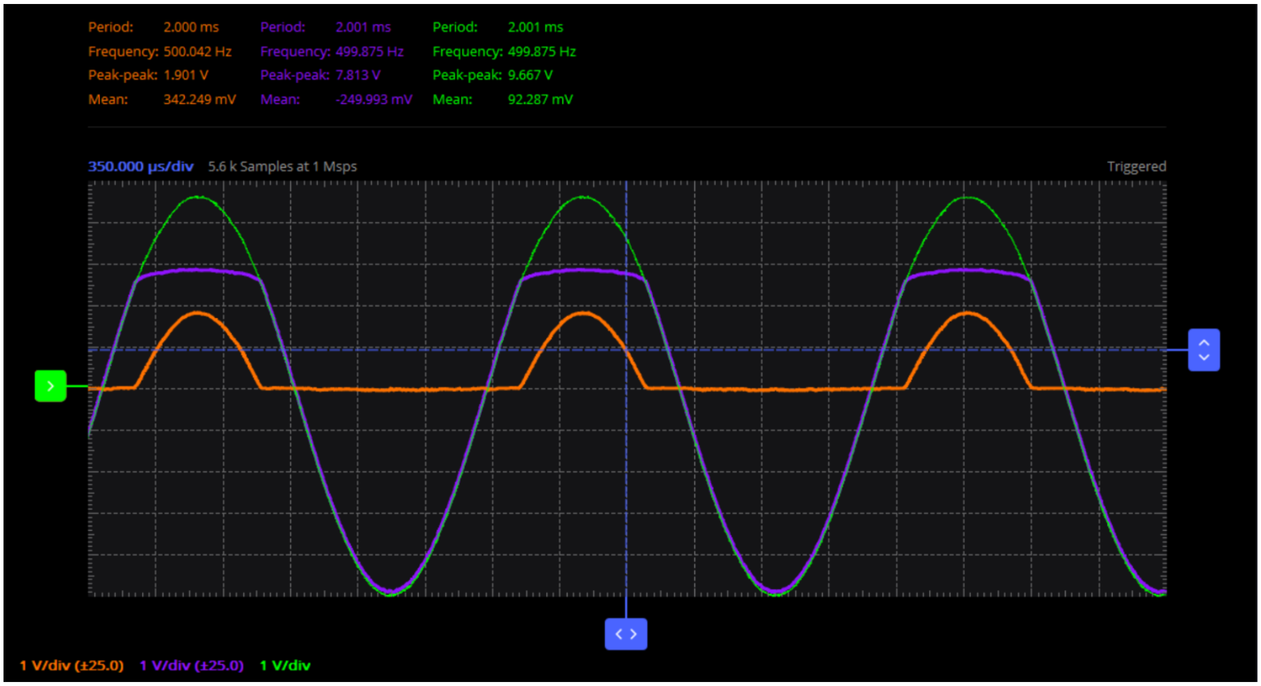


Figure 4. Illuminated LED.



In Scopy, V_S was supplied by channel 1 of the wave generator. V_R was measured with channel 1 of the oscilloscope (shown in orange). V_D was measured with channel 2 of the oscilloscope (shown in purple). V_S was calculated using a math channel in the oscilloscope to sum V_R and V_D according to Kirchhoff's Voltage Law (shown in green).

Figure 5. V_R, V_D, and V_S vs time over three cycles.



The shapes of these voltages make sense. When the source voltage is at its highest, so are the voltages across the resistor and the diode. By KVL, it makes sense that an increase in the source voltage would lead to an increase in the component voltages. The math channel summing V_R and V_D to simulate the source voltage looks like the same function as the source voltage (it has the correct frequency of 500Hz and p-p voltage of 10V), so the circuit is consistent with KVL. The voltage across the resistor is non-zero only when the source voltage is positive. The voltage across the diode is almost flat while the voltage across the resistor is increasing and decreasing. Additionally, the voltage across the diode is increasing and decreasing while the voltage across the resistor is flat.

There are portions of the graph where there is no apparent current flowing. By Ohm's law, voltage across the resistor is equal to current times resistance. The resistance is a constant 330 Ohms, so the portions of the graph where V_R equals zero must indicate zero current. In those portions of the graph, V_R = 0V and V_D= 0V to about -5V. Those are the portions of the graph with negative source voltages.

The portions of the graph where current is flowing are indicated by non-zero voltage across the resistor. In those portions of the graph, V_R = 0V to about +2V and V_D = 0V to about +3V. Those are the portions of the graph with positive source voltages.

Figure 6. No apparent current flowing when V_R = 0.

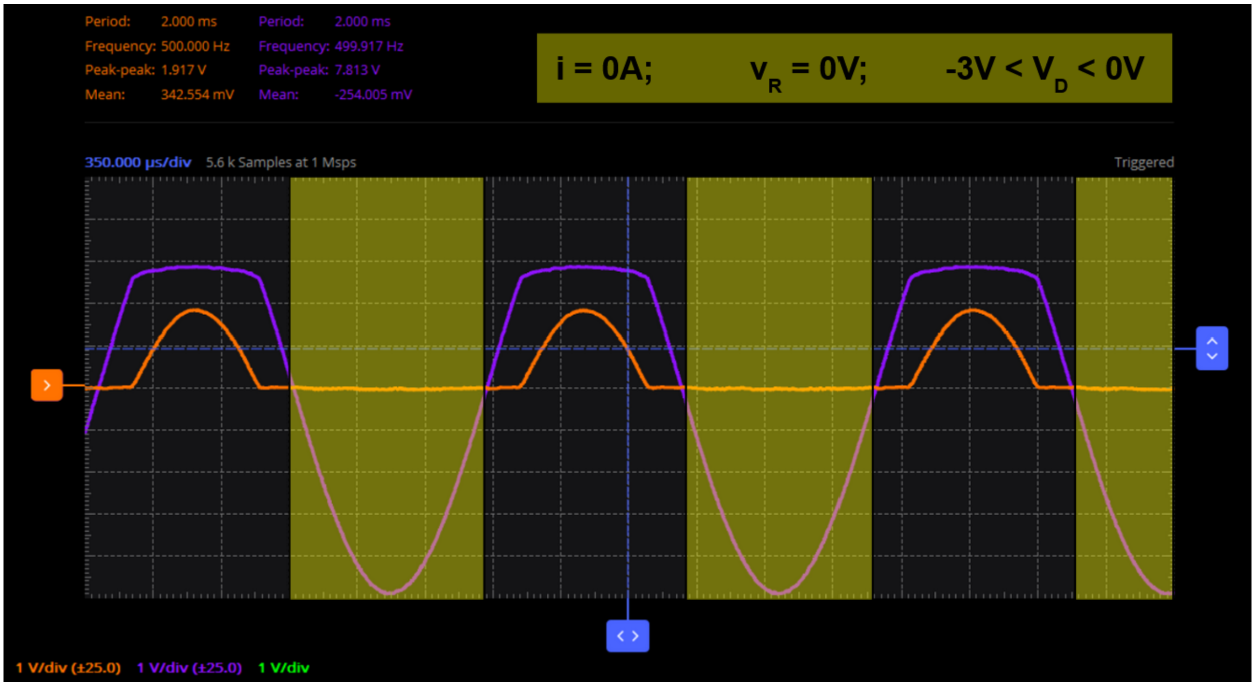


Figure 7. Current flowing when V_R > 0.

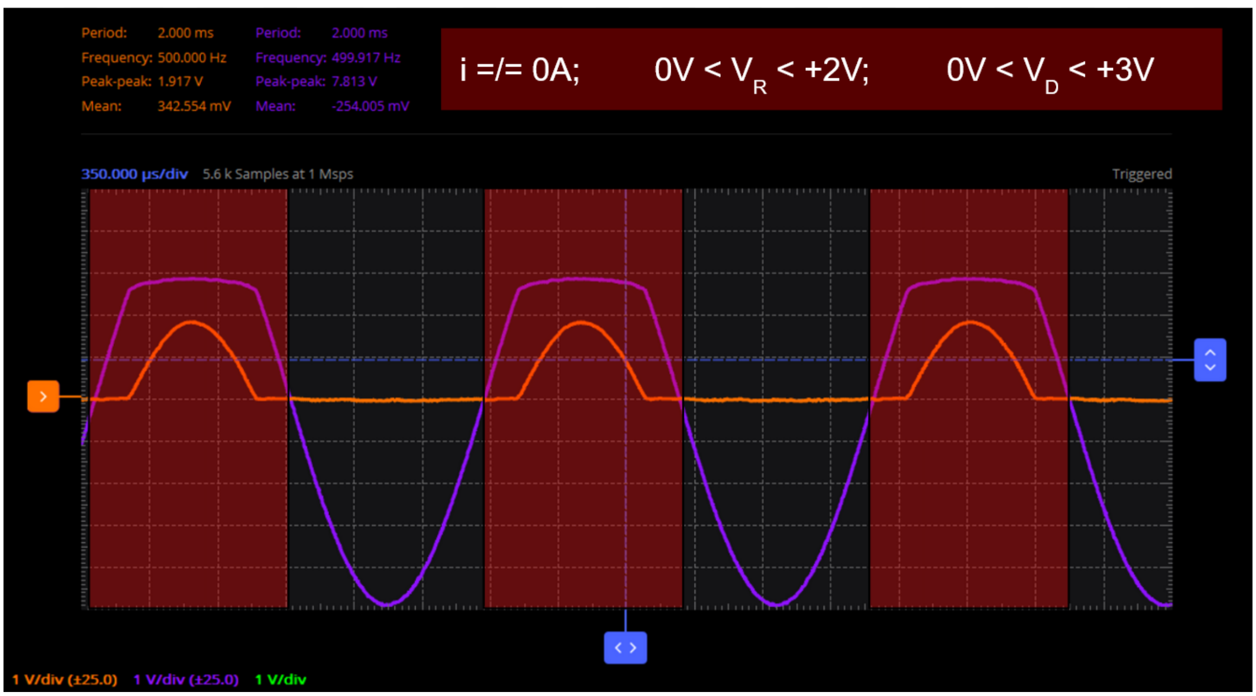
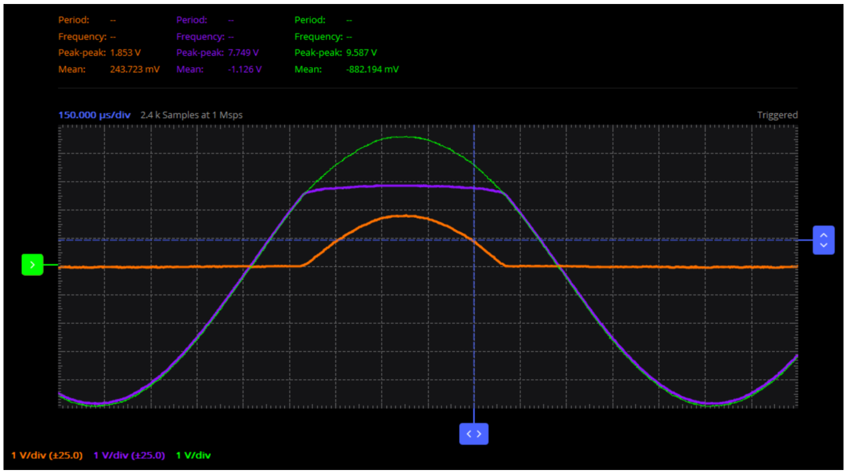


Figure 8. Comparison of V_R, V_S, and V_D when current is flowing over one cycle.

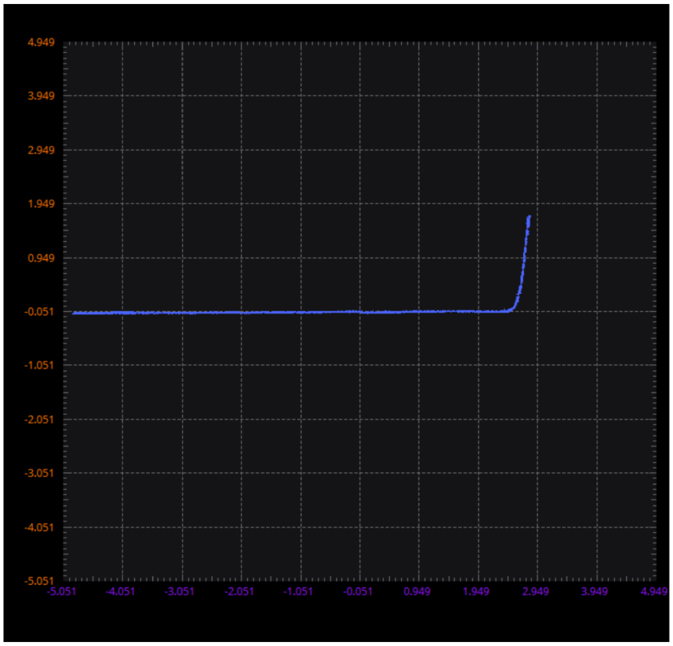


When current is flowing, V_R is less than V_S, though both have a very similar shape. V_D varies by very little - maybe by 0.3V or less.

After slowing down the frequency of the source voltage from 500Hz to 0.5Hz, the blinking of the LED was perceivable. This video shows the effect: https://youtu.be/3JfmbP6aIMU
0.5Hz is 1 cycle every 2 seconds. Based on observing the oscilloscope and the blinking LED, light is produced when current is flowing through the diode, so when the source is in the positive parts of its cycle.

An xy plot of V_R vs V_D has the same shape as an I-V characteristic of the diode, since V_R is proportional to I by a constant resistance. The produced plot does match the expected shape for a diode. Based on this plot, I would expect the diode's forward voltage to be between 2V and 3V.

Figure 9. V_R (orange) vs V_D (purple)



Using Python, the current I through the diode was calculated from Ohm's law, measured voltage across the resistor V_R, and known resistance R=330 Ohms. This calculated current was used to create a true I-V characteristic of the diode.

Figure 10. Python code used to calculate and plot the diode's I-V characteristic.

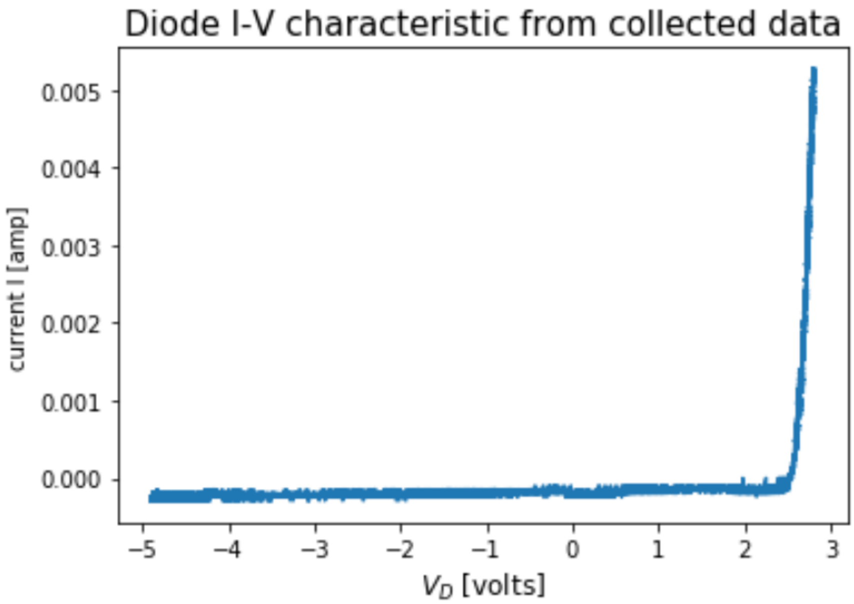
```
# import statements
import matplotlib.pyplot as plt
import numpy as np
```

```
# collected data
data = np.loadtxt('vd_vr_data.csv', skiprows=1, delimiter=',')
vr = data[:,2]    # volts
vd = data[:,3]    # volts
```

```
# calculate current --> vr = i * R
r = 330    # Ohms
i = vr / r
```

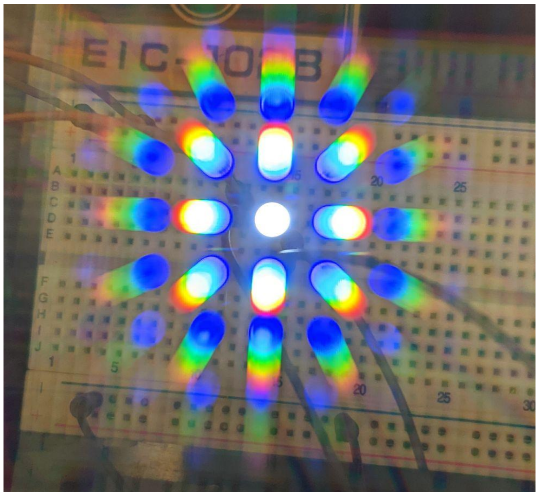
```
plt.title('Diode I-V characteristic from collected data', fontsize=15)
plt.xlabel('$V_D$ [volts]', fontsize=12)
plt.ylabel('current I [amp]')
plt.plot(vd,i,'-')
```

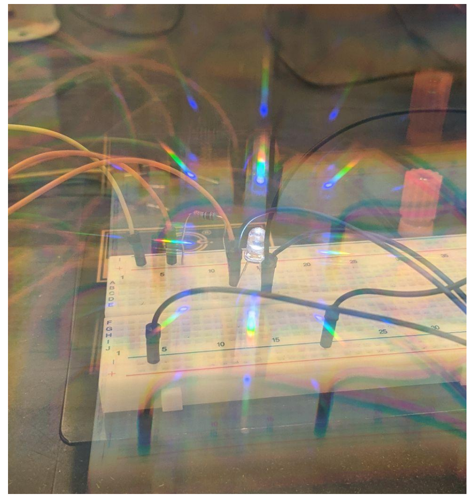
Figure 11. I-V characteristic from collected V_R, V_D data



This I-V characteristic matches the shape of the one created in Scopy, and also shows a forward voltage between 2V and 3V.

Figure 12. White LED viewed through lazer glasses from above (left) and at an angle (right)





3D lazer glasses can be used to see the spectra of different light sources. Looking at the white LED through lazer glasses shows that its light is composed of all different colors, but that red, green, and blue are the main components.

In this video, the effects of distance from the light source as well as different light sources such as overhead fluorescent lights and natural light from a window are shown: https://youtu.be/saxey9Y445E

Figure 13. Circuit diagram for RGB diode.

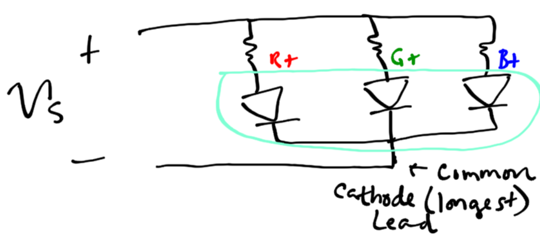
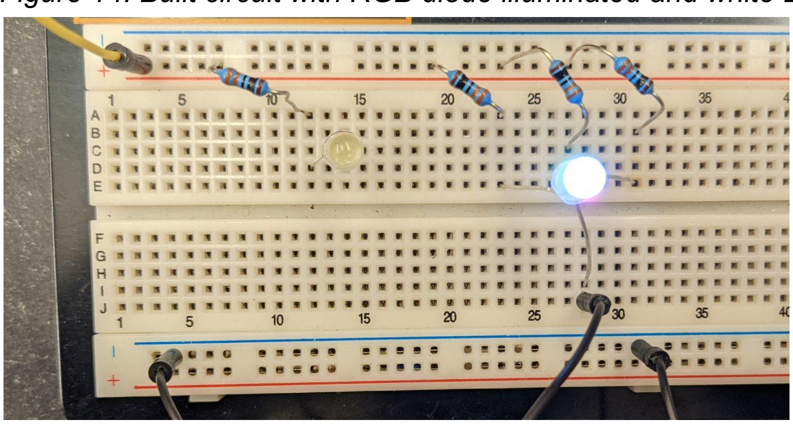
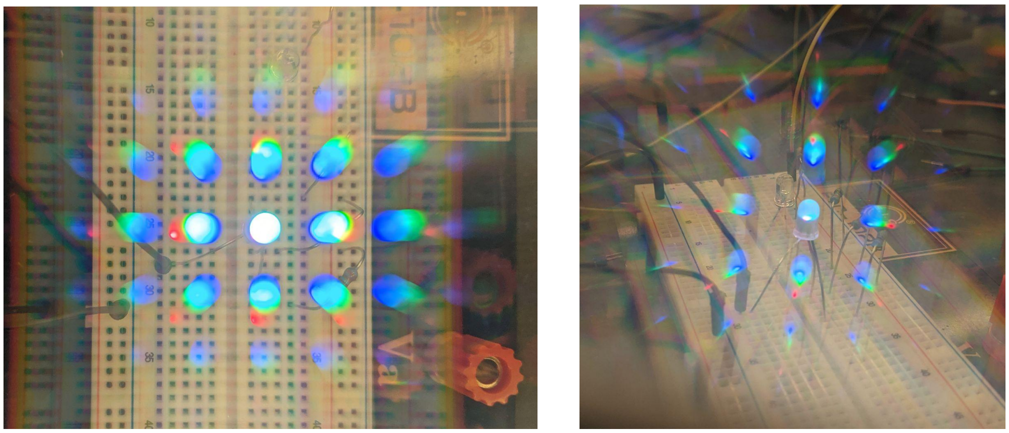


Figure 14. Built circuit with RGB diode illuminated and white LED disconnected from ground.



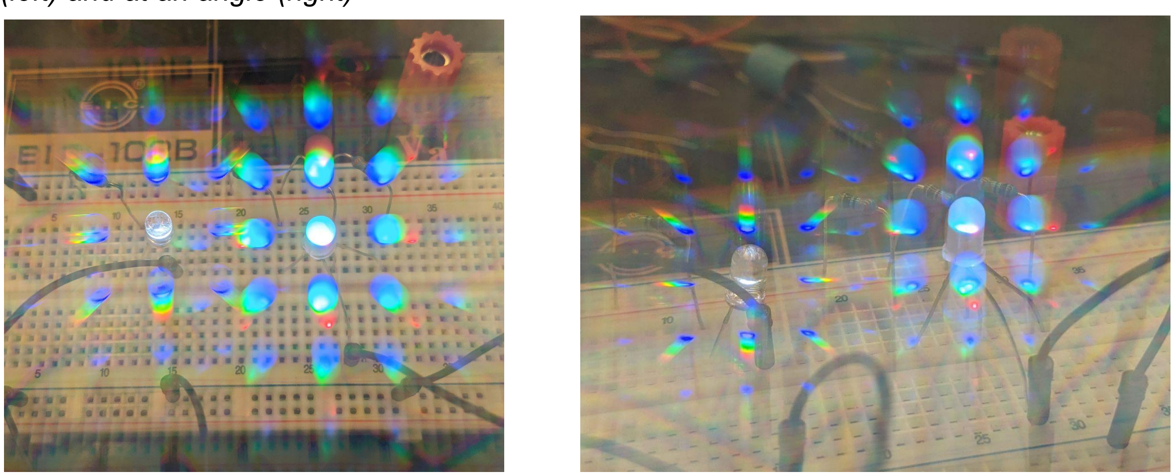
When the white diode was reconnected to ground, both the white diode and the RGB diode were illuminated. Both emitted mostly white light. The RGB diode was much brighter, and the quality of the light was more blue-green tinted than the pure white diode.

Figure 15. RGB diode viewed through lazer glasses from above (left) and at an angle (right)



Through the lazer glasses, it was clear that the spectrum of light emitted by the RGB diode only included red, blue, and green. As could be expected based on naked-eye observations, there seemed to be more blue and green present than red. In theory, if all three colored LEDs inside the RGB diode were receiving the exact same amount of current and were functioning identically, the RGB diode would emit completely white light. In contrast, the white LED's spectrum showed a full rainbow of colors and its red, green, and blue components seemed more balanced, so the light it emitted was much closer to true white.

Figure 16. Comparison of white LED and RGB diode viewed through lazer glasses from above (left) and at an angle (right)



An unrelated, but interesting, observation was that filming the two LEDs and adjusting the brightness of the picture could show high-frequency flickering of the LEDs that is imperceivable to the naked eye. This video shows the effect: https://youtu.be/qFXZ5BQksdI