

An underwater photograph showing a diver in the distance and a large piece of white plastic debris in the foreground. The water is clear blue, and the sun is visible through the surface, creating a bright glare. The overall scene highlights the issue of ocean plastic pollution.

# PlastiSense CDR

SDP Team 2

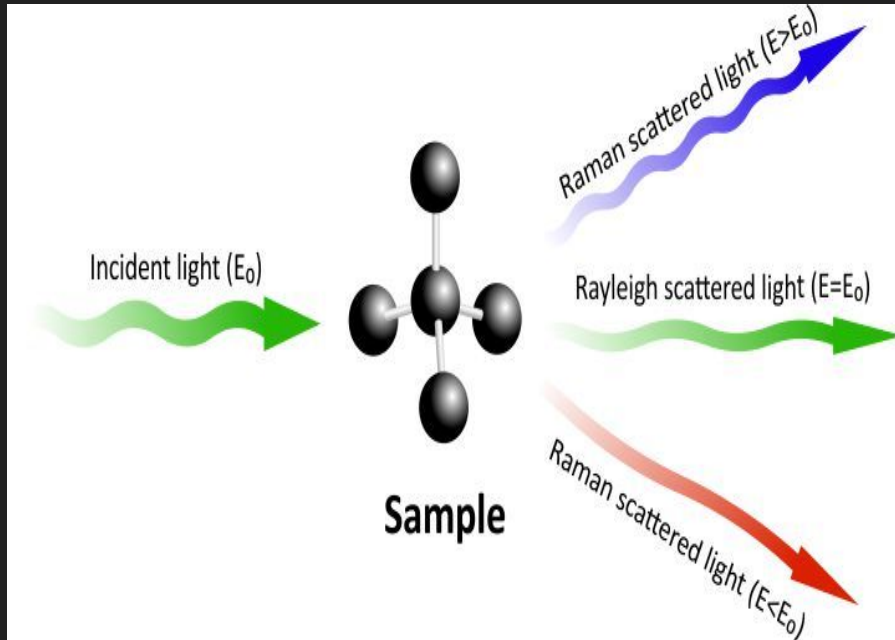
Aaron Achildiyev, Aidan Belanger, Victor Lam,  
Adrian Mora

# Problem Statement

- Did you know microplastics have been found in our rainwater and you could be consuming five grams of microplastics a week -- the equivalent to a credit card?
- This has been linked to negative effects on fertility and increased occurrences of cell mutations and cancer.<sup>1</sup>
- Find out the abundance of microplastics in your water with PlastiSense, an optics-based microplastic sensing device!

[1] [dalberg-advocacy-analysis\\_for-web.pdf](#)

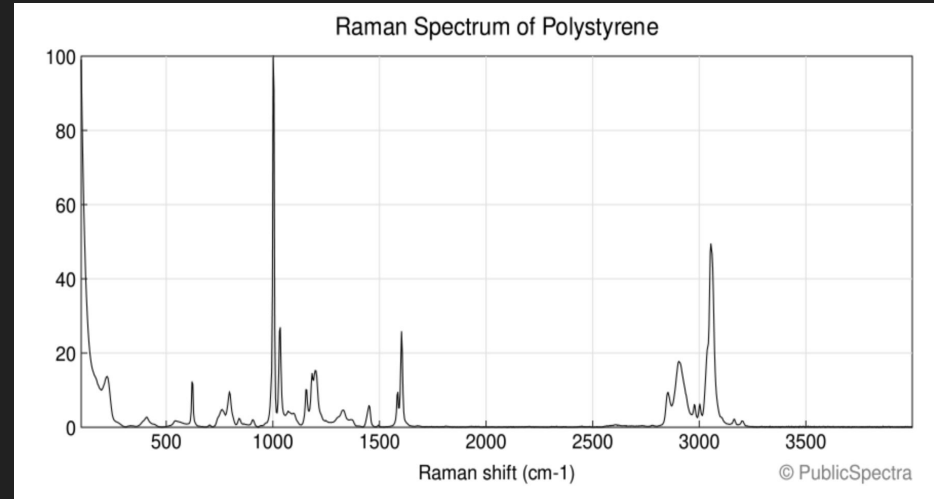
# What is Raman Spectroscopy?



- Raman spectroscopy utilizes an incident laser that points toward a molecular substance
- Affected by the incident laser, the molecule starts to vibrate and let off its own energy in the form of a Raman signal response
- The Raman signal is response is what is measured to detect specific molecules (e.g. polystyrene).

# Raman Spectrum

- We hope to obtain a conspicuous peak representing Raman shift, but we need to calculate in which frequency to expect it in.
- First we reference a Raman Spectrum from the PublicSpectra Online Database for our target molecule, Polystyrene.
- Then we use the spectrum for calculating the Raman shift. We expect 681 nm for Polystyrene if we excite it with a 633 nm laser.



# How Do We Know The Raman Wavelength is 681 nm?

633 nm =  $4.73 \times 10^{14}$  Hz (Excitation Wavelength)

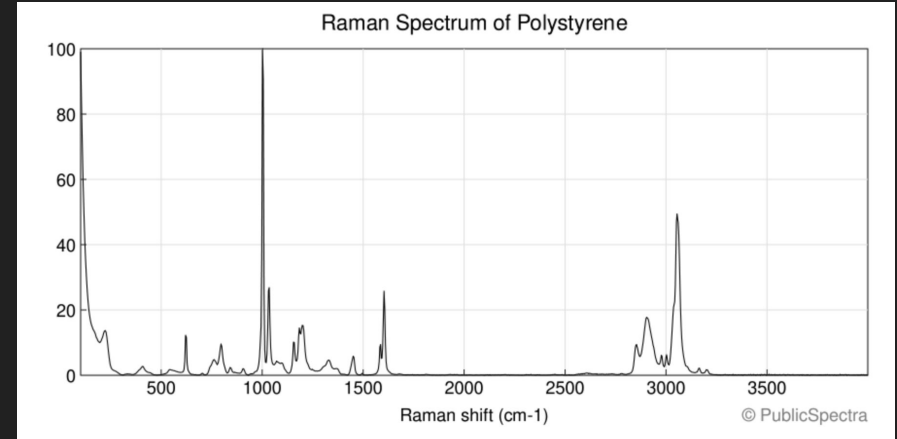
$1100 \text{ cm}^{-1}$  =  $3.30 \times 10^{13}$  Hz (Raman Shift)

Take the difference:  $f_1 - f_2 = f_3$

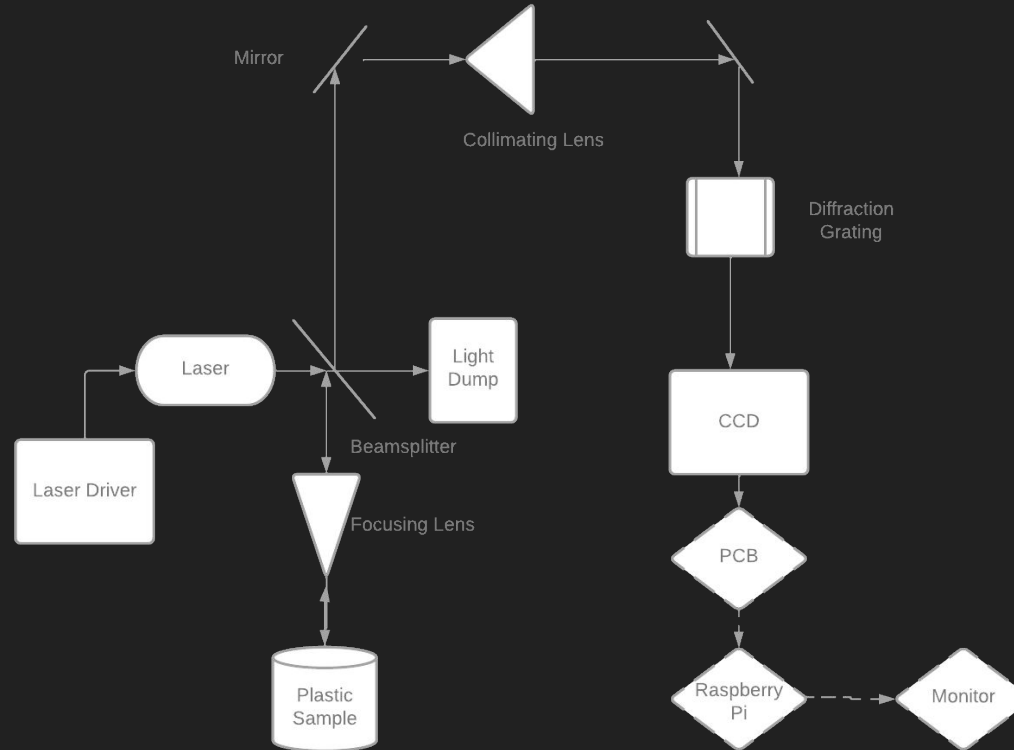
$4.73 \times 10^{14} \text{ Hz} - 3.30 \times 10^{13} \text{ Hz} = 4.4 \times 10^{14} \text{ Hz}$

$4.4 \times 10^{14} \text{ Hz} = 681 \text{ nm}$

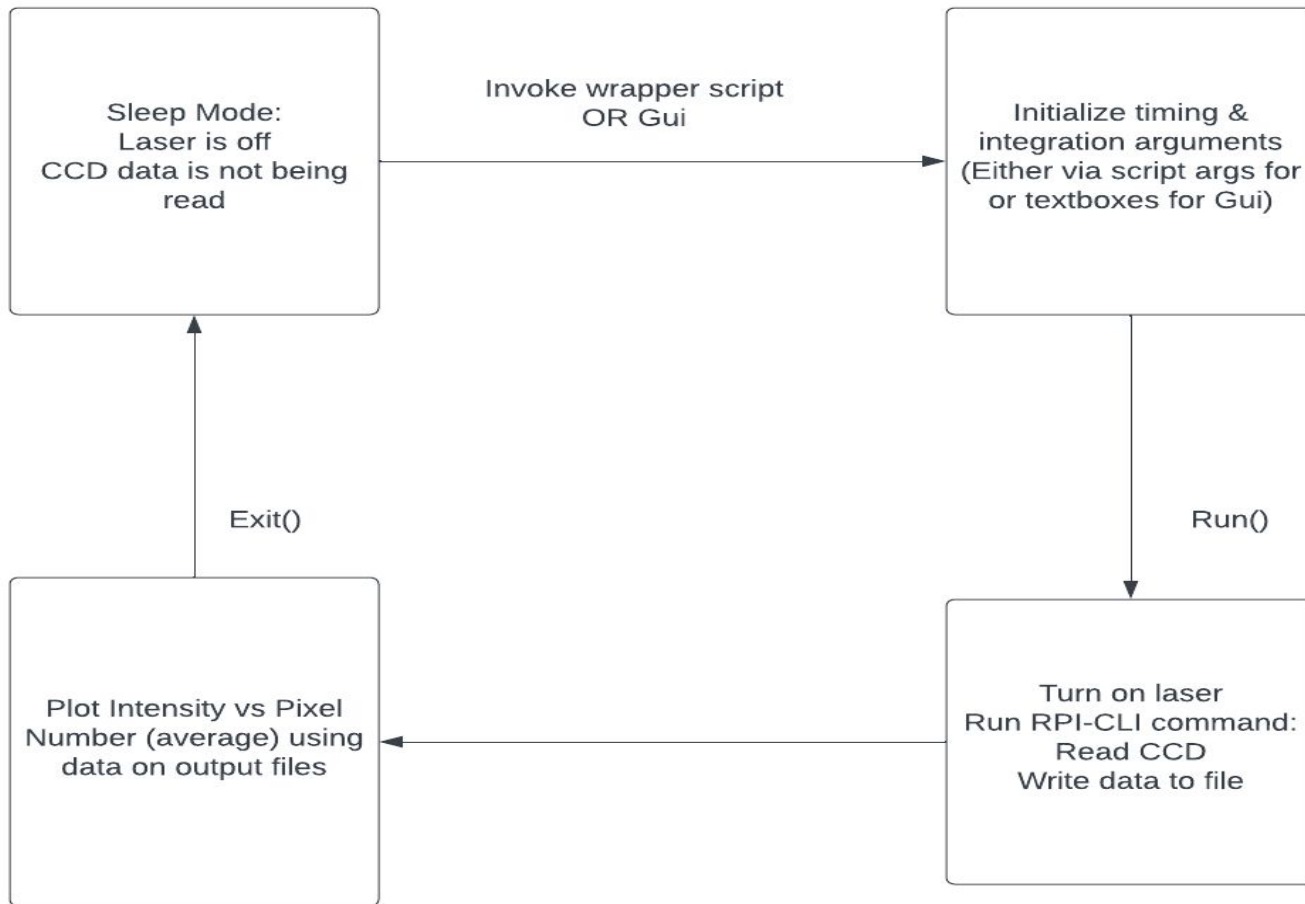
This means that we expect a Raman Signal at the far red section of the visible light spectrum



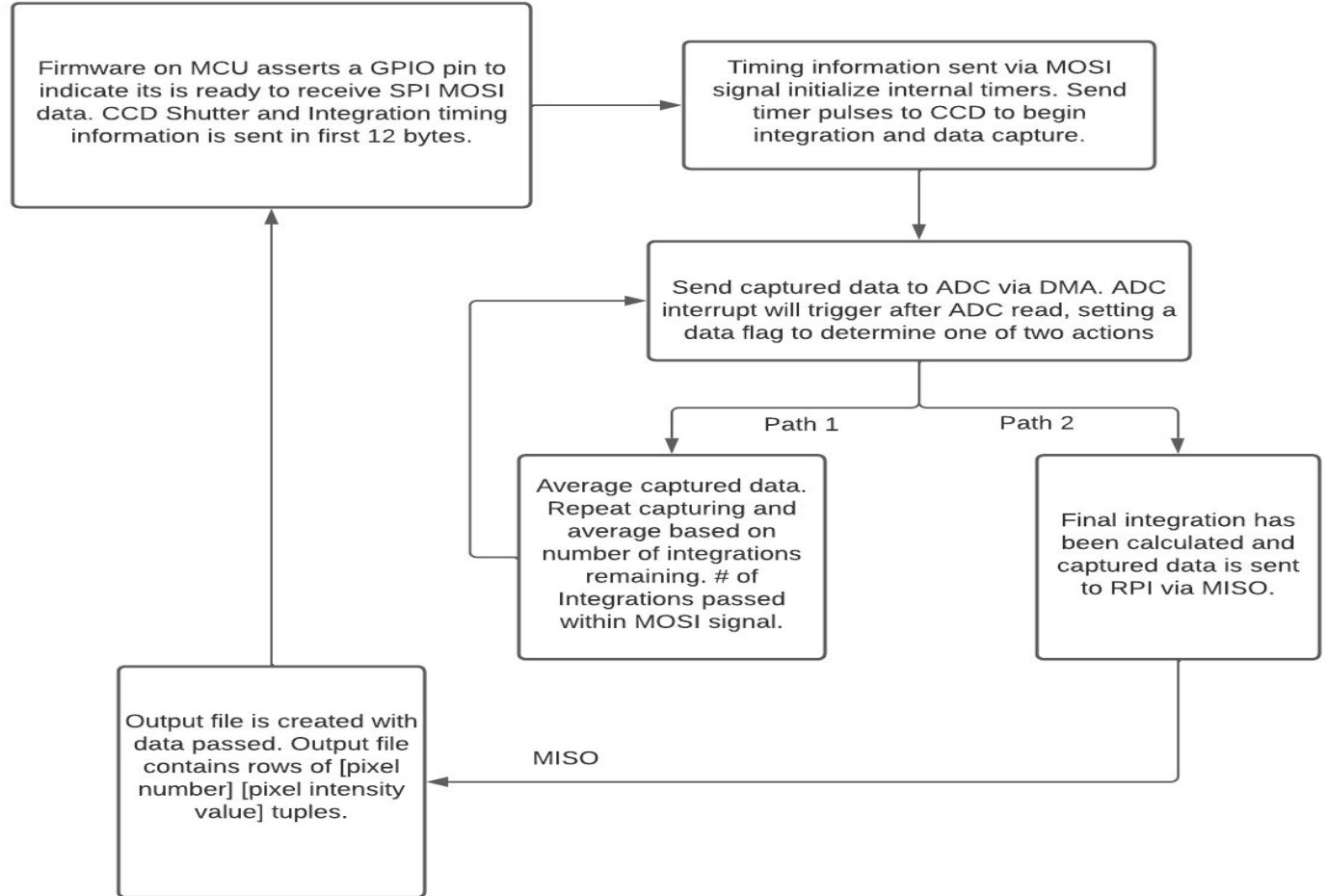
# Hardware Block Diagram



# Software Block Diagram

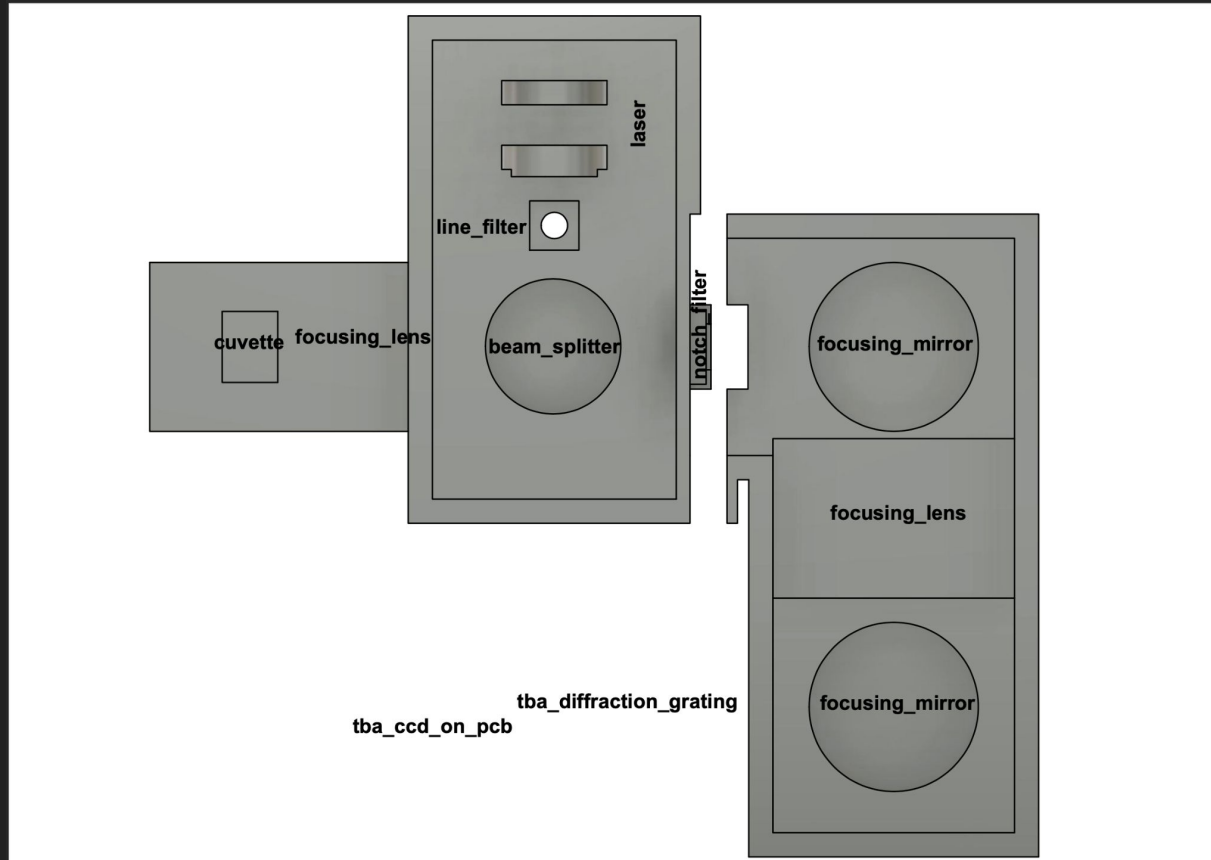


# Firmware Block Diagram





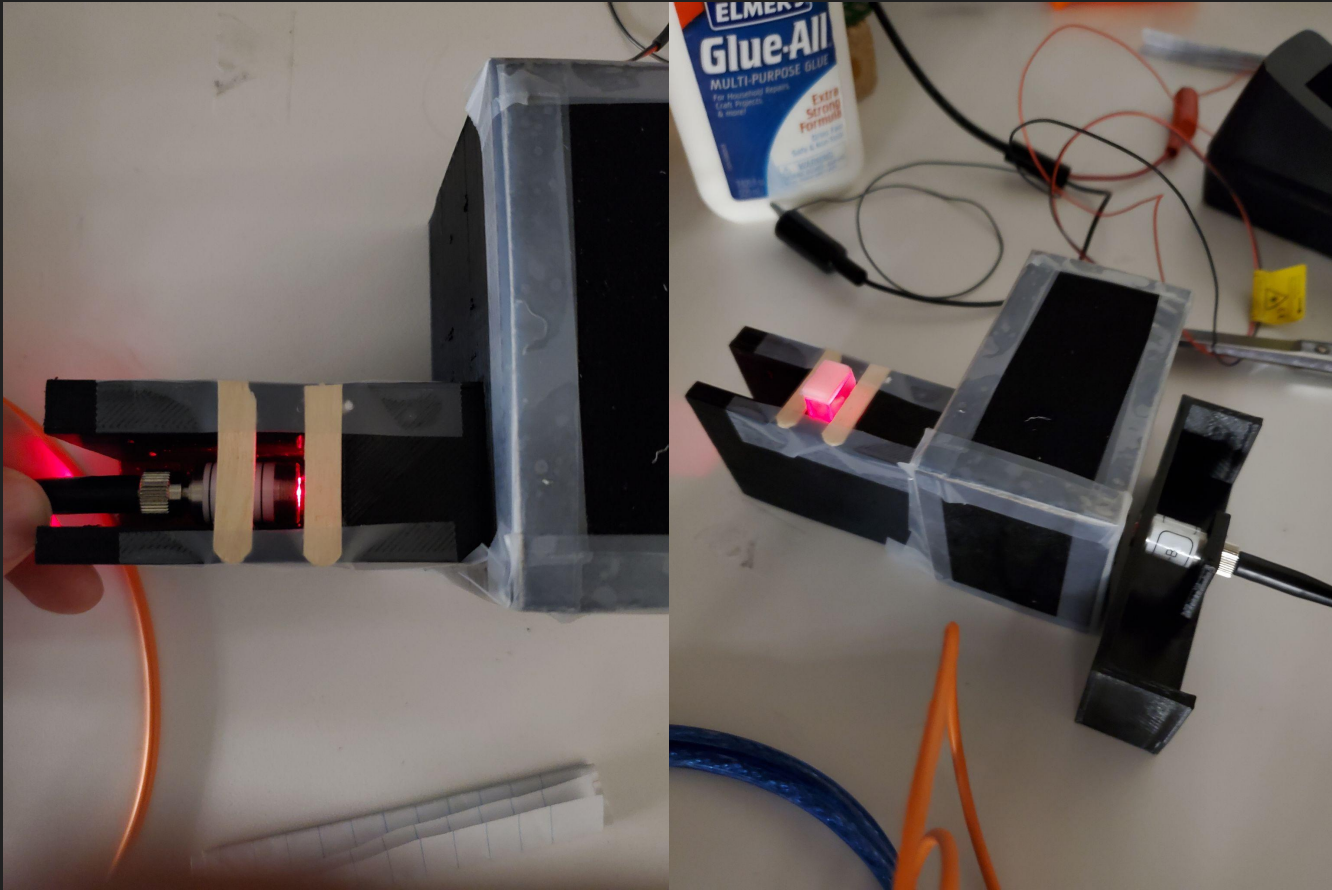
# Current 3D Print Design Diagram



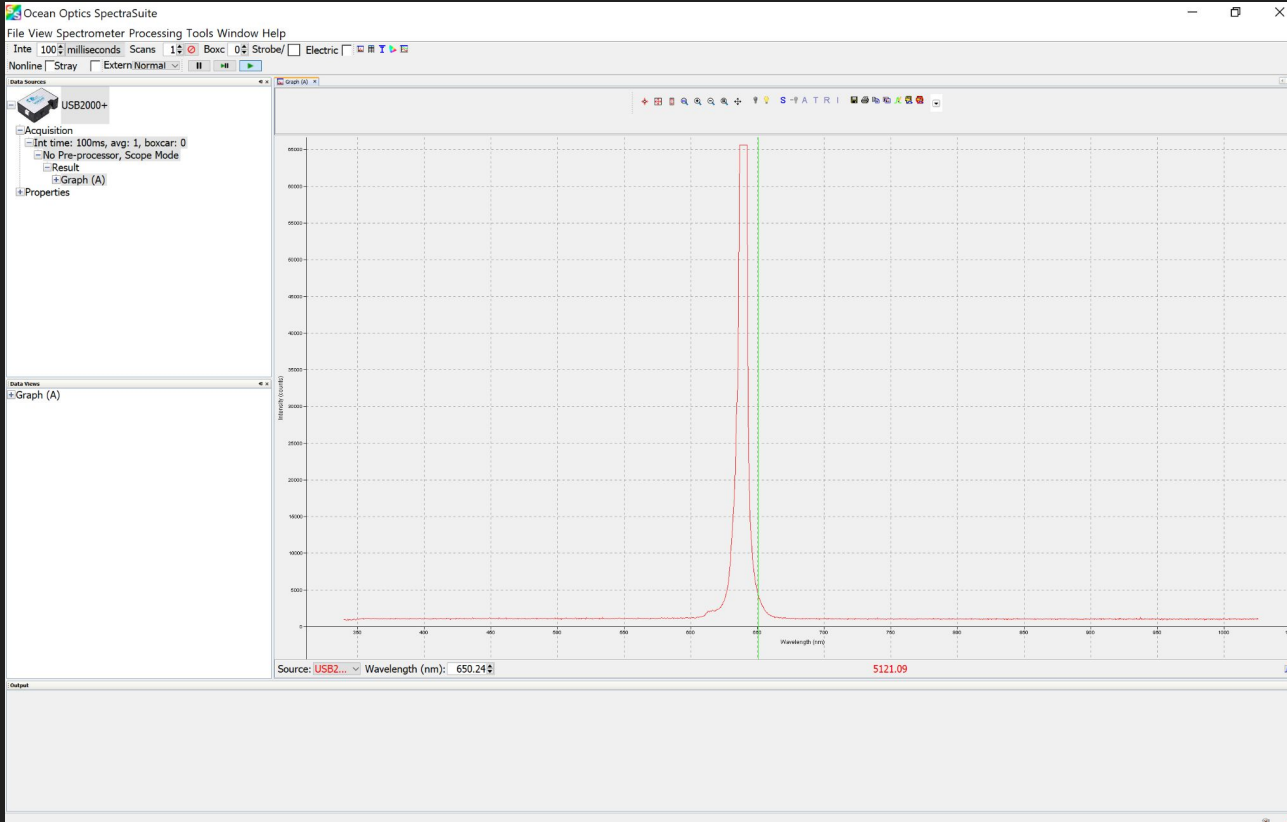
# PlastiSense Demo Video



# Testing Our Alignment and Laser Intensity



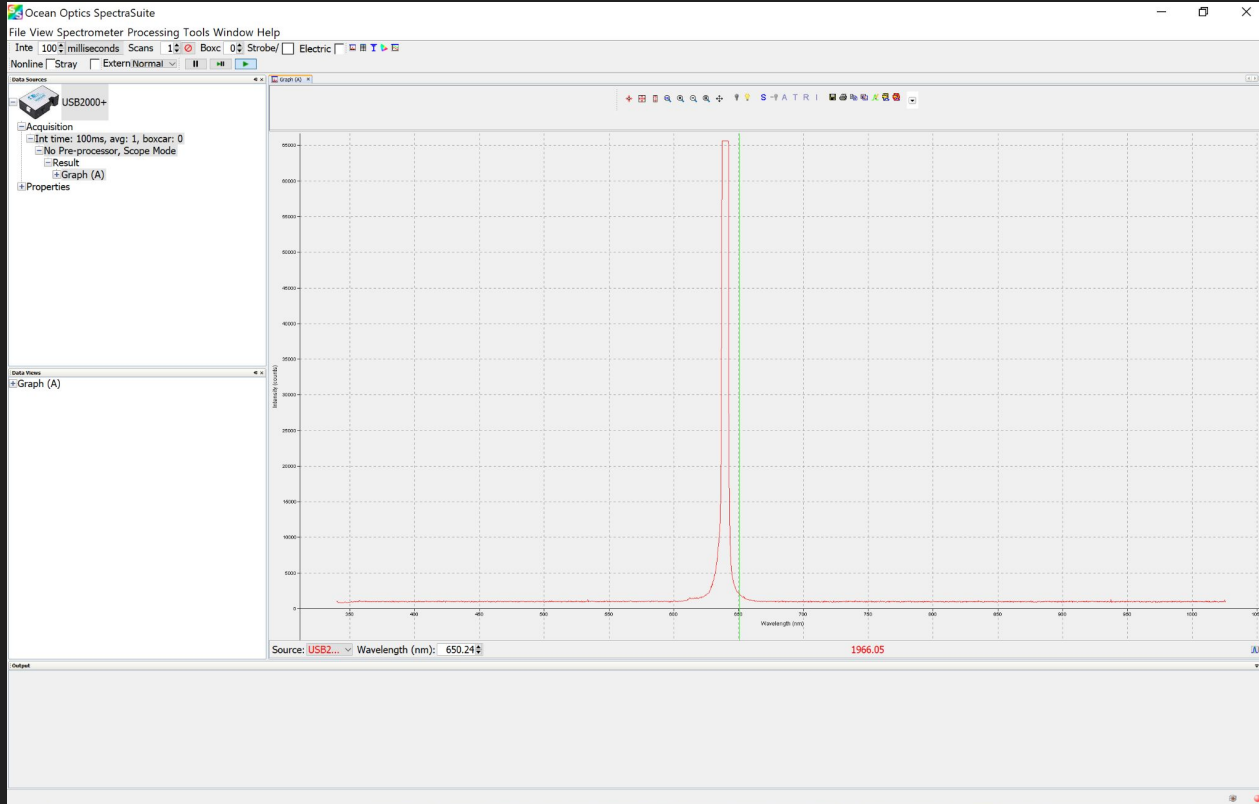
# Light at Sample 100 ms integration time



Here the intensity of the laser saturates the CCD

This demonstrates alignment to the sample

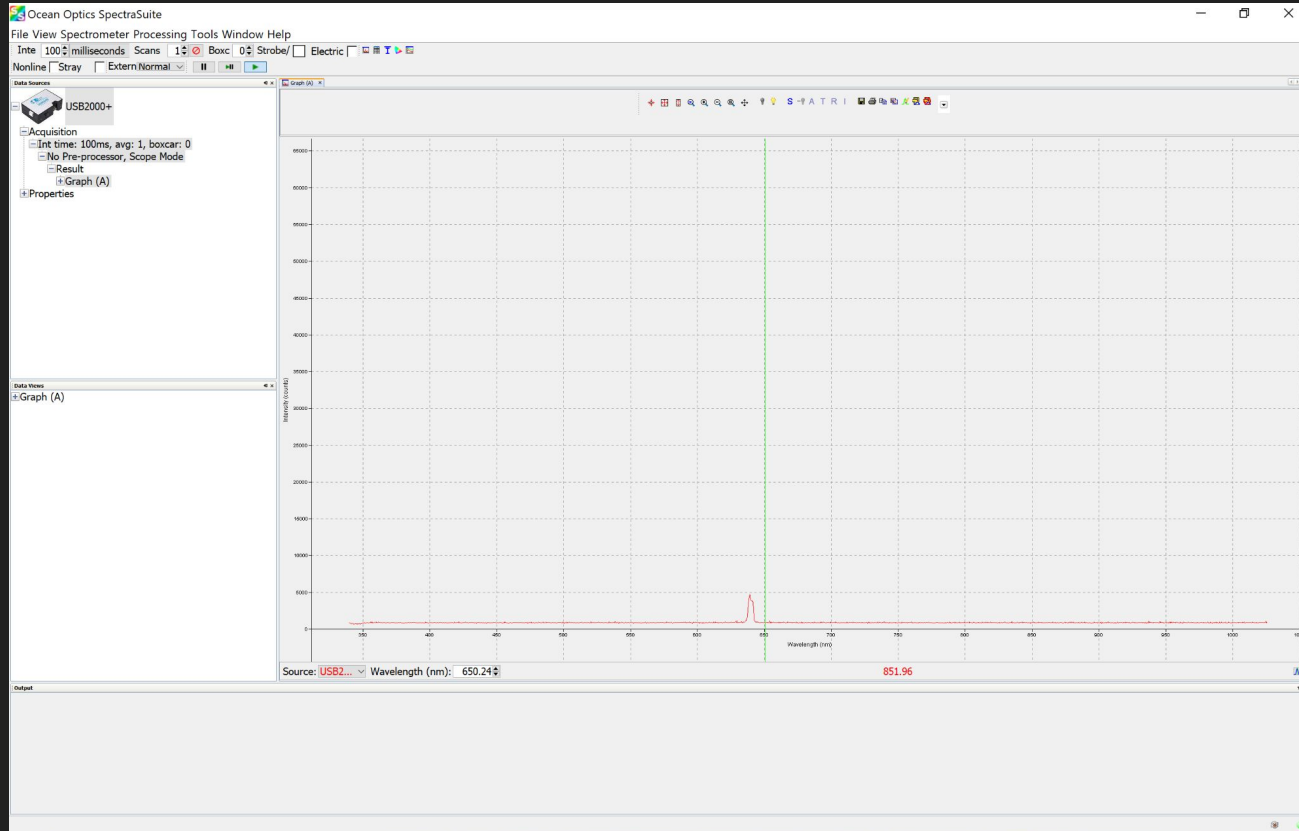
# Output Light without Notch Filter 100 ms integration time



Without the notch filter the laser intensity again saturates the CCD

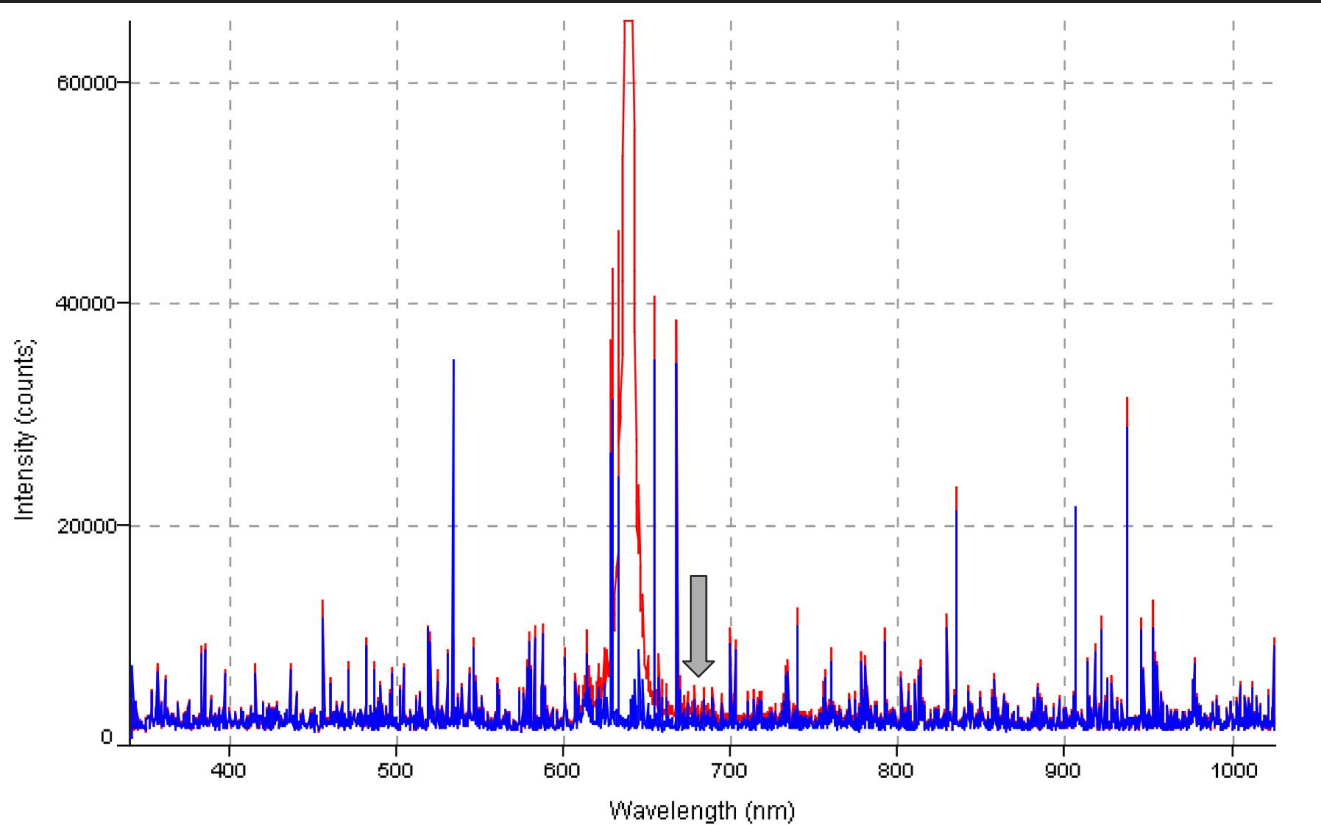
This demonstrates alignment between the sample and output of the chamber

# Output Light With Notch Filter 100 ms integration time



This demonstrates the notch filter filtering the light scattered from our sample.

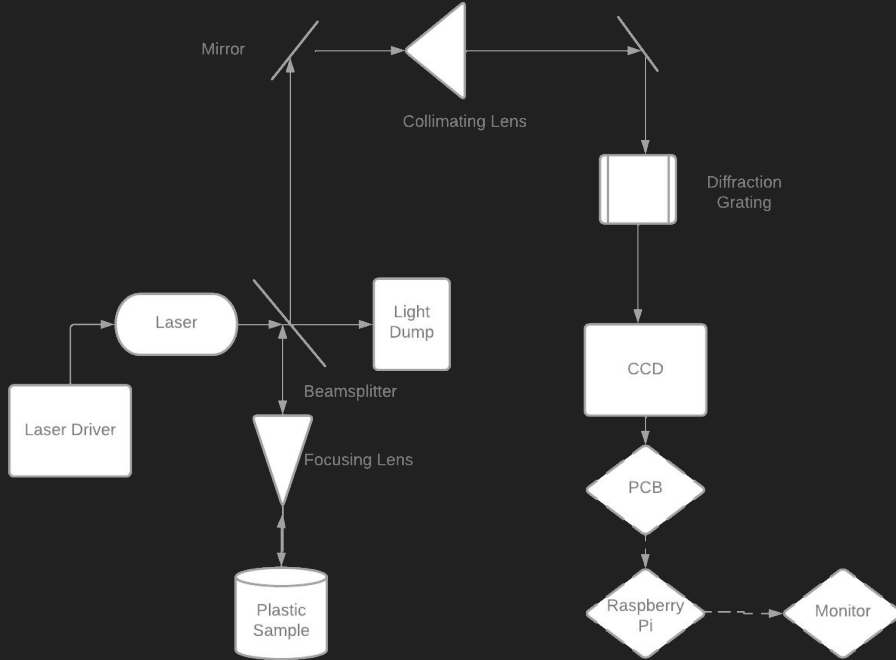
# Output of Notch Filter Vs. Dark Noise Integration Time 10 seconds



Small signal detected,  
not sure whether this is  
the Raman response or  
not

Red = Laser on  
Blue = Laser off

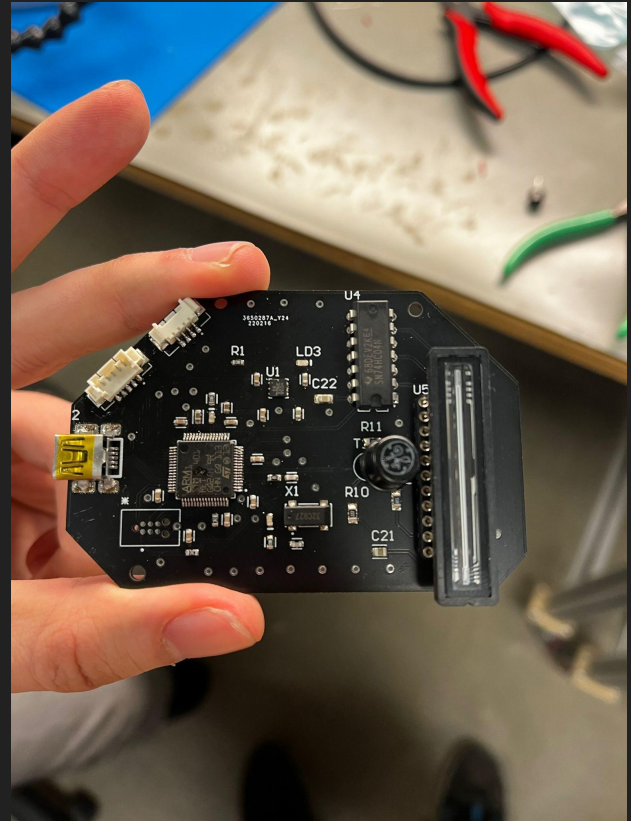
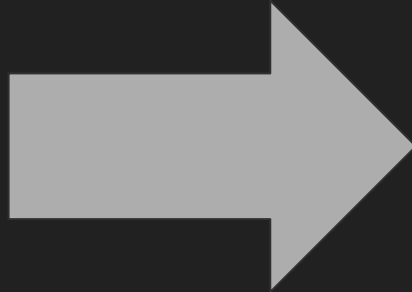
# Demo Recap



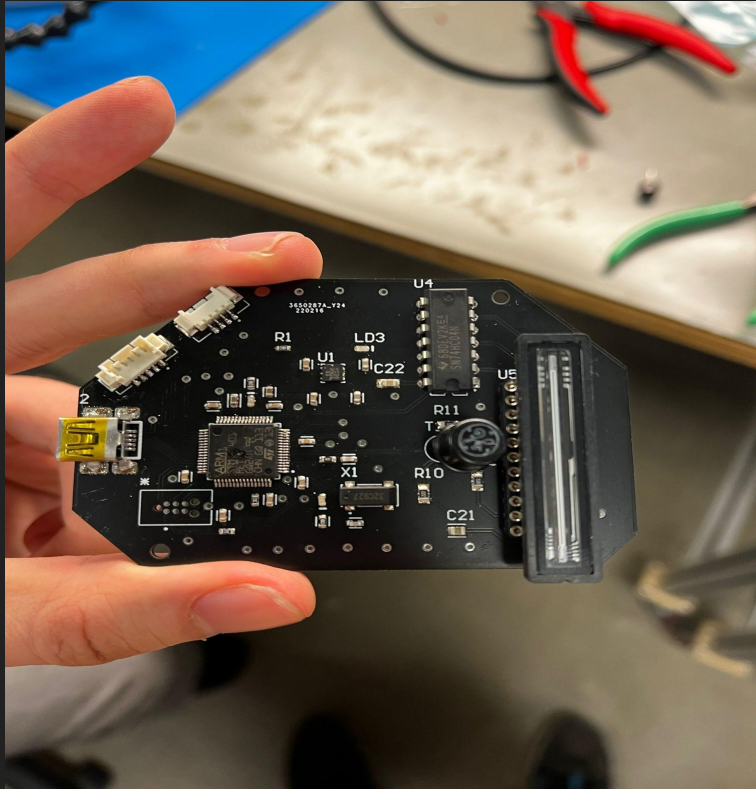
- We do not think we will be able to detect polystyrene samples given the components we have
- This design would work if we had high quality components
- At this point it is proper to say that there is a Raman response, but it is not of great enough intensity to distinguish it from noise



# Populated PCB



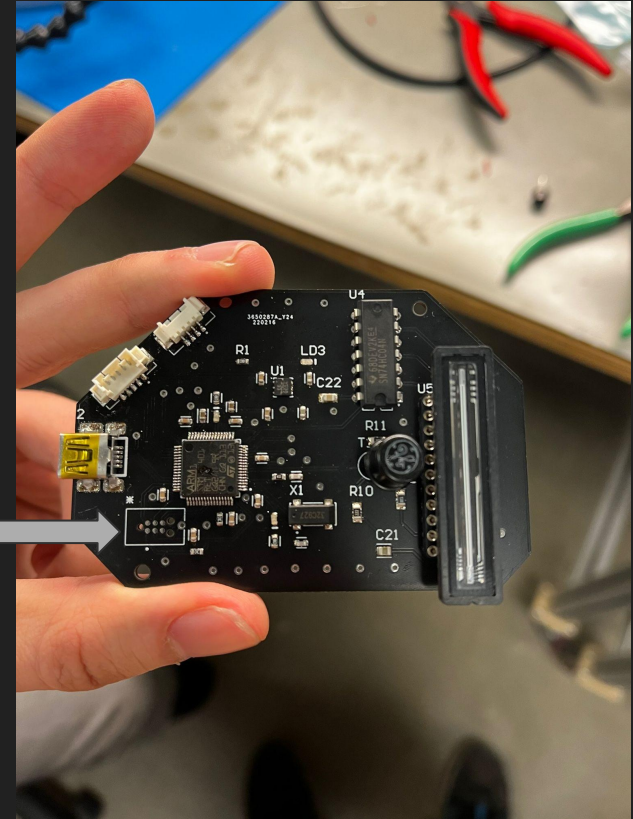
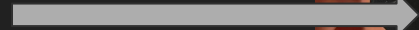
# PCB Explained



- The basics:
  - STM32F01RE MCU
  - Power regulator
  - Signal inverter
  - 32 kHz crystal
  - CCD Sensor
- All of these components were on our STM Dev Board / breadboard for MDR

# ST Link Programmer

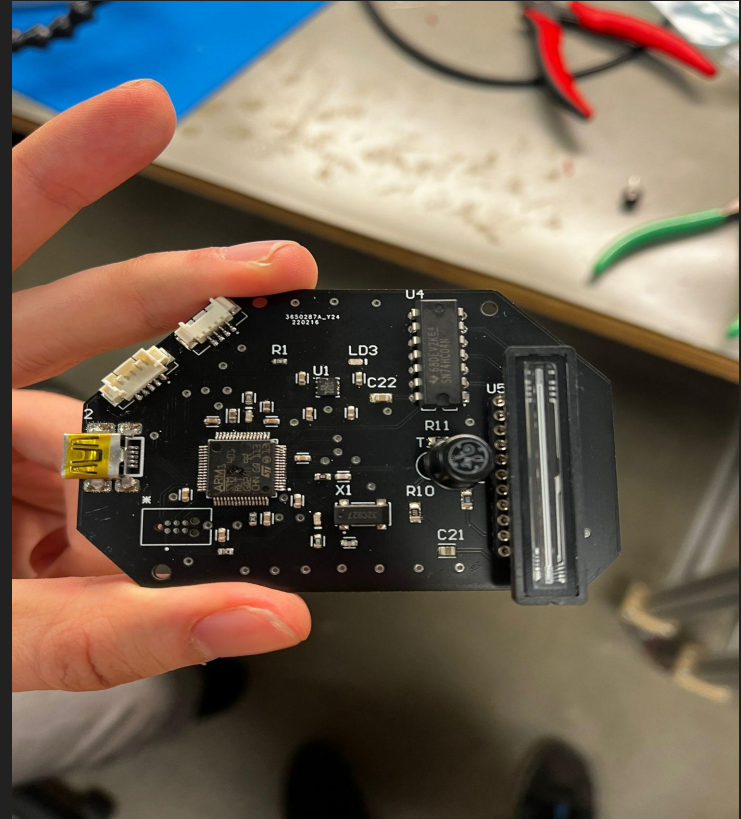
- Bottom Left:
  - ST Link Footprint
    - The STM dev board utilizes a secondary MCU to program / debug the primary MCU.
    - We have implemented a footprint that connects to an ST-Link cable, which allows us to program our MCU



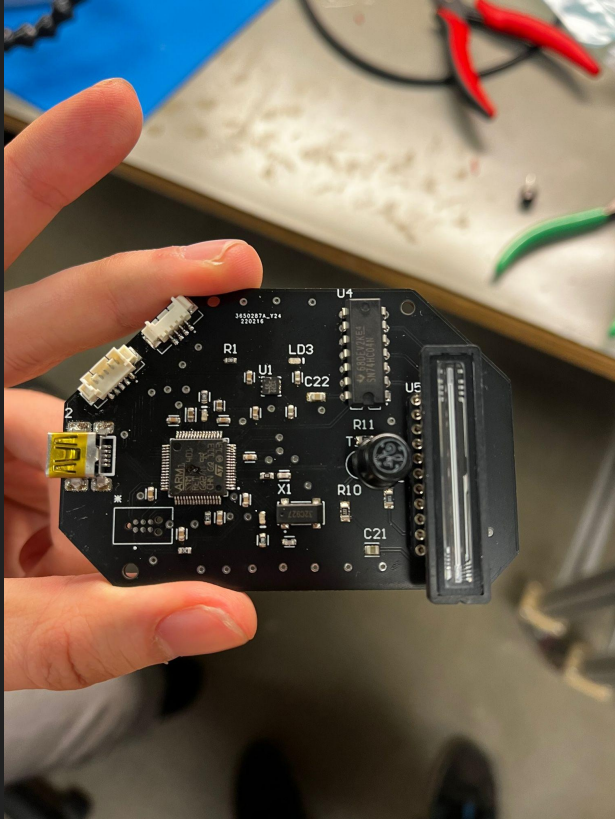


# Left-Side Inputs to PCB

- Mini USB
  - We added a mini USB port to see if it is possible to connect our MCU directly to our computer.
    - This functionality would allow us to “drag and drop” our code onto the MCU.
- SPI ports
  - MOSI, MISO, SCLK ports that connect to an external Raspberry Pi.
    - This functionality allows us to remove the “computer” from our demo, and makes our project more hands-on.
- UART Ports
  - UART\_RX & UART\_TX ports that connect to Raspberry Pi.
    - Works as a substitute if SPI does not work.



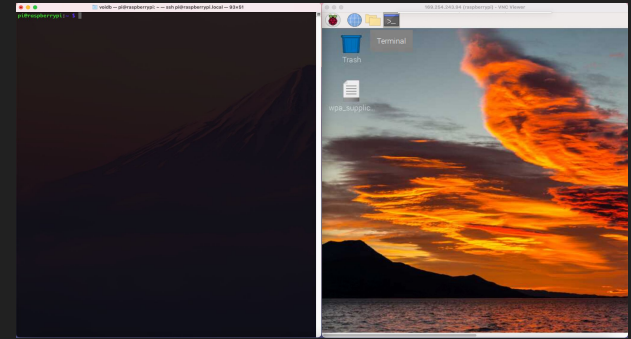
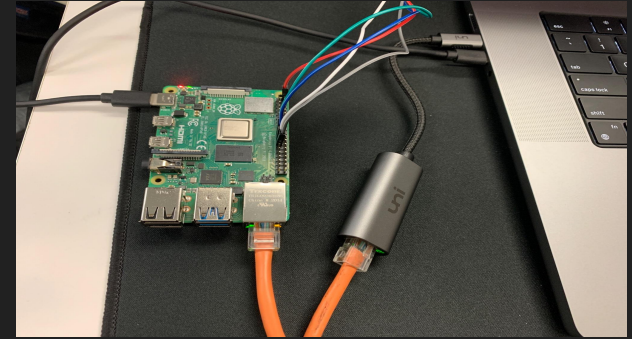
# PCB Problems



- We had to desolder the MCU from the dev board, and solder it on our PCB.
- It has 64 pins so it is difficult to align it.
- Right now, we are not getting an MCU signal
  - However we are sending power to the PCB

# Raspberry Pi Setup

- Substituting USB laptop connection to STM32 Board with Raspberry Pi to Custom PCB via SPI.
- Raspberry Pi is setup in a headless configuration (no monitor, keyboard, mouse)
  - A SSH connection is established between the raspi and any laptop with ethernet connection
  - Currently raspi cannot connect to eduroam wifi but we are working to get that setup
  - The raspi hosts a VNC server and access to the raspi gui interface is available through a VNC viewer
- Raspberry Pi SPI setup with our custom PCB: MOSI ( (color) cable), MISO ( (color) cable), SCLK, ( (color) cable)
- Raspberry Pi FDR goal usage is to wake, connects via ssh, and execute Otterly CLI script with timing arguments.



# Otterly-CLI

- Included with the Esben Rossels CCD Driver; Otterly-CLI commands replace the UART Rx Tx transactions embedded in the UART GUI with equivalent SPI data transactions
- Script can be evoked with the 'sh' command by another wrapper initialization script. Arguments for Shutter timing, Number of Pixel Integrations
- CLI output a .dat file with tuple values [ (pixel number) (pixel value) ]. Using Matplotlib will plot data in real time by buffering or in intervals by averaging file output and mapping data pixel row-value to frequency range.

Example output file

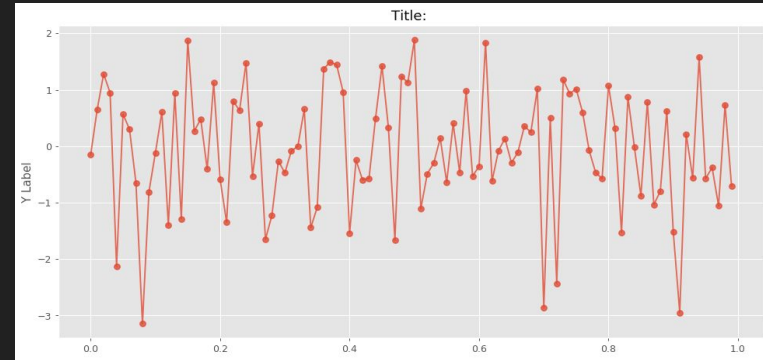
```
1      3920
2      3915
3      3922
..     ..
234    2155
235    2134
..     ..
3694   3905
```

```
Example #1: Otterly-rpiCLI -s 2500 -i 100000 -n 100 -o output
```

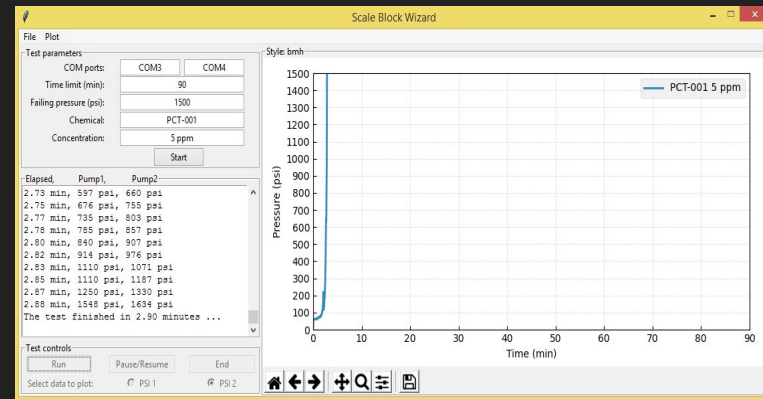
# Gui and Plot

- The GNU gui plot program provided by Esben Rossell is deprecated for the current version SPI firmware. We will create a gui and embed a real time or interval plot using Python's matplotlib, and tkinter modules
- The tkinter module will provide a basic gui template, matplotlib will be used to plot the data from the .dat output files generated by the Otterly CLI commands.
- The CLI commands take the # of integrations as an argument. The number of indicates how many output files will be created by the end of the sampling.

Example of a realtime plot using matplotlib



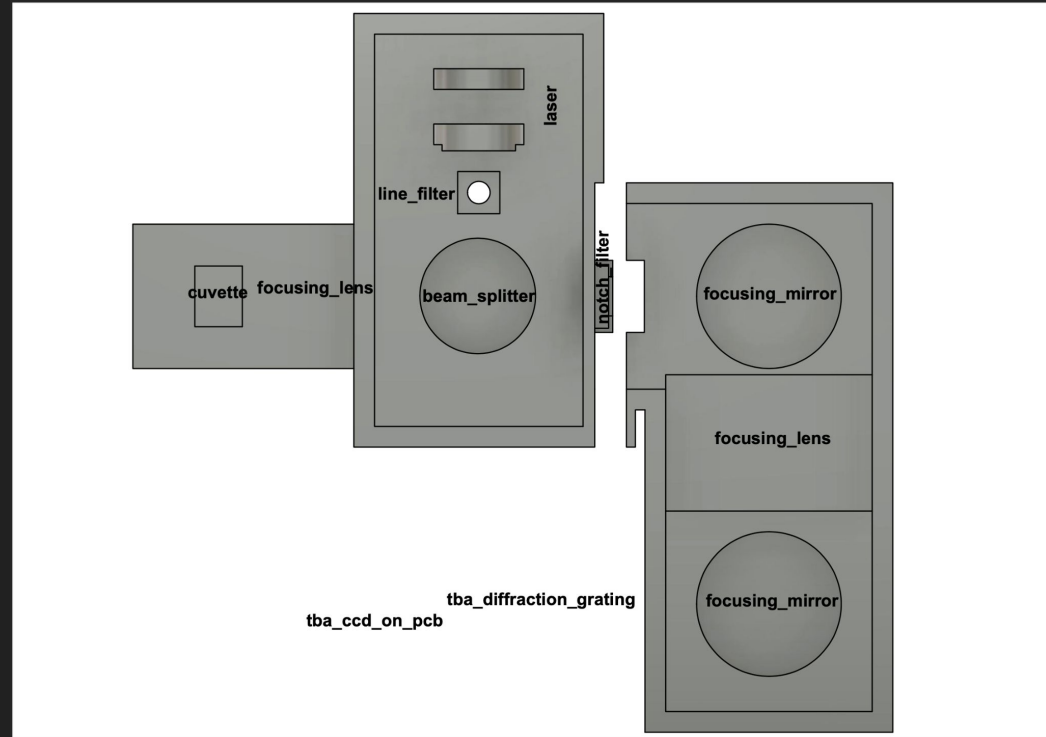
Example of tkinter gui with plot





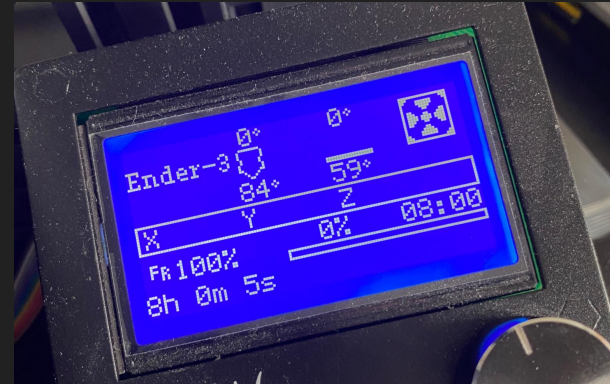
# Optical Chamber Design

- Made using AutoDesk Fusion 360
- Designed to replace our current optical setup with a smaller and more enclosed one
- Mounts for all optical components are included
  - Some mounts are adjustable, such as the beamsplitter and focusing mirror mounts
- Focal lengths for the focusing lenses are observed

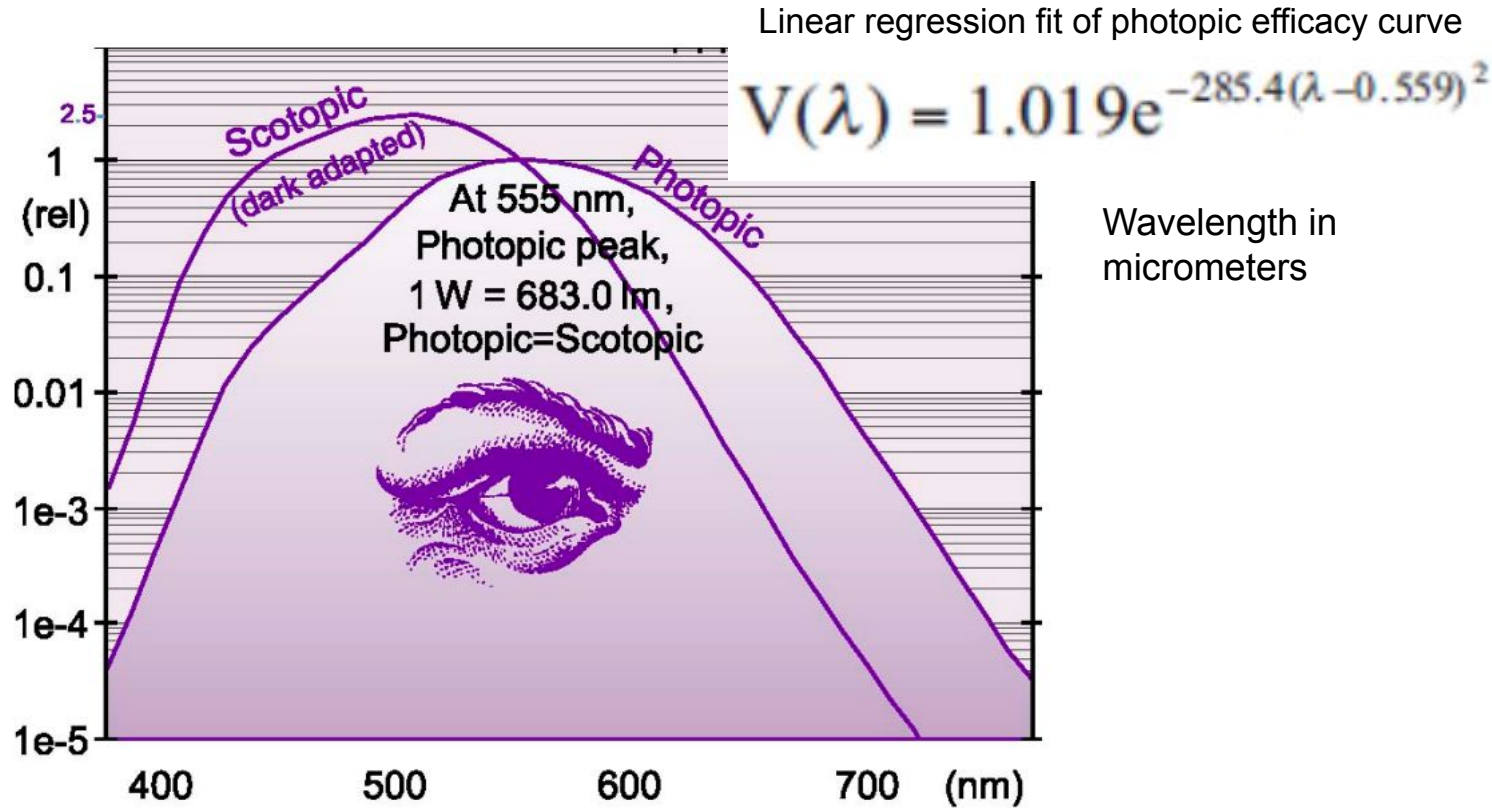


# Optical Chamber

- We currently do not have the spectrometer part printed out
  - we're working on calculating the incidence angle and distance from the diffraction grating to the CCD
- The whole chamber printed out would be huge, so it is split up for easier printing, which, consequently, will allow for minor adjustments to be made more easily
  - Just the optical chamber took 8 hours to print
- The two pieces will be connected with the lid, which will fit over both chambers

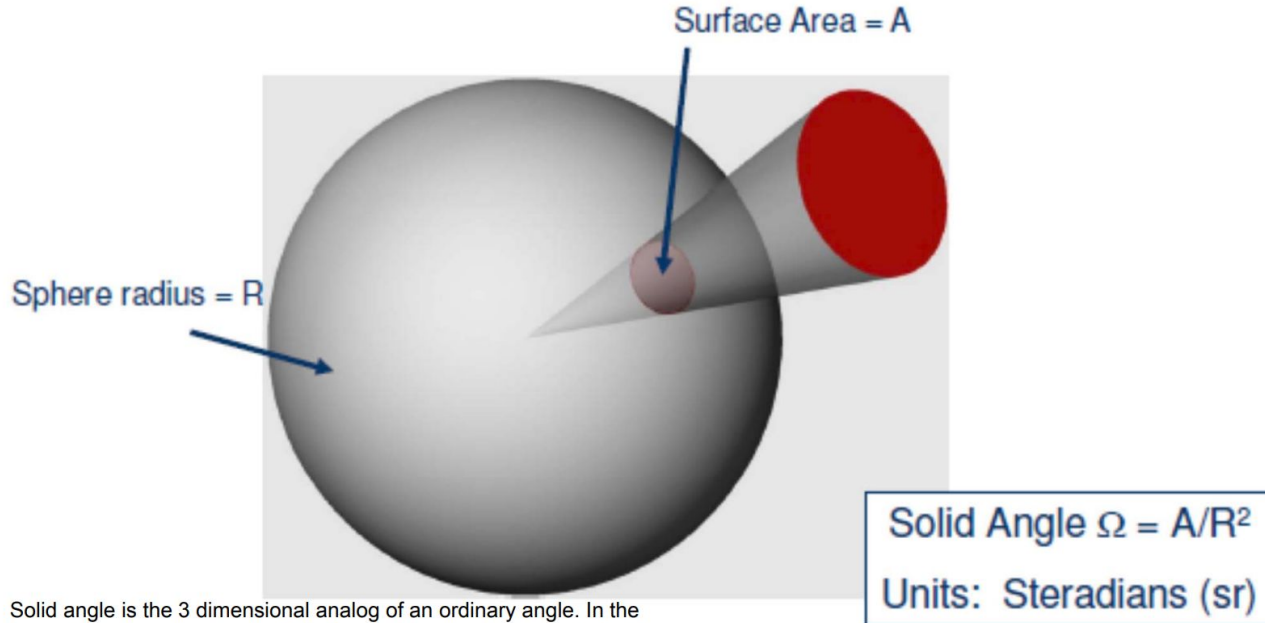


# Luminous Efficacy Curves



## Solid Angle

# Radiant Intensity and luminous Intensity



Solid angle is the 3 dimensional analog of an ordinary angle. In the figure, the edge of a circular disk, the bright red circle, is projected to the center of a sphere. The projection intersects the sphere and forms a surface area A. Solid angle is the area A on the surface of a sphere of radius R divided by the radius squared. The units of solid angle are steradians. Note that it is a dimensionless quantity.

**OSRAM**

# Raman Cross Sections of Chemical Warfare Agents...

## Surprisingly much easier to find than for polystyrene

<b>Chemical</b>	<b>Peak (<math>\text{cm}^{-1}</math>)</b>	<b>Cross Section (<math>\text{cm}^2/\text{sr}/\text{molecule}</math>)</b>
GA	2195	$8.01 \times 10^{-27}$
GB	724	$2.56 \times 10^{-28}$
GD	730 + 751	$7.68 \times 10^{-28}$
GF	752	$2.75 \times 10^{-28}$
HD	No peaks	
VX	No peaks	
DIMP	716	$3.50 \times 10^{-28}$
DMMP	706 + 715	$4.56 \times 10^{-28}$
MES	807	$1.46 \times 10^{-24}$
MPA	774	$4.75 \times 10^{-28}$
TDG	654	Filter cutoff
TEPO	730	$4.43 \times 10^{-28}$

I have been having difficulty finding the Raman Cross Section of polystyrene.

These are the units that I need, but most papers give Cross Sections specific to the size of the particle that they measured and the steradian of light they collected.

For now I will assume the Raman Intensity is 1nW from a solid piece of polystyrene.

# What are the capabilities of our CCD? Is it appropriate for our project?

**Say we collect a Raman Emission of  $\Rightarrow 1$  nW**

CCD sensitivity = 110 volts/(lux\*second) (No indication in datasheet whether this is photopic or scotopic)

$$\begin{aligned} 1 \text{ nW at } 680\text{nm (or } 0.68 \text{ } \mu\text{m)} &= 1 * 10^{-9} \text{ (W)} * 0.0156 \text{ (conversion)} * 683 \text{ lm/W} \\ &= 10.65 * 10^{-9} \text{ lumens (1 lux = 1 lum/m}^2\text{)} \end{aligned}$$

Say all of that light is dispersed across 100 pixels on our CCD 3648 pixel CCD

$$110 \frac{[Volts]}{[lux*second]} * \frac{10.65 * 10^{-9} [lumens]}{8 * 10^{-6} * 200 * 10^{-6} [m^2] * 100 [pixels]} * 10 * 10^{-3} [seconds] = 0.0732 \left[ \frac{volts}{pixel} \right]$$

We can sense this but it will most likely look like noise.

# Our Goal For FPR

- We are having trouble detecting the miniscule Raman Response.
  - We need higher quality, more expensive components that do not fit our budget.
- The goal of our project is shifting from detecting the Raman response, and identifying the microplastics in a sample.
- We are now going to create a spectroscope, with a fully integrated processing system, that would detect microplastics, given if we had higher quality components (i.e. stronger laser).

## FPR Plan Specs (Justifiable Quantitative Benchmarks)

- Have a fully completed and fitted optical and spectroscopy chambers w/ lid smaller than 1 cubic meter and a total system weight of less than 5 lbs.
- Our system will identify the laser with a 10% margin of error, as compared to the higher grade spectroscopy provided to us by Prof. Arbabi
- Raspberry Pi controls the sample collection cycle within 10 minutes. Including turning on laser, sending SPI input, receiving CCD output, and plotting the collected light.



# Testing Plan

## For PCB

- Apply continuity tests between pins and traces
- Use oscilloscope to see signals

## For Laser Chamber

- Collect light with spectroscope provided by Prof. Arbabi to demonstrate alignment and look for Raman response

## For Spectroscope Chamber

- Compare spectrum from our ccd to the spectrum from Spectroscope provided by Prof. Arbabi

# Project Expenditures

Component	Item	Units	Cost/Unit	Shipping/Handling	Total
.8 mW 633nm Laser	<a href="https://www.edmundoptics.com/p/Model-1107P-08mW-Line/">https://www.edmundoptics.com/p/Model-1107P-08mW-Line/</a>	1	\$0.00	\$0.00	\$0.00
Focusing Lens	<a href="#">Achromatic Focusing Lens 7.1mm Working Distance</a>	2	\$21.59	\$0.00	\$43.18
Quartz Cuvette 1	<a href="#">Quartz Cuvette - Amazon</a>	1	\$21.94	\$0.00	\$21.94
Quartz Cuvette 2	<a href="https://www.amazon.com/Quartz-Cuvette-Lightpath-Cuvette/">https://www.amazon.com/Quartz-Cuvette-Lightpath-Cuvette/</a>	1	\$15.80	\$0.00	\$15.80
Notch Filter	<a href="#">632.8nm, 12.5mm Diameter, OD 4.0 Notch Filter</a>	1	\$95.00	\$8.99	\$103.99
Slit	<a href="#">Diaphragm with 4 Double Slits of Different Spacings</a>	1	\$22.19	\$0.00	\$22.19
Diffraction Grating	<a href="#">Diffraction Grating, 1000 lines/mm</a>	1	\$12.95	\$0.00	\$12.95
CCD/Photodiode	<a href="https://www.amazon.com/MyColor-TCD1304AP-TCD1304-T/">https://www.amazon.com/MyColor-TCD1304AP-TCD1304-T/</a>	1	\$14.94	\$0.00	\$14.94
Focusing Mirrors	<a href="https://www.edmundoptics.com/p/25mm-dia-x-50mm-fl-prot/">https://www.edmundoptics.com/p/25mm-dia-x-50mm-fl-prot/</a>	2	\$50.50	\$43	\$143.99
Magnets	<a href="https://www.amazon.com/gp/product/B08HQNVXRG/ref=pp">https://www.amazon.com/gp/product/B08HQNVXRG/ref=pp</a>	1	\$9.99	\$0	\$9.99
beam splitter	<a href="https://www.edmundoptics.com/p/18-x-30mm-70r30t-plate-b/">https://www.edmundoptics.com/p/18-x-30mm-70r30t-plate-b/</a>	1	\$39.00	0	\$39.00
ST link	<a href="https://www.mouser.com/ProductDetail/STMicroelectronics/">https://www.mouser.com/ProductDetail/STMicroelectronics/</a>	1	\$30.00	\$7.26	\$37.26
PCB Components	On DigiKey	x	\$30.00	\$9.90	\$39.90
4 Signal Pin Header	On Newark	x	\$2.56	\$9.99	\$12.55
Tag Connect	On Tag Connect	x	\$63.90	\$10.00	\$73.90
Nucleo Board	On DigiKey	3	\$13.83	\$10.00	\$52.63
PCB	On JLC PCB	1	\$15	\$30.00	\$45.00
			Total Sum:		\$689.21
			Remaining Budget		\$800 - \$689.21
					\$110.79



# Team Responsibilities

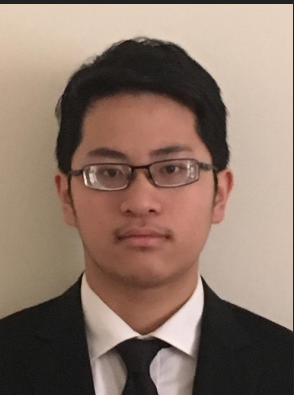


Aaron Achildiyev

- Team Coordinator
- PCB Design

Aidan Belanger

- PCB Design
- Optical Design

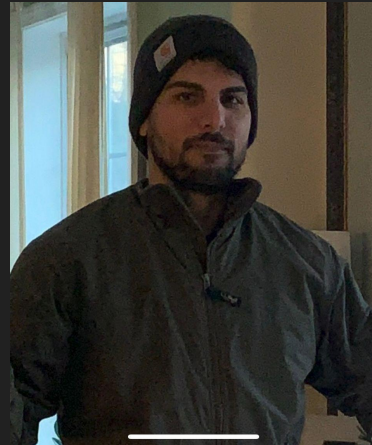


Victor Lam

- Software Design
- 3D Modeler

Adrian Mora

- Hardware Design
- Software Design



Thank you

Questions?