PlastiSense

SDP Team 2
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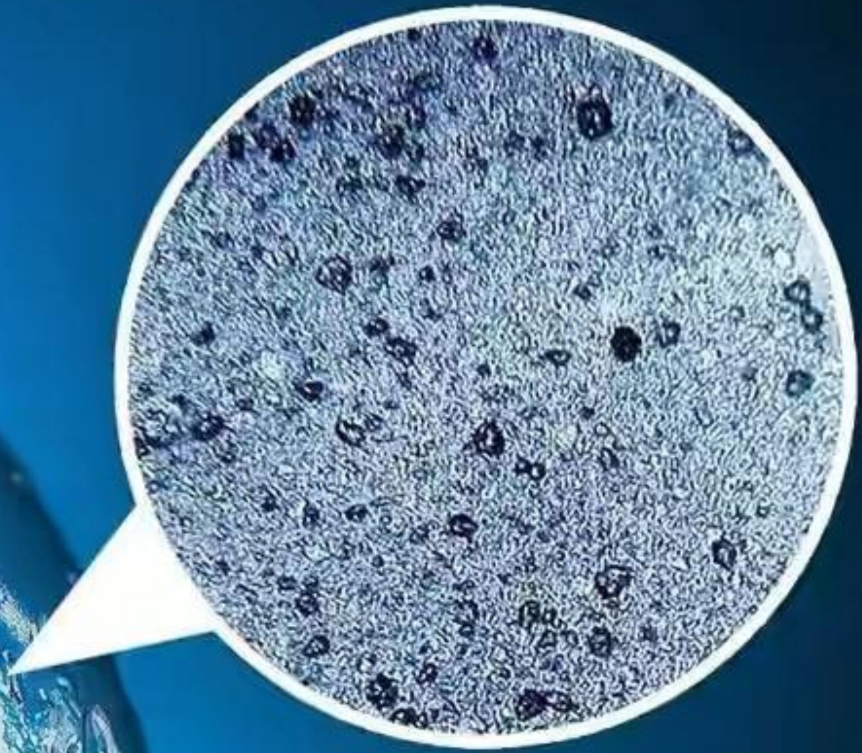
Adrian Mora

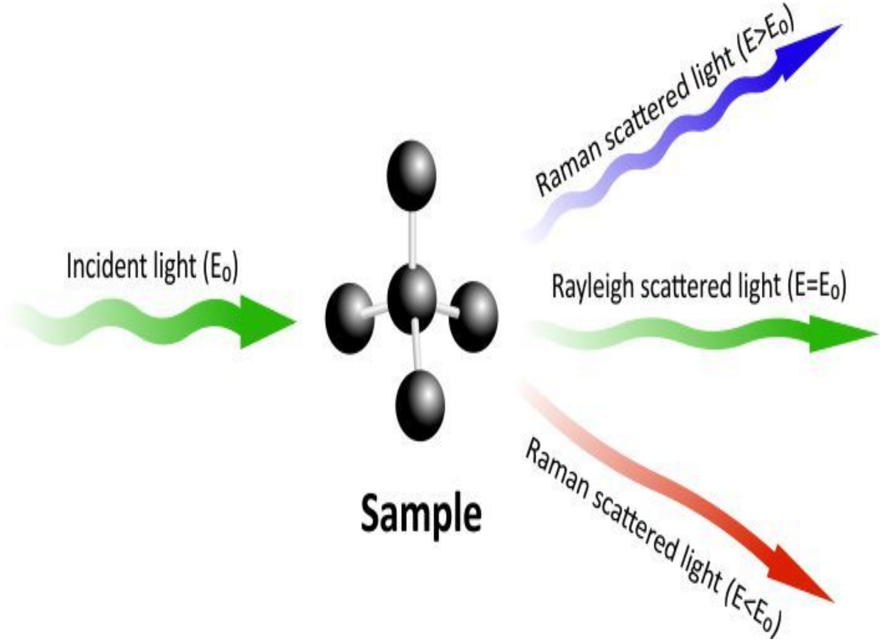
Problem Statement

- 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.[1]
- Find out the abundance of microplastics in your water with PlastiSense, an optics-based microplastic sensing device!



[1] dalberg-advocacy-analysis_for-web.pdf

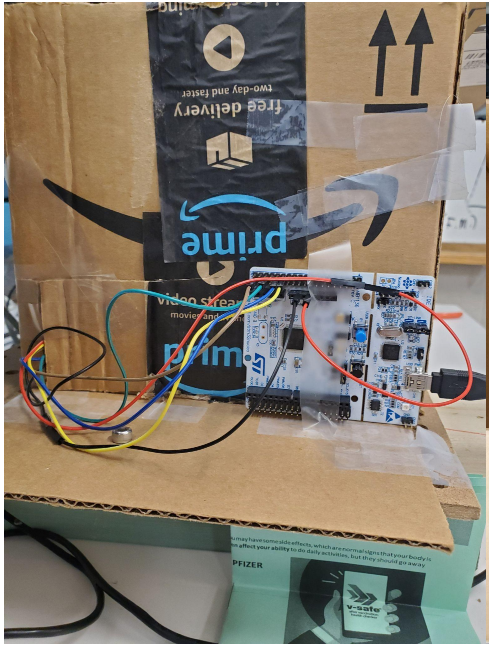
What is Raman Spectroscopy?

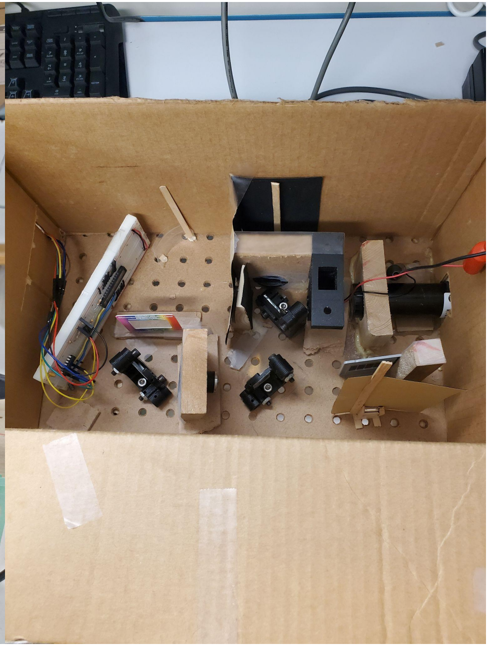


- Raman spectroscopy utilizes an incident laser that points toward a molecular substance
- Affected by the incident laser, the molecule starts to vibrate and let off its own energy in the form of a Raman signal response
- The Raman signal is response is what is measured to detect specific molecules (e.g.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

Our Product: PlastiSense

- Utilizes Raman spectroscopy technology
- PlastiSense is specialized to detect Polystyrene (styrofoam)
- Portable, affordable, programmable





Specs

RSB1 - Raman Spectroscopy Kit Base Unit with Coded Detection, Imperial

Zoom

Complete Product Details

Part Number:	RSB1 -Ask a technical question
Package Weight:	40.96 lbs / EACH
Available:	Today
RoHS:	N/A
Price:	**$13,000.00**
Add To Cart:	Qty : 1
	Add To Cart
Release Date:	Sep 17, 2021

Ocean HDX Raman Series Spectrometers ›

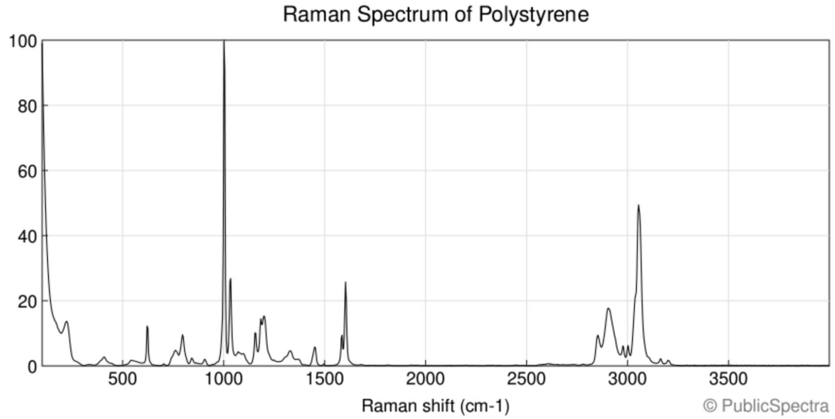
Ocean HDX 785 Preconfigured Raman Spectrometers

From $8,136.00

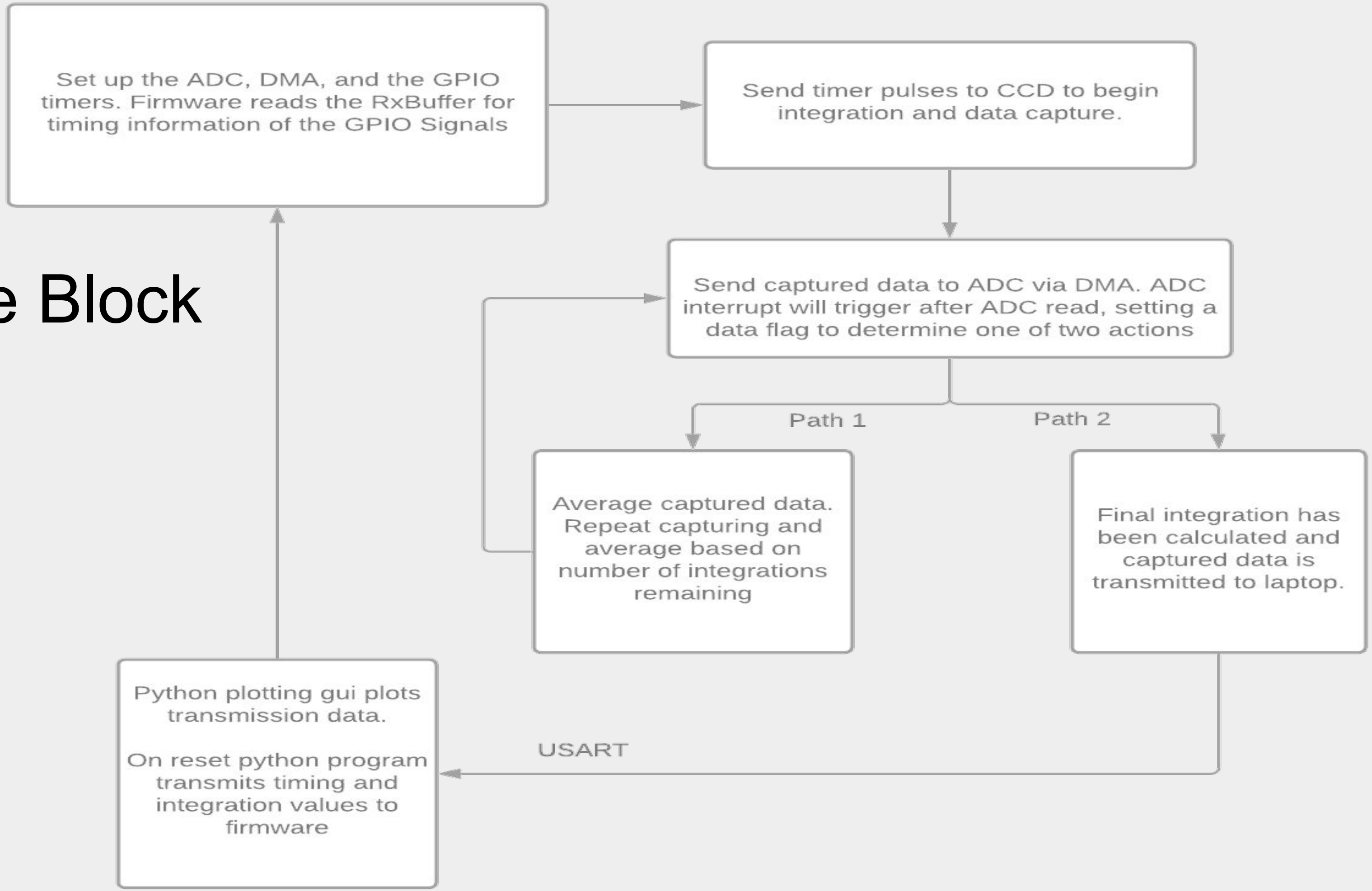
- Portable
  - Less than a cubic meter
  - Less than 20lbs (much less than 40 lbs)
- Affordable
  - ~$500
  - Much less than $13,000 (cost of ThorLabs Modular Spectroscopy kit)
  - The spectrometers shown on the left don’t even include the price of the laser!
- Programmable
  - STLink through USB, JTAG for PCB
  - Measures intensity of sample

Justifiable, Quantitative Benchmarks

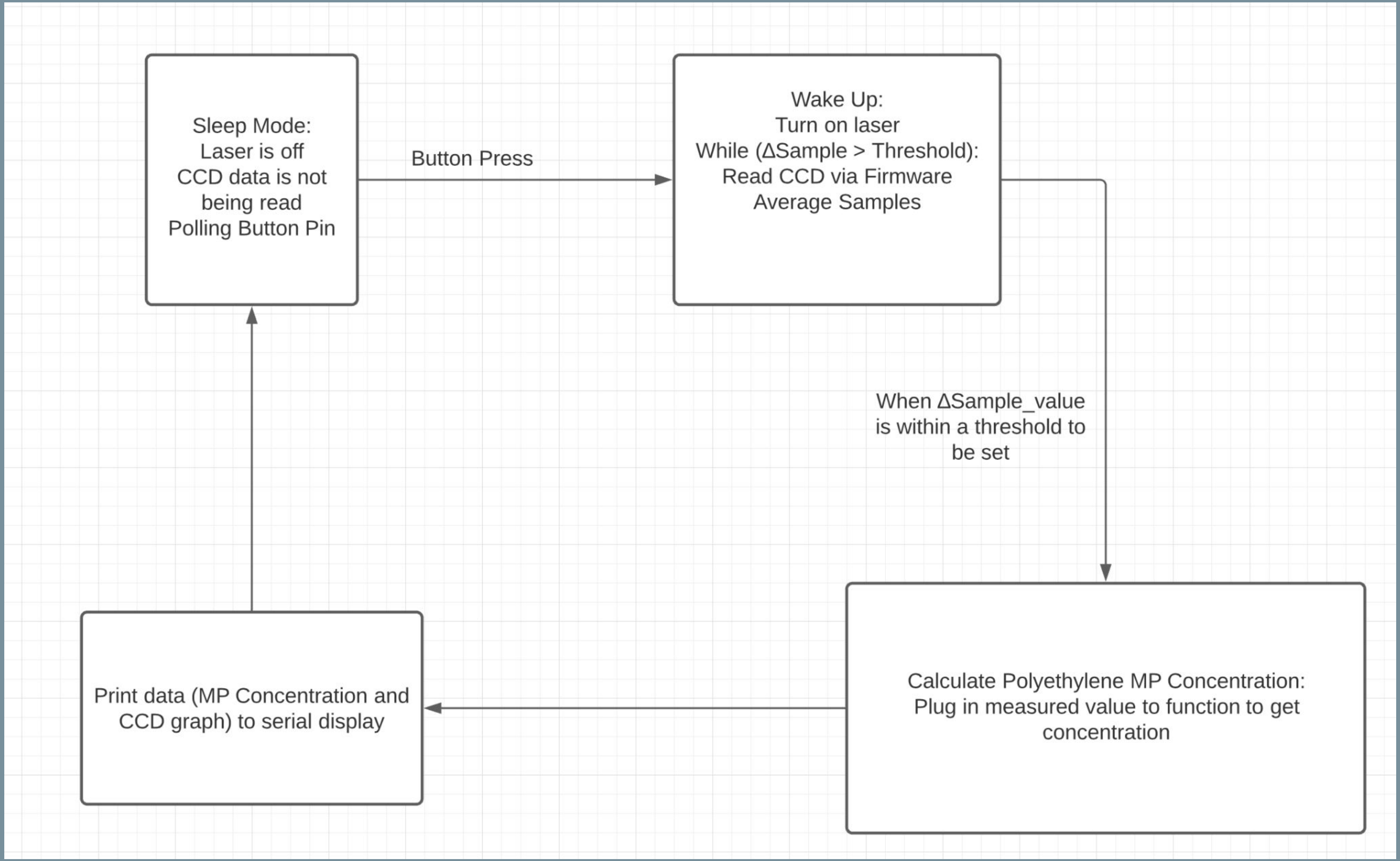
- Sensing Benchmarks
  - Conspicuous peak representing Raman shift at 675 nm resulting from a 633 nm laser exciting polystyrene
- Calculation benchmarks
  - Measure intensity of the signal for five known concentrations and get a regression line and function (w/ r^2 value)
  - Less than 5 minutes



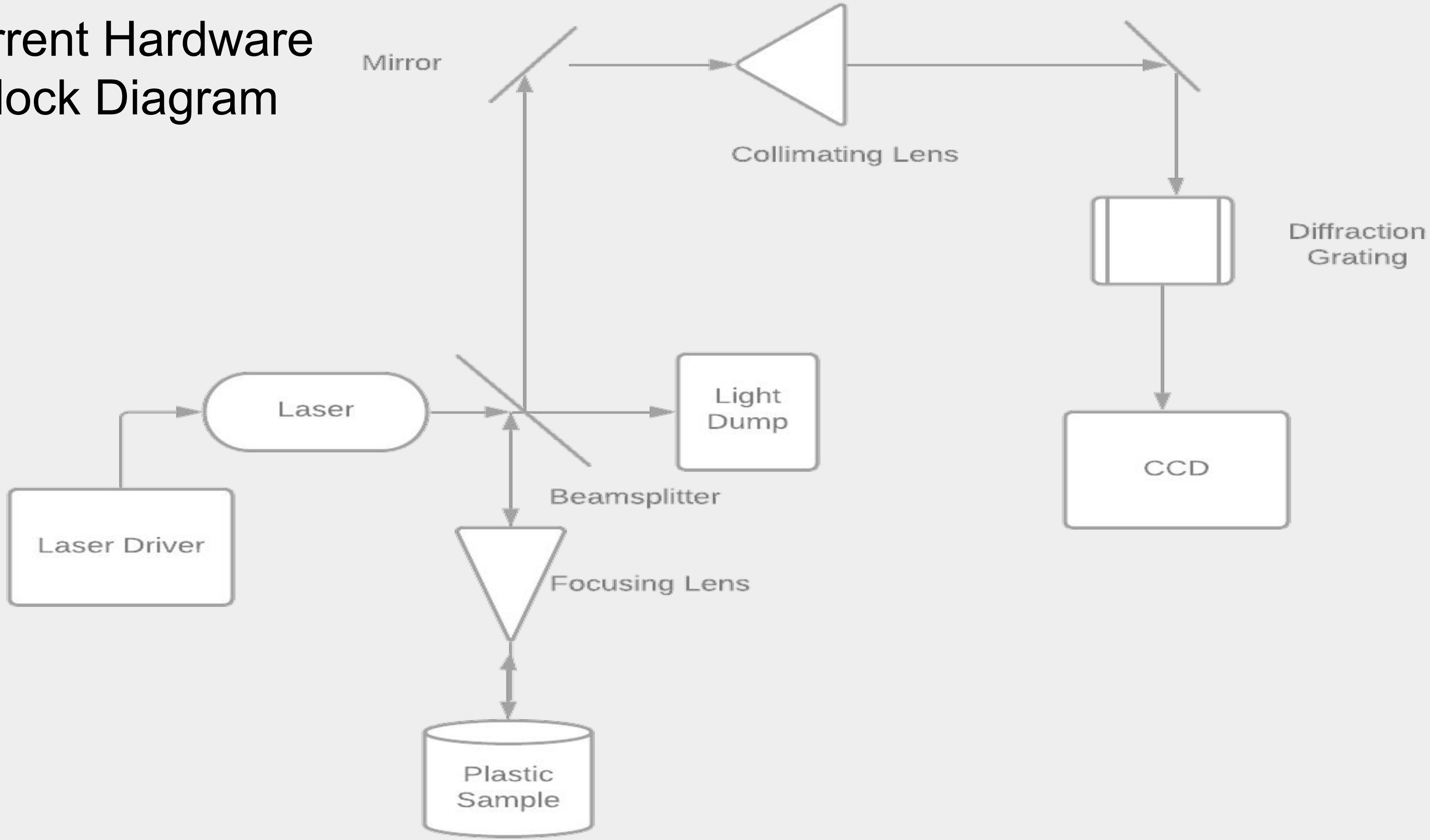
Firmware Block Diagram



Software Block Diagram



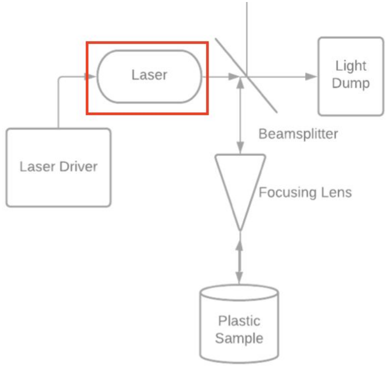
Current Hardware Block Diagram



Detailed List of Hardware Components

5mw 650nm Laser

- Laser with smaller wavelength = greater intensity of signal to be picked up by sensor
- However, the intensity is not at all accurate because of **fluorescence**
- Fluorescence is the emission of light by a substance that has absorbed electromagnetic radiation
- Much less fluorescence near infrared
- Fluorescence can effectively hide our Raman signal! Not good!



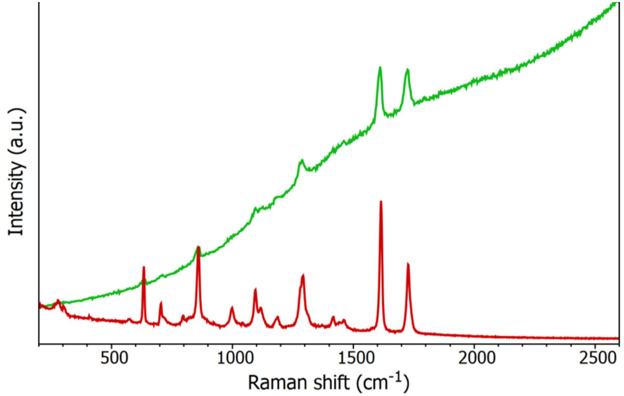
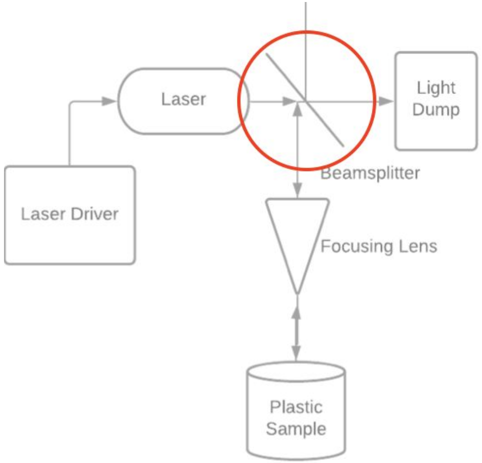
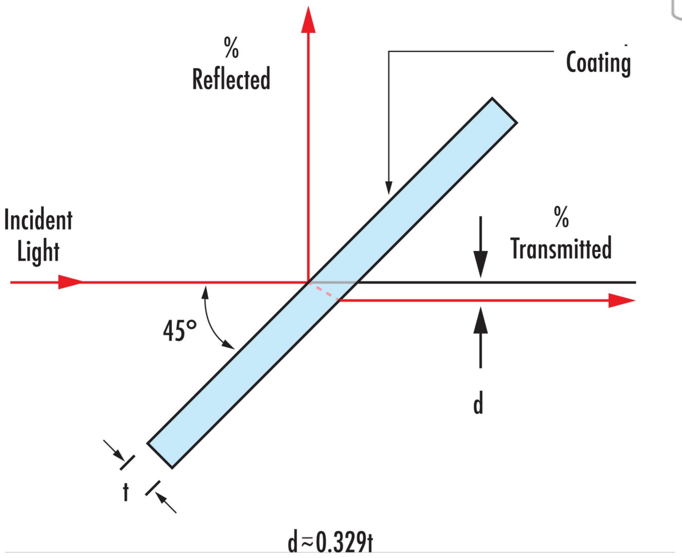


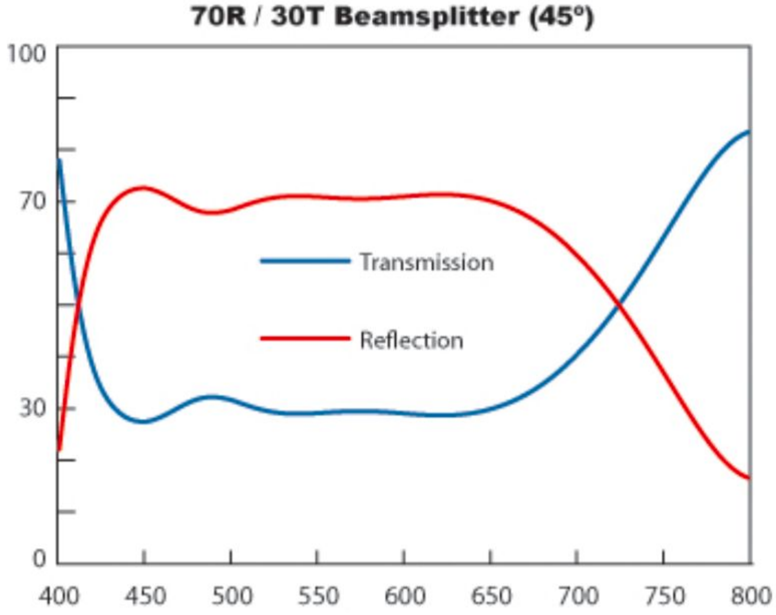
Figure 2: Nicotine patch spectra measured on the RM5 Raman Microscope with a 532 nm laser (green) and a 785 nm laser (red)

BeamSplitter



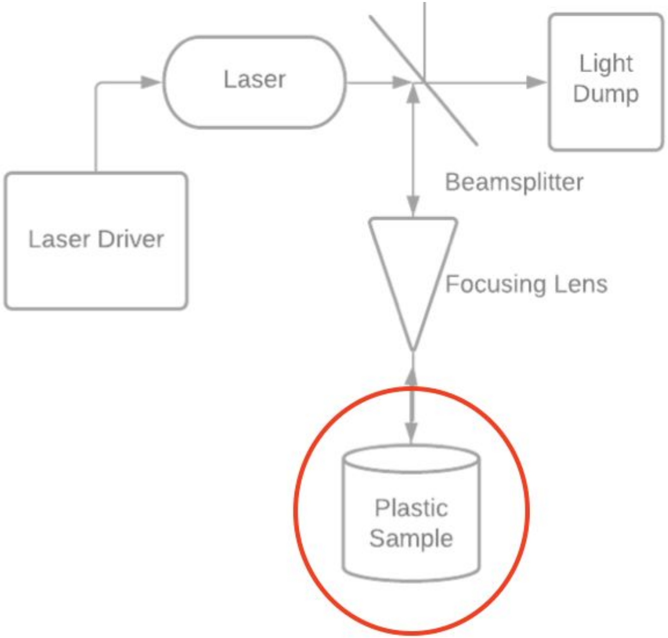
- 70R/30T Beamsplitter reflects 70% of our 635 nm laser towards the sample
- Transmits 70% of our ~675 nm Raman Wavelength



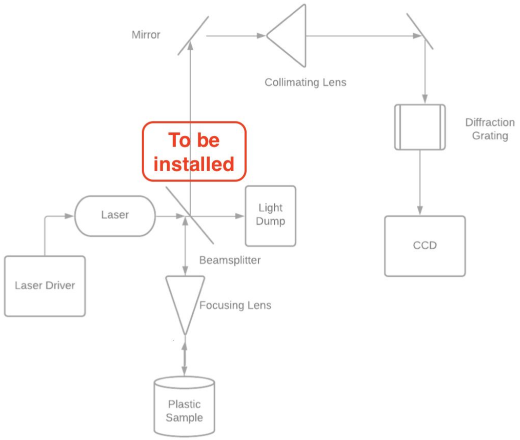


Quartz Cuvette

- Will contain water with a sample of polystyrene
- Quartz excels at transmitting light



Notch Filter



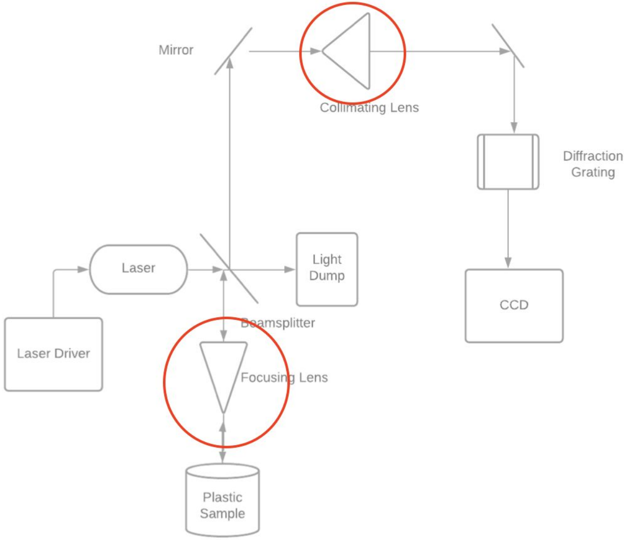
Why?

- Optical filters are used to prevent the undesired (laser) light from reaching the spectrometer, or CCD sensor.
- If we do not include a notch filter, the undesired light can drown out the relatively weak Raman signal.
- Choose a notch filter that corresponds to our laser wavelength.

Collimating/Focusing Lens

Used to magnify intensity of light to a single point.

- Effectively reduces the diameter of the laser that hits the microplastic sample.

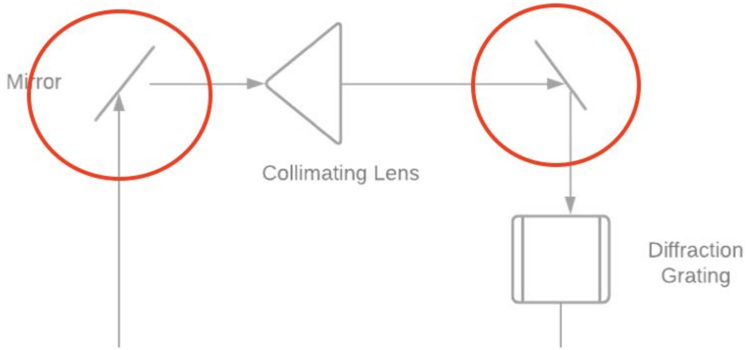


- 10x focus
- 7.1 mm working distance
- Achromatic

Focusing Mirrors

- Concave
- Gold
- f/2 speed
- 50mm focal length

These mirrors will be used to focus our light to the collimating lens and then redirect the light to the diffraction grating.



Diffraction Grating

- The diffraction grating is in charge of dispersing the signal to the sensor
- Measured in grooves per mm (g/mm)
- The higher the groove density, the better the spectral resolution

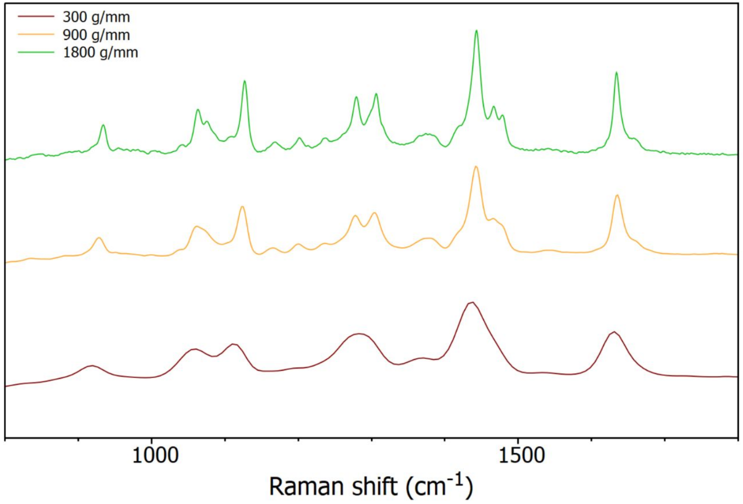
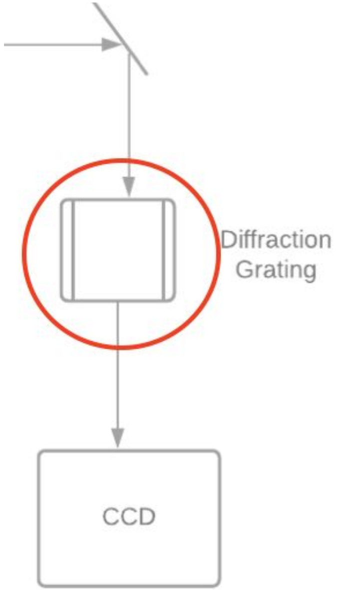


Figure 2: Raman spectra taken on the RM5 Raman Microscope of nylon-6 with a 532 nm laser and three different diffraction gratings



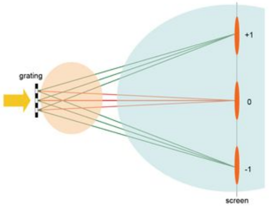
[Diffraction Grating](#)

Diffraction Alignment

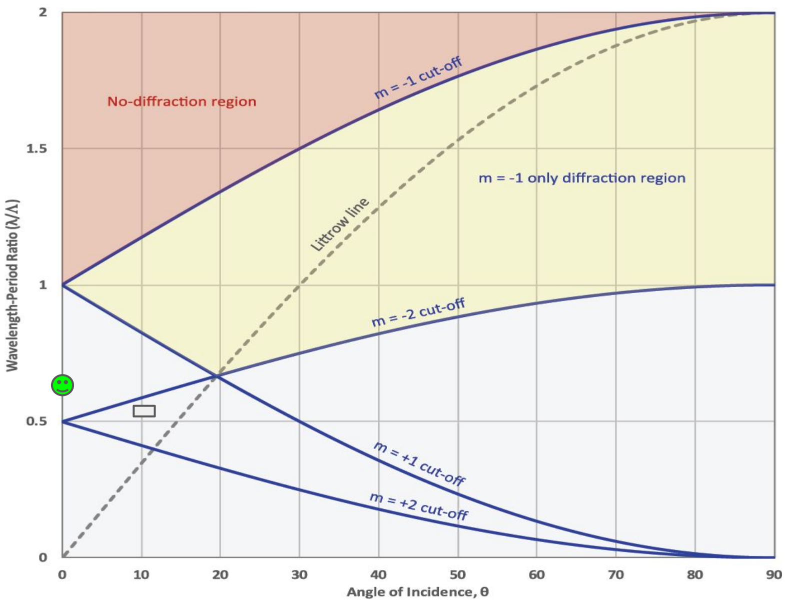
Rough alignment mostly done by eyesight with

flash cards using excitation laser

The Diffraction Grating



This completes the different optical diffraction experiments



For a given angle of incidence, θ, the angle of diffraction θ_m is given for each "order" *m* for which a solution to eq (1) exists.

- Our wavelength period ratio is ~ 0.635.
- Our calculated diffraction center angle is ~ 35.9°

The general diffraction equation is:

$$\sin\theta_i + \sin\theta_m = N \cdot m \cdot \lambda$$

Which for first order diffraction (m=1) with an angle of incidence of 0° (the grating is normal to the collimating lens) reduces to:

$$\sin\theta_m = N \cdot \lambda$$

Charge Coupled Detector (CCD)

- Highly sensitive photon detector (camera); more sensitive than a photodiode making it great for capturing the low sensitivity raman response
- Linear (one dimension) image sensing; 3694 spectral elements for the TCD1304AP
- With precise alignment the diffracted raman response will cover the CCD pixel range.

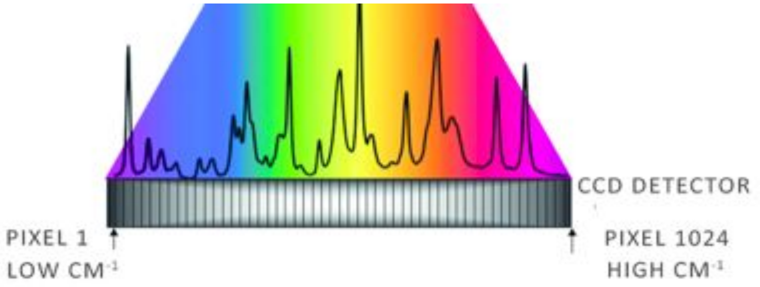
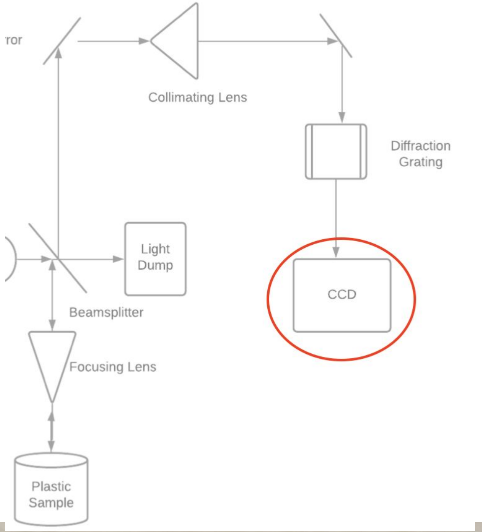
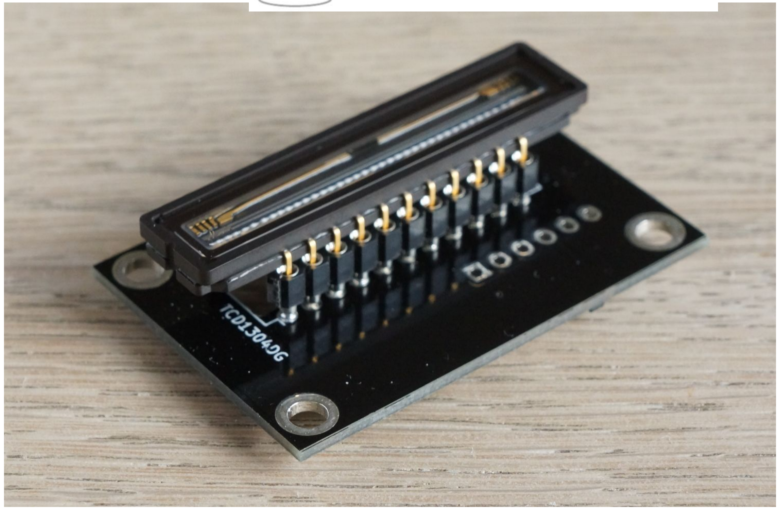


Fig 30: CCD Detector



TCD1304AP



CCD Image Spectrum Image

Demo of Integrated System

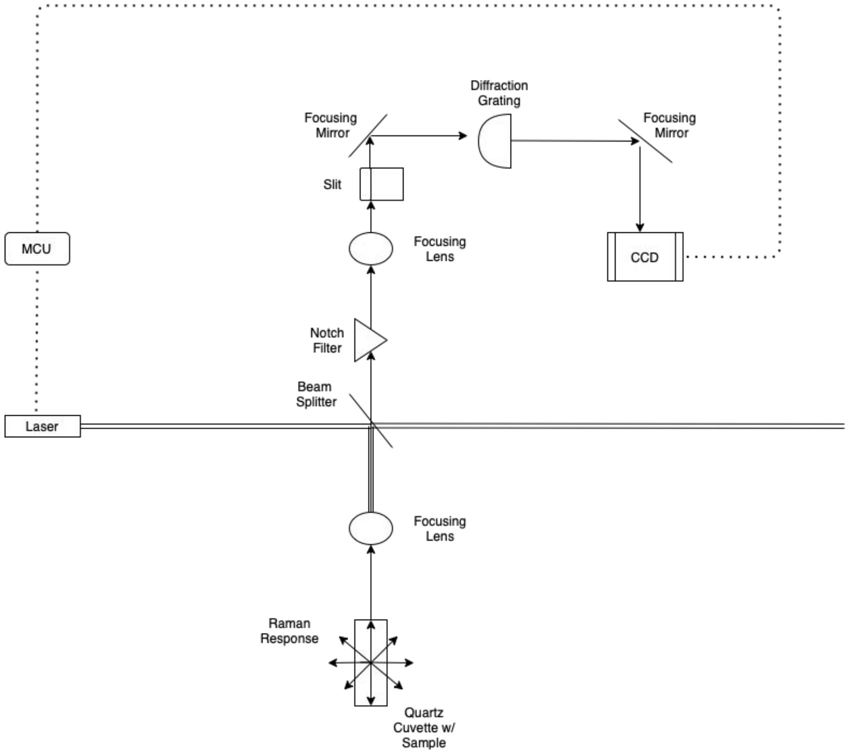
- We have great end to end optics, that can test the critical aspects of our integrated system, but at the end of the day we do not have a Raman response

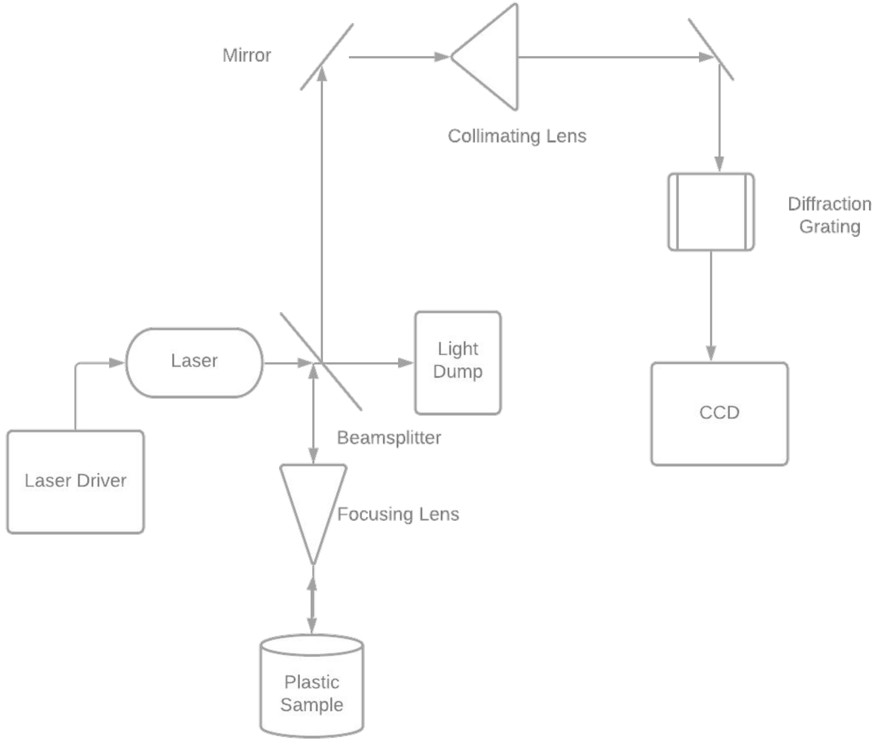
- After the video demonstration, we will show you our plans for debugging

MDR Deliverables

- ❏ Complete optical chamber, built around a development board
- ❏ Physical spectrometer linked to user interface via serial monitor to display results of the laser detection
- ❏ Workbench ready breadboard solution
- ❏ We did not meet testing deliverable as we have not sensed a distinguishable Raman response

Original Block Diagram (left) vs Current (right)





Detailed List of Hardware Components Used

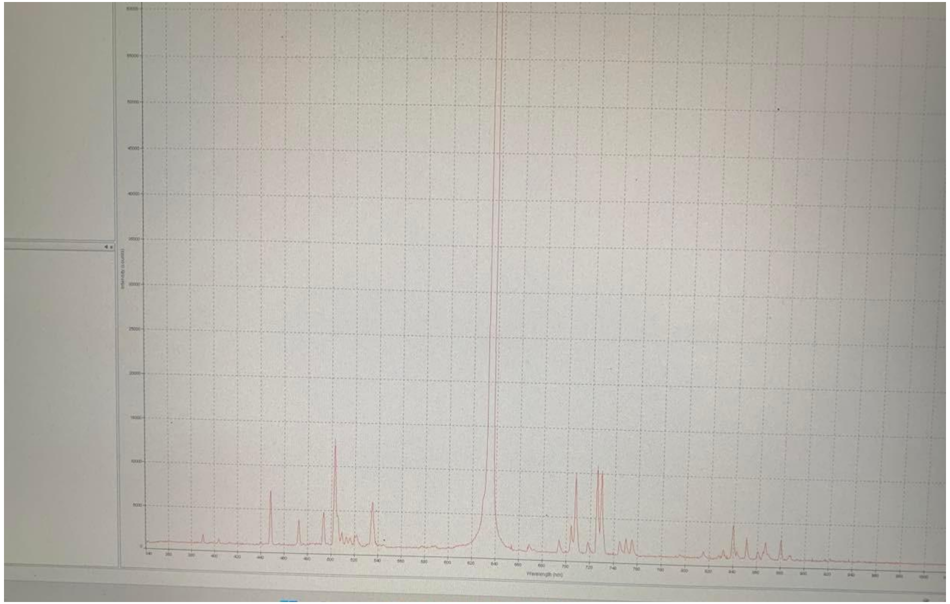
Model 1107P Edmund Optics 0.8 mW 632.8nm laser

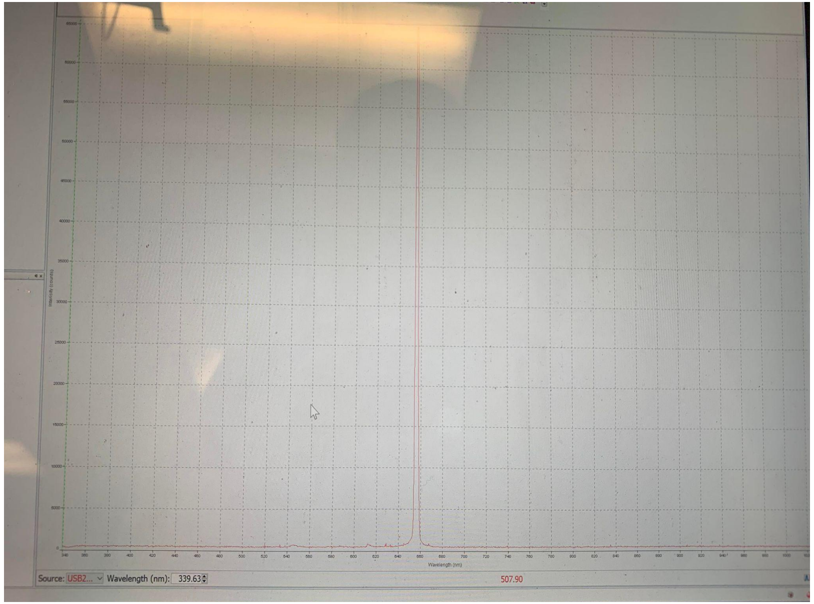
Power Supply for Laser

We originally thought this laser that Professor Arbabi gave us was monochromatic at 635 nm, but after testing it out with a spectrometer, we found out it wasn’t. Prof. Arbabi thinks this is because our power supply is not compatible with the laser.

We will be swapping this with a monochrome 635 nm laser diode for CDR.

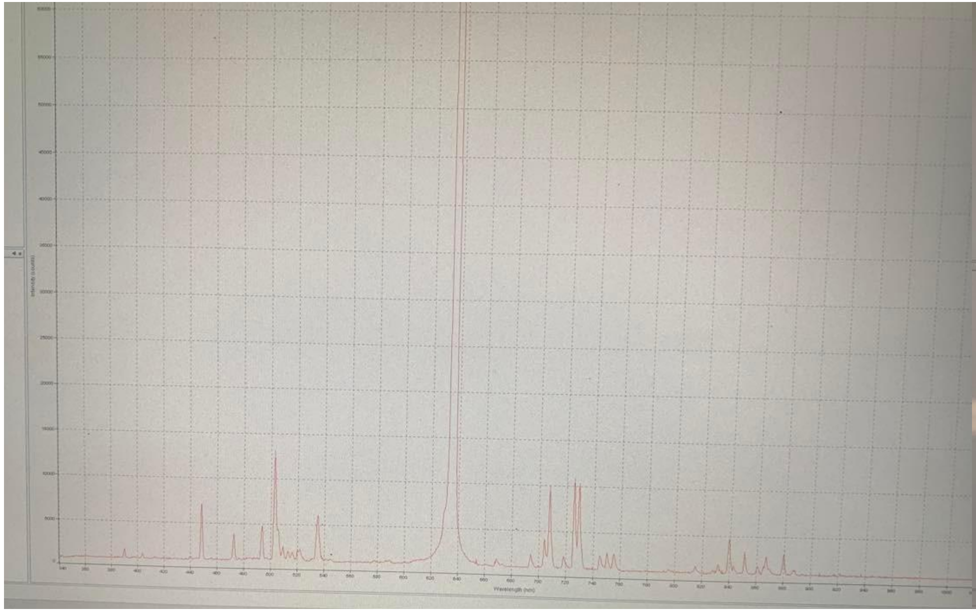
$1000 HeNe laser (left) vs. $10 Digikey laser (right)

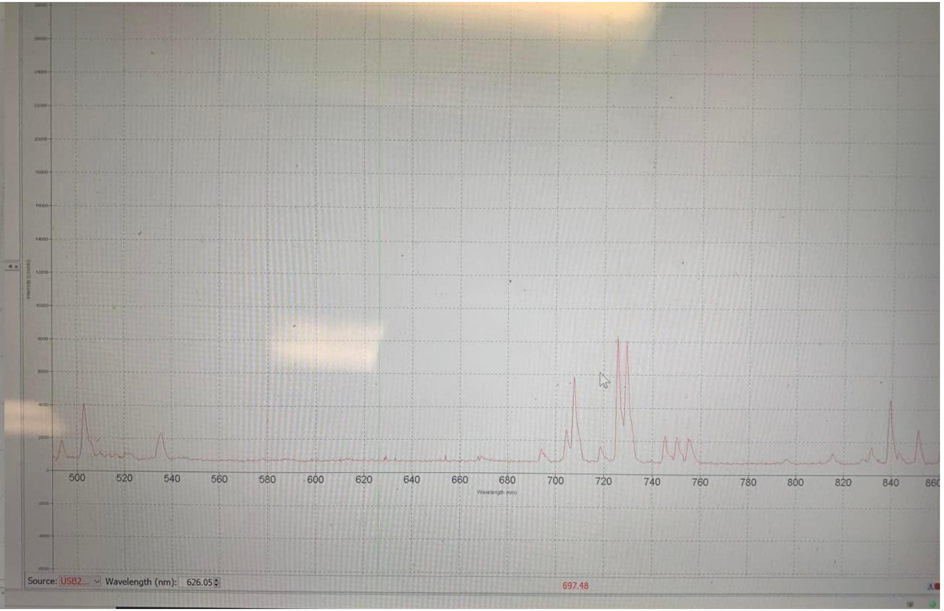




Our problem currently is that our Digikey laser is centered at 655 nm, but we need 635nm. We need to purchase a new one.

HeNe Laser without notch filter (left), with notch filter (right)





Goals for CDR

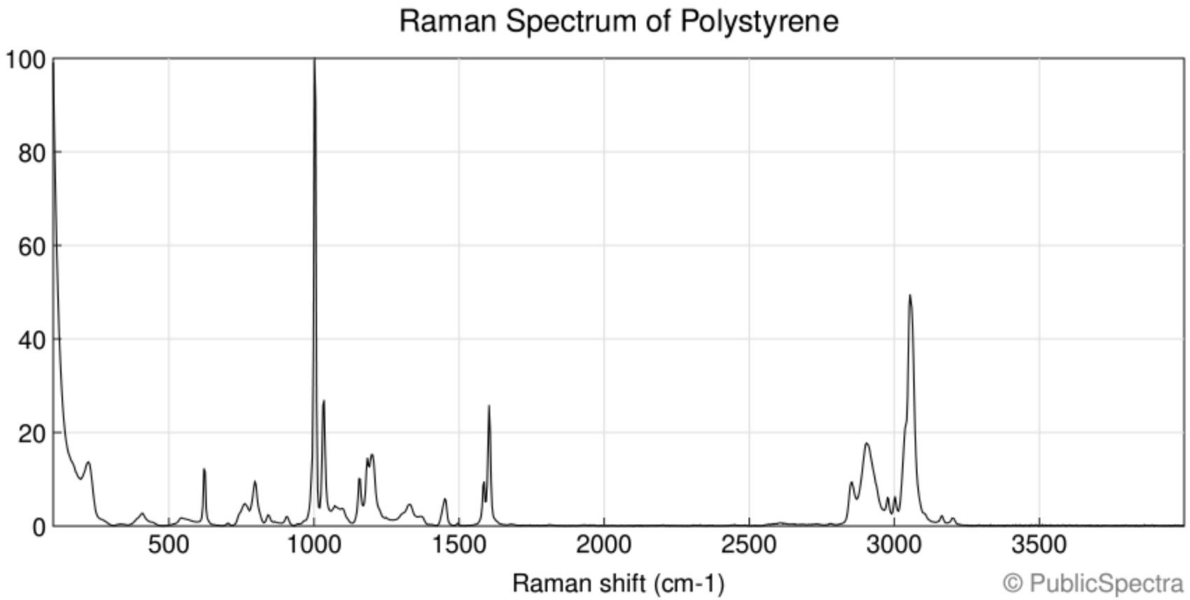
- Sense polystyrene with Raman spectroscopy
- Create a compact optical chamber ready to integrate into a digital circuit
- 3D Printed Optical Chamber that links all components together

Plan for CDR

- Stronger, cleaner Laser (required intensity determined from Raman intensity calculation)
- Debug
- Build PCB
- 3D print linkable chambers which we can drop components into
- Cylindrical Lens rather than Objective Lens on CCD

We are now attempting to sense Polystyrene using a Styrofoam cup

- It is easier to obtain samples of polystyrene than polyethylene.



Raman Shifted Signal Wavelength Calculation (Polystyrene)

Largest peak at 1000 cm^-1

Lambda (nm) = 1cm/lambda(cm^-1)*1m/100cm*(1*10^9 nm)/1m

Lambda (nm) = 10000

$$\bar{v} = \frac{1}{\lambda_0} - \frac{1}{\lambda_1}$$

1/lambda_shifted = 1/632.8 nm - 1/10000 nm

Raman Shifted Laser = 675.54 nm

This is the visible red color!

1/lambda_shifted = 1/632.8 nm - 1/3225.8 nm

Raman Shifted Laser = 787 nm

This new Raman response is very similar to our original of 778 nm!

Raman Intensity Calculation (Still To Come)

$$I_{emission} = I_{laser}\sigma l N \Omega F(\lambda)\Delta\lambda E(\lambda) D(\lambda)$$

I_laser = 2.9 mW (Laser Diode)

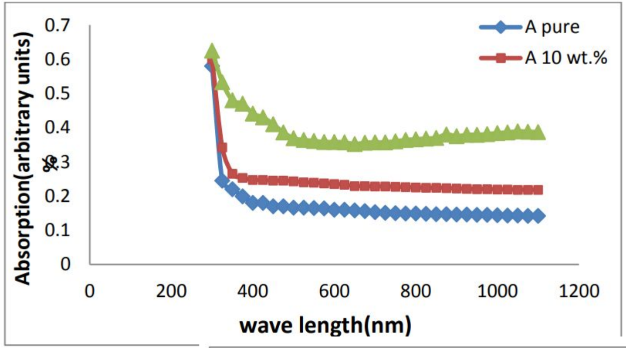
σ = cross section of laser = π*r^2 = pi*(0.5mm)^2

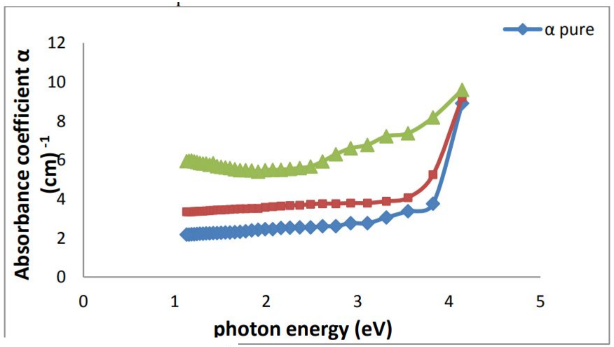
l = optical penetration depth = absorbance/(molar attenuation coefficient * molar concentration) [Obtained from Beer-Lambert law] **Currently getting numbers that are too large**

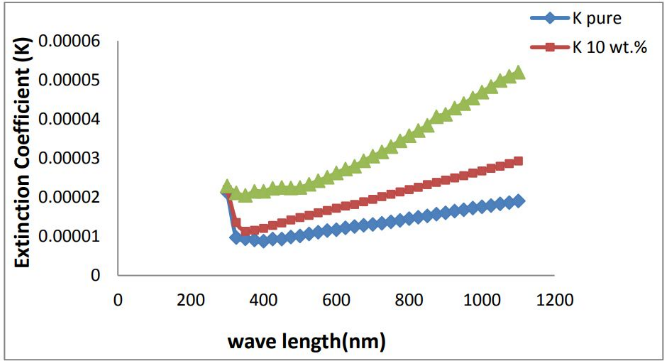
N = number density = Avogadro's number * molar concentration = 2.89*10^26 m^-3

Ω = Lens Solid Angle = Area of lens/ distance to sample^2 = π*(0.5cm)^2/(0.7cm)^2

Optical Properties of Polystyrene







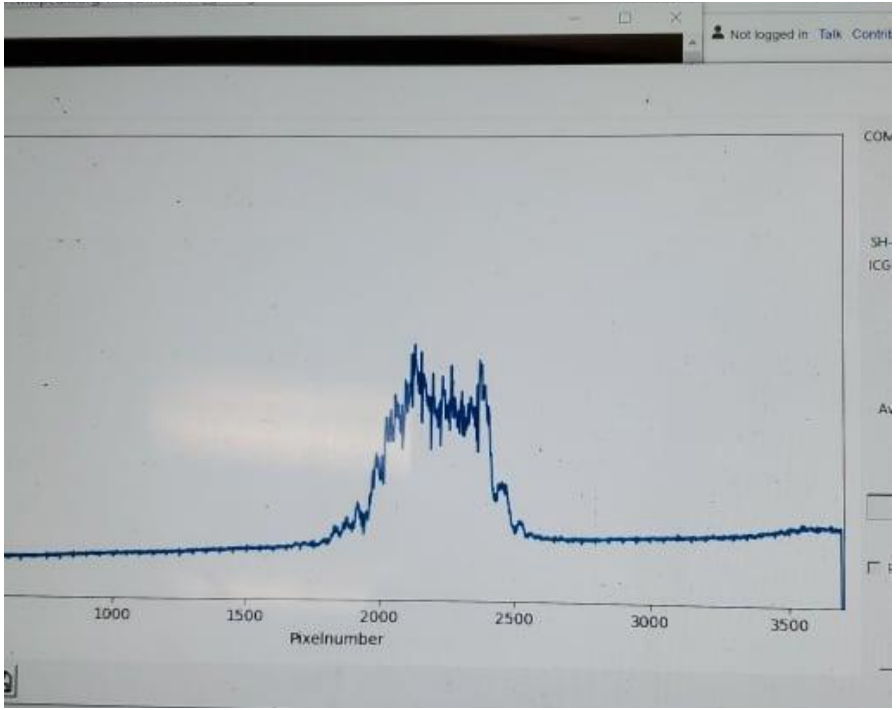
[2] G. J. Habi, “Study the optical characteristics of polystyrene polymer before and after doping with methyl orange,” *Periodicals of Engineering and Natural Sciences*, Sep-2021. [Online]. Available: http://pen.ius.edu.ba/index.php/pen/article/view/2333. [Accessed: 02-Dec-2021].

Debugging Plan

1. Use OceanOptics Spectrometer to detect Raman Signature provided by Prof. Arbabi
2. Once Raman response detected on professional spectrometer, we will detect the Raman response on our own.
3. We will prove that the Raman response is what we expect for polystyrene by comparing to credible spectrums (PublicSpectra)

CCD Debugging Test

- We can sense the exact wavelength of the laser by using a spectroscope (as explained on previous slide).
- We utilize our CCD GUI to compare the spectrum of the Raman Response.



Custom PCB Plan

Finish Design of PCB by January 25th (beginning of spring semester)

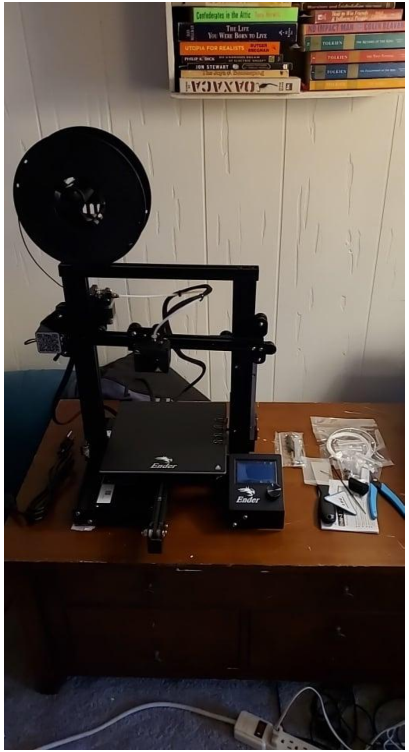
PCB will have

- Programmable by JTAG
- Inverter Chip
- TCD1304 Linear CCD
- ARM-Cortex M4

Order first week of spring semester and receive by third week (2/14-2/20)

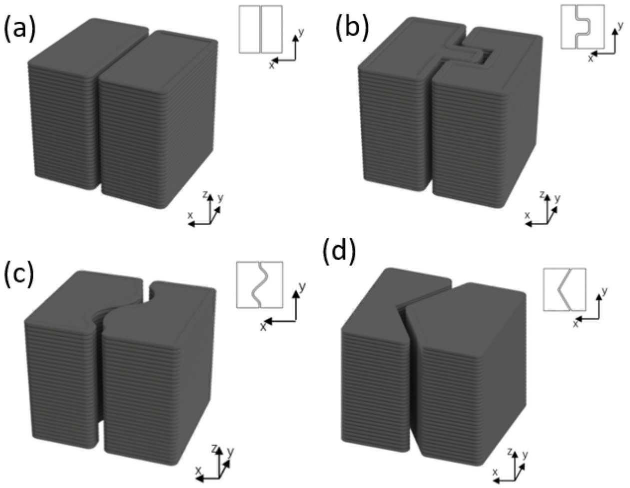
Solder Components by 2/27

Plan for 3D Printed Linkable Chambers

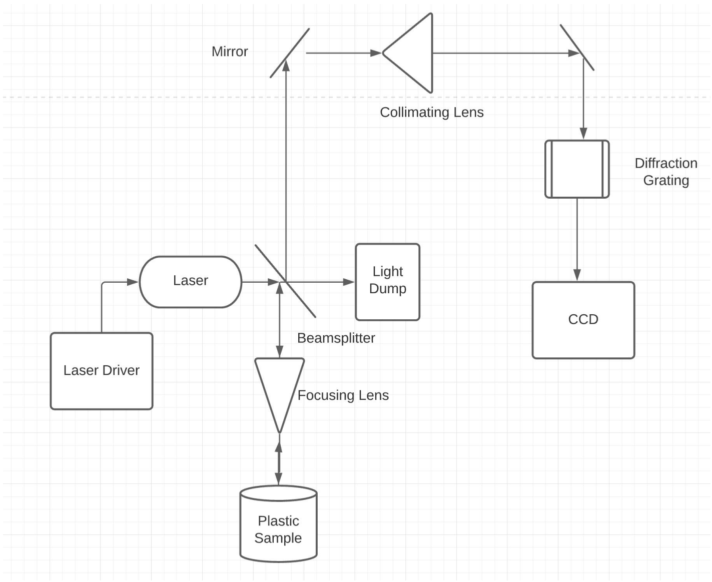


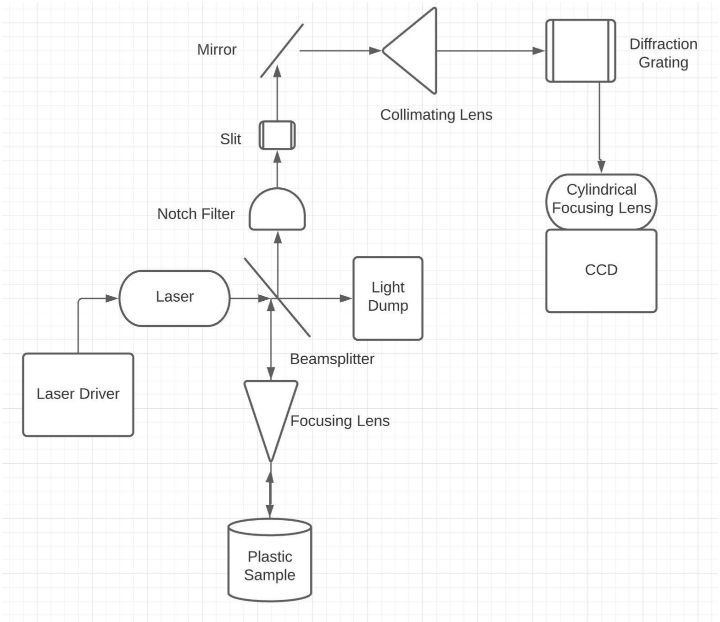
- We have a 3D printer and the necessary modeling software
- Each component can be housed in a unique “block” that can be switched out, or alternatively each component can have unique mounts that can universally attach to blocks
- Blocks will offer modularity and setup speed by using a common interlock design amongst the ends of the component blocks.
- Threaded holes can add stability and increase joint tension

Examples of similar interlocking joint patterns we were thinking, specifically (b)



Current Block Diagram Vs. New Block Diagram





Main differences with new block diagram:

- Only utilizing one focusing mirror --maybe even taking it out from our optical chamber
- Implementing collimating lens that collimates light toward diffraction grating
- Adding a cylindrical focusing lens that totally covers the CCD
- Add correct notch filter and slit

Gantt Chart

Task	Start Date	End Date	Team Members	Winter Break	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20
					M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F	M T W Th F
Calculate Intensity of Raman Response for Polyethylene	12/06/21	01/25/22	AA & AB							
Design PCB	12/16/21	01/25/22	AB & AA & AM							
Design + Print chambers for components we will keep	12/16/21	2/14/22	VL & AM							
Replace Optical Components	01/25/22	2/14/22	AB & AA							
Design + Print chambers for new components	2/14/22	3/7/22	VL & AM							
Receive PCB and Solder Components	2/14/22	2/27/22	AA & AB							
Collect Data	2/27/22	3/7/22	Whole Team							
Switch Communication Channel to SPI	1/25/22	3/7/22	VL & AM							
					01/25/22-01/30/22	01/31/22-02/06/22	02/07/22-02/13/22	02/14/22-02/20/22	02/21/22-02/27/22	02/28/22-03/07/22

Current Expenses

Component	Item	Units	Cost/Unit	Shipping/Handling	Total
.8 mW 633nm laser	https://www.edmundoptics.com/p/Model-1107P-08mW-Linear	1	$0.00	$0.00	$0.00
Focusing Lens	Achromatic Focusing Lens 7.1mm Working Distance	2	$21.59	$0.00	$43.18
Quartz Cuvette 1	Quartz Cuvette - Amazon	1	$21.94	$0.00	$21.94
Quartz Cuvette 2	https://www.amazon.com/Quartz-Cuvette-Lightpath-Cuvettes-	1	$15.80	$0.00	$15.80
Notch Filter	632.8nm, 12.5mm Diameter, OD 4.0 Notch Filter	1	$95.00	$8.99	$103.99
Slit	Diaphragm with 4 Double Slits of Different Spacings	1	$22.19	$0.00	$22.19
Diffraction Grating	Diffraction Grating, 1000 lines/mm	1	$12.95	$0.00	$12.95
CCD/Photodiode	https://www.amazon.com/MyColo-TCD1304AP-TCD1304-Tosl	1	$14.94	$0.00	$14.94
Focusing Mirrors	https://www.edmundoptics.com/p/25mm-dia-x-50mm-fl-protec	2	$50.50	$43	$143.99
Magnets	https://www.amazon.com/gp/product/B08HQNVXRG/ref=ppx_	1	$9.99	$0	$9.99
beam splitter	https://www.edmundoptics.com/p/18-x-30mm-70r30t-plate-be	1	$39.00	0	$39.00
MCU	ATMega1284P-PU	1	$0.00	$0.00	$0.00
Dev Board	ATMEGA1284P-XPLD	1	$0.00	$0.00	$0.00
PCB	Custom PCB	3	$0.00	$0.00	$0.00
			Total Sum:		$427.97
			Remaining Budget		$72

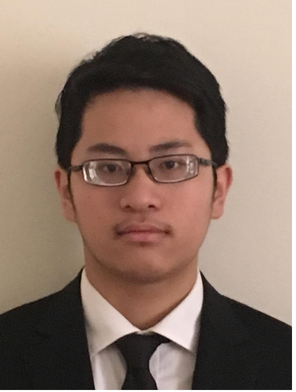
Team Responsibilities

Aaron Achildiyev

- Team Coordinator
- PCB Design
- Optical Design

Aidan Belanger

- PCB Design
- Optical Design



Victor Lam

- Software Design
- 3D Modeler

Adrian Mora

- Hardware Design
- Software Design

Thank You

Questions?