Final Presentation

ECOspec

Microplastic Detection via Raman Spectroscopy

ECO
spec
RAMAN DETECTION

GROUP #6

MEMBERS

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Logan Sullivan (CPE)

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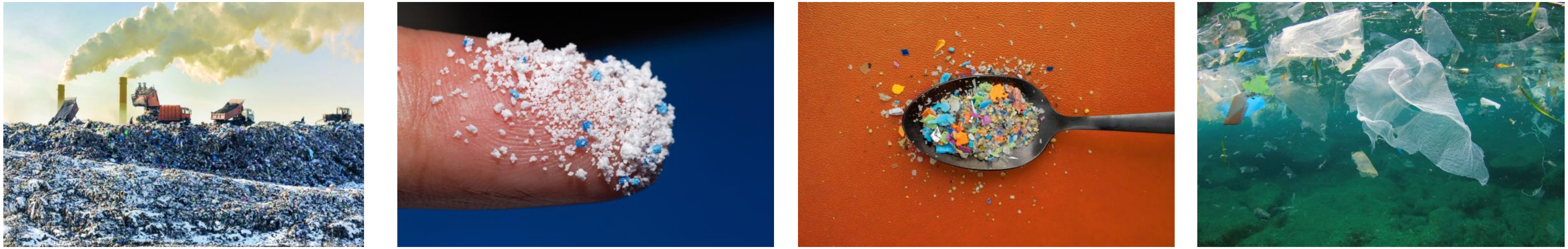
PROBLEM, MOTIVATION, & PROJECT SOLUTION

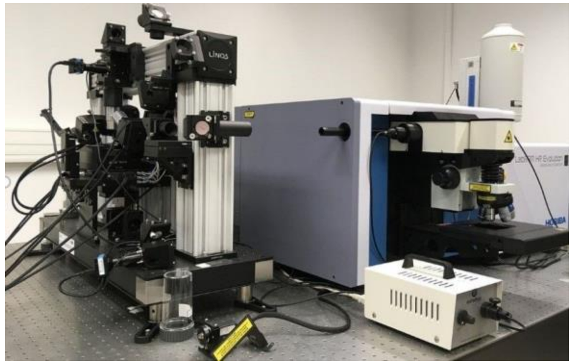


Microplastics are a **NEW**, **PERVASIVE**, and **HARMFUL** pollutant in every global environment.

1. Environmental **contamination** poses a **global health issue**
2. They are known to **disrupt** the **human endocrine** and **immune system**.
3. They are known to be in our **water supply**, **food supply**, **ocean**, and **atmosphere**.
4. Their **long term effects** are largely **unstudied** and **unknown**
5. Detecting and identifying contamination from microplastics is key for understanding their impact.

PROBLEM, MOTIVATION, & PROJECT SOLUTION

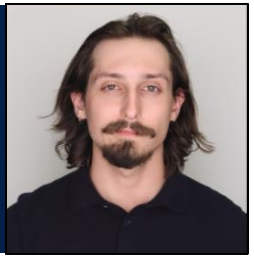
- **Current solutions are limited**
  - Manual inspection slow, human error
  - Plastic identification burn methods destroys the sample
  - Lab grade micro-Raman systems are expensive $75,000 +



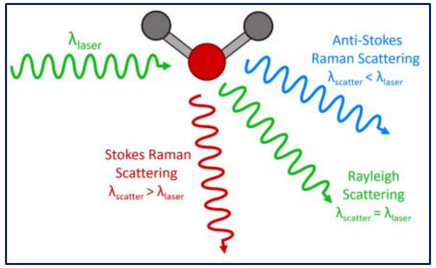
HORIBA LabRAM in UCF NTSC

- **ECOspec is a compact Raman spectroscopy system** designed to detect and identify microplastics in water
  - Our project lays the groundwork for an electro-optical solution to improve environmental monitoring, water quality analysis, and research into microplastic pollution

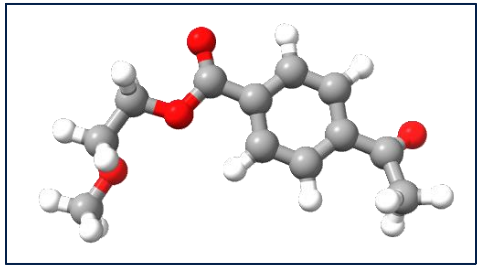
BACKGROUND



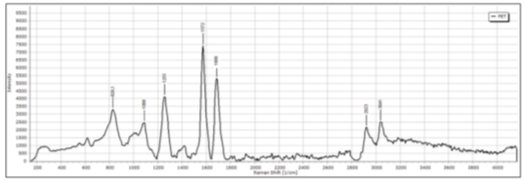
- **Scattering**
  - There are two main categories of scattering: elastic and inelastic
    - **Elastic**: Photon does **not** experience change in energy (common)
    - **Inelastic**: Photon experiences change in energy (uncommon)
  - **Raman Scattering** is **inelastic** and occurs ~1/10^8 interactions



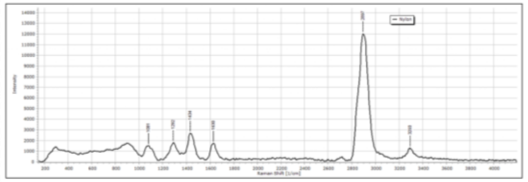
Scattering Diagram



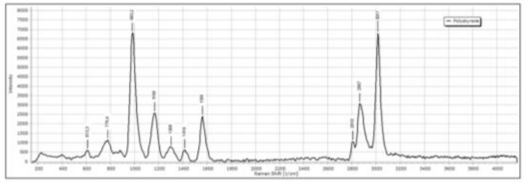
Model of PET from NIH



PET



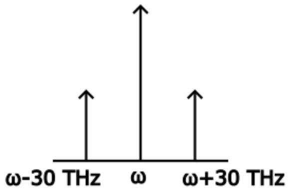
Nylon



Polystyrene

Spectra of Plastics

- **Different molecules have unique Raman spectra**
  - This comes from the ***unique electron clouds*** of the molecules caused by atomic bonds and structures
  - Laser light **polarizes** a molecules electron cloud, causing it to oscillate at optical frequencies (785 nm = 382 THz)
  - The molecule is also vibrating due to heat (@ 10s of THz)
  - ***The laser light oscillates the electron cloud while the molecule is vibrating***
  - The molecular vibration modulates the cloud's "polarizability"



- **Sideband Generation**
  - Sum/difference frequencies are seen, where the molecules **vibrational modes** add/subtract energy to the incident photon.
  - These sum/diff frequencies correspond to the shifts in energy of Raman scattering
  - ***Each Raman peak is a different vibrational mode of the molecule***

GOALS

Basic Goals

- Collect spectra of infrared sources
- Collect Raman Spectra of known strong emitters
- Collect Raman Spectra of specified polymers 1-5 mm^2 in maximum size
- Detect presence of PET, Polystyrene, and Nylon, in a non-mixed premade sample using fingerprint spectra
- Control the laser through external means
- Ensure safety and ease of use for users

Advanced Goals

- Detect microplastics down to 500 micrometers in length and 100 micrometers in width.
- Identify the type of plastic present in a non-mixed premade sample between PET, Polystyrene, and Nylon.
- Create a database server with all previously taken samples and their result.

Stretch Goals

- Detect and identify microplastics of mixed pre-made water solution samples.
- Detect and identify microplastics with a sample from the environment, such as tap water or lake water sample.
- Portable, battery powered, field deployable version instead of a bench system.

ENGINEERING SPECIFICATIONS

Engineering Requirement	Specification	Unit
High spectral resolution so common polymer raman peaks can be resolved clearly with enough detail to distinguish one from the other for plastic identification purposes.	< 20	wavenumbers
The user needs to know the **smallest size of microplastic the system can detect.**	500	um
The device must perform collection and analysis in a reasonable **time frame**	<10	minutes
The device must achieve a sufficient **detection accuracy** to ensure reliable microplastic identification.	≥66%	Accuracy
Dimensions of device needs to remain user friendly and reasonable.	< 50 x 100 x 100	cm x cm x cm

UCF-SD2-sp2026-G6-ECOspec

Hardware Block Diagram

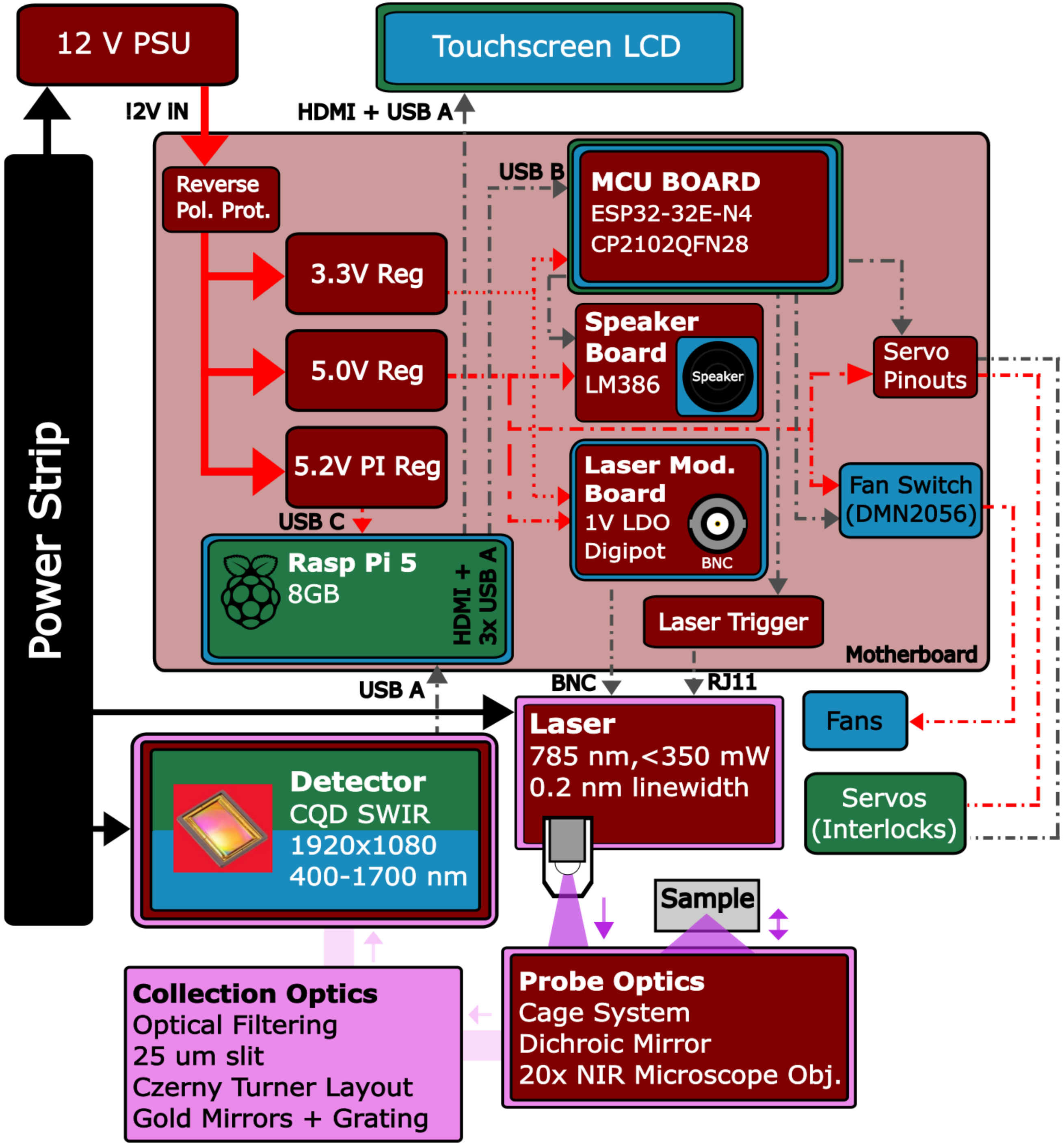
ECOspec
RAMAN DETECTION

Role

- 🟣 Sophia (PSE)
- 🟤 Michael (PSE/EE)
- 🟢 Landon (CPE)
- 🔵 Logan (CPE)

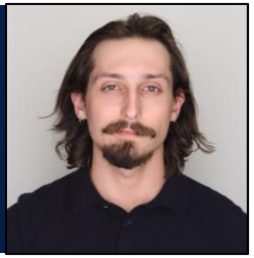
Connections

━━━	120 V AC
━━━	12 V DC
─ · ─ ·	5.2 V DC
· · · · · ·	3.3 V DC
─ · ─ ·	DATA
▬	785 nm Laser
▬	Raman Scattering



12 V PSU
12V IN
Touchscreen LCD
HDMI + USB A
Power Strip
Reverse Pol. Prot.
3.3V Reg
5.0V Reg
5.2V PI Reg
USB C
USB B
MCU BOARD
ESP32-32E-N4
CP2102QFN28
Speaker Board
LM386
Speaker
Servo Pinouts
Laser Mod. Board
1V LDO
Digipot
BNC
Fan Switch (DMN2056)
Rasp Pi 5
8GB
HDMI + 3x USB A
Laser Trigger
Motherboard
USB A
BNC
RJ11
Laser
785 nm,<350 mW
0.2 nm linewidth
Fans
Servos (Interlocks)
Detector
CQD SWIR
1920x1080
400-1700 nm
Sample
Collection Optics
Optical Filtering
25 um slit
Czerny Turner Layout
Gold Mirrors + Grating
Probe Optics
Cage System
Dichroic Mirror
20x NIR Microscope Obj.

PROBE OPTICS SELECTION

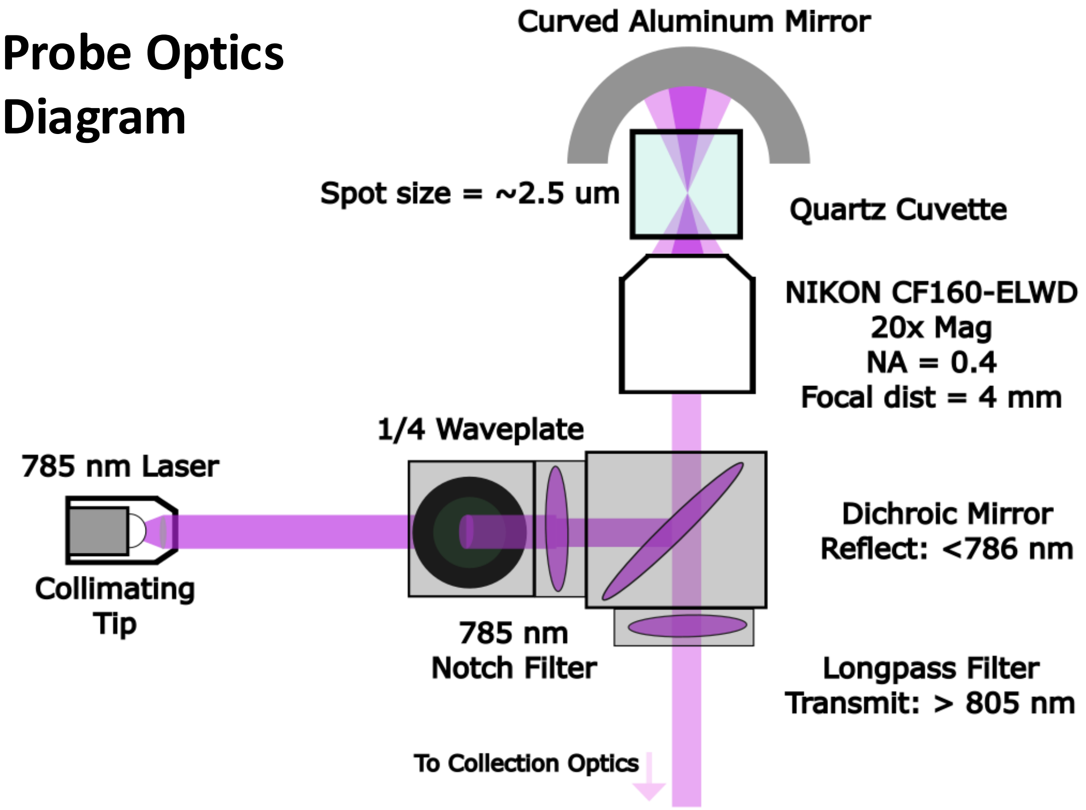


Laser	Fluorescence	Raman Response	Detector Response
532	High	High	High
785	Low	Medium	Medium
1064	Very Low	Low	Very Low

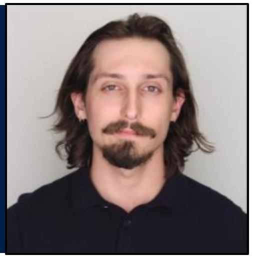
Laser Clean up	Aberration	Loss	Extra Components
ND+IRIS	Minimal	High	2
Waveplate + Notch	Minimal	Low, adjustable	1

Objective	Mag	NA	Coating	Spot Diameter
Newport M-10x	10x	0.25	VIS	2.98 um
Nikon CF160 20x	20x	0.4	VIS-NIR	2.5 um
Nikon CF160 50x	50x	0.6	VIS-NIR	1 um

Probe Optics Diagram



PROBE OPTICS POWER CALCULATIONS



$V_{in} = 0.34$ V
$P_{in} = 120$ mW
Beam Radius = 2 mm
Aperture Radius = 1.8 mm

$A = \pi * r^2$
$A_{1mm} = \pi$
$A_{1.1mm} = \pi*(1.8)^2$
$T = A_{1mm} / A_{1.1mm} = .81$

$P_{loss} = 120*(1-.81) =$ ~24 mW

$P_{incident}$
= 120 mW * .8 * .99 * .99 * .99 * .87
= 81 mW incident on sample

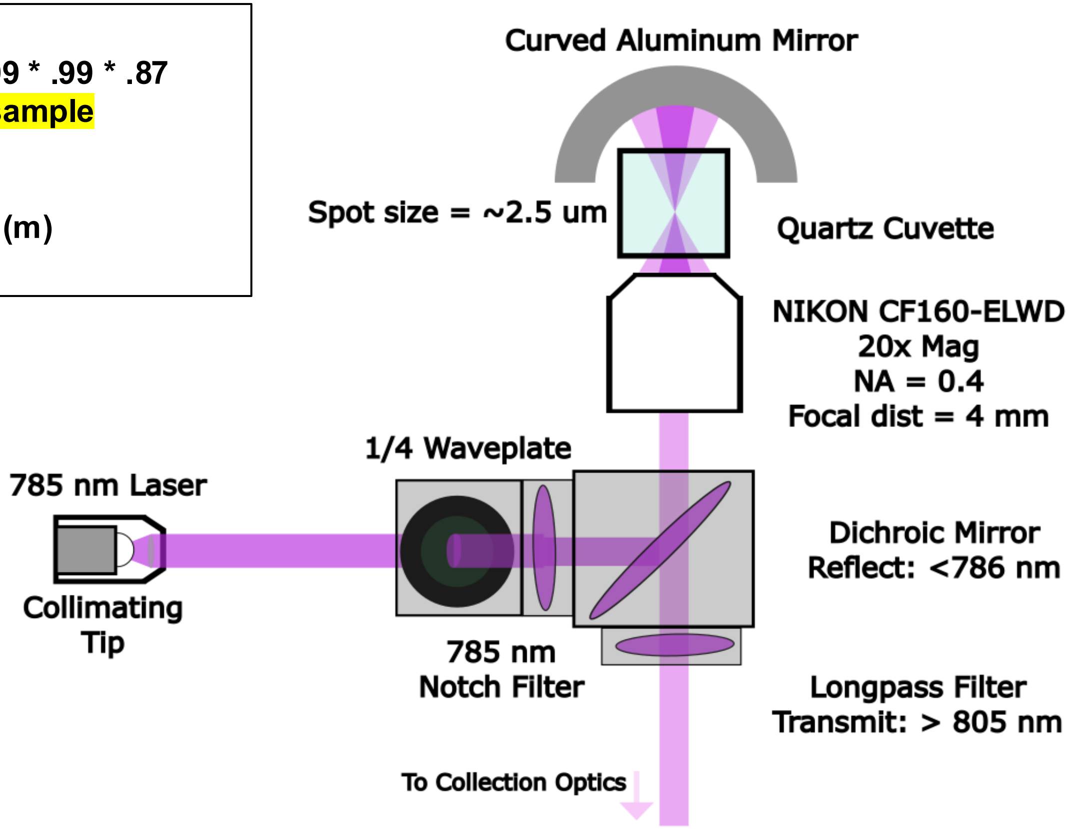
Intensity
$= 80*10^{-3}$ (W) / $2.4*10^{-6}$ (m)
= 33750 W/m^2

Total energy >> 81 mW = 81 mJ in 1 second
$3.2*10^{17}$ photons/s @ 785 nm

Raman occurs $1/10^8$ interactions
$= 3.2*10^9$ Raman photons/s

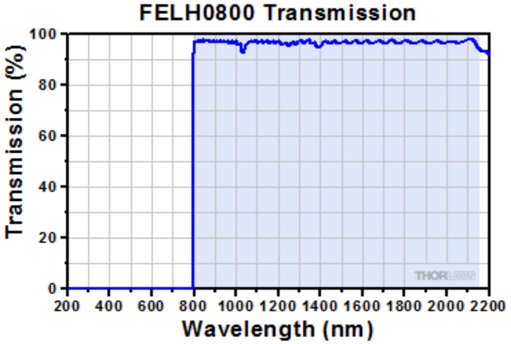
@ 935 nm
>> $2.126*10^{-19}$ J/photon
>> 0.680 nJ of Raman scattering per second

1 mW = 0 dBm
1 uW = -30 dBm
1 nW = -60 dBm
0.5 nW = -63 dBm >> 0.68 nW = -61.7 dBm Raman



COLLECTION OPTICS SELECTION

- **Finite vs infinity-corrected objective**
  - Finite microscope objective will introduce spherical aberrations with filters
  - Choice: infinity-corrected objective with a tube lens
    - AC254-00-B-ML, 650-1050 nm, acromatic doublet
- **Additional Laser Filtering**
  - Longpass vs Notch filter
  - Choice: Longpass filter



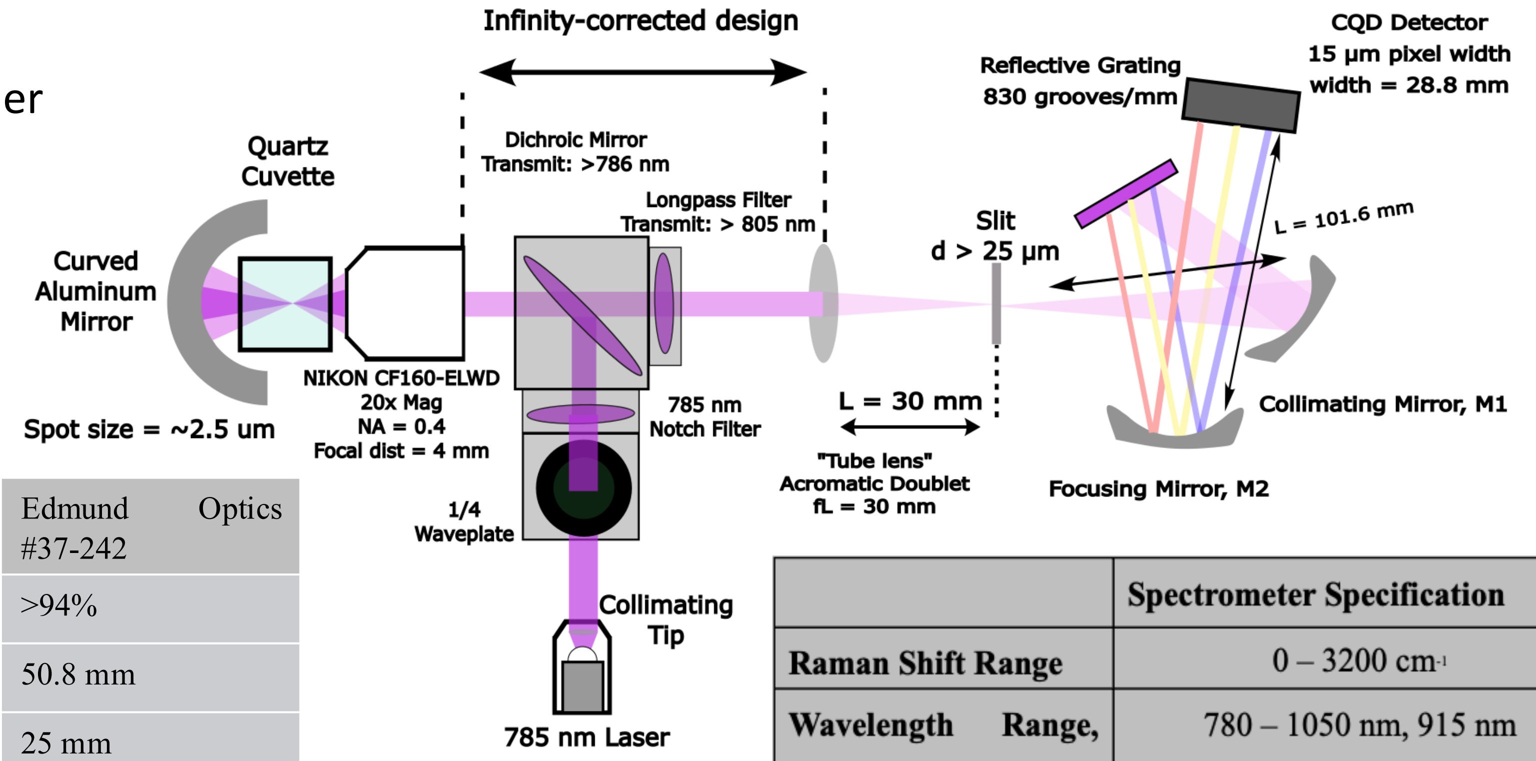
- **Slit size design choice**
  - <50 um
  - Smaller slit size improves resolution and reduces spherical aberrations, but also reduces optical power reaching detector
  - Optimize trade-off by matching real image size produced by objective to slit size

	785 nm Longpass Filter	**800 nm Longpass Filter**
Vendor	RazorEdge, LP02-785RU	Thorlabs, FELH0800
Transmission Range	791.6-1770.7 nm	800 – 2150 nm
Rejection Range	< 785 nm	200-813 nm
Cost	Borrowed	$635.55

	AC254-030-B-ML	**LA1805-ML**
Vendor	Thorlabs	Thorlabs
Coating	BBAR, 650-1050 nm	Uncoated
Focal Length	30 mm	30 mm
Cost	Borrowed	$43.62

SPECTROMETER DESIGN & HARDWARE SELECTION

- **Spectrometer type:** Crossed Czerny-turner spectrometer
- **Ruled Diffraction grating selection**
  - Groove density: 830 groves/mm
  - Blaze wavelength: 800 nm



	Thorlabs, CM750-200-M01	**Torrent**	Edmund Optics #37-242
Reflectance	>94%	>94%	>94%
Focal Length	-200 mm	101.6 mm	50.8 mm
Diameter	75 mm	1 inch	25 mm
Substrate	N-BK7	N-BK7	NA
Type	Concave	Concave	Off-axis parabolic
Coating	Gold	Gold	Gold
Price	$217.73	Borrowed	$291.50

	Spectrometer Specification
Raman Shift Range	0 – 3200 cm^{-1}
Wavelength Range, Center	780 – 1050 nm, 915 nm
FHWM @ 785 nm	0.7 nm, 10 cm^{-1}

SPECTROMETER DESIGN CALCULATIONS

- **Spectral resolution assuming we illuminate entire slit:** 0.2345 nm
  - Goal: 0.7 nm FWHM

- **Minimum detector length** for our wavelength range (270 nm) and pixel size (15 microns) = 16.875 mm
  - **Selected detector length:** 28.8 mm

- **Maximum grating groove density** for our wavelength range to ensure longest wavelength (1050 nm) does not exceed the diffraction limit at 90 degrees: 952.3 lines/mm
  - **Selected grating groove density:** 830 lines/mm

$$\omega_{slit} = \frac{G\,\Delta\lambda\,L_c}{cos(\alpha)}$$

$$20\ um = \frac{830\ g/mm\ \ \Delta\lambda\ \ 101.6\ mm}{cos(7.7607)}$$

$\Delta\lambda$ = 0.234 nm = 4 - 15 cm^{-1} (wavelength dependent)

$$L_{d,min} = \frac{2.5 * w * (\lambda range)}{\Delta\lambda}$$

$$L_{d,min} = \frac{2.5 * 15\ um * (270\ nm}{0.6\ nm} = 16.875\ mm$$

$$G_{max} = \frac{1}{\lambda max * 10^{-6}}$$

$$G_{max} = \frac{1}{1050\ nm * 10^{-6}} = 952.381 \text{ lines/mm}$$

PROCESSING COMPUTER COMPARISON

- **Onboard processing:** A Raspberry Pi 5 handles camera communication and spectral data processing.
- **Linux compatibility:** Runs Linux and supports the camera SDK, enabling onboard analysis without an external computer.
- **Avoids Windows dependency:** OEM imaging software is Windows only, using the SDK allows full camera control on Linux without virtual machines.
- **Simplified integration:** SDK supports custom Linux GUIs and UART commands for camera control (TEC temperature, integration time, pixel data).

Specs	**Raspberry Pi 5**	**NVIDIA Jetson**	**External PC**
Processor	Broadcom BCM2712 Arm Cortex-A76	ARM Cortex-A57	N/A
Clock Rate	2.4 GHz	1.43 GHz	2.4+ GHz
RAM	8 GB	4 GB	8 GB+
Storage	Custom with microSD	Custom with microSD	Custom with SSD/HDD
Operating Voltage	5 V	5 V	N/A
Max Current	5 A	2 A	N/A
Max Power Draw	25 W	10 W	N/A

MCU COMPARISON

- **MCU-based control:** An MCU is sufficient for control and safety, an FPGA is unnecessarily complex.
- **Independent safety system:** The MCU operates separately from the Raspberry Pi to ensure reliability.
- **ESP32 functionality:** A dual-core ESP32 manages safety interlocks, laser power, and status indicators.
- **Fail-safe shutdown:** The laser turns off if interlocks fail, doors open, or runtime limits are exceeded.

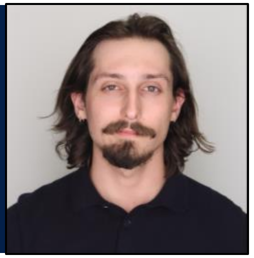
	ESP32	**Teensy 4.1**	**STM32**
Max Clock Rate	240 MHz	600 MHz	168 – 250 MHz
Dual Core	Optional	Optional	Optional
Flash Memory	4 MB	8 MB	16 – 128 KB
I/O Ports	36	40	40
Operating Voltage	3.3 V	3.3 V	3.3 V
Max Current Draw	500 mA	~150 mA	~150 mA

LCD COMPARISON

- **Standalone system design:** A Raspberry Pi enables us to operate without an external PC.
- **Integrated display choice:** An onboard LCD simplifies user interaction and avoids complex external communication setups.
- **Improved data visibility:** Larger screen size and higher resolution make Raman spectra easier to view and interpret.

Specs	Geeekpi 10.1” Touchscreen	Waveshare 7” LCD	Raspberry Pi Official 7” Touchscreen
Screen Size	10.1 inches	7 inches	7 inches
Resolution	1024 x 600	1024 x 600	800 x 480
Touch Capability	Capacitive Touchscreen	Not Touchscreen	Capacitive Touchscreen
Interface	HDMI	HDMI	DSI (Ribbon)
View Angle	178 degrees	170 degrees	170 degrees
Power Supply	5 V DC	5 V DC	5 V DC (GPIO)
Raspberry Pi Compatible	Yes	Yes	Yes
Dimensions	9.25" W x 5.59" H	6.5" W x 4.5" H	6.5" W x 4.25" H
Cost	$60	$45	$80

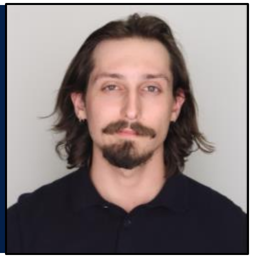
ELECTRICAL - DETECTOR



- **onSEMI ACUROS 2MP CQD SWIR**
  - 400-1700 nm
  - Integrated TEC to 15 °C
  - USB interfacing
  - Normalized Uniformity Correction (NUC) Table
  - ePleora SDK compatible with Linux
  - GenICAM
  - Added heatsinks and fans

Laser	Detector	Range	QE at laser	QE at Δ+200nm	Pro	Con	Expense
785	ACUROS **CQD SWIR** (2.2 MP)	400-1400	30%	25%	Has SDK USB Interface Integrated Stage 1 TEC for +15 C	Very bulky Difficult software interfacing	Borrow
785	**CCD**| Hamamatsu S10141 (2000 x 500)	200-1100	75%	20%	High sensitivity in NIR Stage 2 Integrated TEC for –14 C	Would need to design…, TEC control, signal amplification	Borrow
785	**CMOS** | Sony STARVIS IMX327 (2 MP)	VIS-NIR	70% relative	12% relative	Easier than CCD	Not cooled, typically has IR filter,	$180
785	**CMOS** | OSRAM OS05A20 (5 MP)	VIS-NIR	N/A	N/A	Easier than CCD	Not cooled	$80
532	**CCD** | Toshiba TCD1304DG	VIS	100% relative	10% relative	More resilient to noise than 785	Would need to design… Not sensitive enough	$13
532	**CMOS** | BlackFly FLIR Sony IMX265 (3.2 MP)	VIS	68.5%	40%	Shown to work with OpenRaman project SDK CMOS are easier to interface	Not cooled	$1000 New, $250 used
532	**CMOS** | Raspberry Pi Cam (8 MP)	VIS	95% relative	40% relative	Easier than CCD Not cooled High resolution	Not cooled, has IR filter	$50

ELECTRICAL - DETECTOR



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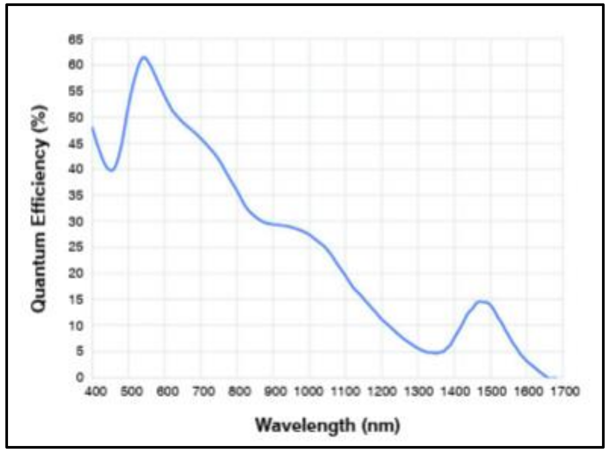


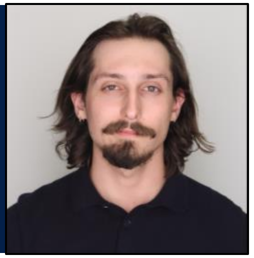
Q.E. vs. Wavelength (nm)

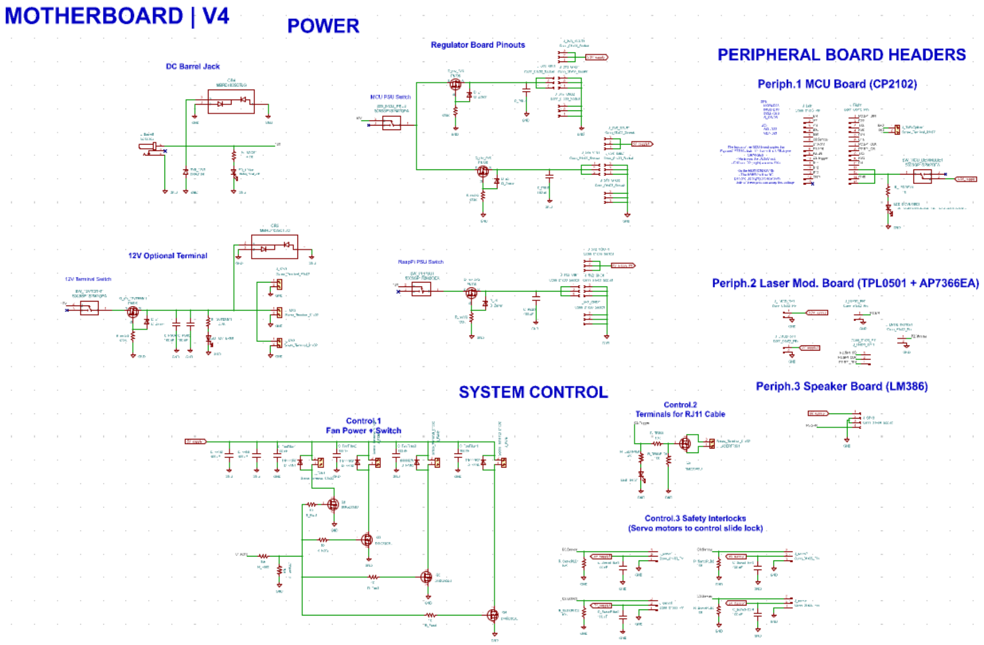
Dynamic Range: 70 dBm = 20log(FWC/noise)
Read Noise: 80 e- /pix
>> Full Well Capacity: 252982 e- /pix
Max integration time = 30 ms = 33 FPS

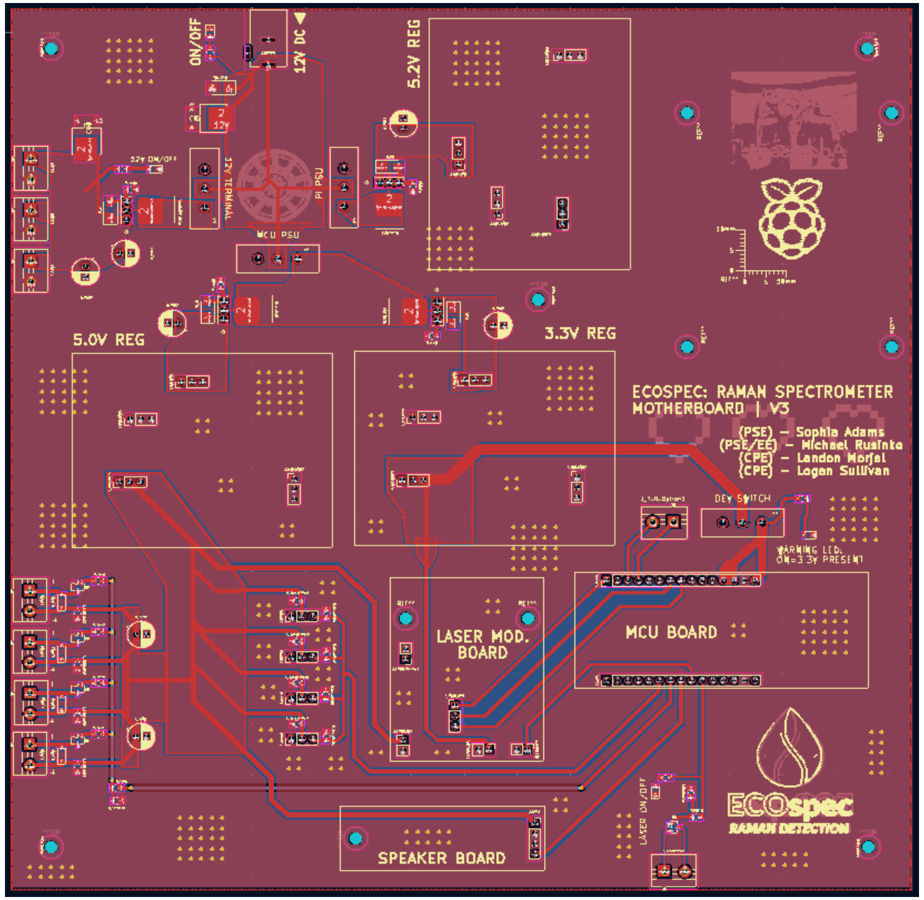
81 mW incident > 0.68 nW = -62 dBm Raman signal
= 0.68 nJ * 0.03 = .0204 nJ in 1 frame
>> $95*10^6$ Raman Photons/frame
Spread over 200 pixels = ~ 475K photons/pix/frame
>> 475K * 27% Q.E. = ~128K converted photons

128K photons is greater than 80 e-
>> 127.9K available photons/pixel above noise @ 120 mW output

ELECTRICAL - MOTHERBOARD

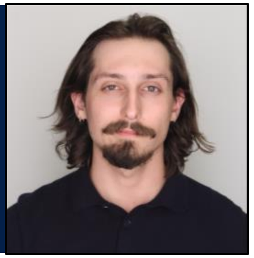


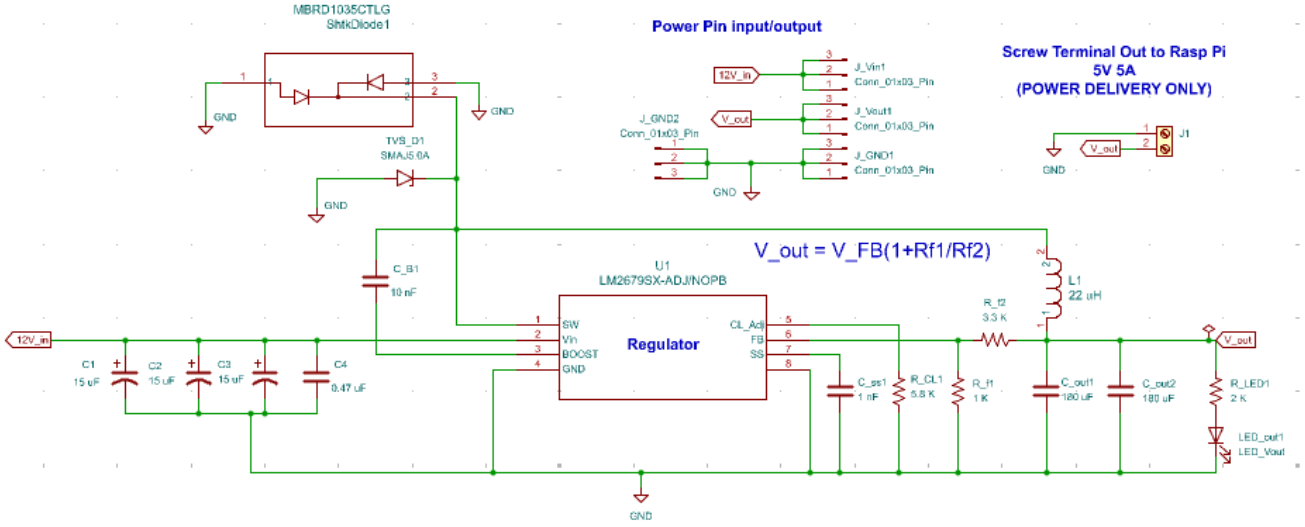


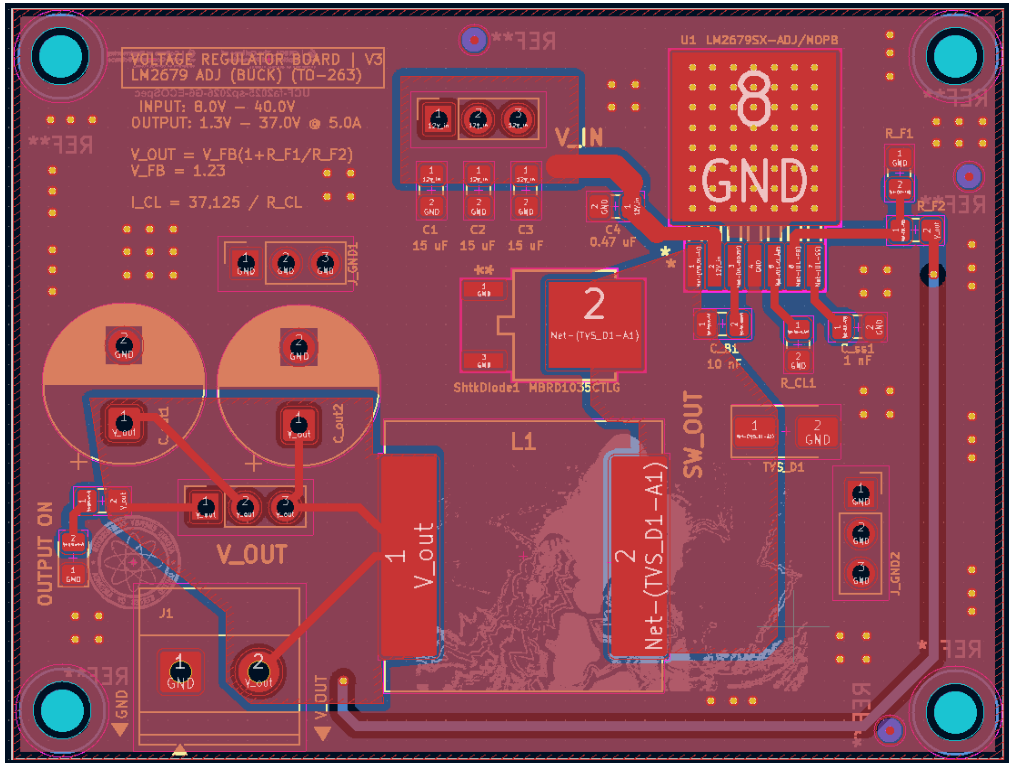


- Motherboard
  - Takes in 12 V DC from a COTS power supply
  - Reverse polarity protection implemented with PMOS FET
  - Holds headers and terminals for MCU board, peripheral boards, fans, servos, and external laser control
  - Switches for debugging and dev board testing

ELECTRICAL - REGULATOR

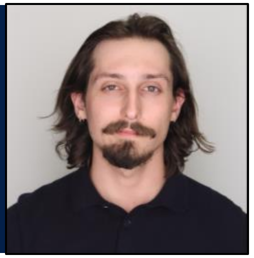


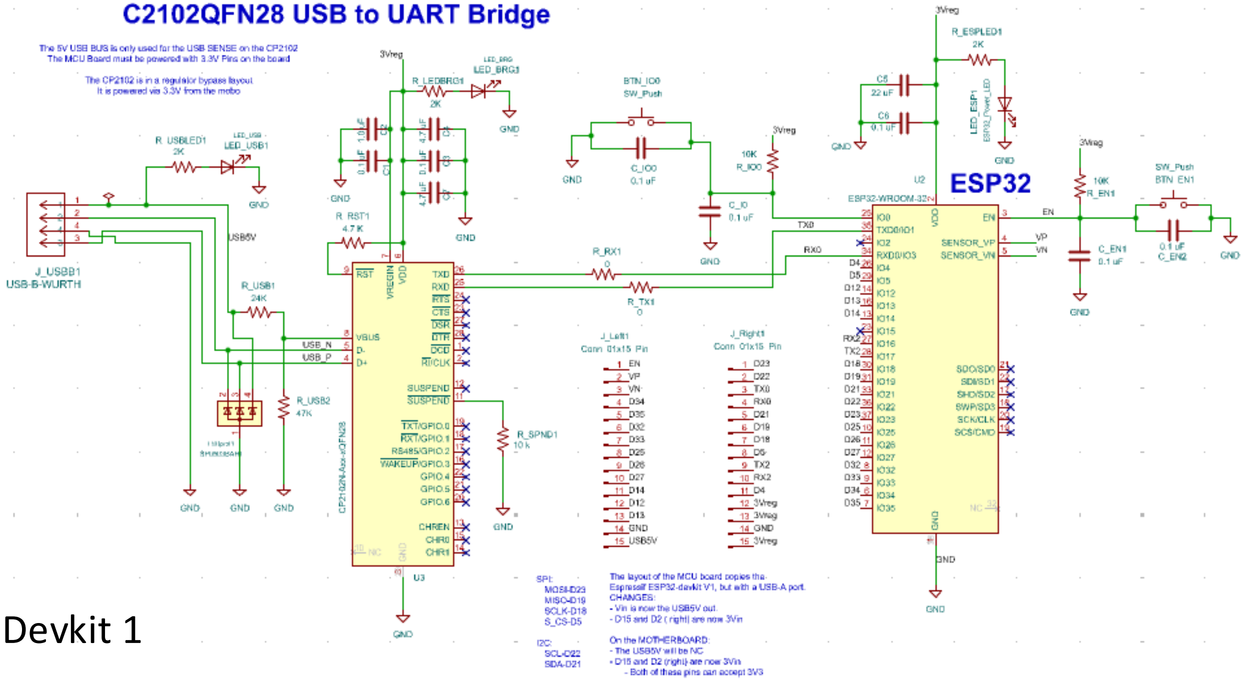




- Voltage Regulators
  - Modular board for 3.3 V, 5.0 V, and 5.2 V
  - TI LM2679SX ADJ
  - Screw terminals for access to additional power and USB-C to Rasp-Pi
  - Up to 5 A of output current, set by R_{CL}

ELECTRICAL – MCU+CP2102





The 5V USB BUS is only used for the USB SENSE on the CP2102
The MCU Board must be powered with 3.3V Pins on the board

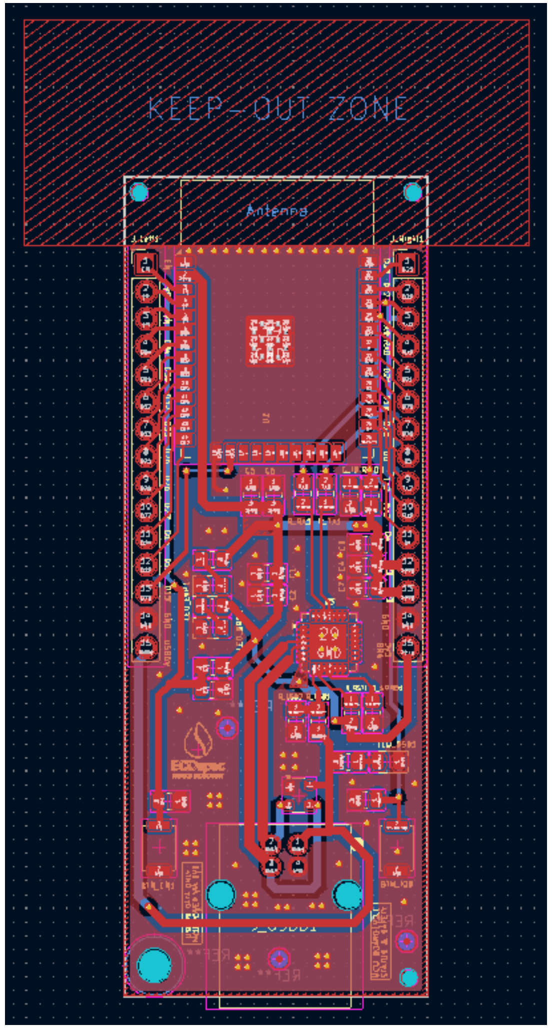
The CP2102 is in a regulator bypass layout
It is powered via 3.3V from the mobo

SPI:
MOSI-D23
MISO-D19
SCLK-D18
S_CS-D5

I2C:
SCL-D22
SDA-D21

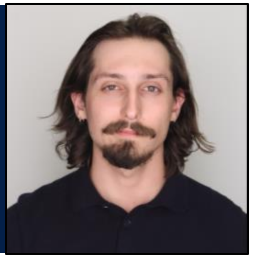
The layout of the MCU board copies the
Espressif ESP32-devkit V1, but with a USB-A port.
CHANGES:
- Vin is now the USB5V out.
- D15 and D2 (right) are now 3Vin

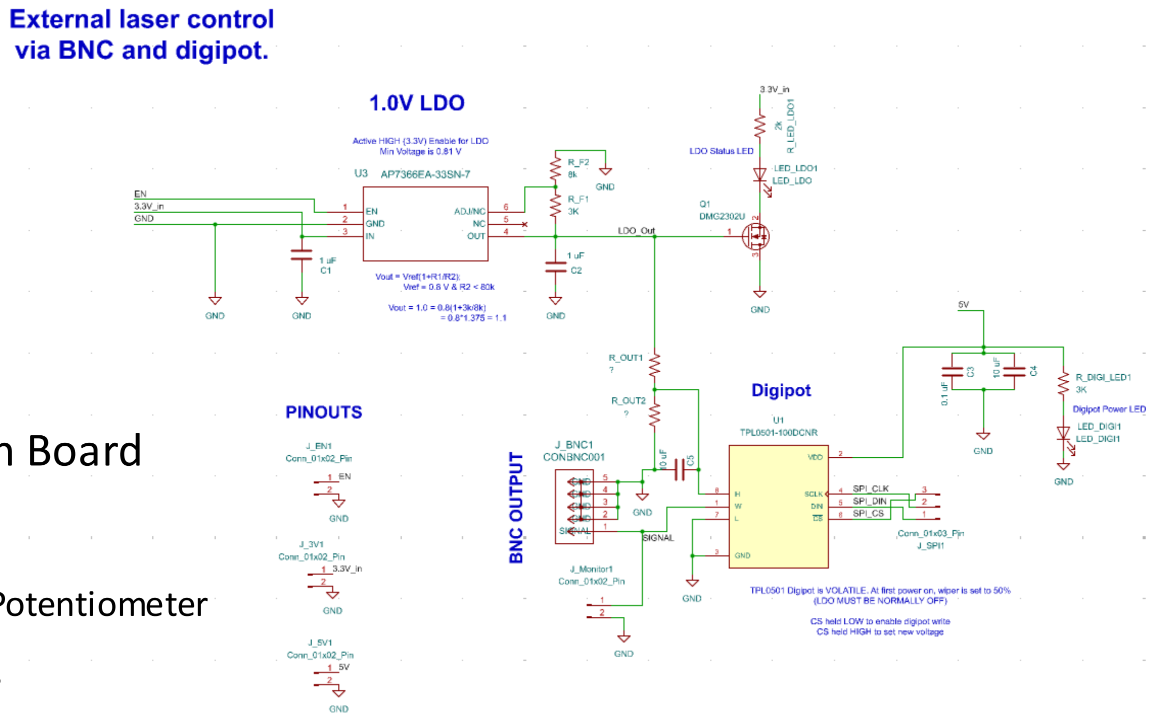
On the MOTHERBOARD:
- The USB5V will be NC
- D15 and D2 (right) are now 3Vin
  - Both of these pins can accept 3V3



- ESP32 MCU Board
  - Deviation of ESP32 Devkit 1
  - Includes CP2102QFN28 USB-to-UART-Bridge
  - Controls peripherals, system controls, and communicates with the Raspberry Pi
  - Serves as an independent controller for the safety systems

ELECTRICAL – LASER MODULATION BOARD

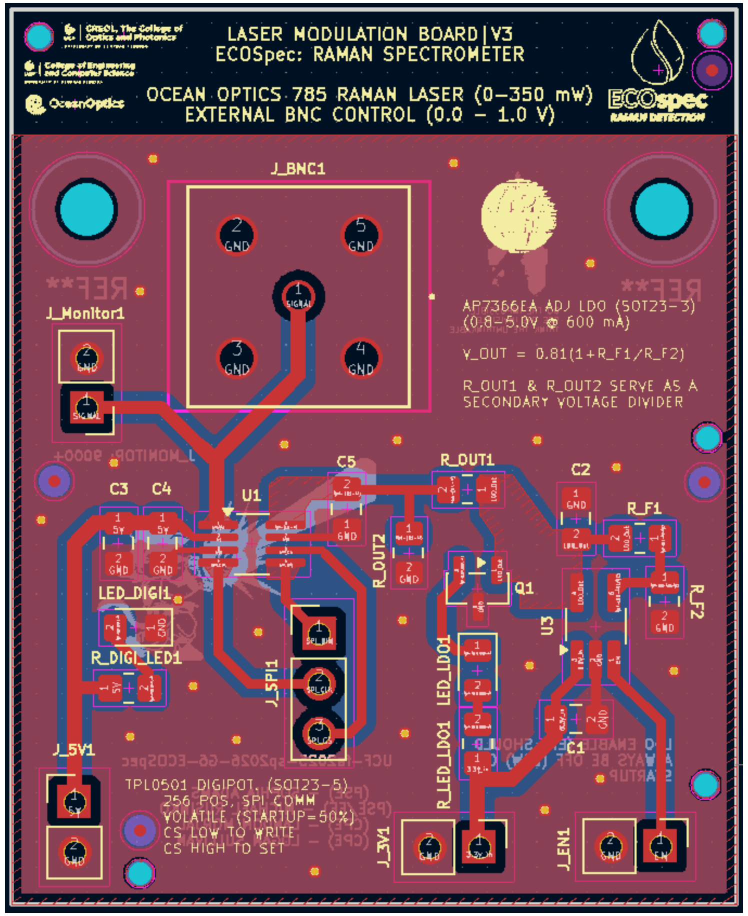




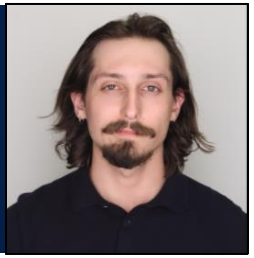
TPL0501 Digipot is VOLATILE. At first power on, wiper is set to 50%
(LDO MUST BE NORMALLY OFF)

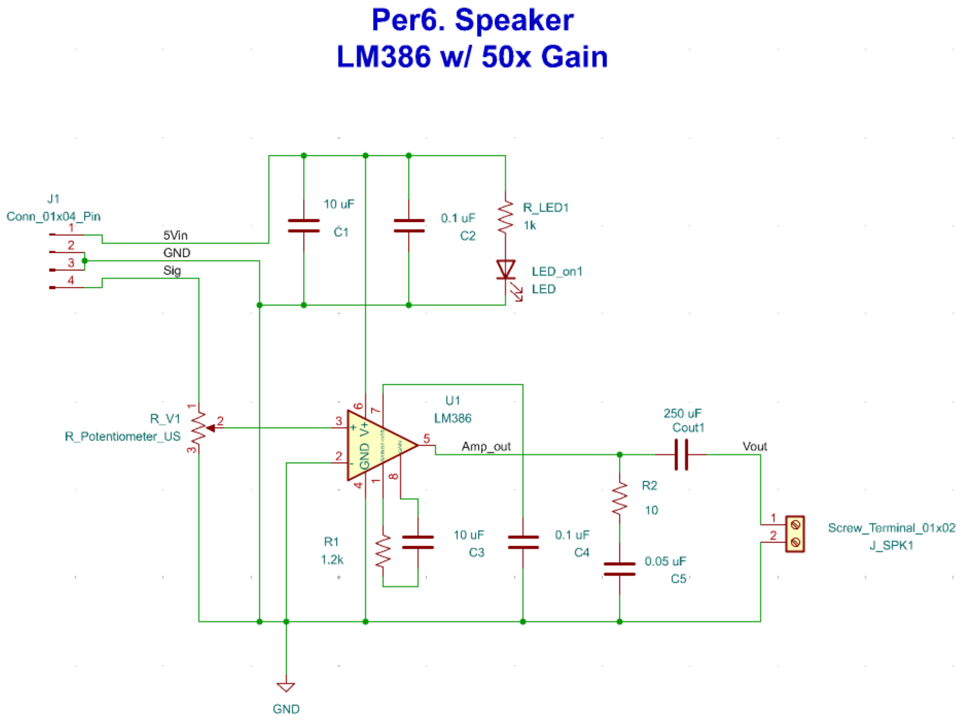
CS held LOW to enable digipot write
CS held HIGH to set new voltage

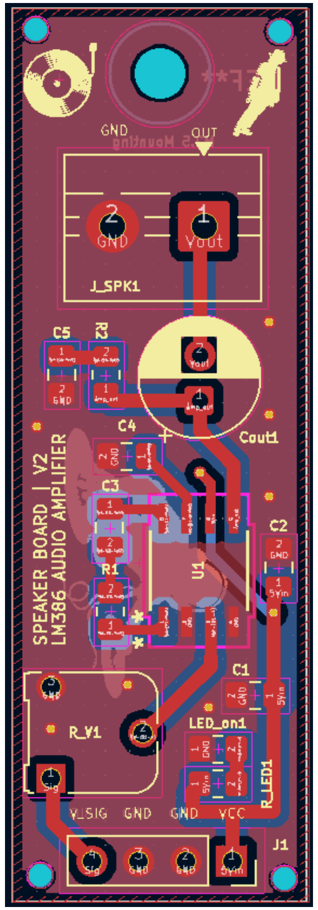
- Laser Modulation Board
  - TI TPL0501
    - 100k Digital Potentiometer
    - 256 positions
    - SPI Communication
  - AP7366EA ADJ LDO – 1.0 V
  - BNC Output

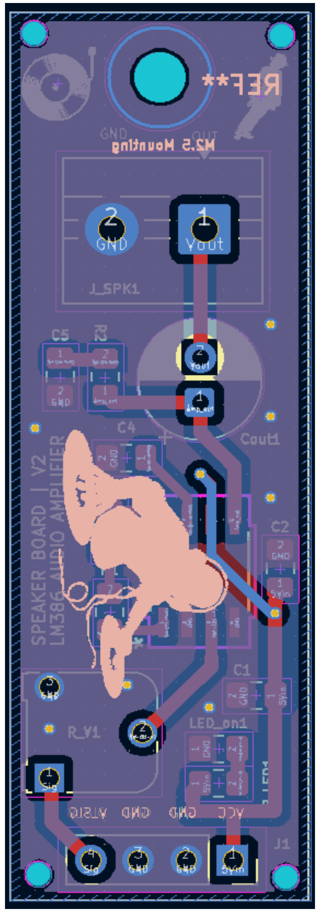


ELECTRICAL - SPEAKER BOARD



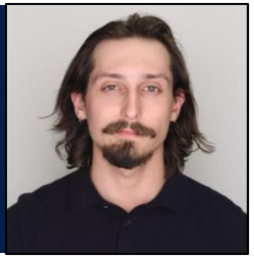


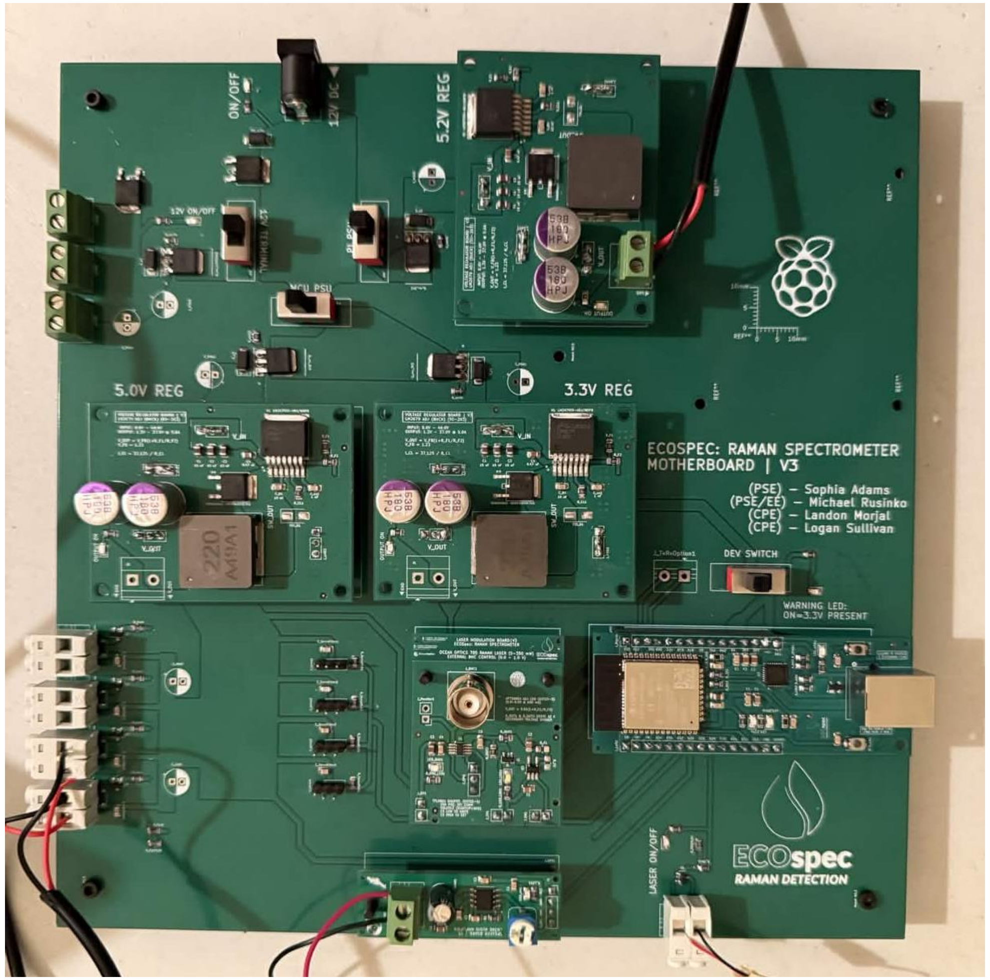




- Speaker Board.
  - LM386 Audio Amplifier
  - 8Ω Speaker
  - DAC output from ESP32
  - Indicator for system status when LEDs not visible

ELECTRICAL – FABRICATED PCBS





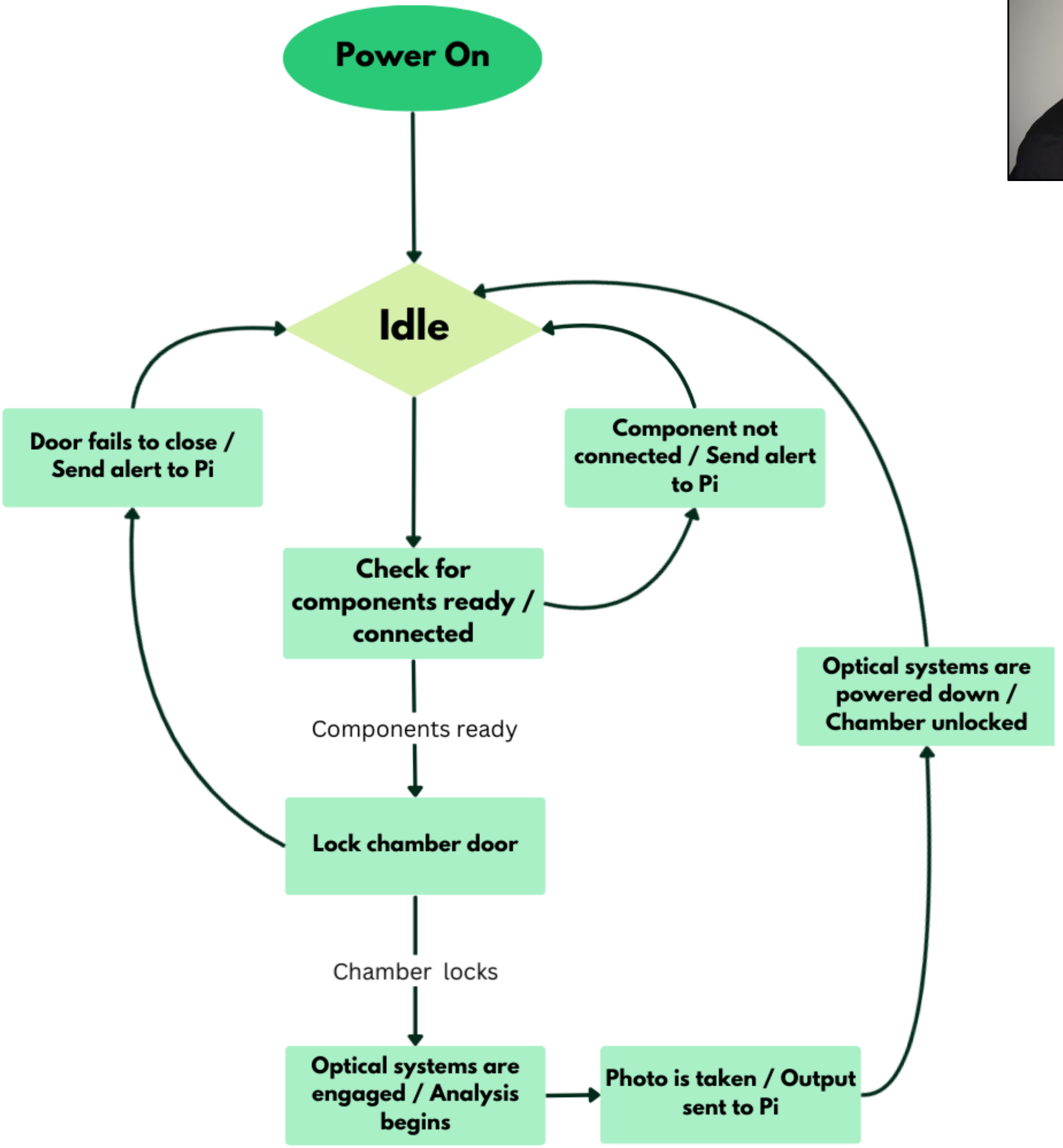
SOFTWARE DESIGN – TECHNOLOGY CHOICE

- Two points of computation
  - ESP32
    - System control / upkeep
  - Raspberry Pi
    - User-Facing
    - Data processing

Language	Python	Java	C/C++
Execution Method	Interpreted	Interpreted/Compiled Hybrid	Compiled
Memory Management	Automatic	Automatic	Manual
Embedded Support	MicroPython	Not Feasible	Arduino, ESP-IDF

SOFTWARE BLOCK DIAGRAM – ESP32

- Handles operation of the test chamber
- Communicates with Pi via UART
- System status checked before any optical components are triggered



Power On

Idle

Door fails to close / Send alert to Pi

Component not connected / Send alert to Pi

Check for components ready / connected

Components ready

Lock chamber door

Chamber locks

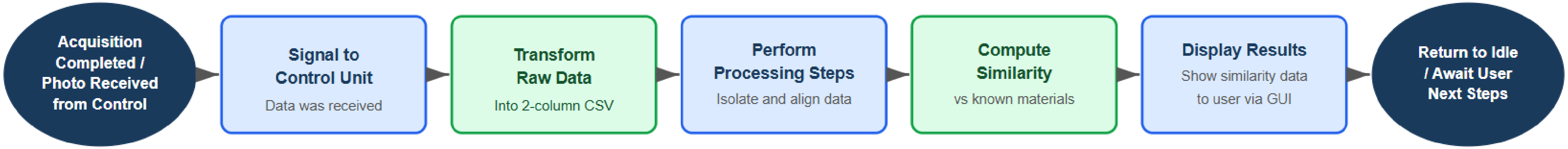
Optical systems are engaged / Analysis begins

Photo is taken / Output sent to Pi

Optical systems are powered down / Chamber unlocked

SOFTWARE BLOCK DIAGRAM – RASPBERRY PI

- Pi handles more computationally intense tasks
  - Control & display GUI
  - Data processing pipeline
  - Communicates with ESP32 using a system of codes.



Acquisition Completed / Photo Received from Control

Signal to Control Unit
Data was received

Transform Raw Data
Into 2-column CSV

Perform Processing Steps
Isolate and align data

Compute Similarity
vs known materials

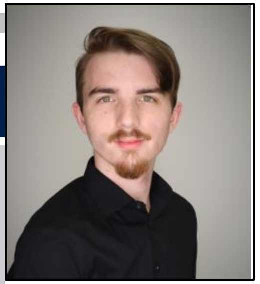
Display Results
Show similarity data to user via GUI

Return to Idle / Await User Next Steps

DATA PROCESSING PIPELINE

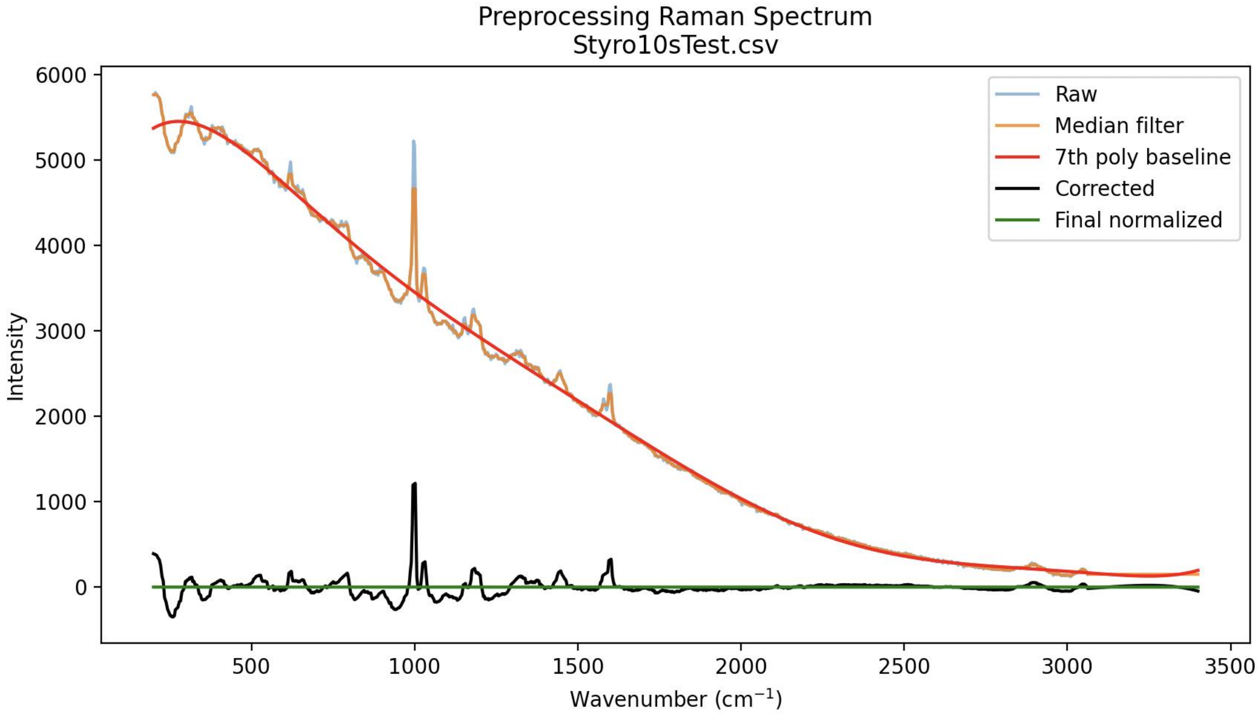
- Multi-stage pipeline focused on isolating Raman signals before identification
  - 4 data transformations
  - Processed data used for comparison
  - Library entries also processed

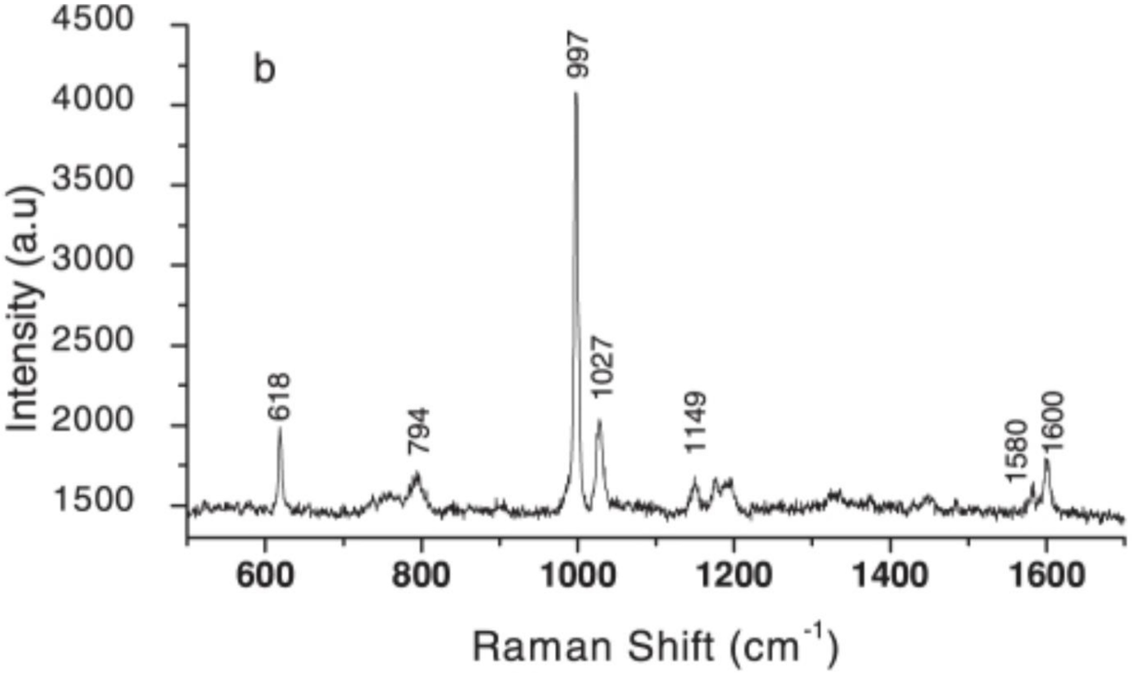
Step	Purpose
Negative Removal / Rounding	Clean up the data for ease of computation later
Interpolation	Put dataset on a uniform grid
Median Filter	Removes noise and cosmic rays
Baseline Correction	Removes the fluorescence background from the spectra
Normalization	Additional removal of noise, baseline shifts, and light-scattering effects
Scaling	Removes differences in magnitude, brings focus to shape of the data
Comparison	Compare sample data to known material data to find a best match



SOFTWARE TESTING – DATA PROCESSING

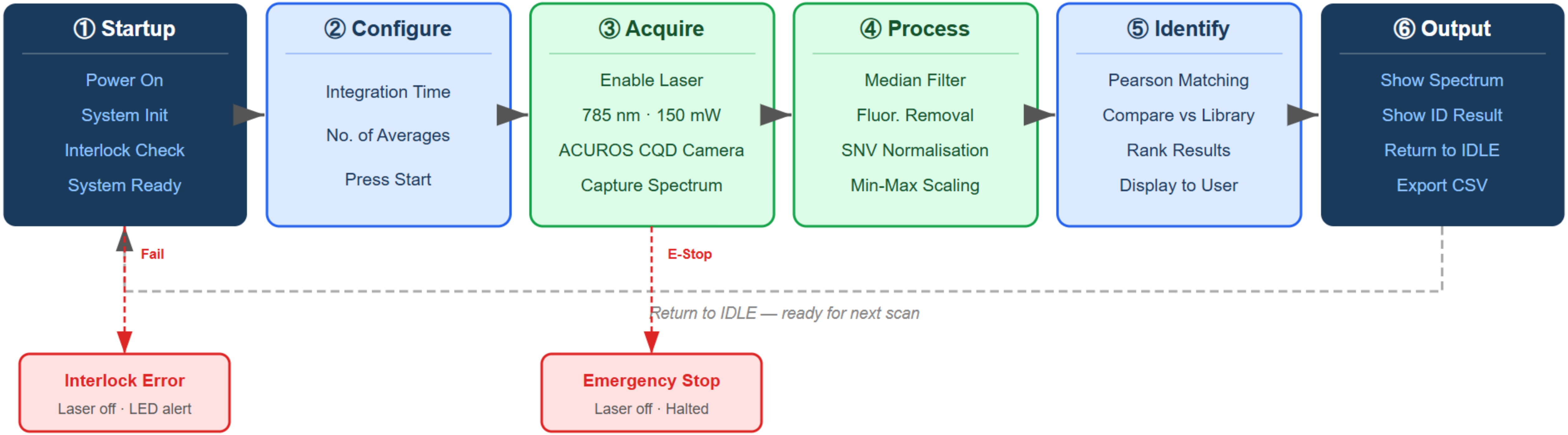
- Processing pipeline tested on lab-acquired data
    - Compared to publicly available spectra





Bankapur, Dr. Aseefhali & Zachariah, Elsa & Chidangil, Santhosh & Valiathan, Manna & Mathur, Deepak. (2010). Raman Tweezers Spectroscopy of Live, Single Red and White Blood Cells. PloS one. 5. e10427. 10.1371/journal.pone.0010427.

USER INTERFACE FLOWCHART



① Startup

Power On

System Init

Interlock Check

System Ready

② Configure

Integration Time

No. of Averages

Press Start

③ Acquire

Enable Laser

785 nm · 150 mW

ACUROS CQD Camera

Capture Spectrum

④ Process

Median Filter

Fluor. Removal

SNV Normalisation

Min-Max Scaling

⑤ Identify

Pearson Matching

Compare vs Library

Rank Results

Display to User

⑥ Output

Show Spectrum

Show ID Result

Return to IDLE

Export CSV

Fail

E-Stop

Return to IDLE — ready for next scan

Interlock Error

Laser off · LED alert

Emergency Stop

Laser off · Halted

GRAPHICAL USER INTERFACE

ECOSPEC Raman Spectroscopy – Microplastic Identification

● Pi 5 ONLINE ● ESP32 ● CQD CAM ● LASER STBY 17:15:02

LIVE RAMAN SPECTRUM · COMPLETE

ACQUISITION SETTINGS

Integration Time 250 ms

Laser Power 0%

IDENTIFICATION RESULT

Styro10sTest

Pearson Similarity 94%

#1	Styrol0sTest	94%
#2	PETWater_raw	3%
#3	HDPE_raw	-2%

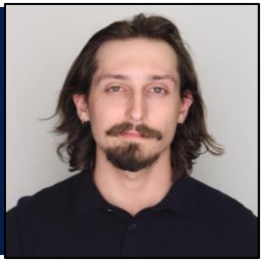
SYSTEM LOG

```
[17:14:47] System initialized
[17:14:47] TEC detector stabilized at -15°C
[17:14:47] All interlocks nominal
[17:14:47] Checking hardware...
[17:14:47] ESP32 not detected – check USB connection
[17:14:47] Camera not detected – check USB connection
[17:14:51] Debug mode opened
[17:14:54] Debug scan started – Styrol0s.csv
[17:14:54] Skipping hardware – running pipeline only...
[17:14:54] Debug pipeline complete – 3201 points
[17:14:54] Scan complete
[17:14:54] Result: Styrol0sTest – 94%
```

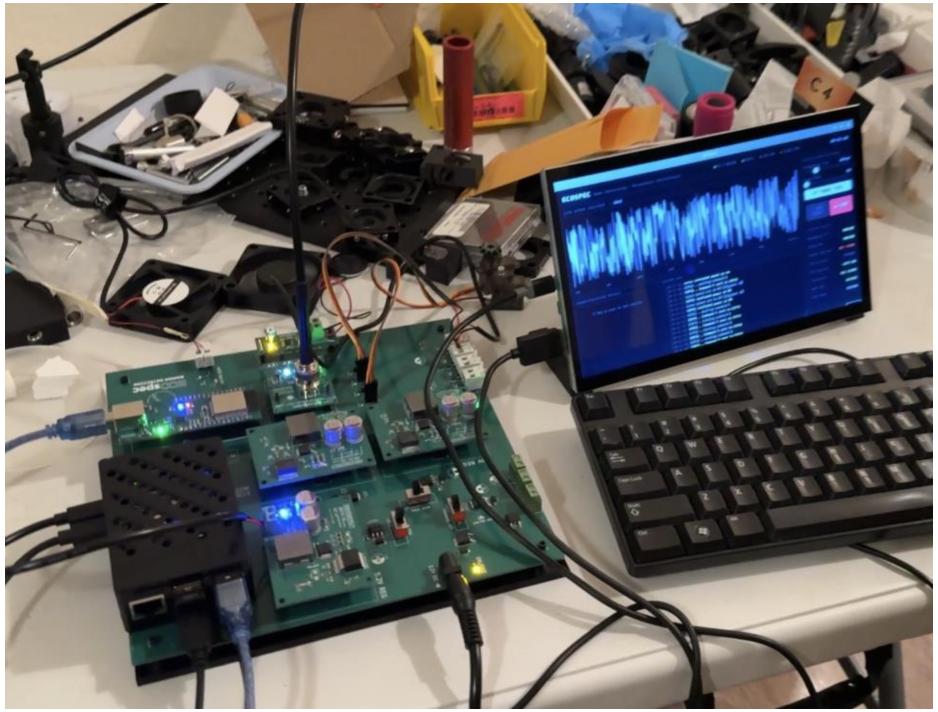
SYSTEM STATUS

Raspberry Pi 5	ONLINE
ESP32 MCU	NOT FOUND
ACUROS CQD Cam	NOT FOUND
785 nm Laser	STANDBY
TEC Detector	-15°C OK
Interlocks	ALL CLEAR
eBUS SDK	ACTIVE
UART Baud	115200

ELECTRICAL SYSTEM



- **PCBs**
  - "Breakout Board Style"
  - Extensive overvoltage and reverse voltage protection
  - Multiple pin headers for power pins
  - Compatible with ESP32 Devkit1
- **Instrument Control**
  - External Laser Control (BNC + RJ11)
  - *Camera interfacing via USB*
  - Laser system controllable with LCD Touchscreen
  - Fan terminals
  - Servo interlocks
- **Dedicated 5V 5A PSU for Raspberry Pi + LCD**



Powered System

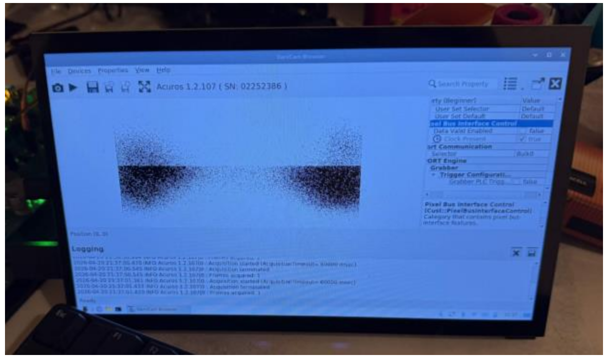
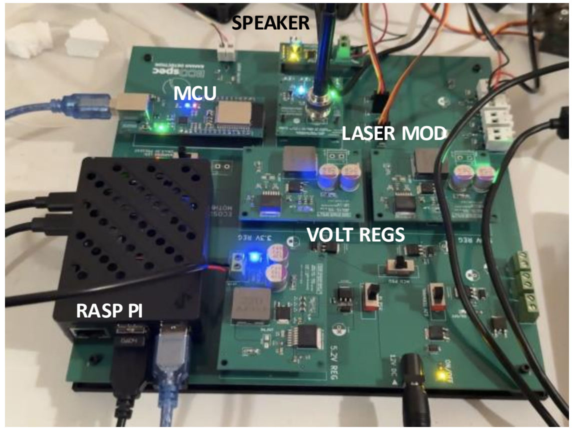
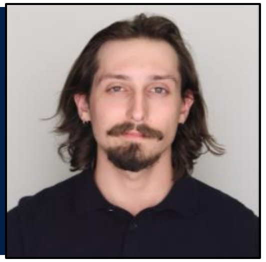


Image captured on camera with Pi
Common Vision Blox – GenICam Browser App

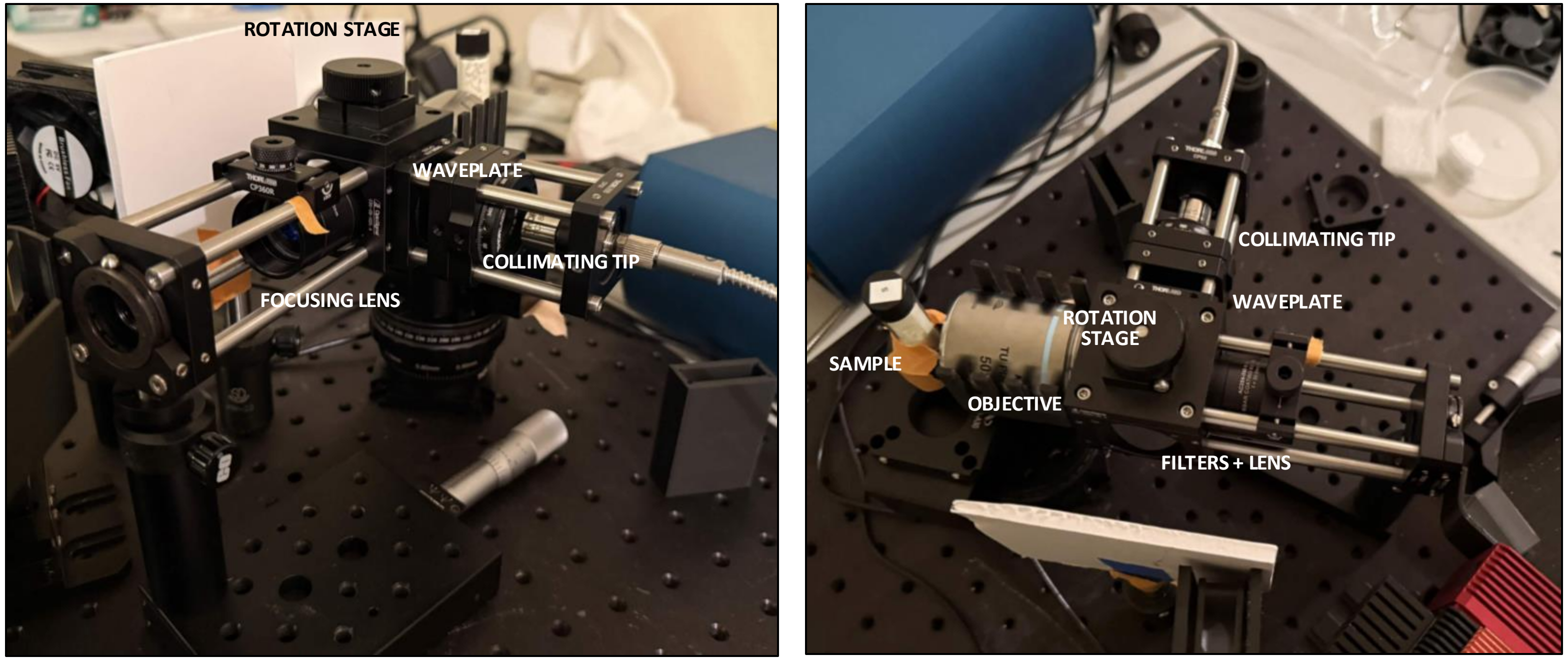


PCB Closeup

PROBE OPTICS



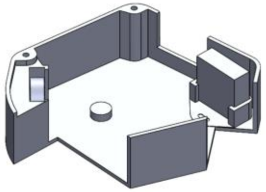
- **Probe Optics**
  - **785 nm Laser**
    - 0.2 nm linewidth, >350 mW output
    - Metal fiber and collimating tip
  - **Microscope Objective**
    - Nikon CF160 Infinite conjugate 20x microscope objective
  - **Cage System**
    - COTS and custom printed mounts
    - Dichroic mounted within rotation stage
  - **Filtering**
    - Dichroic mirror - "Semrock 785 nm RazorEdge®"
    - 785 nm Notch Filter
    - 805 nm Long Pass Filter



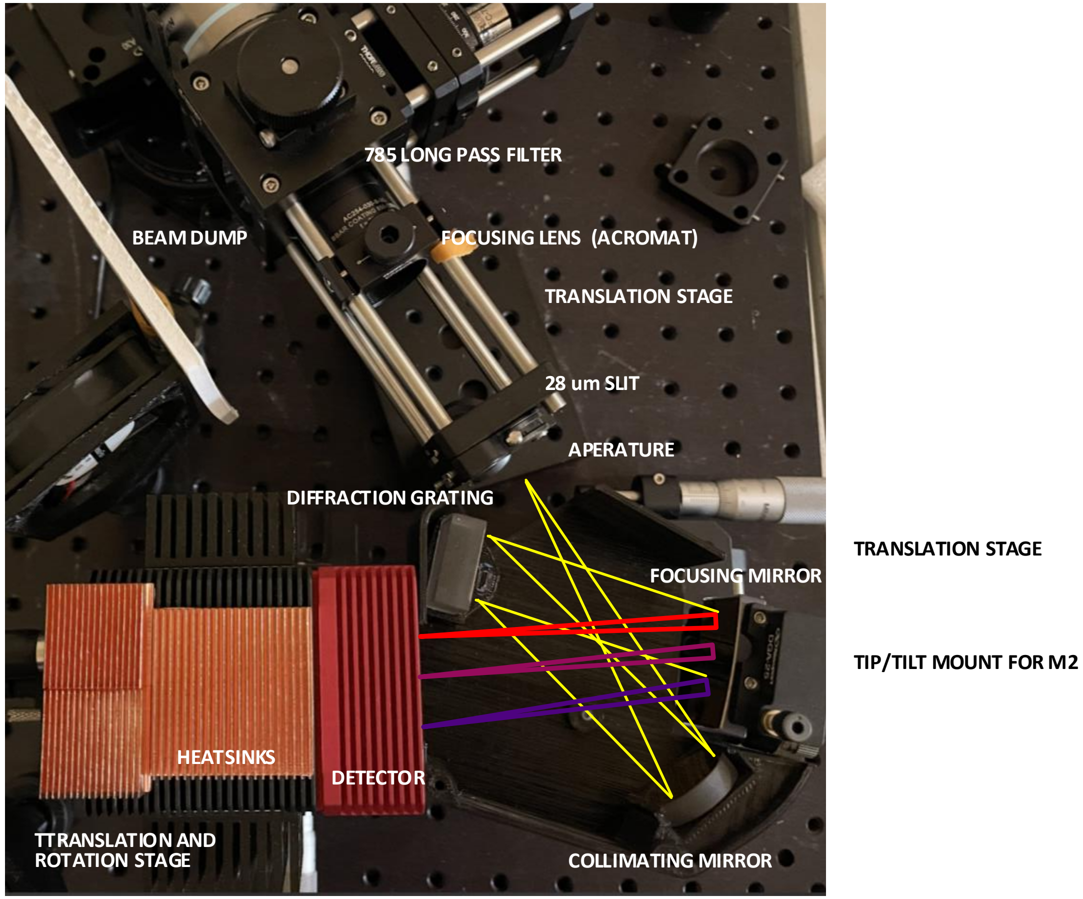
Probe Optics

COLLECTION OPTICS

- **Spectrometer Optics**
  - **Slit:** 25-50 um
  - **Mirrors**
    - Collimating/Focusing Mirror
    - Torrent, Spherical, gold goated, 98% reflectance, F = 102.4 mm
  - **Grating**
    - 830 grooves/mm
    - 800 nm blaze wavelength
  - **Collection**
    - Focusing lens: AC254-030-B-ML Achromatic Doublet
      - BBAR Coating 650-1050 nm, F = 30 mm
    - 785 nm RazorEdge® ultrasteep long-pass edge filter

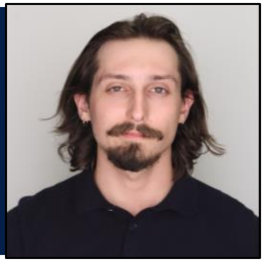


Spectrometer 3D Housing

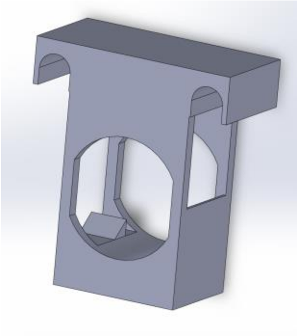


Spectrometer and Collection Optics

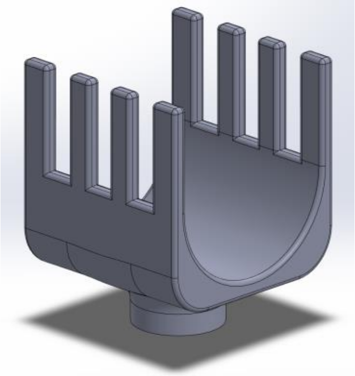
CUSTOM OPTOMECHANICS



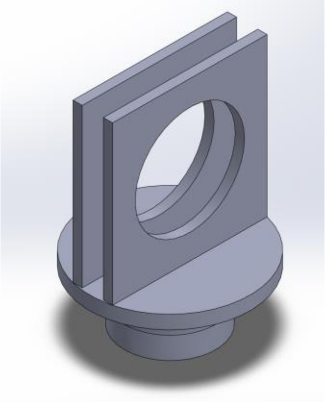
- **3D-Printed Optomechanics**
  - Microscope Objective Mount
  - Lens Mounts
  - Filter Mounts
  - Cuvette Holder
- **Electrical Casing**
  - PCB Case
  - Fan Mounts



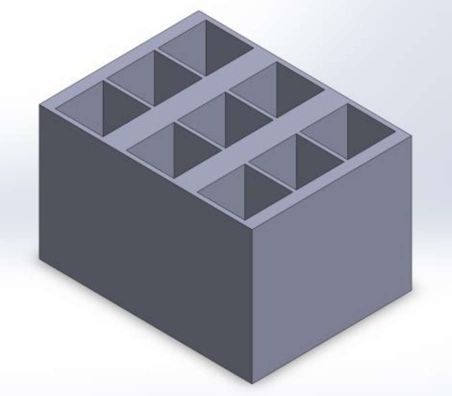
Cage-mounted Swappable Filter Holder



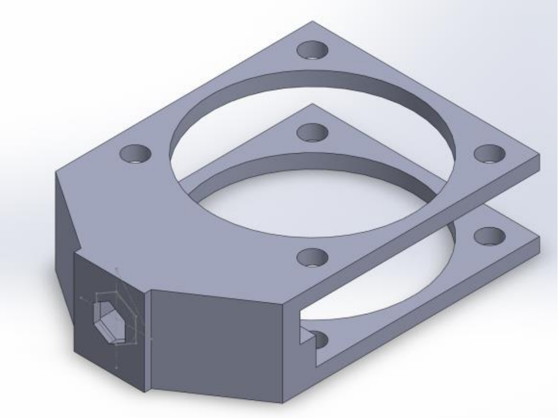
Microscope Objective Mount



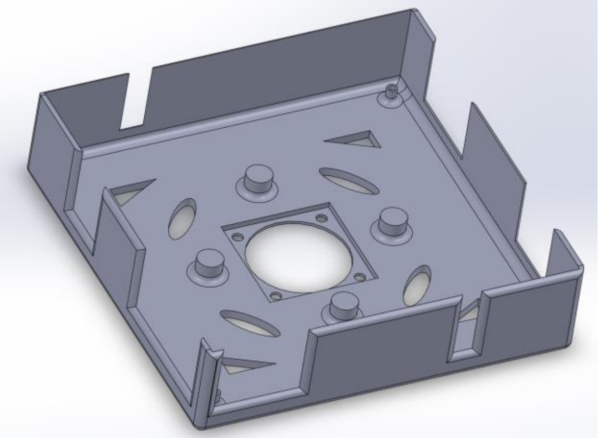
Lens/Slit/Card Holder



Cuvette / Sample Holder



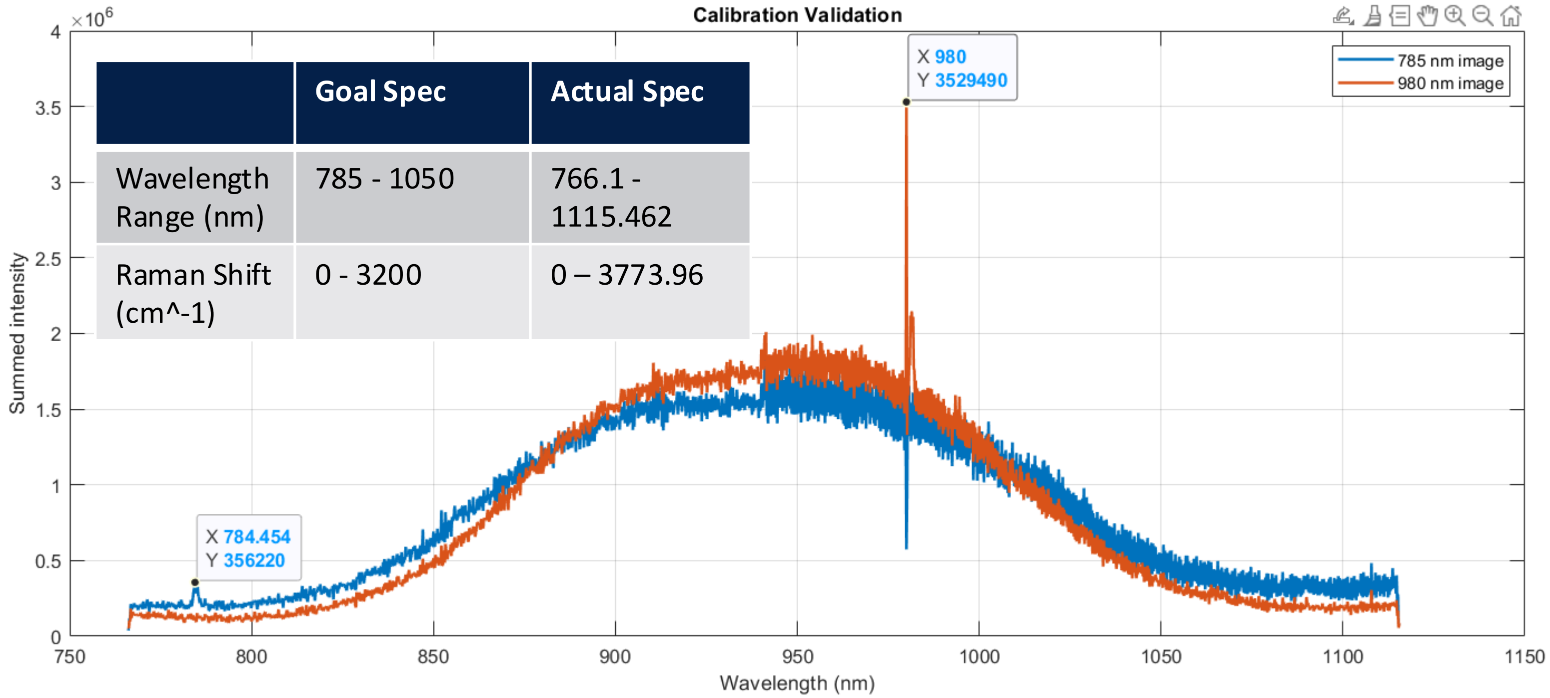
Fan Mount



PCB Casing

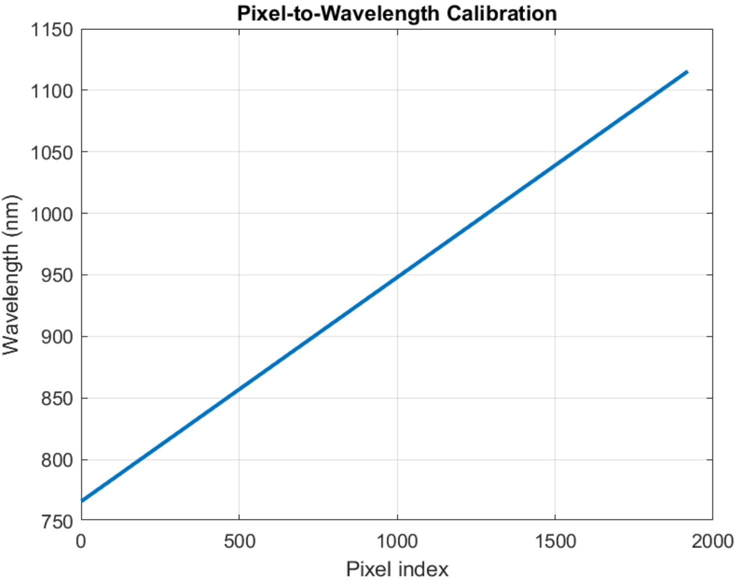
SPECTROMETER ALIGNMENT + CALIBRATION

- **Problem:** Is our spectrometer aligned to our goal wavelength range of 785-1050 nm?
- **Solution:** See where 785 nm and 980 Laser will hit on the detector
- Create a calibration curve based on those 2 locations, and solve for a wavelength at each pixel location

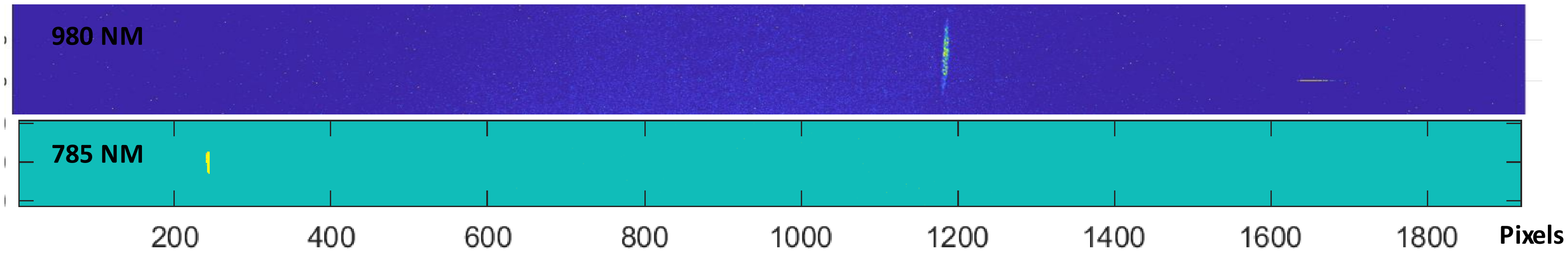


Calibration Validation

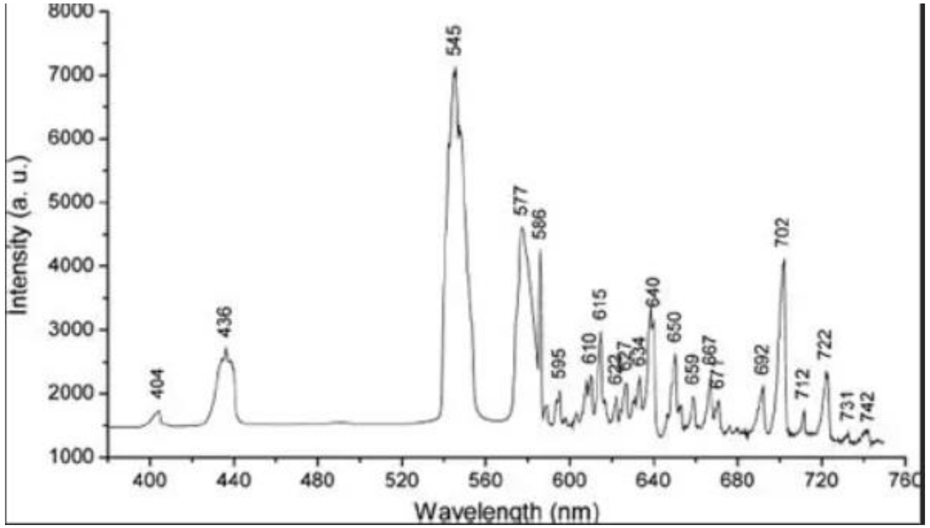
	Goal Spec	Actual Spec
Wavelength Range (nm)	785 - 1050	766.1 - 1115.462
Raman Shift (cm^-1)	0 - 3200	0 – 3773.96

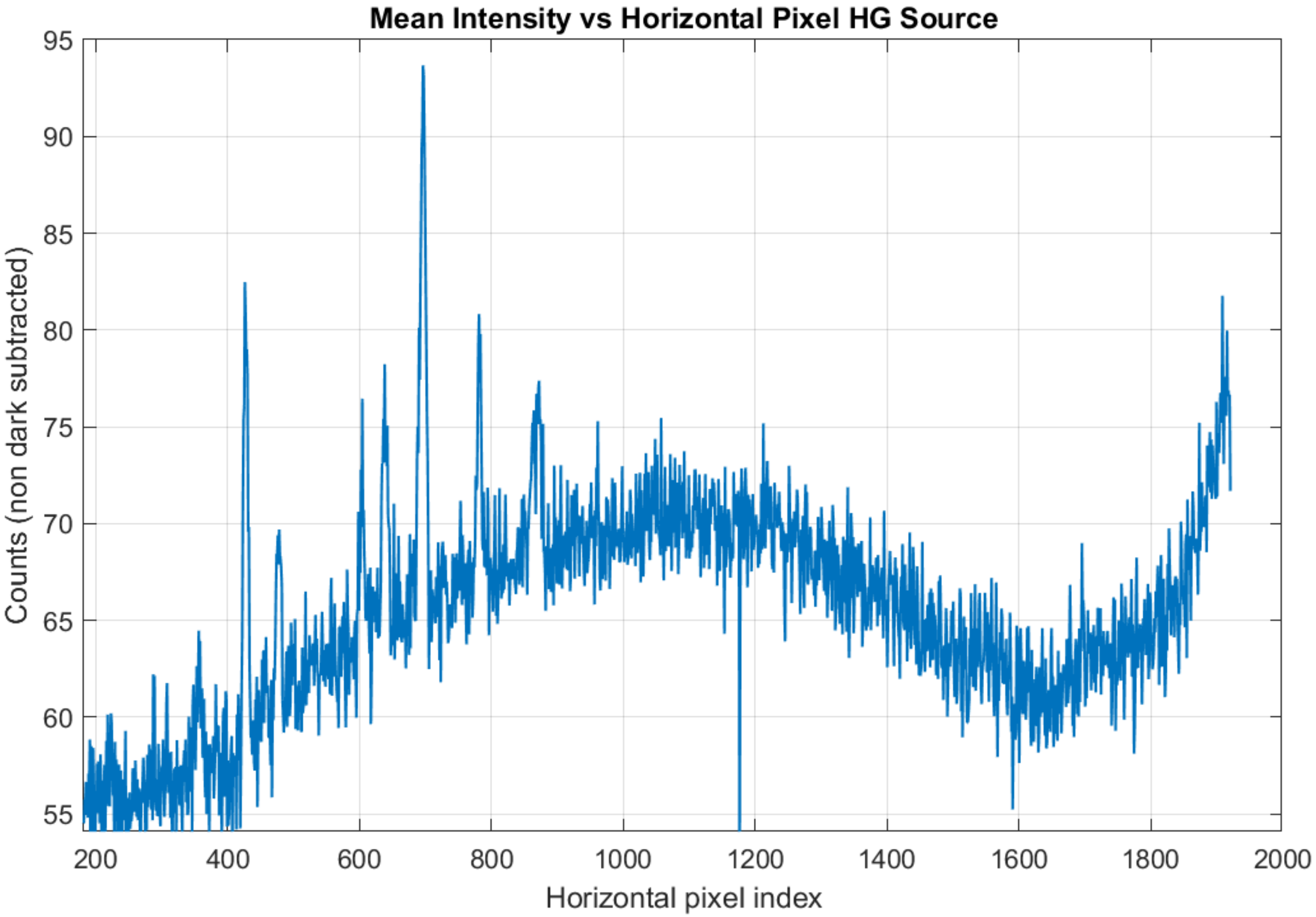


Pixel-to-Wavelength Calibration

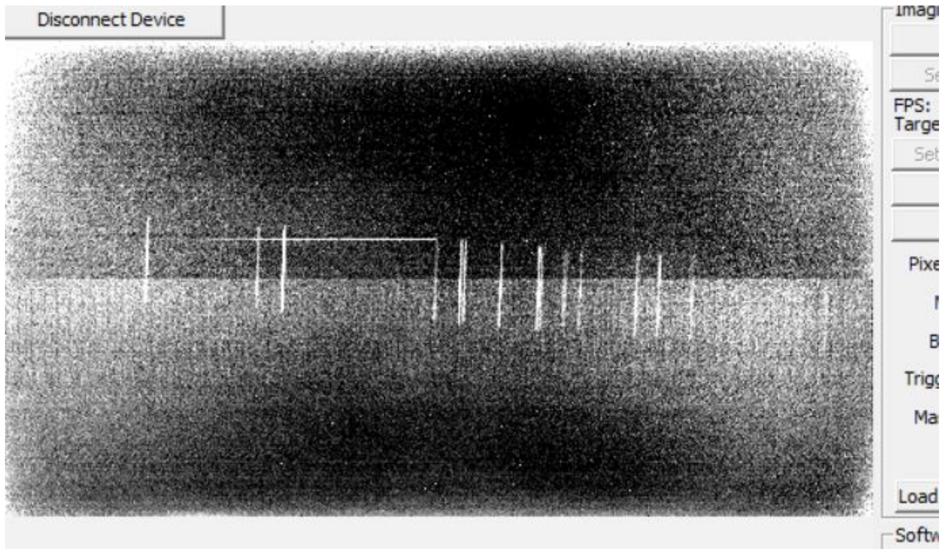


HG AND ARGON PEAKS FOR ALIGNMENT

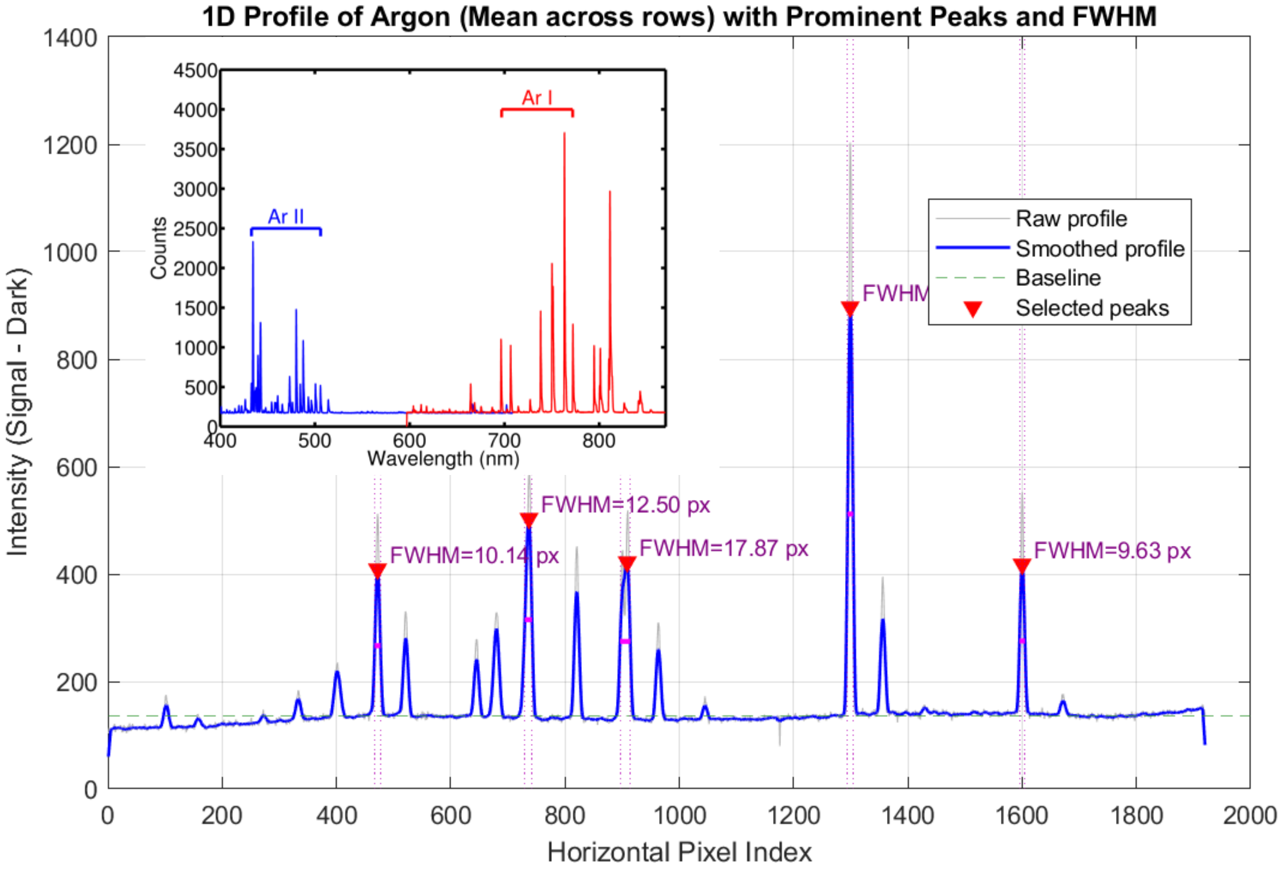




RESOLUTION TESTING, 100 MICRON SLIT

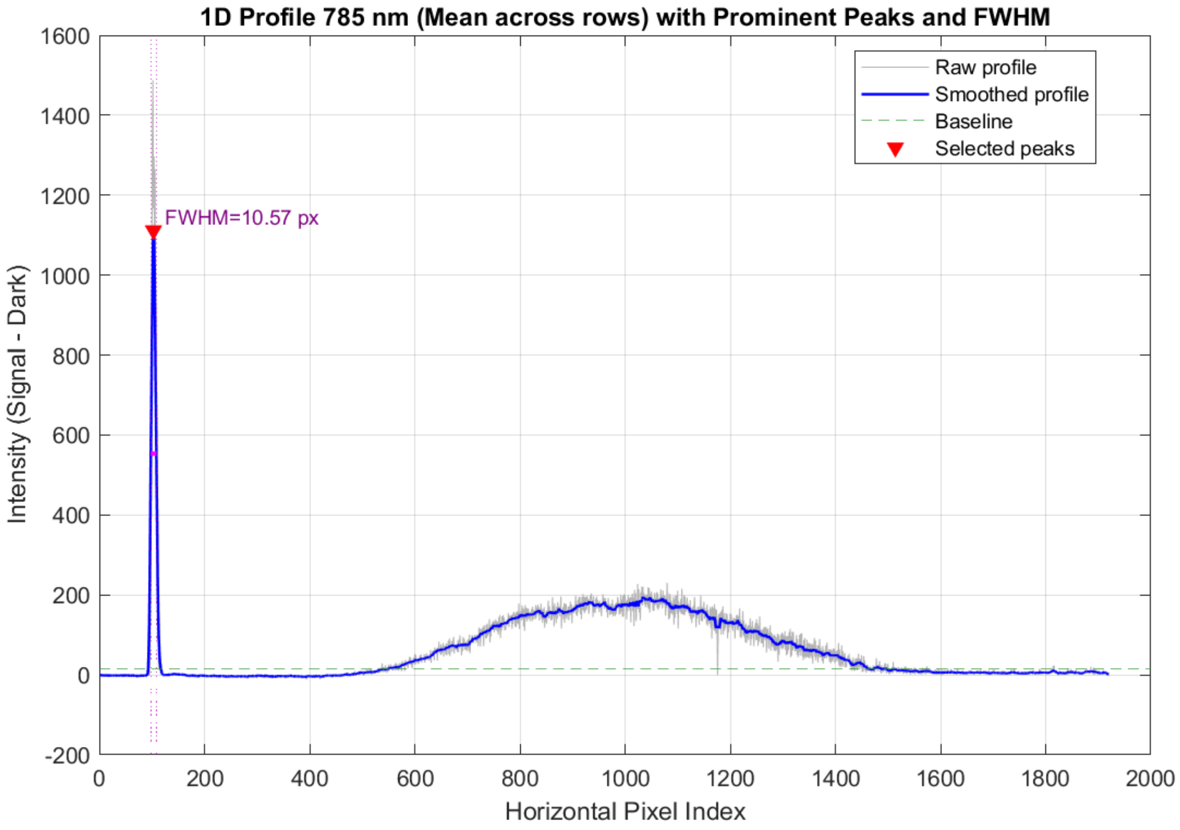


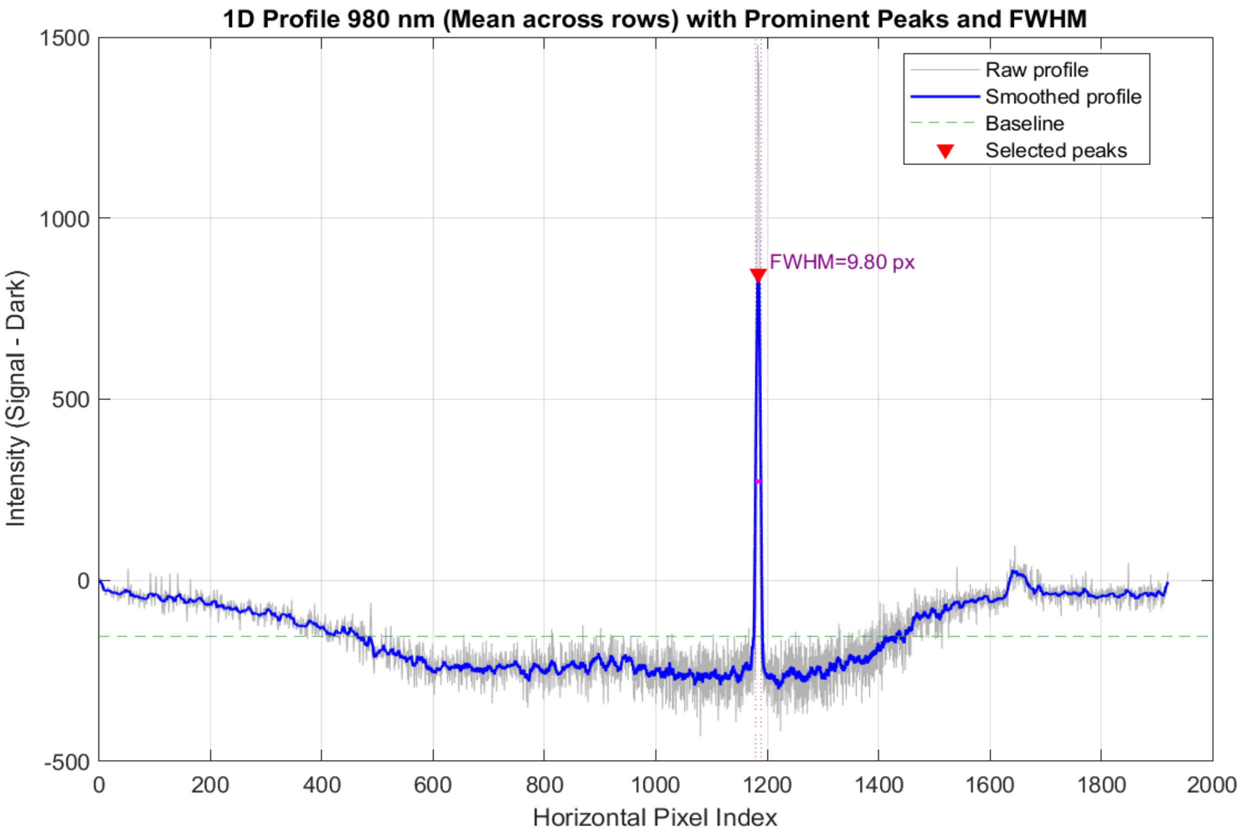
Live Image of Argon Peaks On Detector



Average Res: 10 pix @ 920 nm, FWHM ~ 1.52 nm, 19 cm^-1

RESOLUTION TESTING, 50 MICRON SLIT



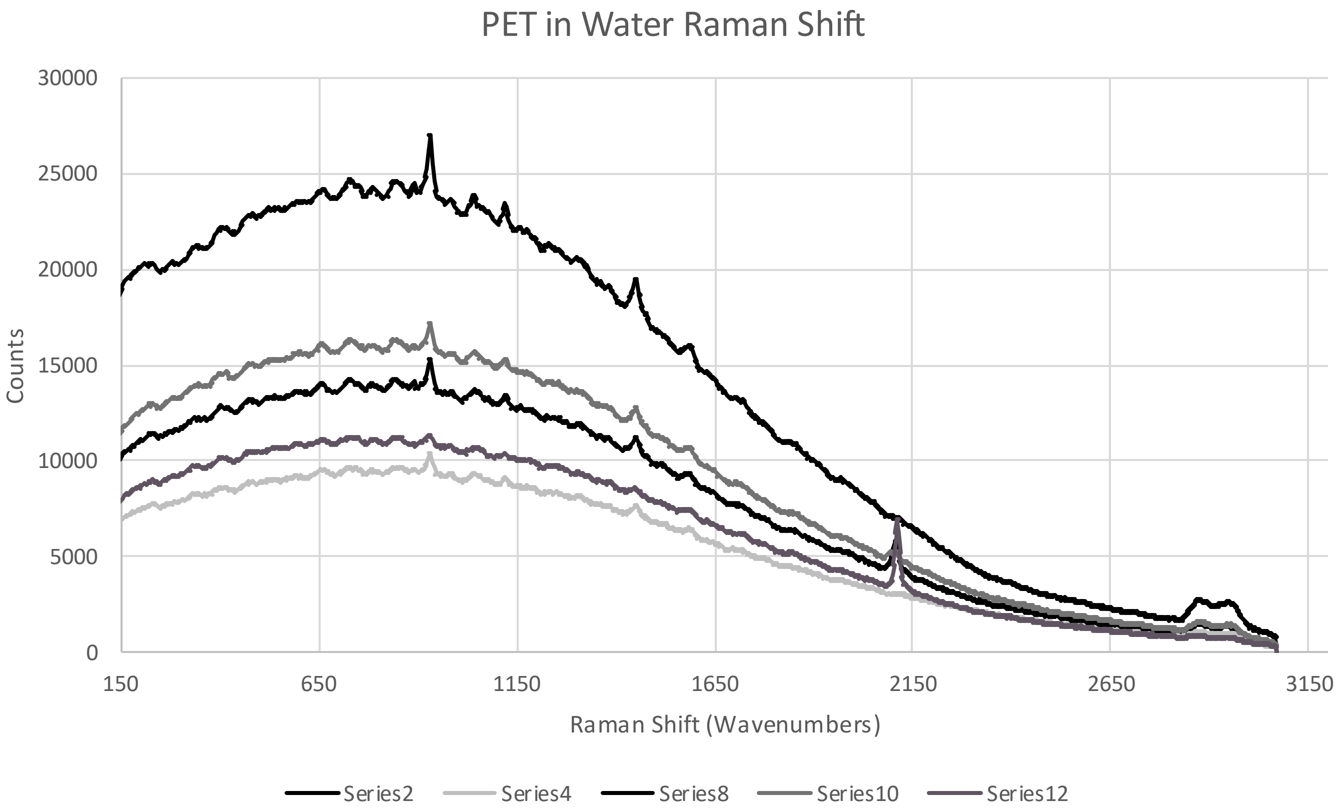


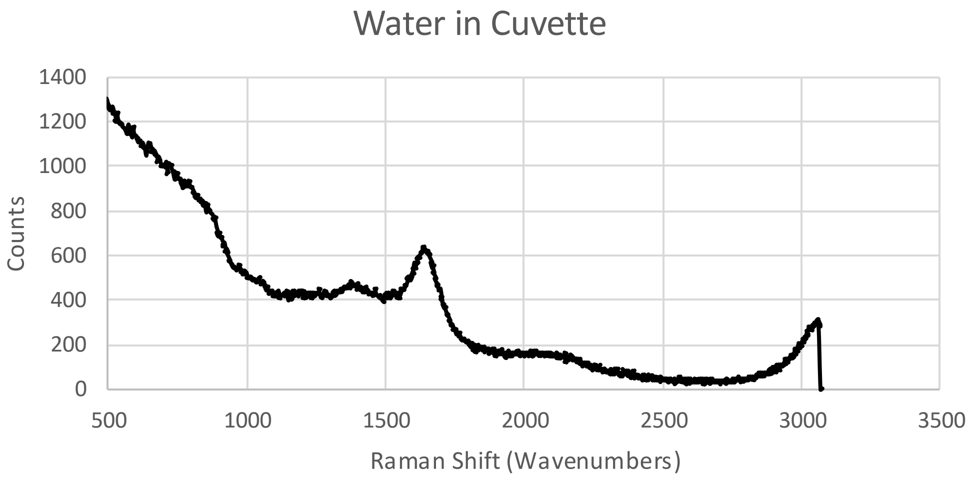
Average Res: 10.57 pix @ 785 nm, FWHM ~ 1.62 nm, 25 cm^-1

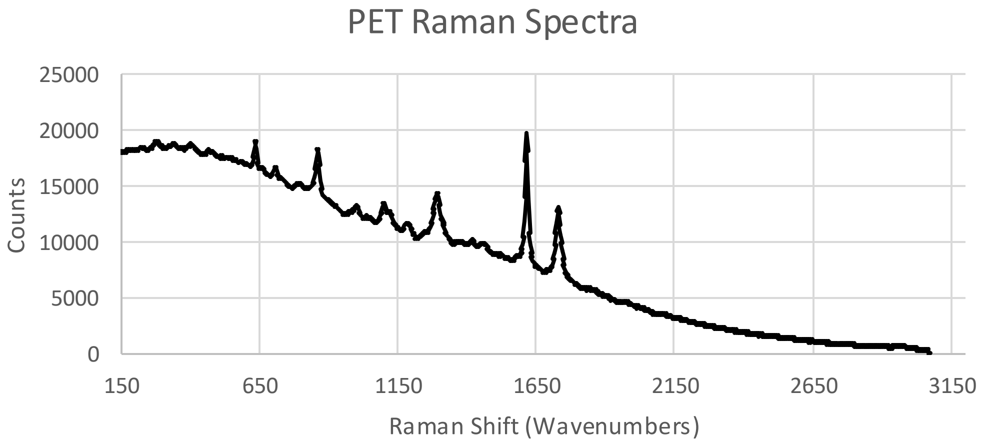
Average Res: 9.8 pix @ 980 nm, FWHM ~ 1.49 nm, 15 cm^-1

TEST VALIDATION OF MICROPLASTIC RAMAN

- Test validation Raman signal of plastics sized 1 – 5 mm^2 in water using a Raman probe and QE-PRO spectrometer using a 785 nm laser


PET in Water Raman Shift

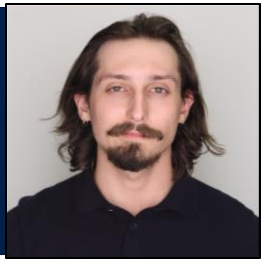

Water in Cuvette


PET Raman Spectra

WORK DISTRIBUTION

Member	Responsibilities
Sophia Adams	Project Lead
	Collection/Probe Optics
	Detector Interfacing
Michael Rusinko	Probe Optics
	PCB Design
	Detector Choice and Integration
Landon Morjal	Data Processing
	Detector Interfacing
	Safety MCU Firmware Development
Logan Sullivan	MCU Integration
	User Interface Integration
	Safety MCU Firmware Development

BUDGET



Subsystem	Part	Quantity	Price	Total
Optical	Laser + Fiber	1x	Borrowed	-
	Lenses	2x	Borrowed	-
	Dichroic Mirror	1x	Borrowed	-
	Microscope Objective	1x	Borrowed	-
	Optomechanics	-	Borrowed	-
	Curved Mirrors	2x	Borrowed	-
	Reflective Grating	1x	Borrowed	-
Electrical	CQD Detector	1x	Borrowed	-
	Rasp Pi 5	1x	$95.40	$95.40
	PCBs	2x	$294.53	$600
	PCB Components	2x	~$200.00	~$400.00
	12V Power Supply	1x	$34.97	$34.97
	LCD	1x	$52.24	$52.24
	Fans (4-pack)	1x	$7.35	$7.35
	Servos (4-pack)	2x	$13.48	$26.99
	Misc	-	$300.00	$300.00
			Grand Total: $1516.95	

PROGRESS PLAN FOR COMPLETION

Tasks	Start Date	Notes
Testing	1/12/26	Begin testing of all subsystems
Fabricate PCB	When boards arrive	Fabricate PCB boards with necessary components
Begin fabrication of housing	3/2/26	Start building housing
PCB design revision	When/if needed	Revise PCB design if needed
Calibration of spectrometer	3/9/26	Finalize calibration of spectrometer
Begin Building Raman Library	3/9/26	Collecting Raman spectra of plastics for library
Finalize housing	3/16/26	Finish housing and seating of components in housing
Final Adjustments	Up until the week before Demo	Ensure all systems are running properly
Final Demonstration	April 20- 23rd	Show the work

QUESTIONS?