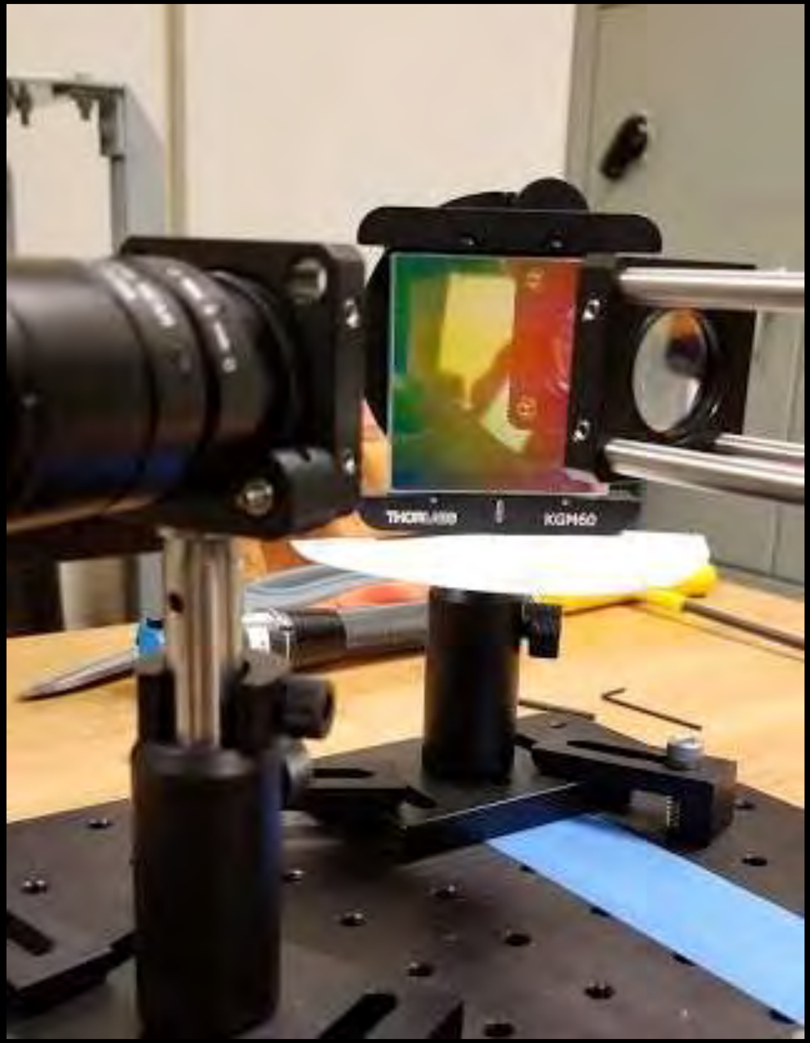
Raman Spectroscopy Project Status & Prototype Update



ENSC 62

Conrad Weeks and Ethan Durbano

Project Background

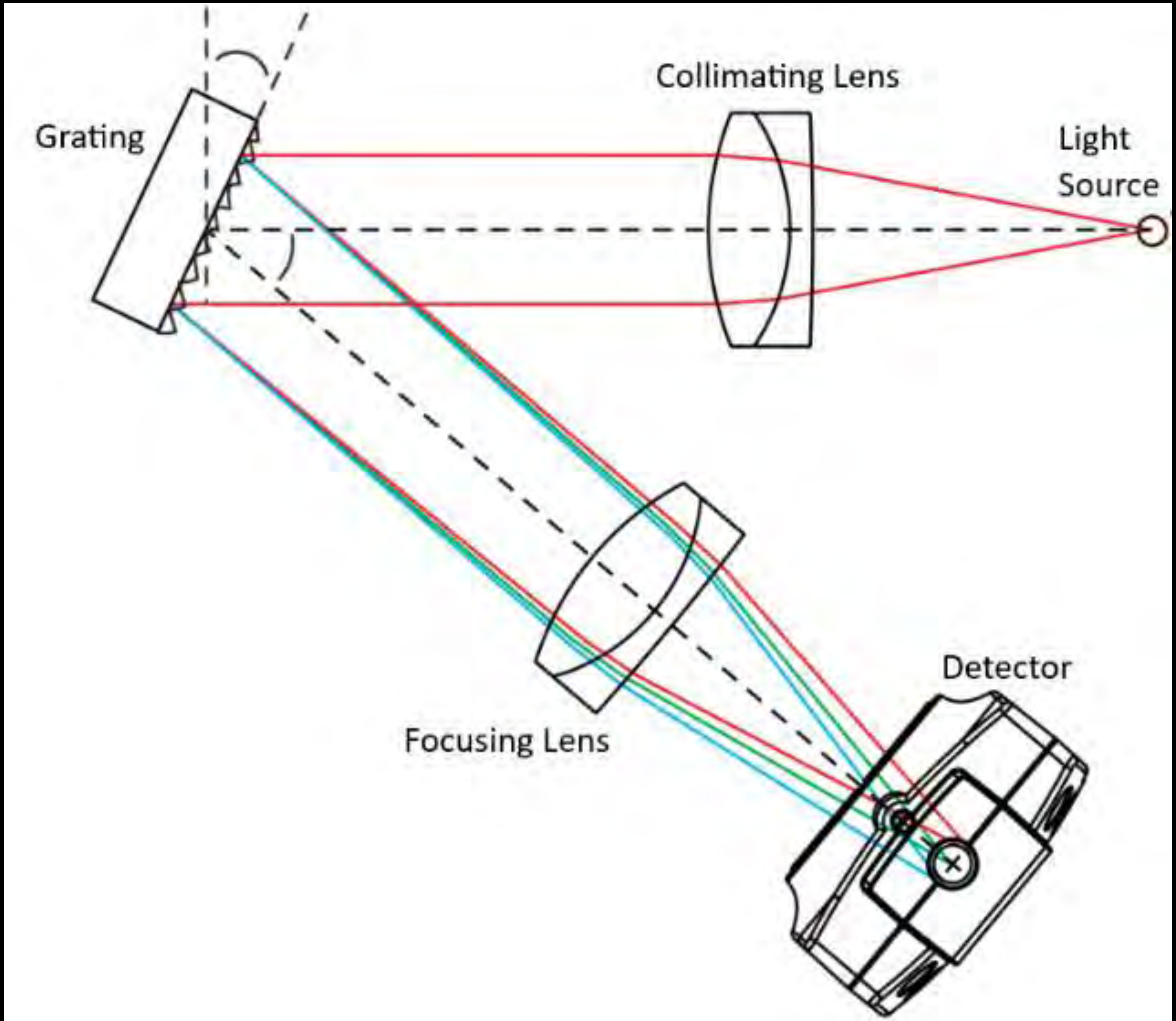
Project Goal

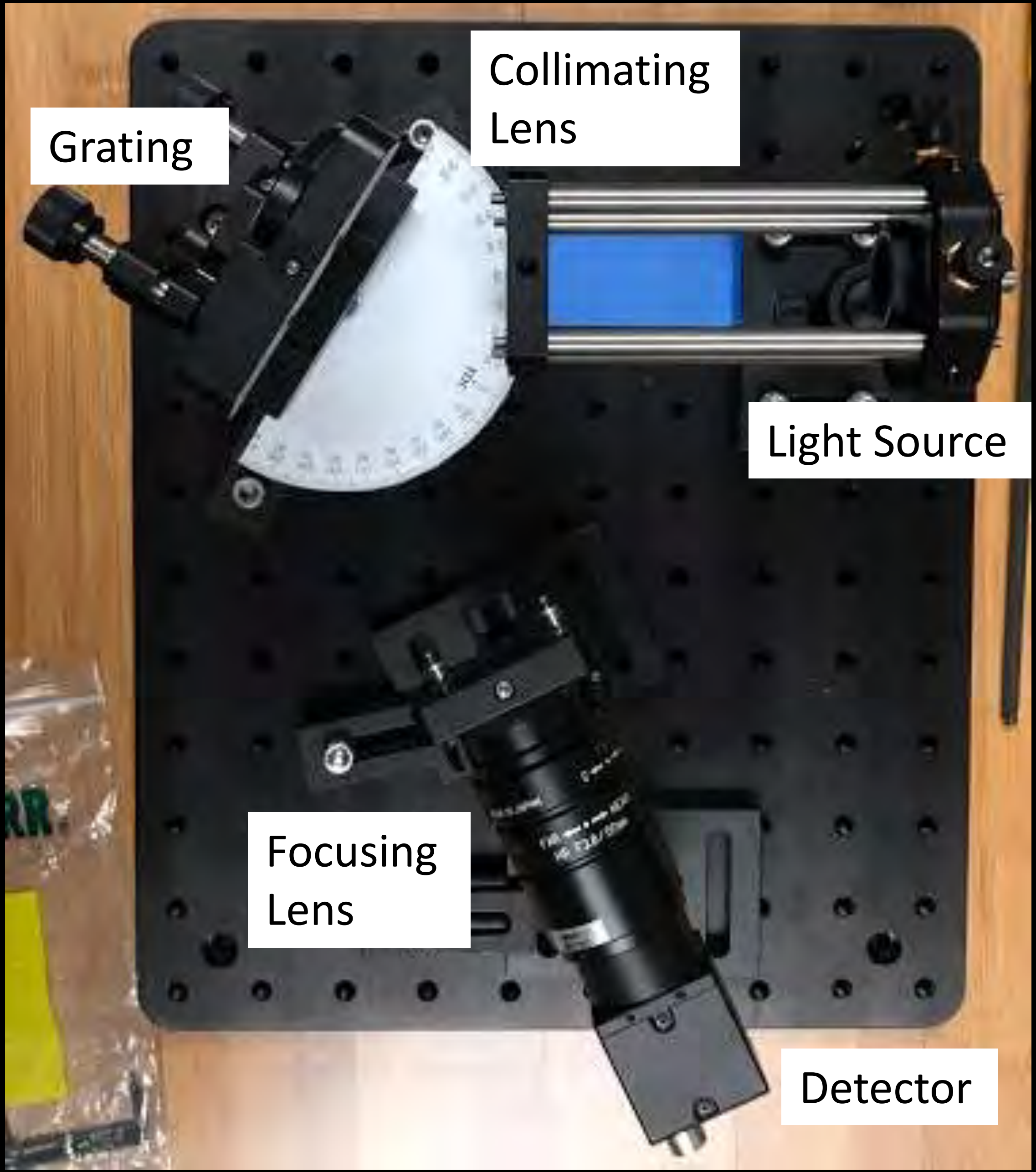
- Build a Raman Spectrometer for Dr. Baumgardner to advance his research in the Combustion Lab

Why it is Needed

- Current spectrometer's resolution is too coarse to detect the Raman shift

Fundamental Components





http://www.thepulsar.be/article/complete-400-800-nm-spectrometer-design-from-a-to-z/

How It Works

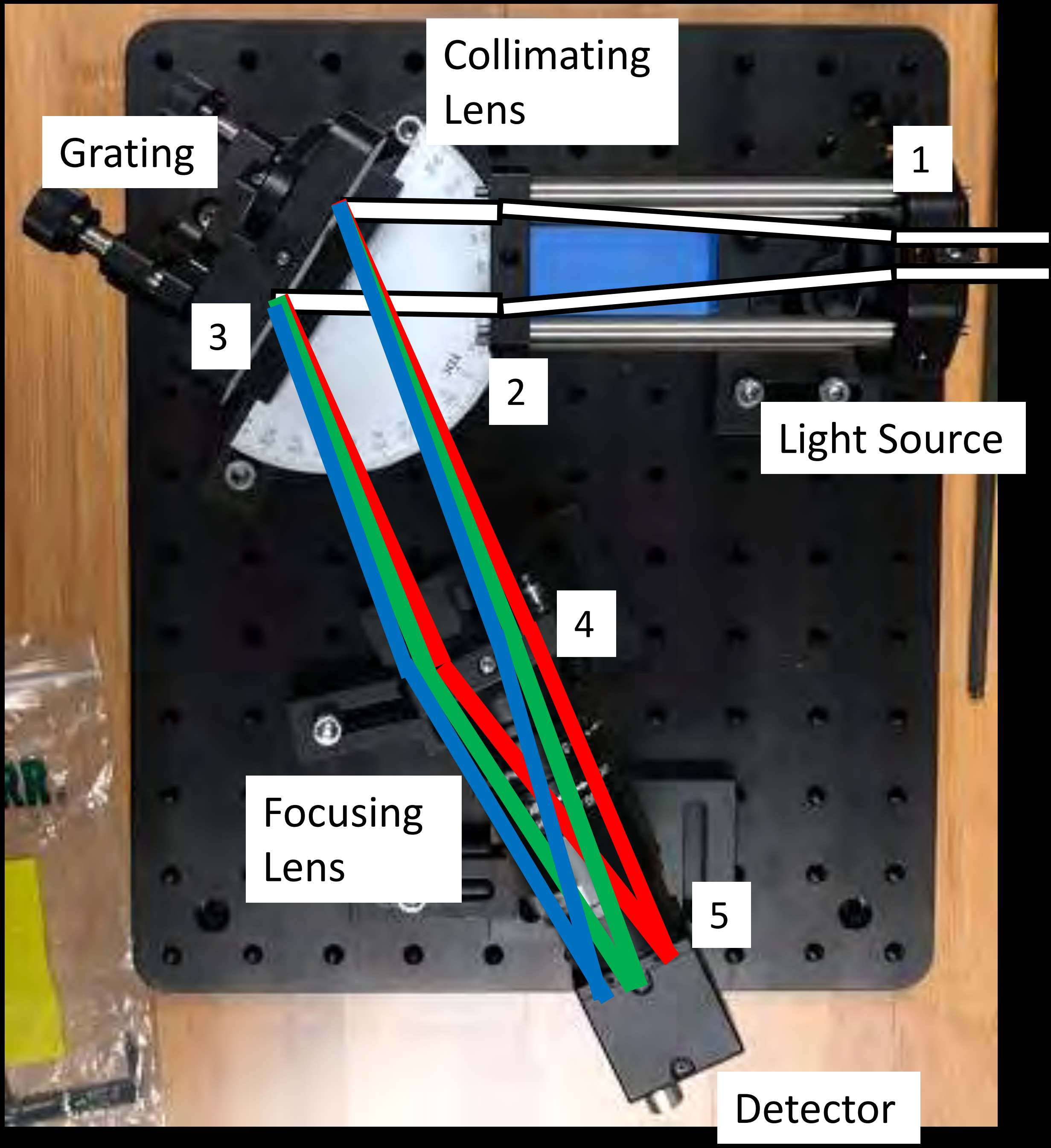
1. Light enters the spectrometer through fiber optic cable

2. Light is collimated through the collimating lens

3. Collimated light is dispersed with the grating

4. Dispersed light travels to the focusing lens

5. Light is focused down into the detector



Project Deliverables

- Completed Raman spectrometer
  - Components assembled and aligned
  - Detector calibrated for desired wavelength range
  - Ready and able to collect data from at least a liquid sample
- Enclosure for the spectrometer assembly
  - 80/20 T-slotted aluminum
  - Thorlabs black Hardboard
  - Rubber grommets to allow fiber/USB cable access
- User manual
  - Components list
  - Safe operation
  - Calibration procedure
  - Experiment procedure

Unexpected Setback

- Due to the COVID-19 virus, physical progress on the spectrometer was stopped.
- Updated Goals:
  - Create User Manual
  - Design Testing/Calibration Procedures
  - Prepare all information needed to complete project

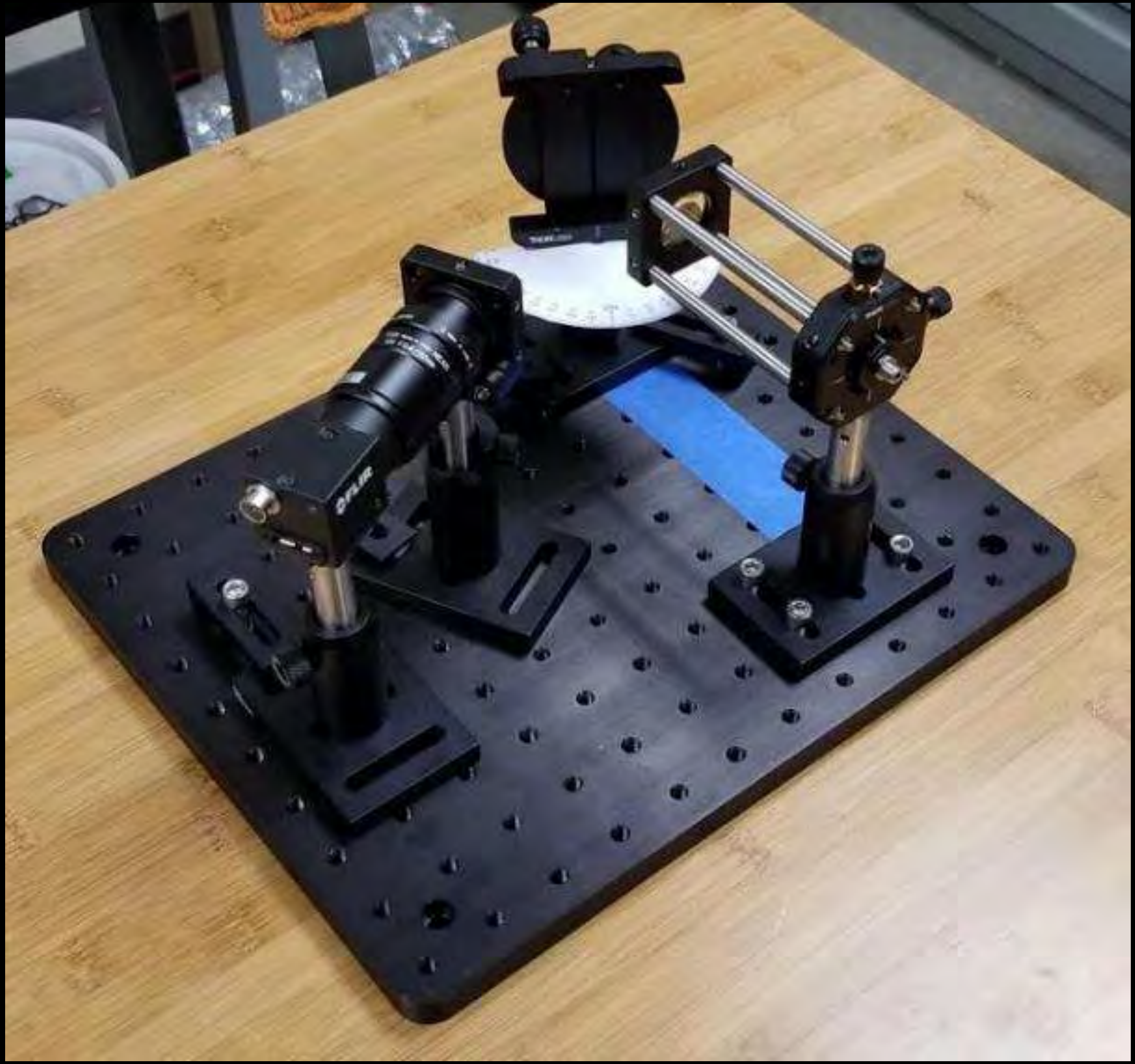
Deliverables

Spectrometer

- Components assembled and alignment is still required

- Calibration
  - Neon lamp from physics department
  - Neon is common calibration standard for Raman Spectrometers

- Data collection
  - Can begin following calibration
  - Utilize detector software to collect data being output by spectrometer
  - Input data to MATLAB



Deliverables

Enclosure

- Leftover 80/20 from Combustion Lab
- Thorlabs Black Hardboard
  - Light-tight material to prevent stray light entering experiment
- Thorlabs Black Masking Tape
  - Very low transmittance
  - Used to seal edges/corners from stray light
- Cut-to-Size Grommets
  - Allows for cable access in/out of enclosure

https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=45

Deliverables

User Manual

- Safe Laser Operation
- Complete List of Components and SolidWorks Drawings of each Assembly
- Calibration/Experiment Procedure
- Proper Spectrometer Use/Handling

Experiment Procedure

- Preparing the sample
  - Liquid: Cuvette
  - Gas: Micro-reactor Flame

Cuvette

Micro-reactor Flame

https://connect.gonzaga.edu/baumgardner/news

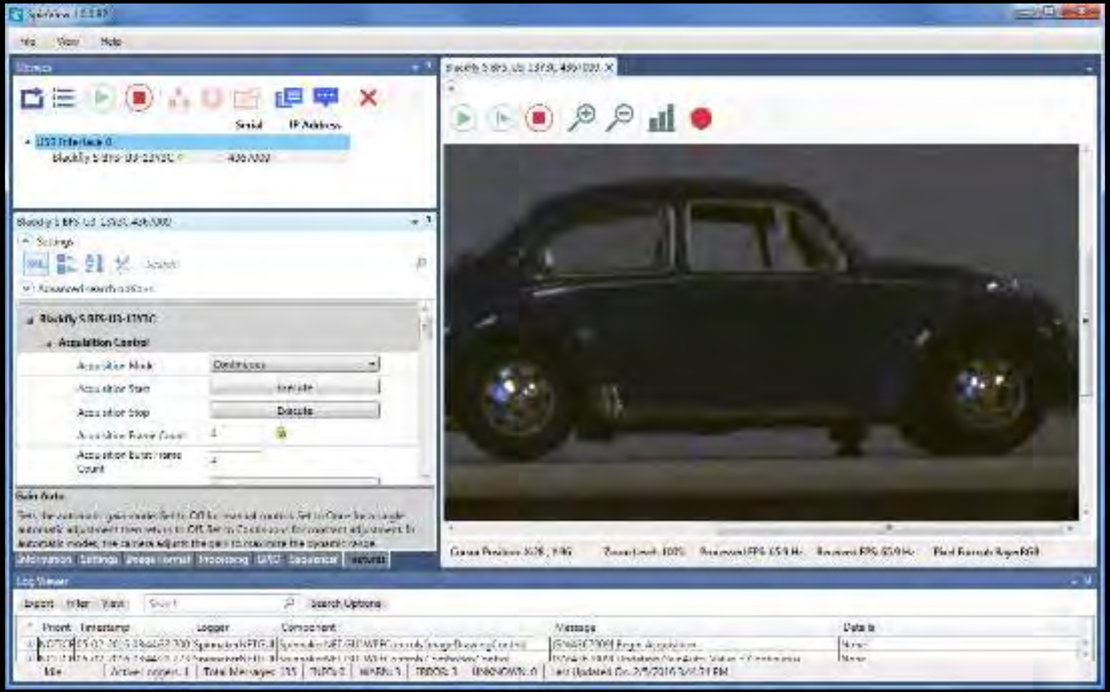
Experiment Procedure

- Set up the Spectrometer
  - Place Spectrometer in the enclosure
  - Laser and Camera plugged in
  - Fiber Optic cable attached to collector and Spectrometer

https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=45

Experiment Procedure

- SpinView camera software
  - Change camera exposure
  - Start/Stop Data collection
  - See and save images



http://softwareservices.flir.com/Spinnaker/latest/page4.html

Experiment Procedure

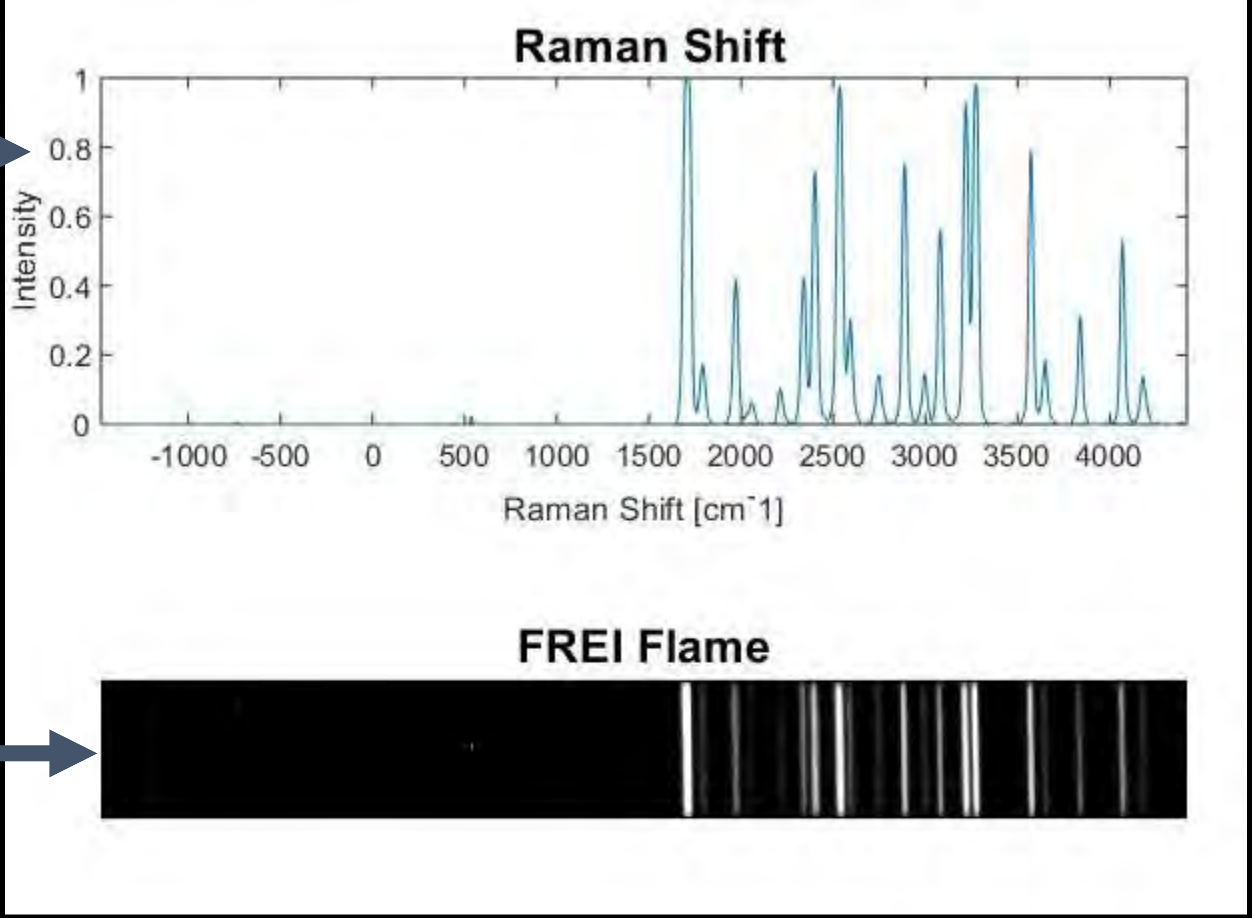
- Collecting Data
  - Safety
    - Close safety curtains around laser and sample
    - Secure spectrometer enclosure
    - Laser safety goggles
  - Turn on laser to desired power level
  - Turn off lights in the room and start the camera

Experiment Procedure

- Analyzing the Data
  - Import camera images into MATLAB
  - Perform vertical binning on image
  - Plot results

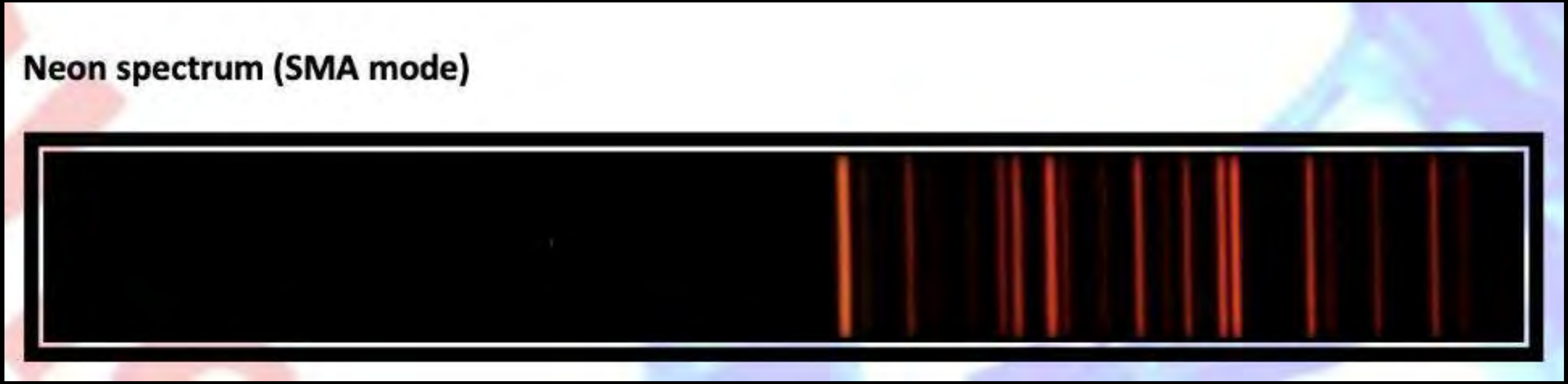
After processing in MATLAB

Image from Camera



Calibration

- Use sample data in place of actual spectrometer image



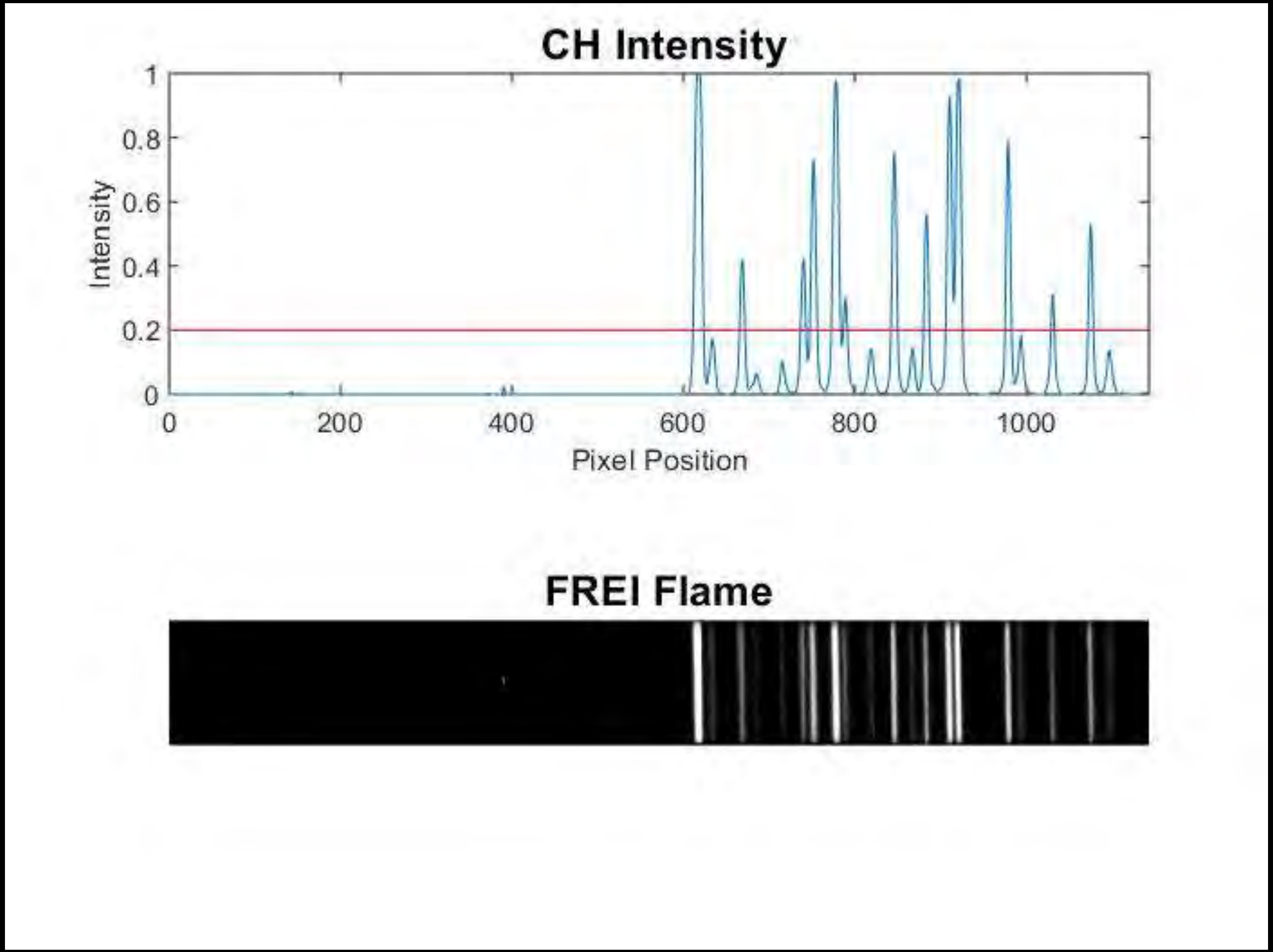
Resource: [1]

Calibration: The Steps

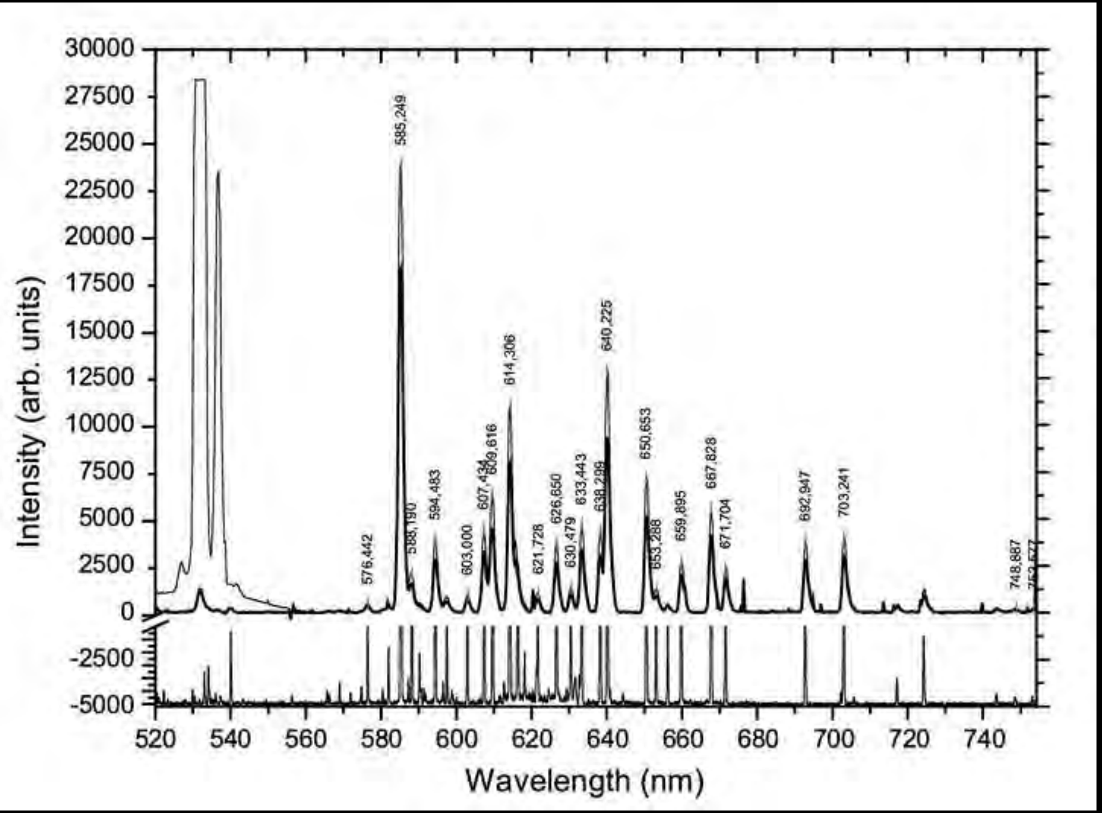
- Crop image to size:
  - Include as much of the spectrum lines as possible
  - Cut out excess background to reduce noise in the data

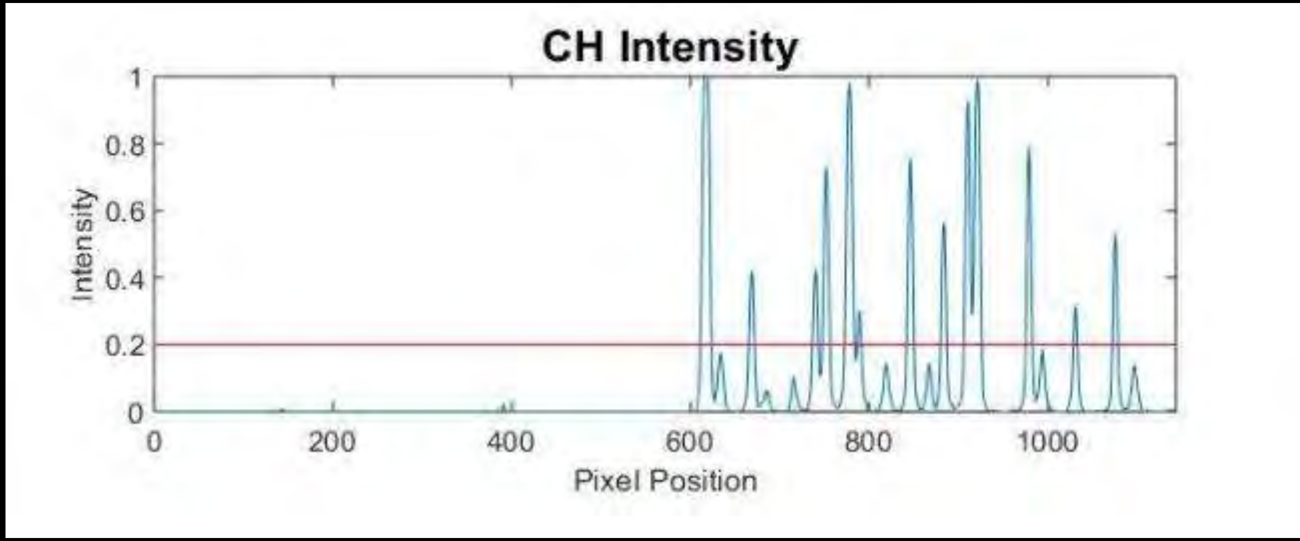
Calibration: The Steps

- Import cropped image into hz_intensity.m MATLAB file
  - Obtain sample spectrum data; match adjacent peaks



Calibration: Comparing Peaks

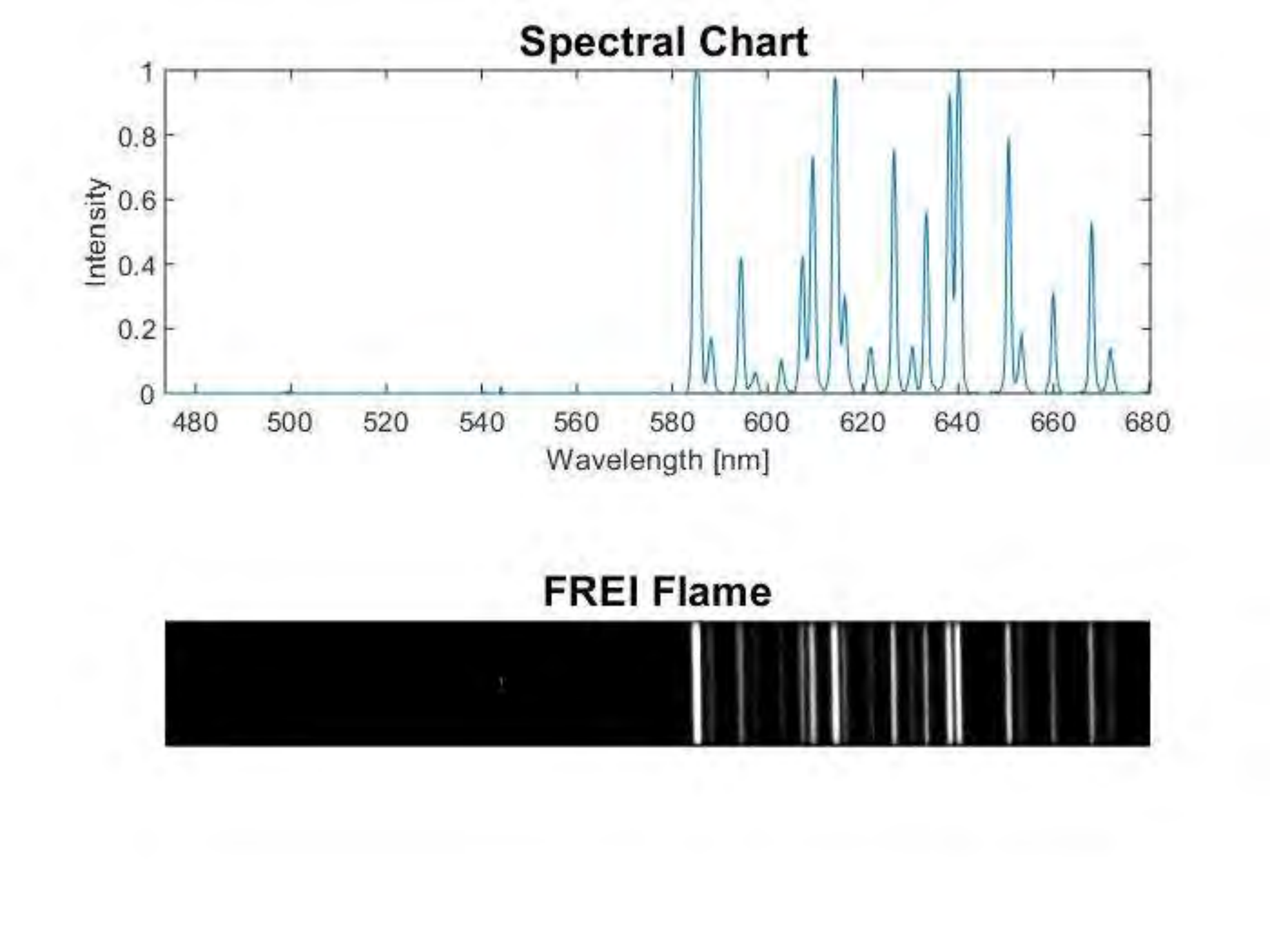




Resource: [2]

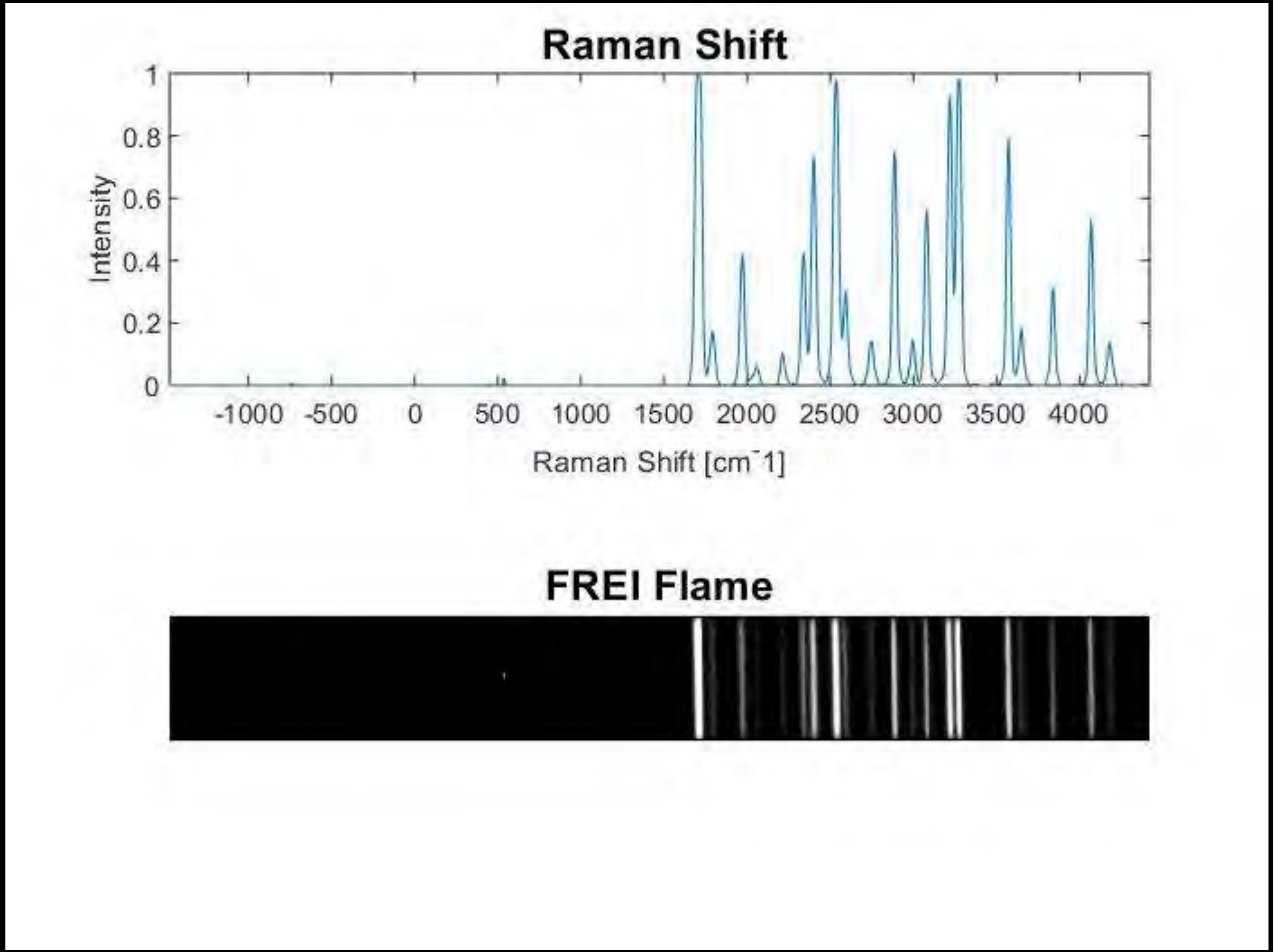
Calibration: The Steps

- Determine the calibrated wavelength values for the x-axis
  - Calculate wavelength resolution, and starting/ending wavelengths

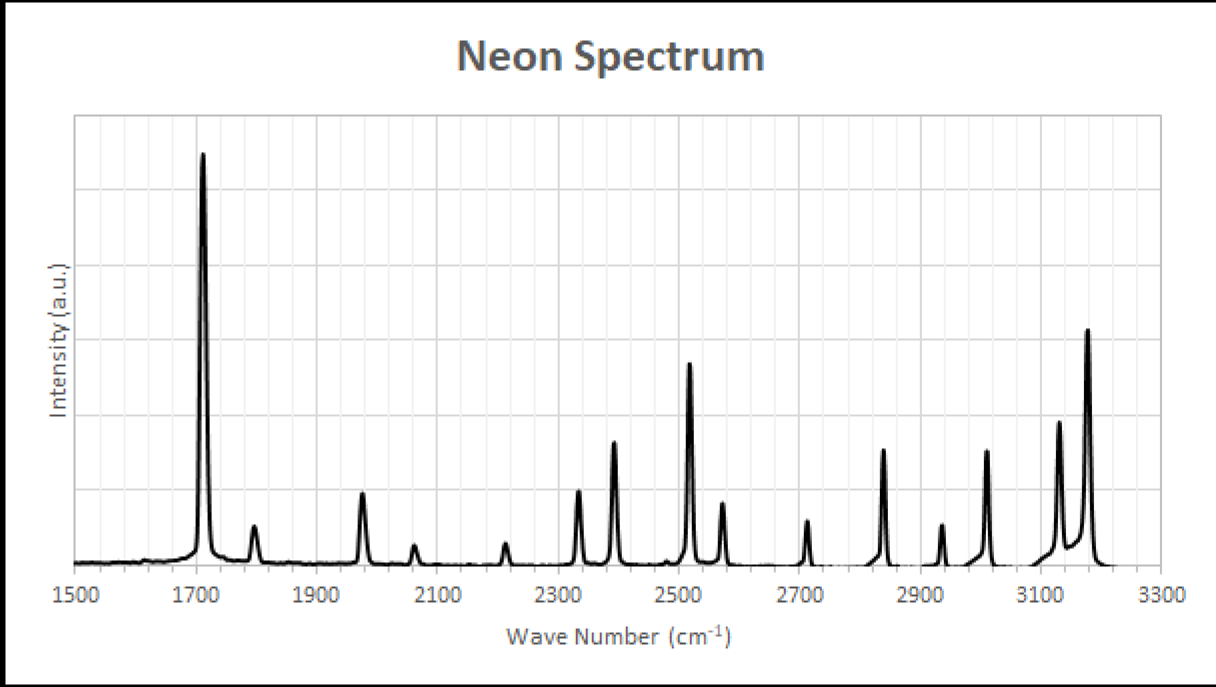


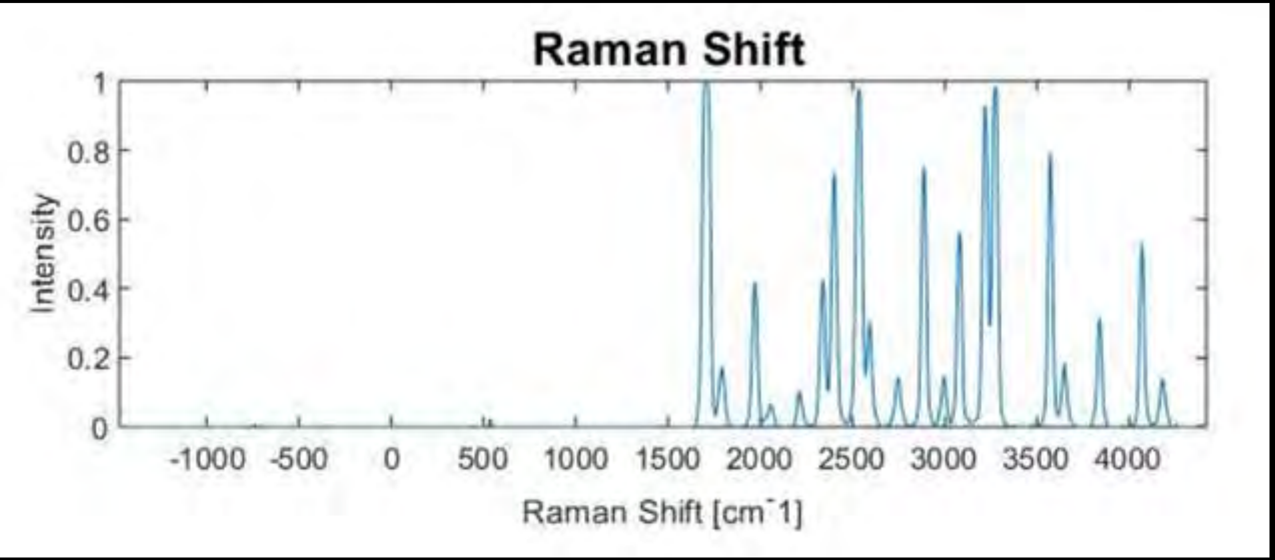
Calibration: The Steps

- Determine the calibrated Raman shift values for x-axis
  - Same procedure as calibrated wavelength axis



Calibration Results





http://www.thepulsar.be/article/diy-raman-spectroscopy/

Spectrum Status

- First "test" spectrum obtained using LED flashlight
- Gradient shown is coming from the end of imaging lens
  - This is roughly how the gradient will appear on the face of the detector

Project Risks

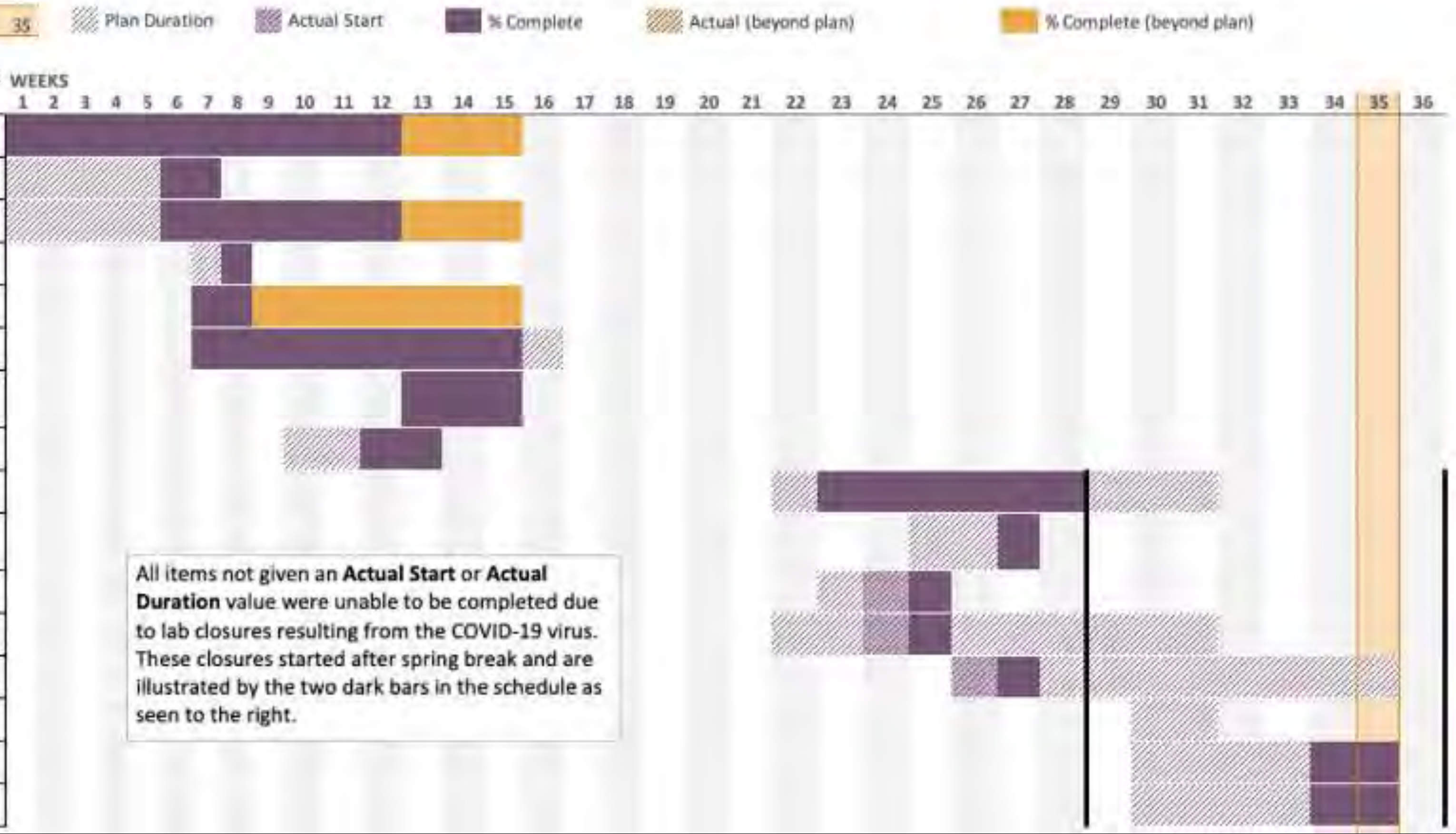
- **Global Pandemic**
- **Risk of Low Signal Strength**
  - Weak signal: Gas-phase samples, small fiber optic input
  - Can be overcome by extending exposure times
- **Physical Risk Posed by Laser**
  - Proper Laser Safety
    - Laser training
    - Appropriate laser goggles/laser curtains

Schedule

Raman Spectrometer Project

Period Highlight: 35

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Research	1	12	1	15	100%
Project Plan	1	7	6	2	100%
Lit. Review	1	12	6	10	100%
Presentation Prep	7	2	8	1	100%
Specs	7	2	7	9	100%
Pricing and Ordering	7	10	7	9	100%
Project Status Presentation 1 Prep.	13	3	13	3	100%
Final Status Report	10	4	12	2	100%
Spectrometer Assembly	22	10	23	6	100%
Project Status Presentation 2 Prep.	25	3	27	1	100%
Enclosure	23	3	25		20%
Software	22	10	25		45%
Testing	26	10	27		10%
Calibration	30	2			0%
Final Project Report	30	6	34	2	100%
User Manual	30	6	34	2	100%



Budget

ORDER NAME	TOTAL
Thorlabs 1	$1,369.02
FLIR 1	$913.92
Thorlabs 2	$243.09
Thorlabs Grating	$375.06
FLIR cable	$16.32
Thorlabs 3	$316.82
Amazon	$28.96
Baselab Tools	$125.85
McMaster-Carr	$5.56+S&H
Super Bright LEDs	$26.36
Est. Total:	~ $3,420.96

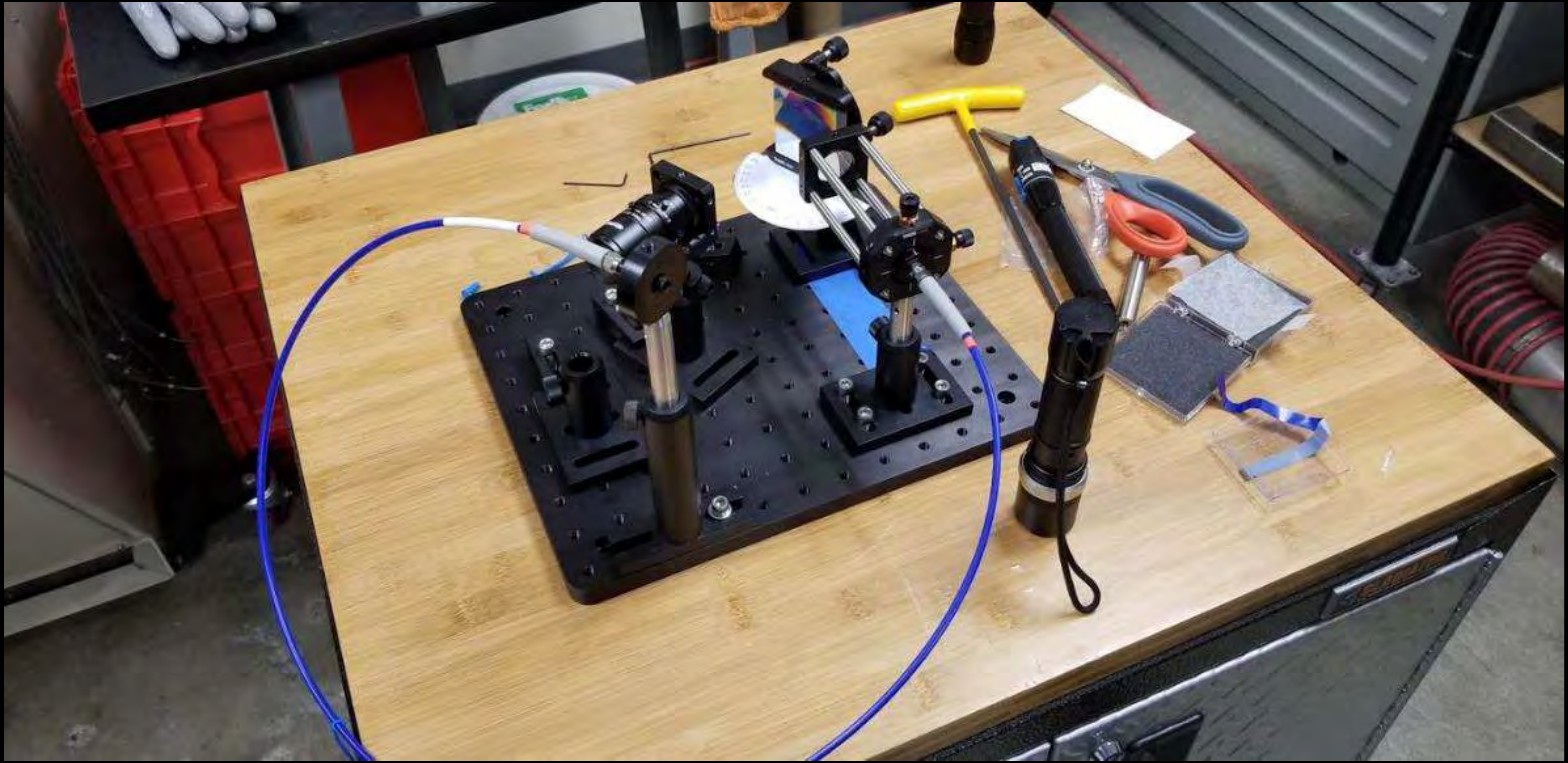
Thank You!

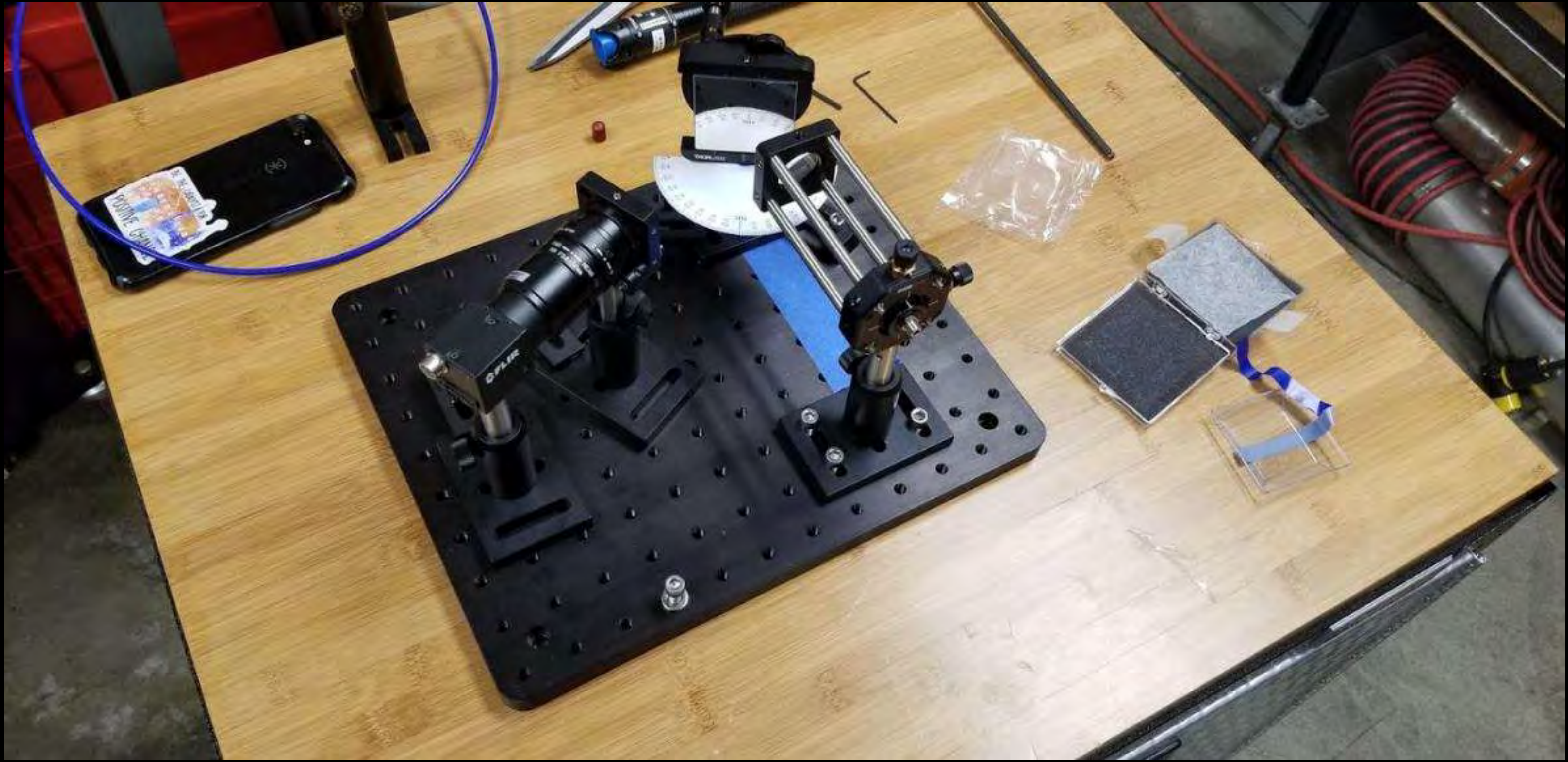
Questions?

Resources

1. Jean Dubessy, Marie-Camille Caumon, Shiv Sharma, & Fernando Rull.*Instrumentation in raman spectroscopy, part 2: How to calibrate your spectrometer.*

2. Usachev, A. D., Zobnin, A. V., Shonenkov, A. V., Lipaev, A. M., Molotkov, V. I., Petrov, O. F., . . . Padalka, G. I. (2018). Influence of dust particles on the neon spectral line intensities at the uniform positive column of dc discharge at the space apparatus “Plasma kristall-4”. *Journal of Physics: Conference Series, 946*, 12143. doi:10.1088/1742-6596/946/1/012143

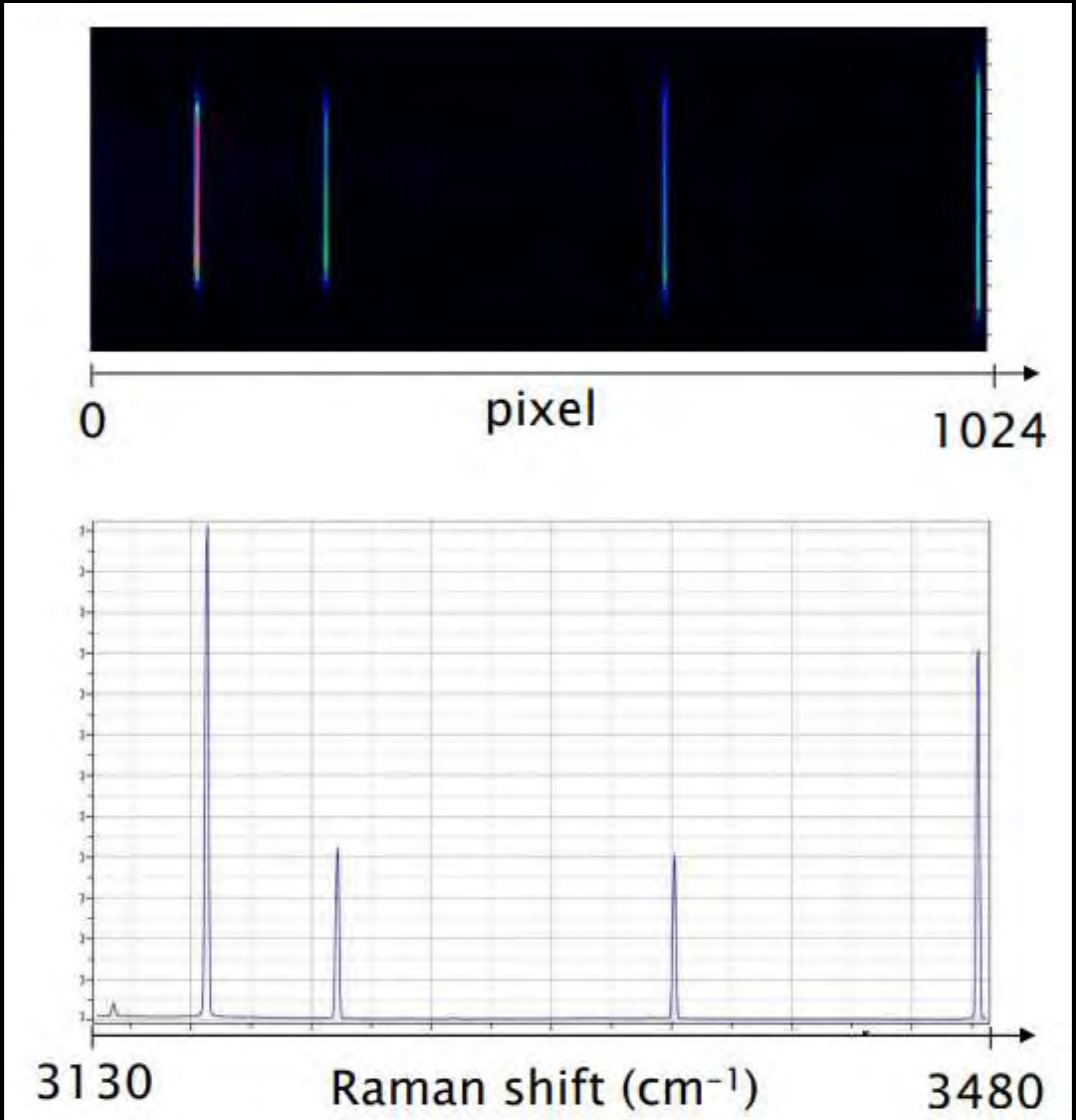


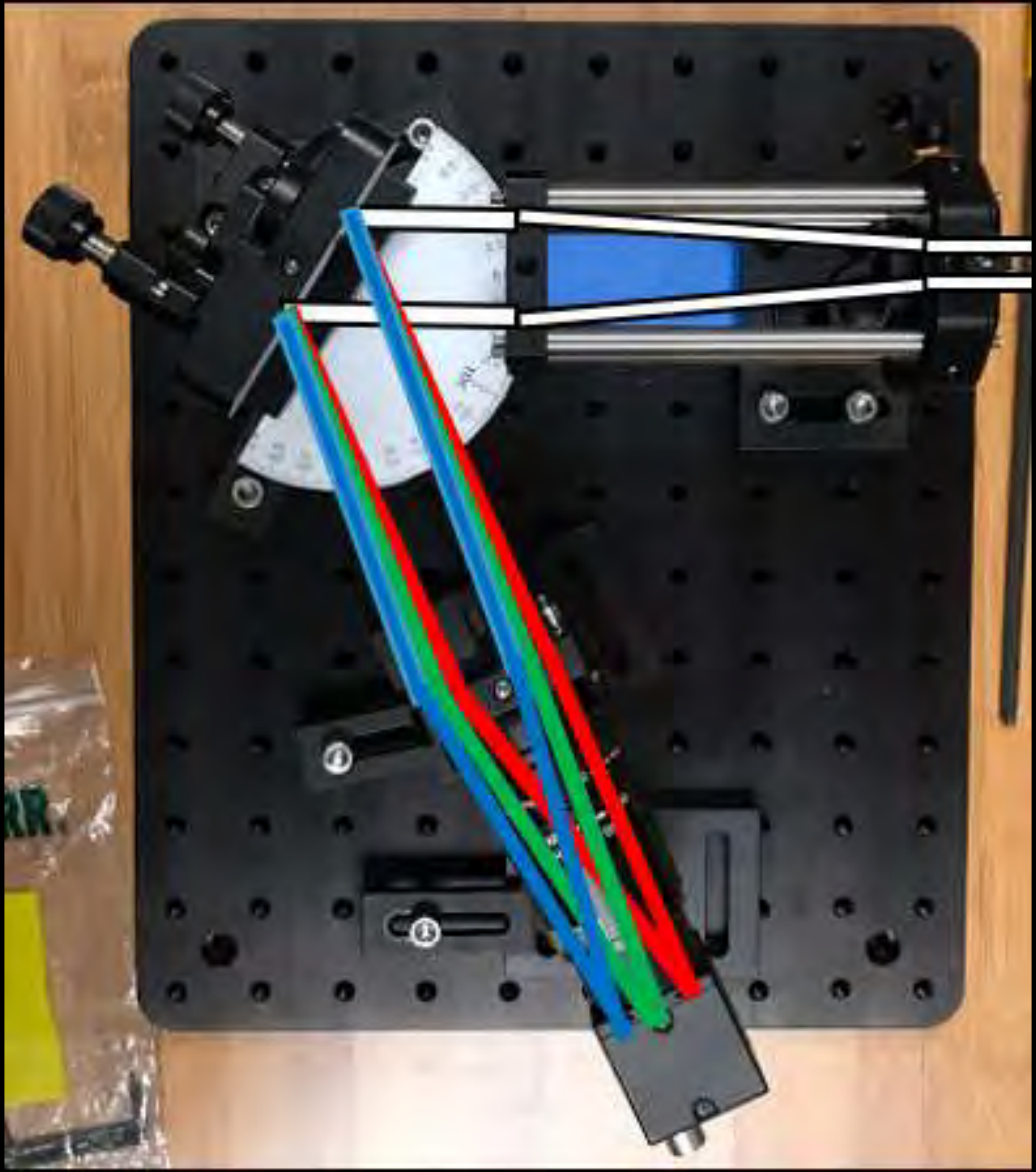

FLIR

Next Steps

- Precise alignment
- Building enclosure
- Creating user manual
- Calibration using neon lamp
- Creating test-stand to hold cuvettes for liquid samples
- Software/data analysis
- Testing using liquid and/or gas samples

Cuvette





http://georaman2014.wustl.edu/previous/2012/georaman10.uhp-nancy.fr/planchesInternationalschool/003%20Calibration_MC-Caumon.pdf

Components

Detector: FLIR Blackfly S Camera

- 2448 pixels in horizontal direction
- Includes software for image collection
- Unlimited exposure time with trigger

https://www.flir.com/globalassets/imported-assets/image/blackflys-cmount-usb.png

Components

Imaging Lens: Navitar Fixed-Zoom Camera Lens

- 50 mm Focal Length
- C-mount allows for easy attachment to FLIR camera

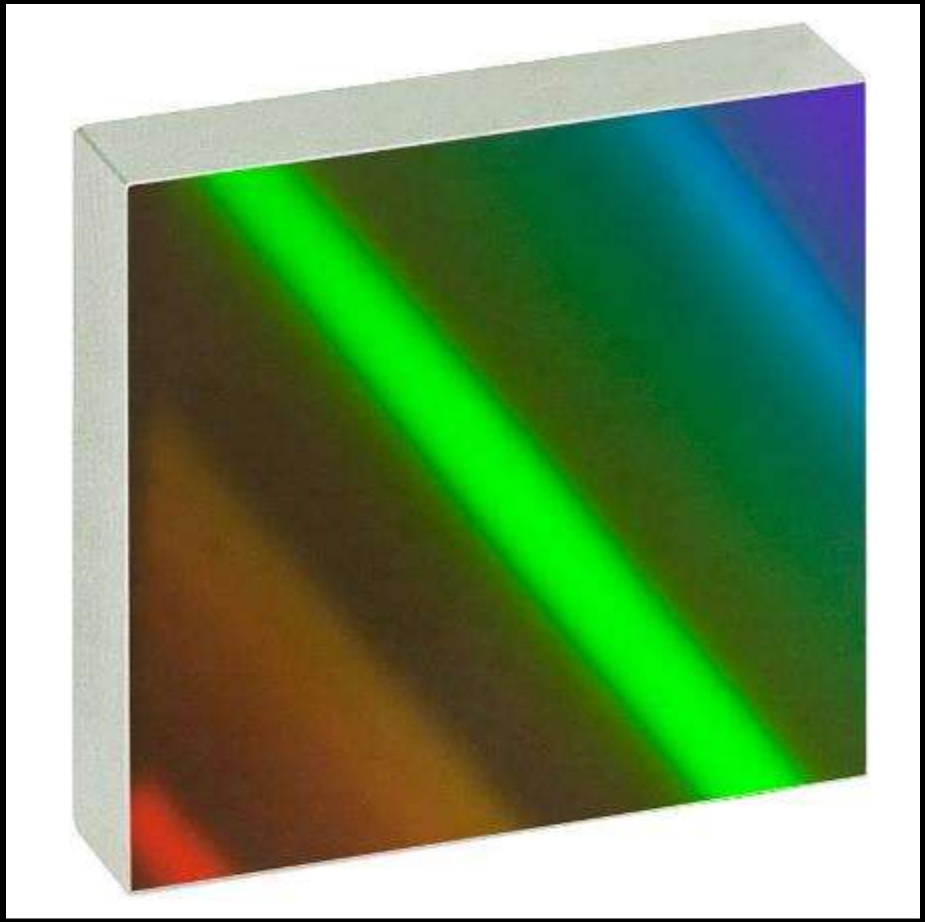
https://www.thorlabs.com/images/TabImages/machine_vision_lens_8mm_A1-780.jpg

FLIR Camera Mounted to Imaging Lens

Components

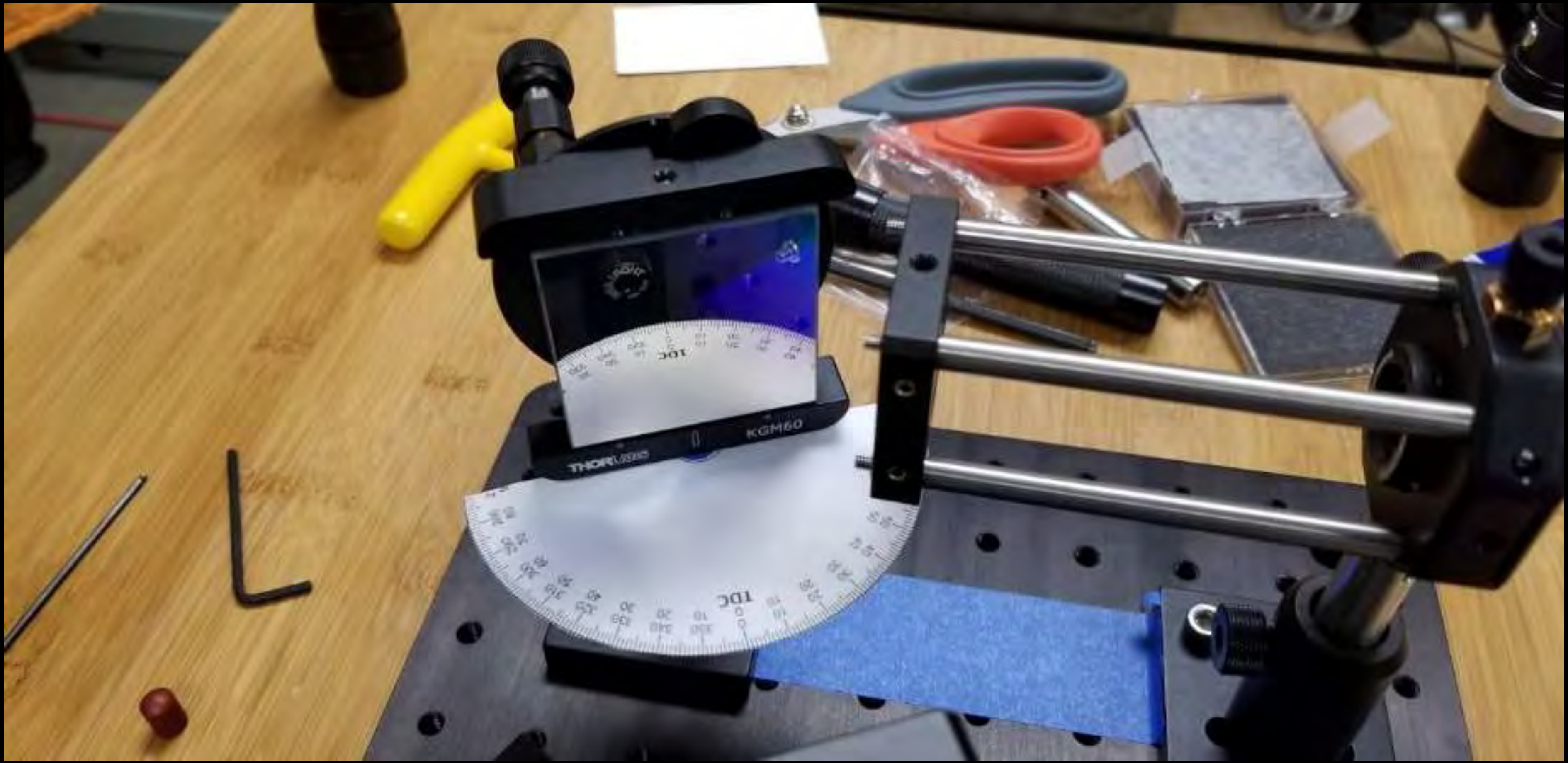
Grating: 1800 groove/mm Holographic Grating

- Chosen for ideal dispersion angles found using the grating equation
- Should give a total angle of about 66 deg. between incident beam and median diffracted beam



https://www.thorlabs.com/images/xlarge/11795-xl.jpg

Diffraction Grating Mounted in the Assembly



Design Choices

Fiber Optic

- 10 and 25 micron core dia. fiber optic cable
- NA: 0.10
- SMA connectors at both ends

https://www.thorlabs.com/images/xlarge/TTN021025-xl.jpg

Components

Collimating Lens: 1" Spherical Plano-Convex Lens with 100mm Focal Length

- Focal length chosen to provide a clear image with about 90% of the lens aperture filled (determined by NA of fiber optic chord)

- Common choice for collimating/focusing applications

https://www.thorlabs.com/images/large/3270-lrg.jpg

Components

ThorLabs 30mm Cage System

- Will hold 1" optics/components
- Simplifies alignment and reduces number of Degrees of Freedom

https://www.thorlabs.de/images/TabImages/60mm_Cage_System_Assembled_A3-780.jpg

Budget

Budget Provided: $3500

Budget Utilized: $3400

Component	Part #	Quantity	Price per unit	Total price	Link
1800 ln/mm, holographic, visible grating	GH50-18V	1	$333.29	$333.29	https://w
50 mm FL Navitar Camera Lens	MVL50M23	1	$212.10	$212.10	https://w
100 mm FL Plano-Convex Lens 1" dia.	LA4380-YAG	1	$105.70	$105.70	https://w
10 micron fiber SMA connectors (1 meter)	M65L01	1	$123.36	$123.36	https://w
25 micron fiber SMA connectors (1 meter)	M68L01	1	$125.53	$125.53	https://w
FLIR Blackfly Camera	BFS-U3-50S5M-C	1	$835.00	$835.00	https://w
XYZ Translation Mount (CXYZ05)	CXYZ05	1	$353.86	$353.86	https://w
Thread Adapter (Ex. M27x0.5) (Int. SM1)	SM1A36	1	$21.86	$21.86	https://w
30mm Cage Plate with 1.2" dia. Bore	CP36	2	$22.07	$44.14	https://w
Lens Tube 1/2" long	SM1L15	1	$16.17	$16.17	https://w
1" dia. Mirror Mount (for grating adapter)	KM100	1	$39.86	$39.86	https://w
Grating Mount Adapter	KGM60	1	$177.47	$177.47	https://w
Standard 1/2" dia. Post Holder	PH2	4	$7.93	$31.72	https://w
1/2" dia. 3" Stainless Steel Optical Posts	TR3	4	$5.58	$22.32	https://w
Mounting Base	BA2	4	$7.52	$30.08	https://w
3" ER Assembly Rods (4 Pack)	ER3-P4	2	$25.83	$51.66	https://w
30mm Cage Mounting Bracket	CP02B	2	$14.94	$29.88	https://w
1/2" thread to SMA adapter	SM05SMA	1	$30.30	$30.30	https://w
Arctic Silver Arctic Alumina 5g Premium Ceramic Thermal Cooling Adhesive Set (AATA-5G)	N/A	1	$13.60	$13.60	https://w
Black Hardboard	TB4	1	$69.26	$69.26	https://w
Cut-to-size Grommet (5 pack)	#2633N14	1	$5.56	$5.56	https://w
1.5" ER assembly rods	ER1.5-P4	1	$22.89	$22.89	https://w
4" ER assembly rods	ER4-P4	1	$27.79	$27.79	https://w
Black High-Performance Masking Tape	T743-1.0	1	$21.10	$21.10	https://w
1/2" dia. 2" Stainless Steel Optical Posts (5 pack)	TR2-P5	1	$24.06	$24.06	https://w
Slip-On Post Collars (5 pack)	R2-P5	1	$25.75	$25.75	https://w
Neutral Density Filter AR-coated OD:1.3	NE13A-A	1	$76.83	$76.83	https://w
8-32 3/8" long Cap Screws (50 pack)	SH8S038	1	$6.93	$6.93	https://w
Awxlumv Large Aluminum Heatsink 3.94" x2.71" x 1.41" / 100 x 69 x 36mm Heat Sinks Cooling 27	N/A	1	$12.99	$12.99	https://w
Vollong 5W White High Power LEDs – 5 Watt Cool White	#VL-H01W60005	1	$6.95	$6.95	https://w
700 mA Constant Current LED Driver	#LD-CU7012-01	1	$8.95	$8.95	https://w
Power Cord for Power Supplies	#_POWERCORD	1	$4.95	$4.95	https://w
Blackfly Camera Tripod Adapter	ACC-01-0003	1	$5.00	$5.00	https://w
Table Clamps for Bases (5 pack)	CL5-P5	1	$21.88	$21.88	https://w
1" dia. Lens 30mm Cage Mount	CP33	1	$16.89	$16.89	https://w
Post Thread Adapter for Camera Mount	AP8E25E	1	$2.10	$2.10	https://w
USB Cable for FLIR Camera	ACC-01-2301	1	$16.32	$16.32	https://w
Optical Breadboard	SAB1012	1	$130.00	$130.00	http://ww
			Base Total:	$3,104.10	