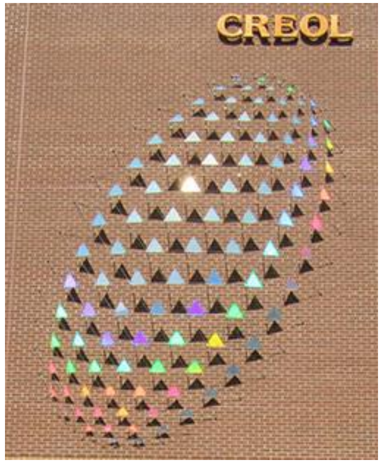
Low-Shift Raman Microscope

Group # 17
Kevin Orkis - EE
Brandon Seesahai - PSE
Matt Aviles – EE/CpE
Chris Beck - PSE



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Motivation

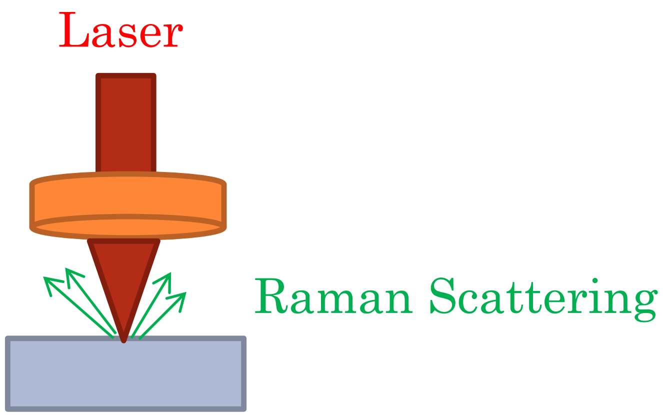
- Sponsor: Professor of Chemistry and Forensic Science wants a Raman spectroscopy system in his lab that detects low-shift signals.
- Raman spectroscopy has applications in forensic science for analyzing drugs, explosive substances, and other materials for forensic applications.
- Raman spectroscopy and microscope integration: Microscope allows for easy sampling, sample visualization with high magnification, and can focus light to a small point to easily create a Raman Signal.
- Low-shift signals provides a more detailed "fingerprint" of a sample.

Goals

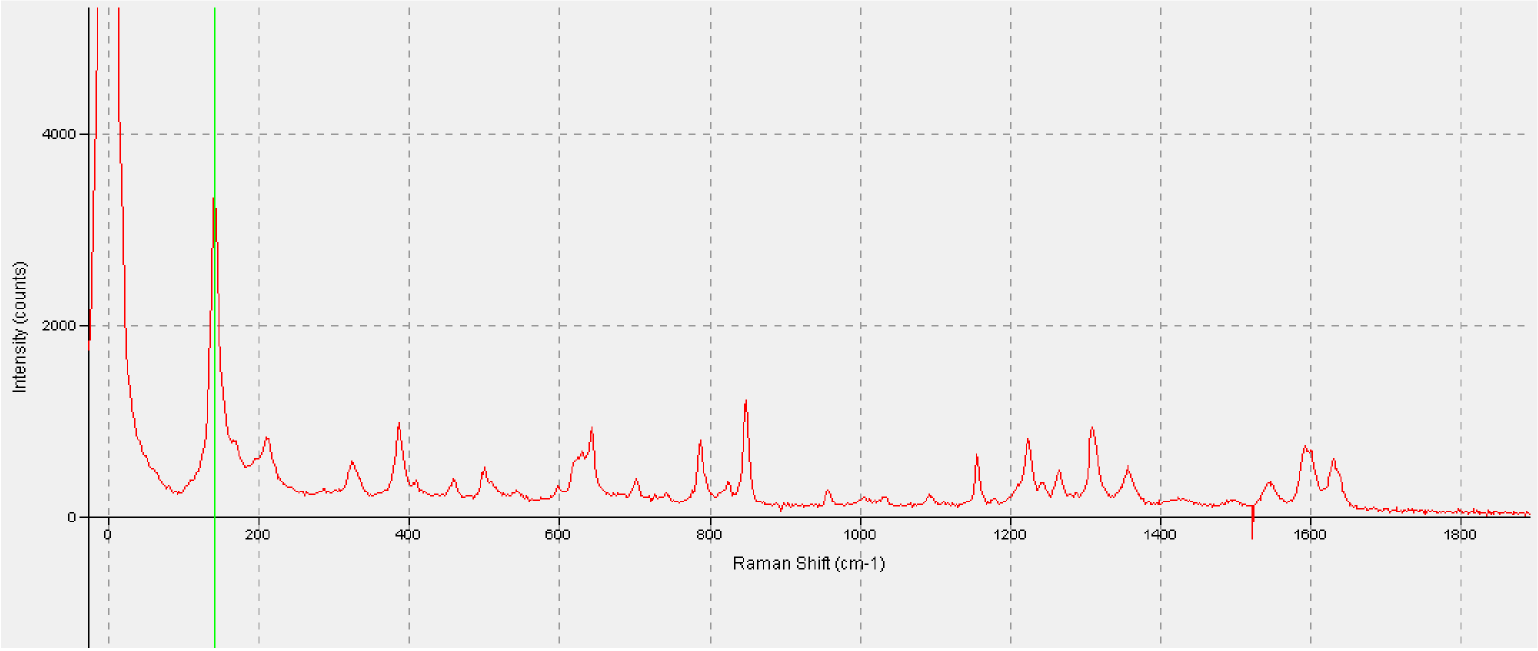
- Integrate Raman spectroscopy with a microscope.
- Create a Raman spectroscopy system that can detect low-shift Raman signals.
- “Cheaper”, safe, and easy to use system for non-optics majors.

What is Raman Spectroscopy?

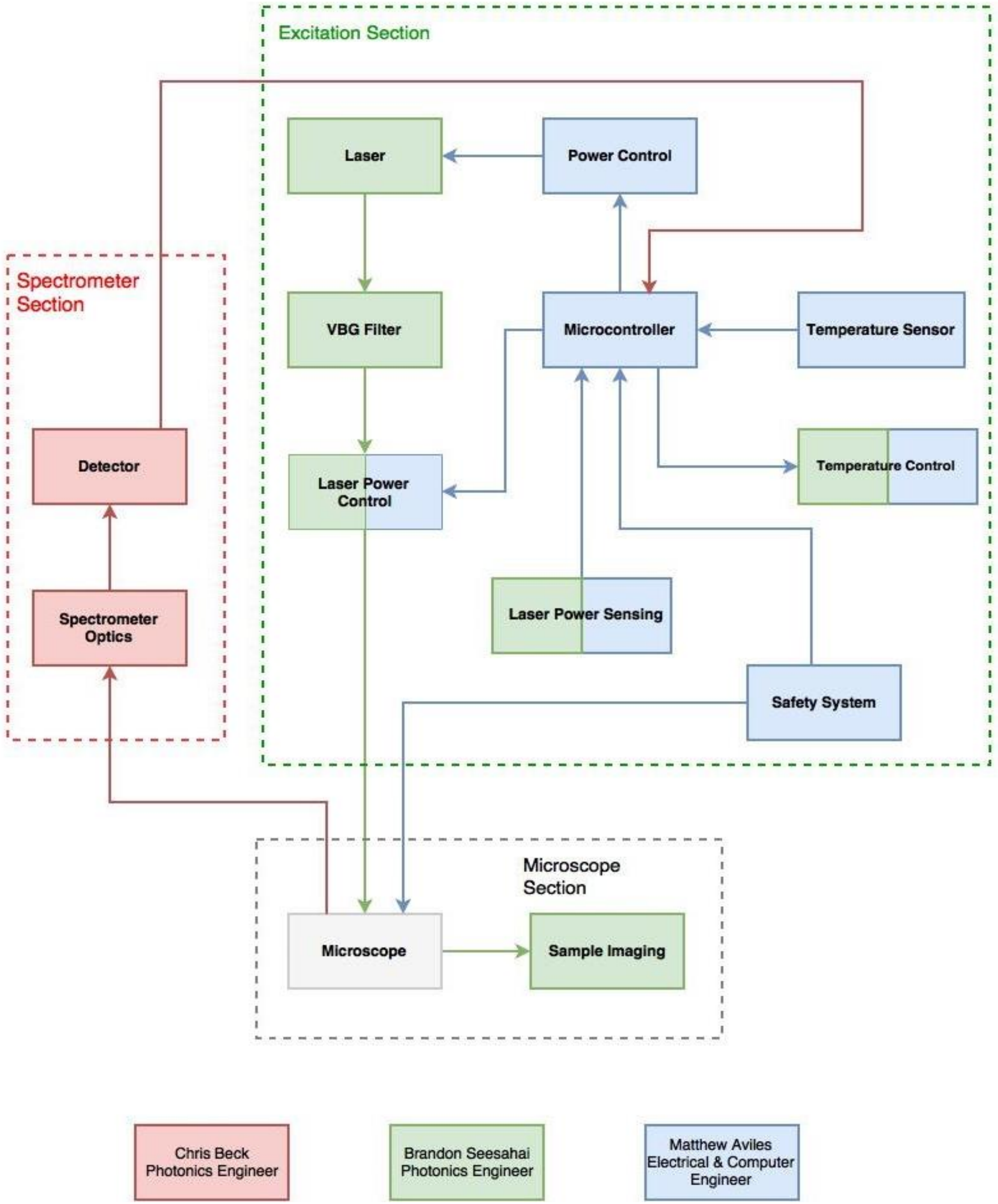
- Focus Laser light to a sample to create Raman scattering.
- Raman scattering can provide a spectrum that provides the molecular signature of a material.
- Raman scattering: Rayleigh scattering and inelastic scattering (stokes and anti-stokes).



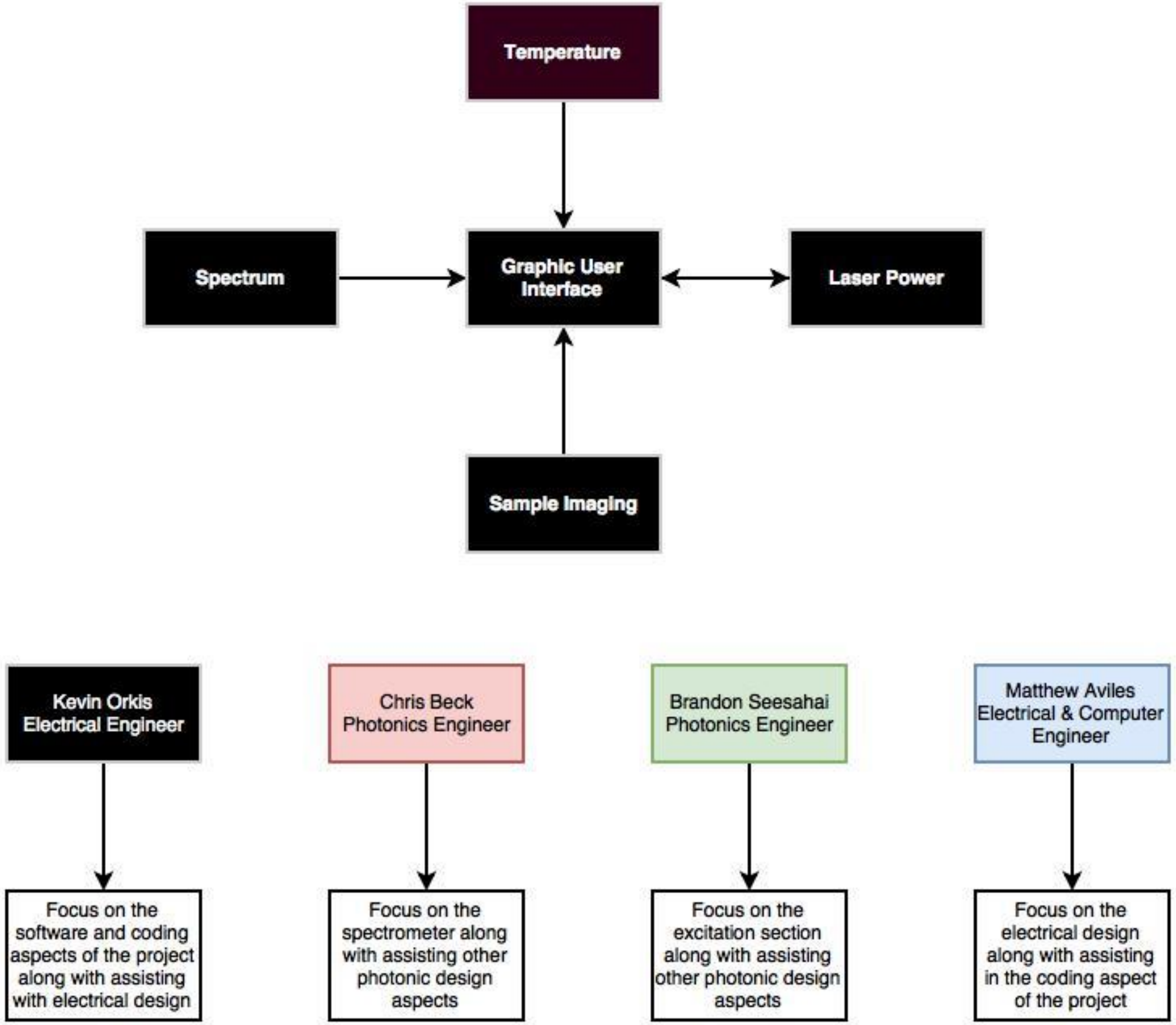
Stokes Signals of Excedrin Tablet



Hardware Diagram



Software Diagram



Work Distribution

	Main	Secondary
Spectrometer	Chris Beck	Brandon Seesahai
Excitation	Brandon Seesahai	Chris Beck
Hardware	Matt Aviles	Kevin Orkis
Software	Kevin Orkis	Matt Aviles

Overall Requirement Specification

- Laser Wavelength = 785 nm
- Resolution ≤ 5 cm^{-1}
- Detect Peaks ± 200 cm^{-1} (770.87 nm to 799.13 nm).
- Class 1 Laser System
- Fit on a Chemistry Lab Table

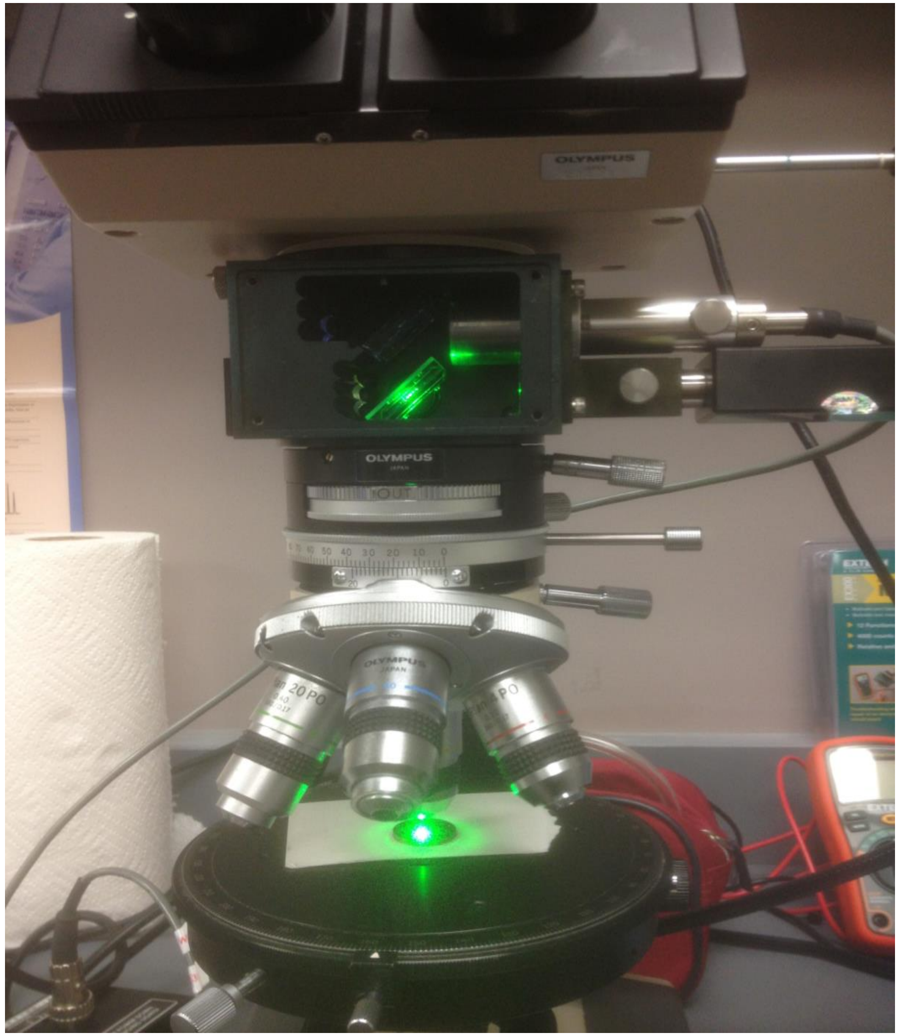
Excitation Section Requirements

- Inject a narrow line width laser into a microscope
- Focus as much laser power as possible to a sample
- Generate Raman scattering that can be detected by a spectrometer.
- Camera imaging of sample

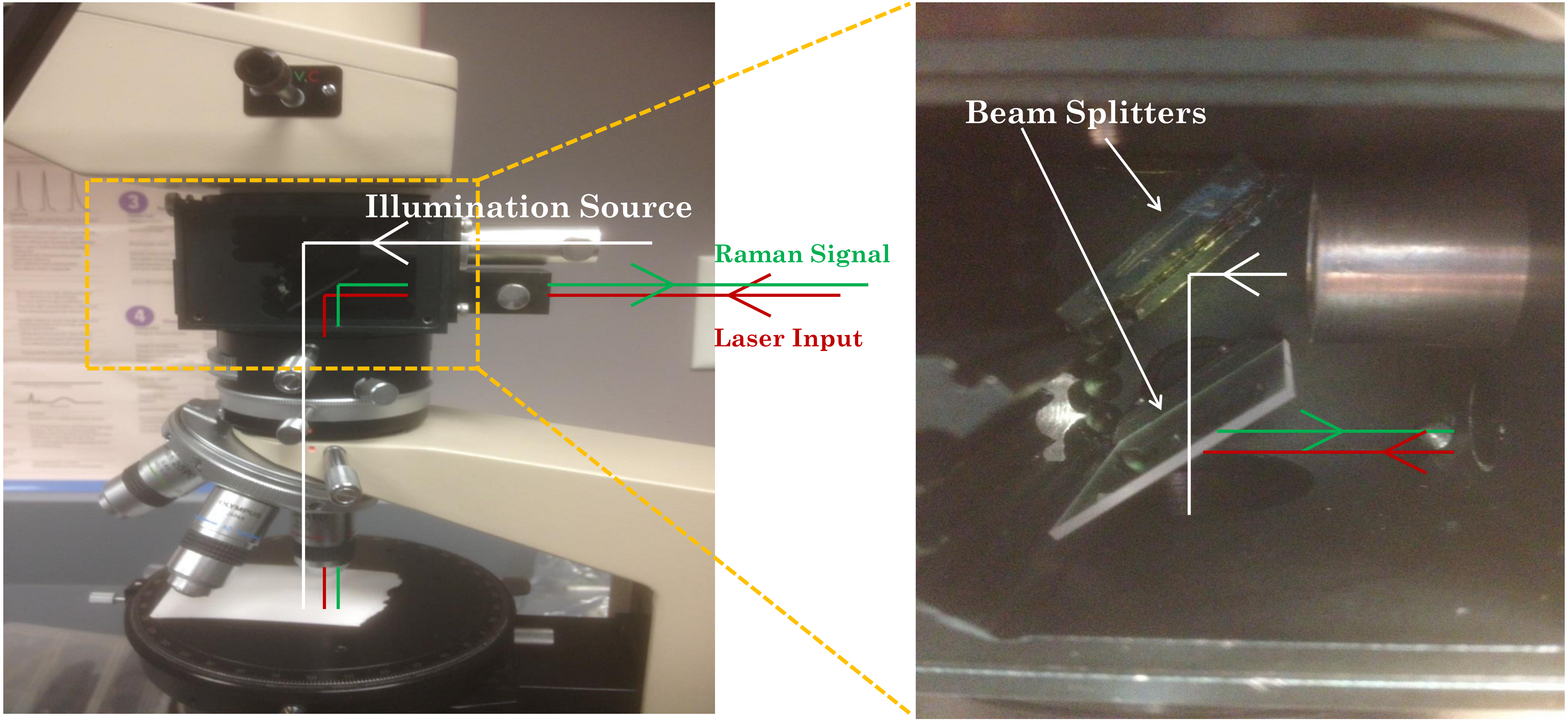
MICROSCOPE

- Olympus BH2 Microscope

Magnification	4 X	10 X	20 X	40 X
N.A.	0.10	0.25	0.40	0.65
Focal Length (mm)	34.23	17.69	8.99	4.61

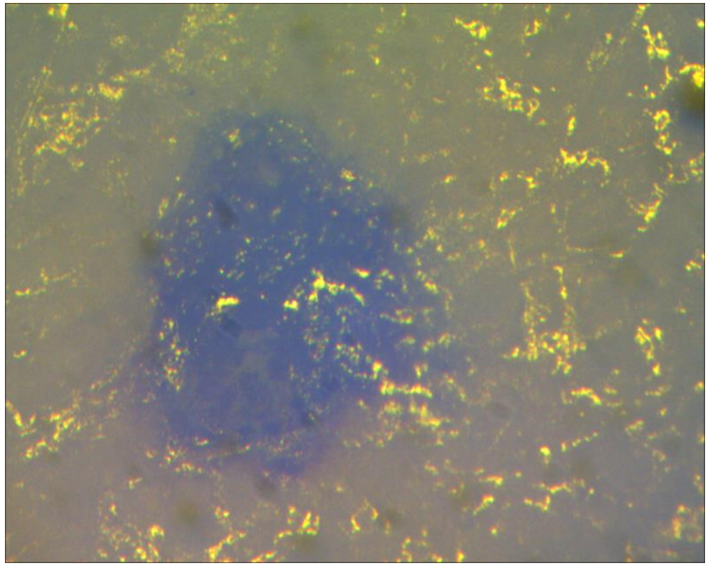


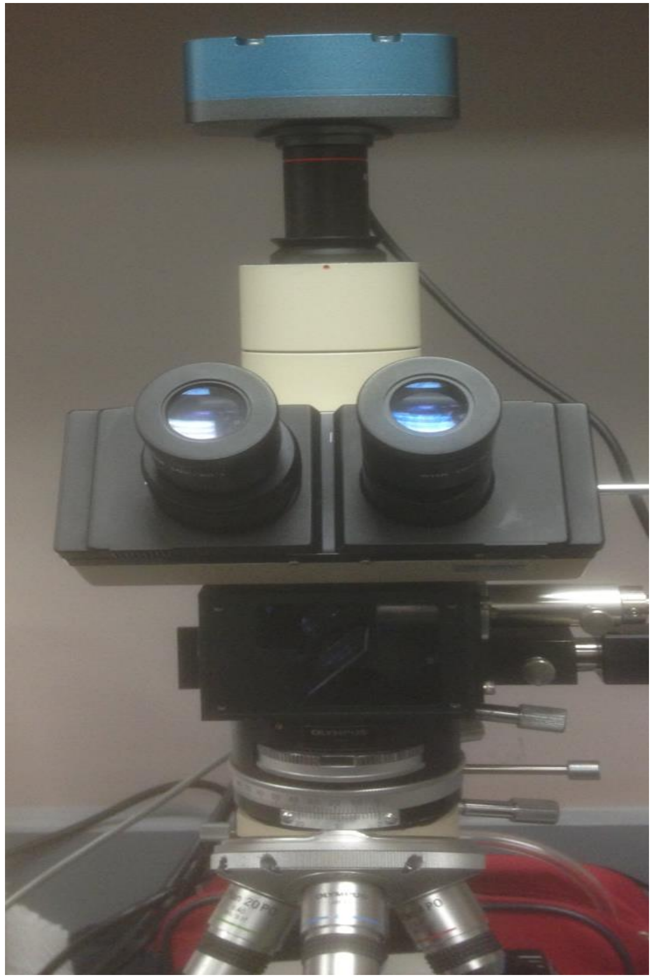
Inside the Microscope



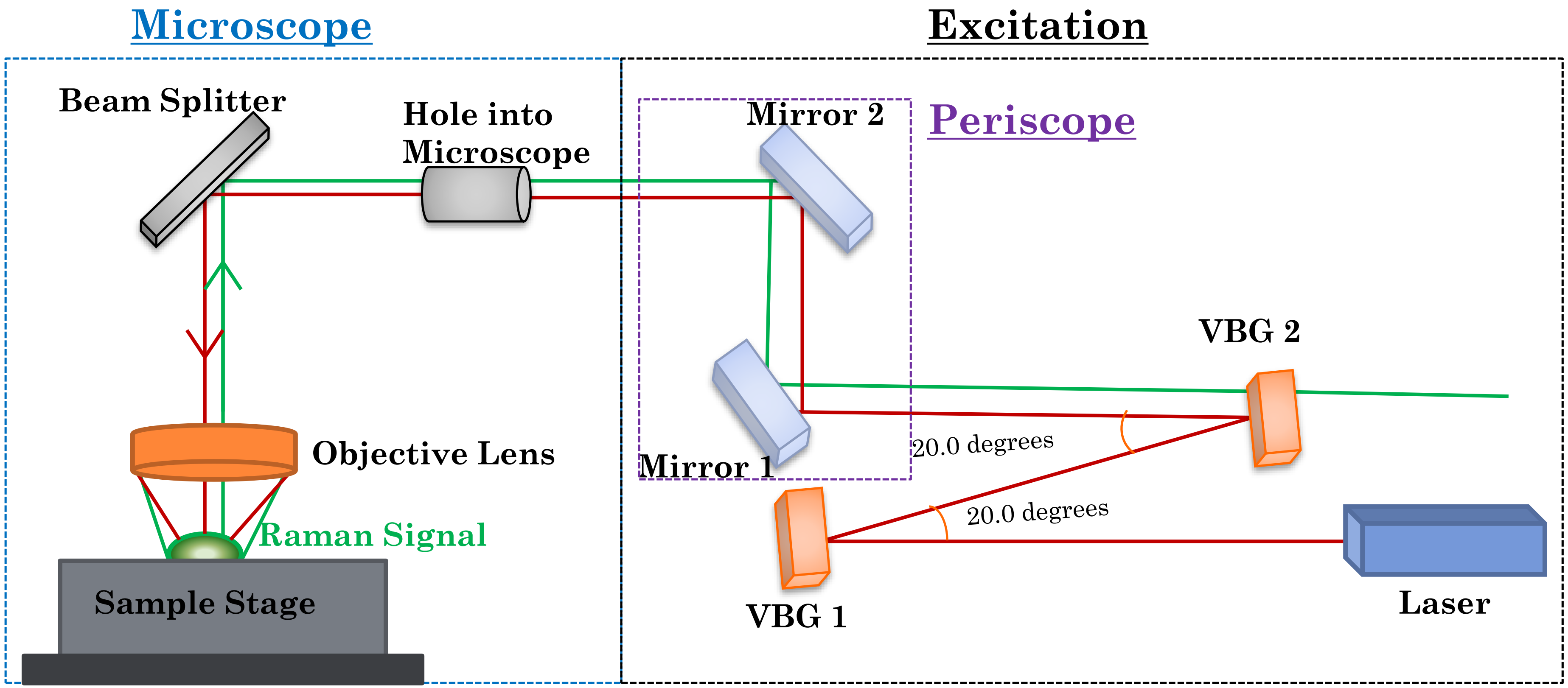
Camera

- Camera is on top of the microscope.
- Camera has the same field of view as the objective
- Camera imaging of sample
- Image of a white card with a pen mark (4X objective).





Optic Schematic



Laser

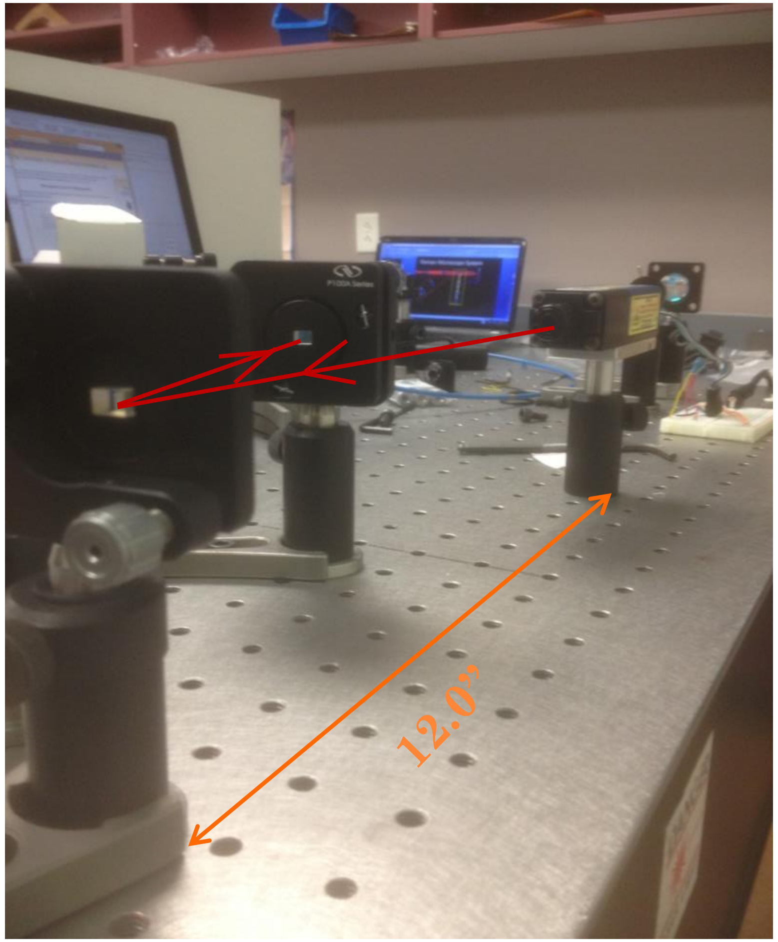
- Laser Wavelength = 785 nm from Innovative Photonic Solutions (IPS)
- Single Mode
- Collimated Output Beam with FWHM 0.018 nm.
- Maximum output ~100 mW
- Optical Isolator

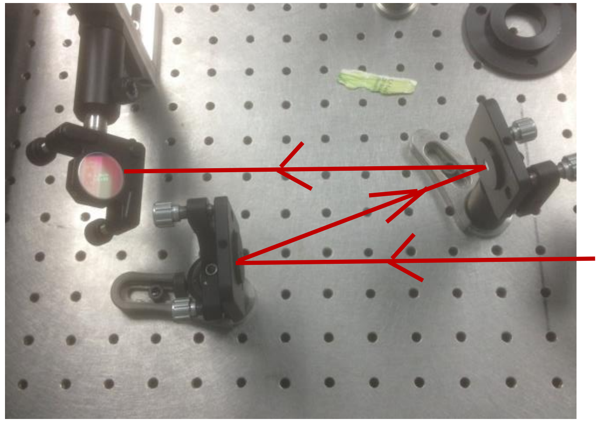
	532 nm	785 nm	1064 nm
Excitation Efficiency	high	medium	low
Fluorescence	high	medium	low
Heat Absorption	low	medium	High

$$P_{scattered} \propto \frac{I_o}{\lambda^4}$$

Volume Bragg Gratings (VBG)

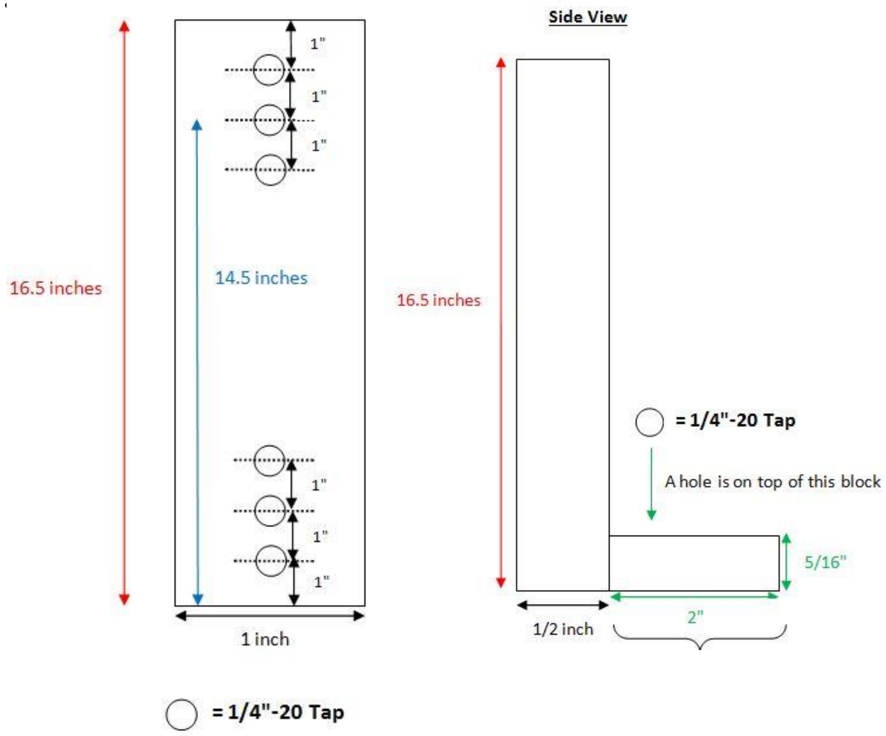
- VBG is a dispersive element for a single wavelength at a single angle.
- Reflects 785 nm and transmits other wavelengths.
- Narrow spectral profile of laser down to less than 5 cm^{-1} or 0.31 nm.
- Cleans intensity profile.

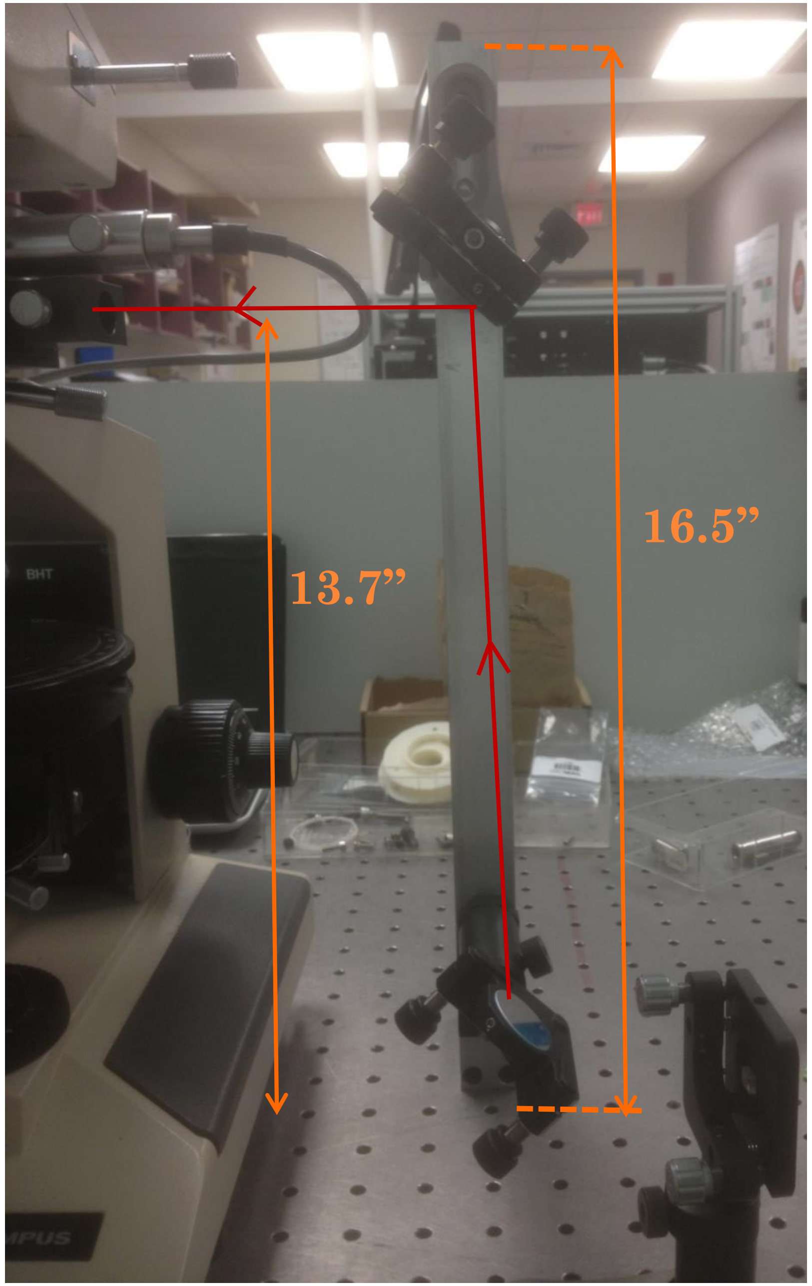




Periscope

- Thorlabs sells a periscope mount for $285.
- Periscope is made out of aluminum with ¼”-20 taps to mount mirrors. Has a ¼”-20 slot to screw into optical bench.





Periscope Mirrors

- Broadband Dielectric Mirror
- 0.5" or 1" mirrors? Raman signal will have a diameter of 0.49" if 10 X is used. 1" Mirrors cost ~$24 more

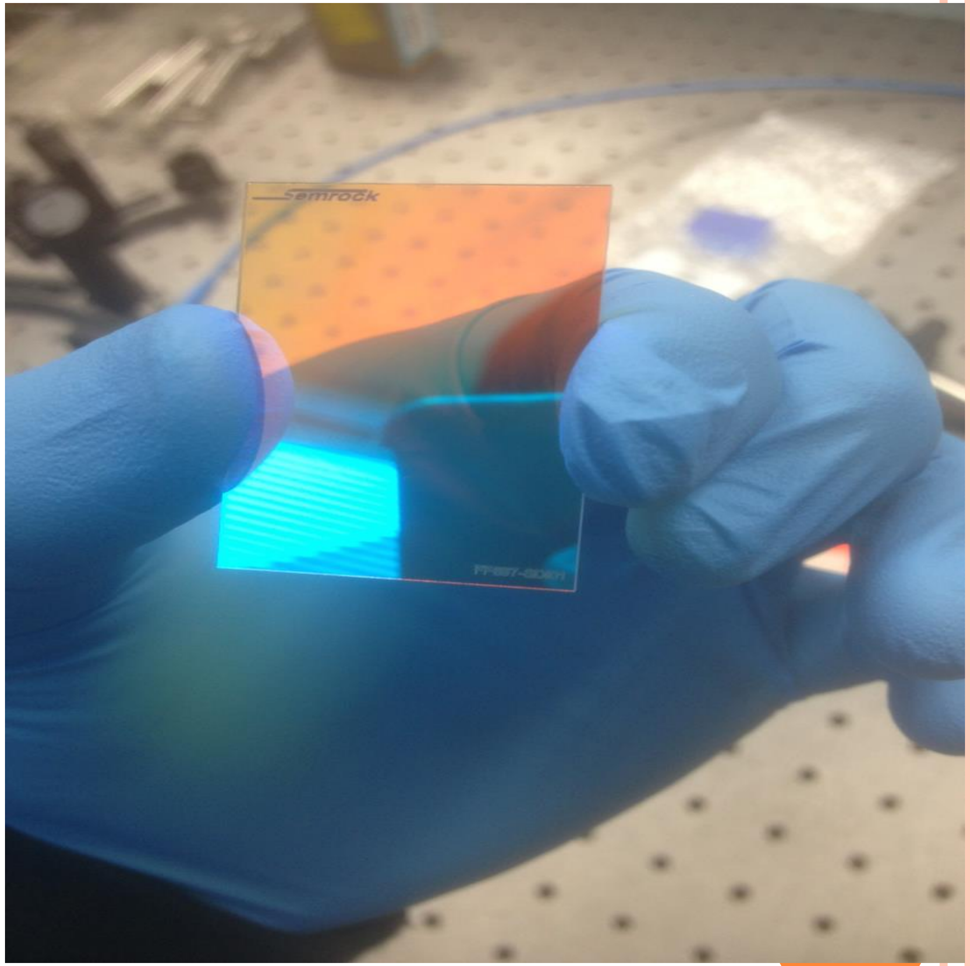
Part	BB1 – E02	BB1 – E03
Wavelength Range (nm)	(99 %) 400 – 750	(99 %) 750 – 1100
Cost	$75.10	$75.10

Magnification	4 X	10 X	20 X	40 X
Pupil Diameter (in)	0.27	0.35	0.28	0.24
Raman signal diameter on Mirror (in)	0.38	0.49	0.40	0.34

Semrock Filter

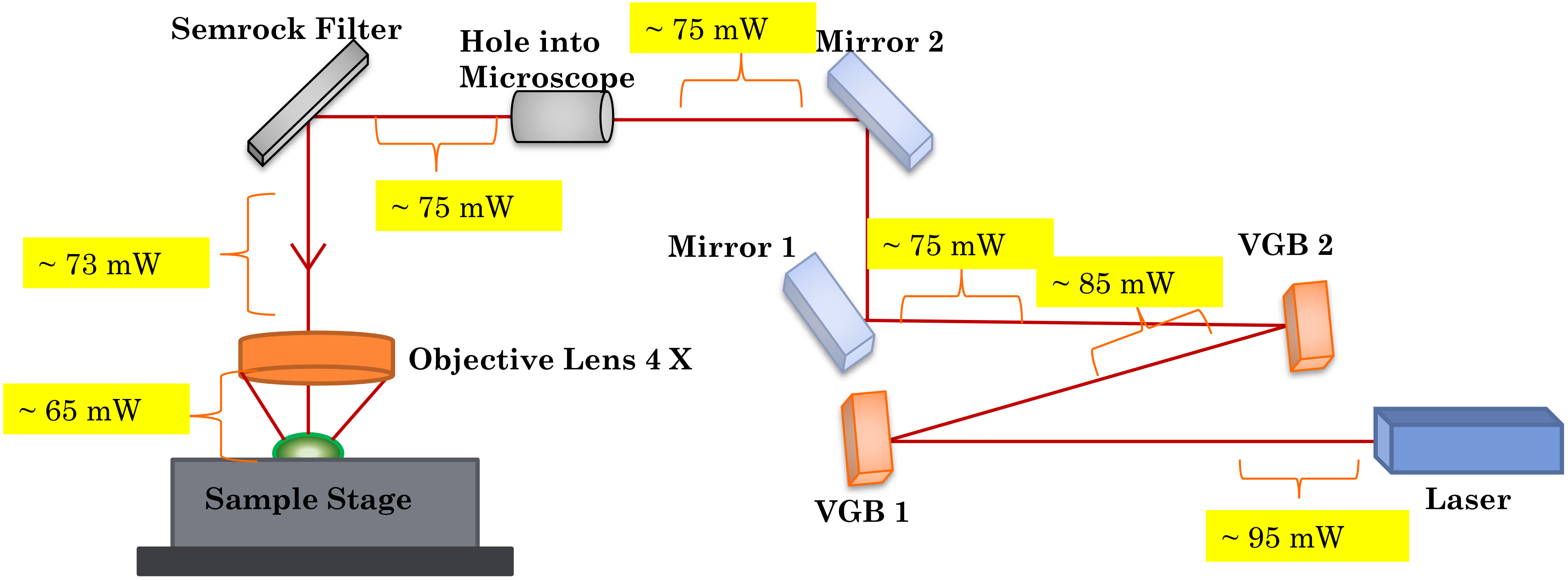
- Single-Edge Short Pass Dichroic Beamsplitter
- Efficient at 45 degrees

Cost	$ 225	$335	$335
Reflection Band (nm)	(97 %) 705 – 900 nm	(90 %) 750 – 1140 nm	(96 %) 770 – 1100 nm
Tranmission Band (nm)	(93 %) 532 – 690 nm	(90 %) 430 – 700 nm	(93 %) 400 – 730 nm



Laser Power Trace

Magnification	4 X	10 X	20 X	40 X
Output Power (mW)	~65	~61	~58	~51 (22 mW loss)

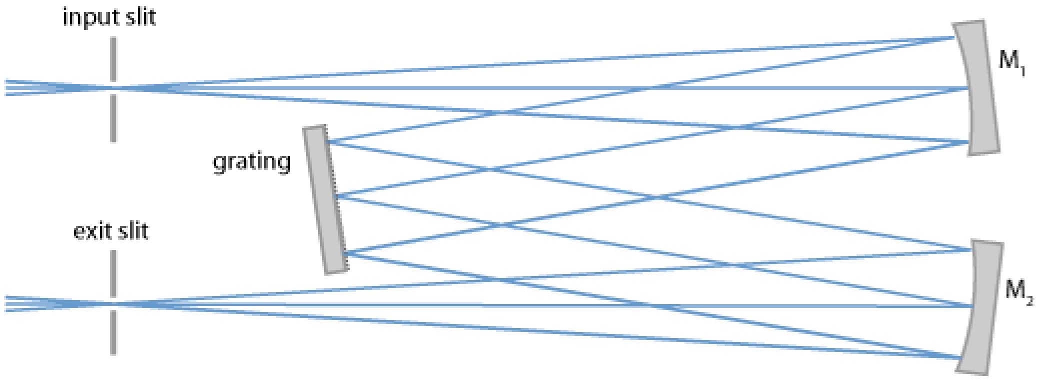


Design Issues

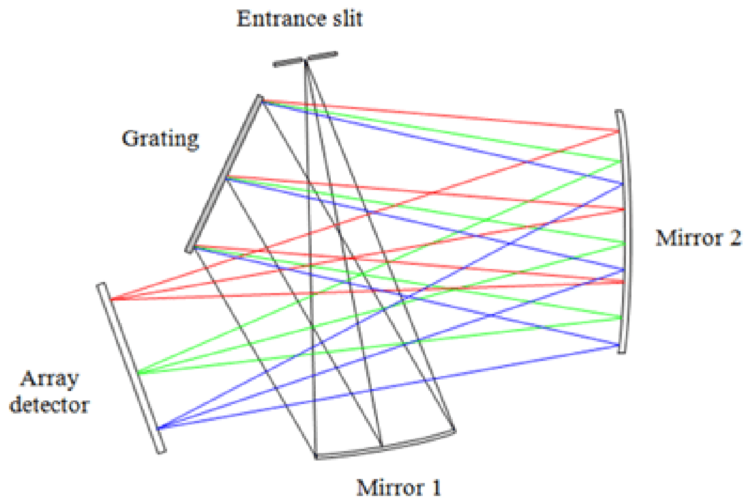
- Excitation optical alignment

Common Spectrometer Design

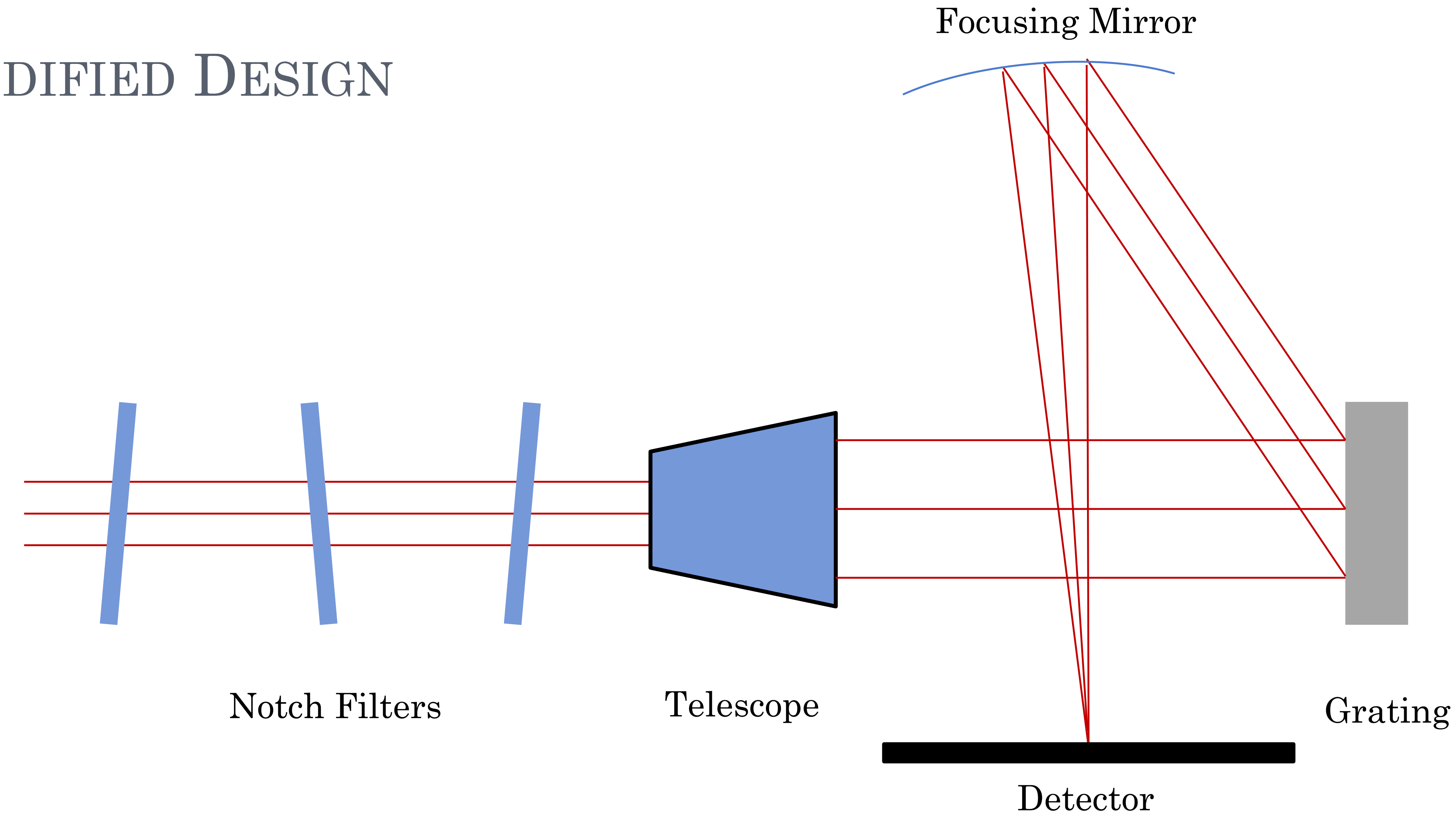
Czerny-Turner



Folded Czerny-Turner

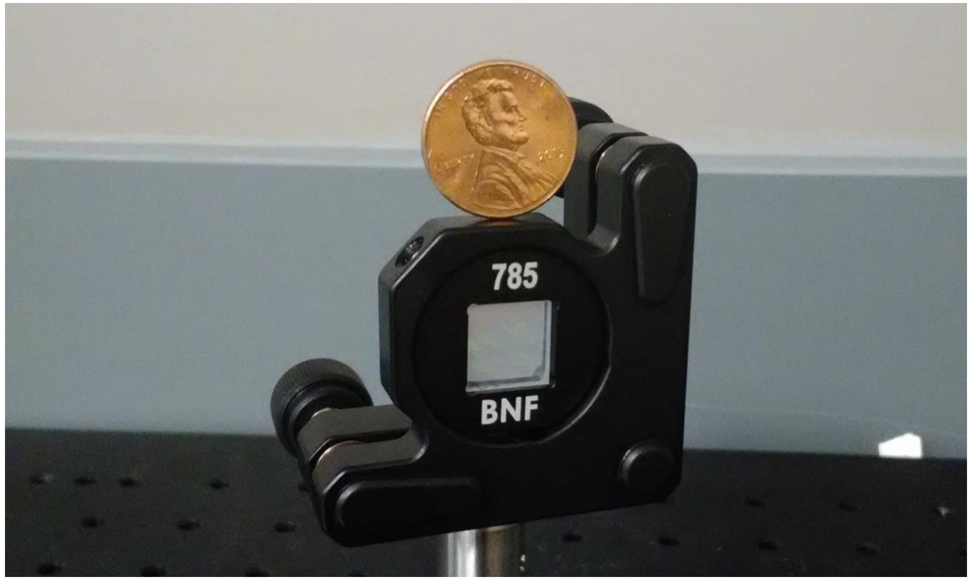


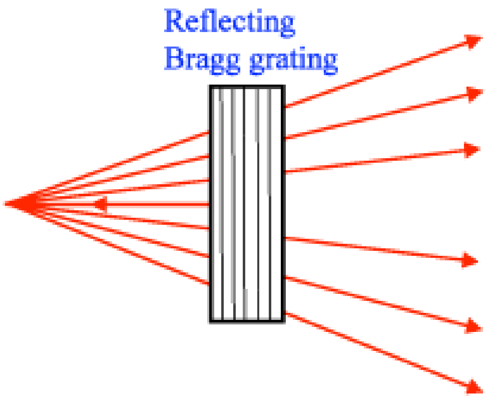
Modified Design

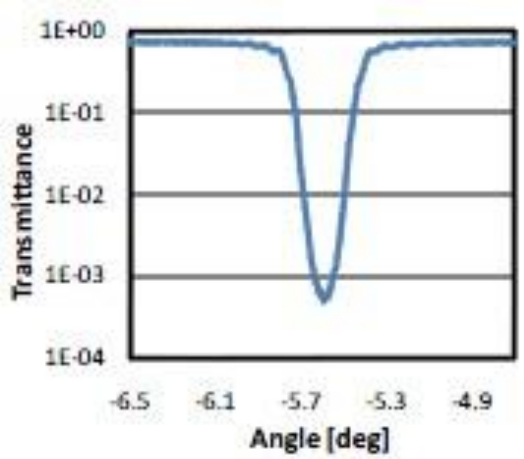


Notch Filters

- Transmits most light, reflects very narrow bandwidth
- Used to remove the laser line
- Very sensitive to angle

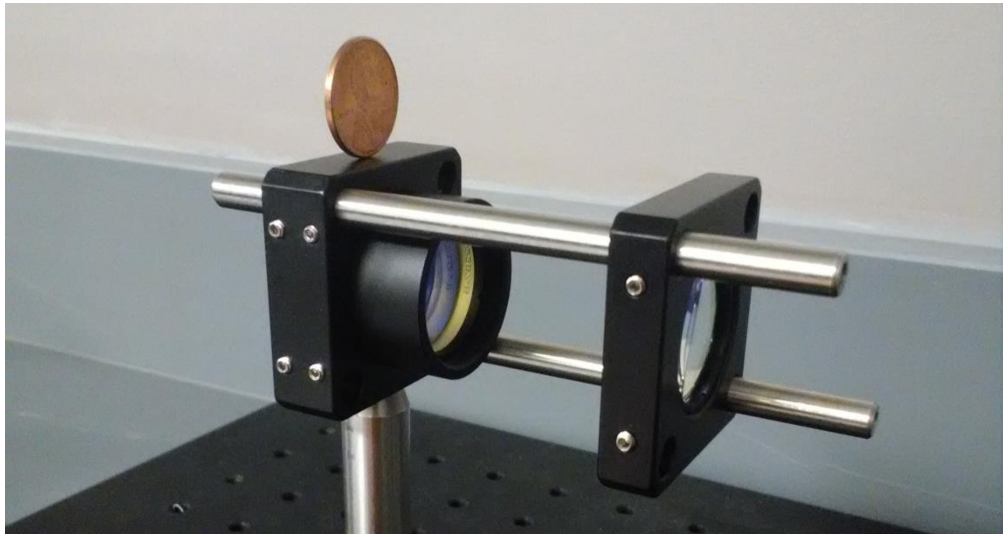






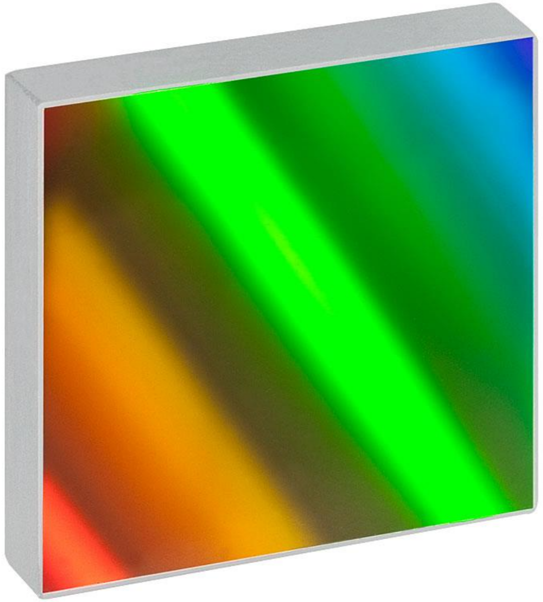
Telescope

- Input beam width is only 7 mm
- For best resolution, beam width should be grating width (12.5 mm)
- Magnification: 2x
- F_1 = -25 mm
- F_2 = 50 mm



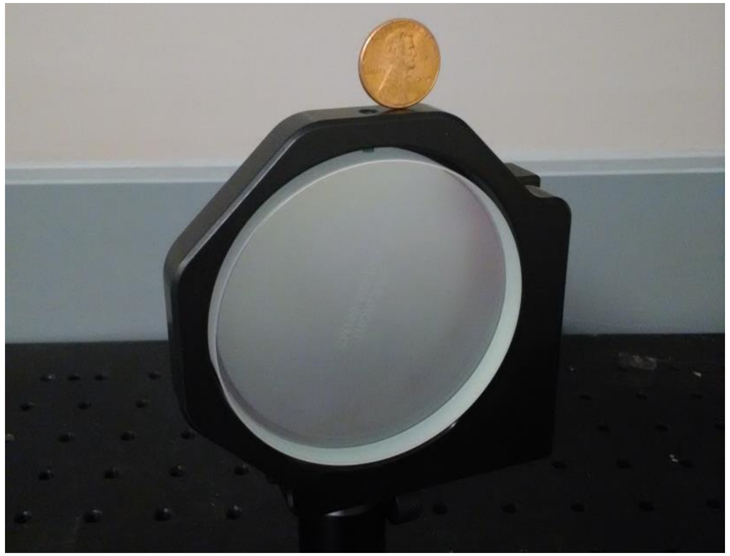
Grating

- Disperses light based on wavelength
- For best resolution, incident beam should fully cover grating
- Line density = 1200 lines/mm
- Size: 12.5 mm x 12.5 mm



Mirror

- Focuses dispersed light onto detector
- Focal length determines spectral range and resolution
- F=500 mm



Detector

- Collects spectrum
- Each pixel represents a single wavelength
- TCB1304AP
  - Highly sensitive, low dark current linear image sensor
  - 3648 Pixels
  - 8 um x 200um Pixel Size
- Commonly used, cheap, easy to use

Electrical Design Specifications

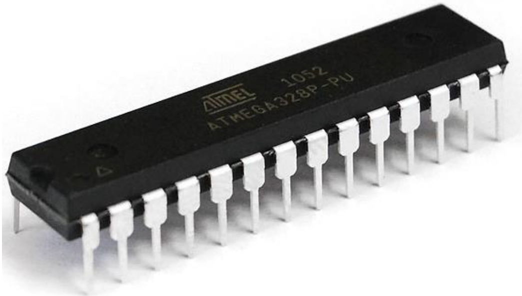
- Temperature Monitoring
- Laser blocking
- Backlight Control
- Laser Power Control
- Obtain spectrum with CCD

Microcontroller

Atmega328P

- 5V System Voltage
- 16 MHz
- 23 Programmable I/O
- 6 Pulse Width Modulation

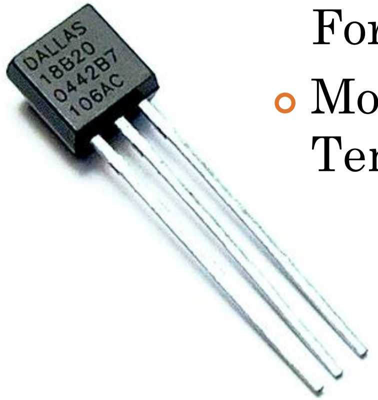
- Easier to Solder (28 pin DIP)
- Cheap - $2.21
- Easy to use



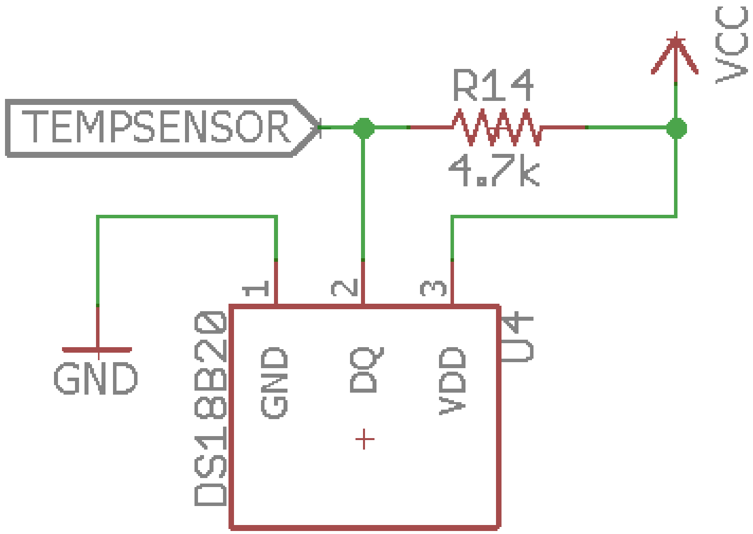
TEMPERATURE MONITORING

- Constantly Monitor temperature with Automatic Cooling
- Parts Used:
  - Temperature Sensor – Digital
  - Fans

- DS18B20 - Digital Temperature Sensor
  - Uses "One – Wire" Communication For multiple sensors on a single bus
  - More Accurate than Analog Temperature Sensors



- Circuit Diagram

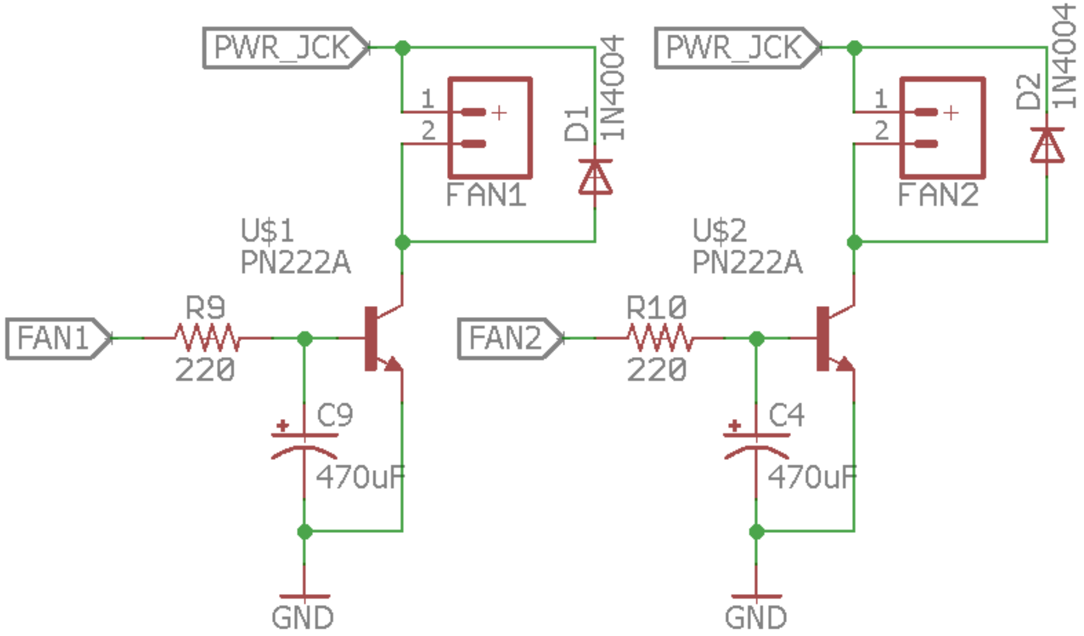


Temperature Monitoring

- Provides air flow to the system
- 1 Intake fan and 1 Outtake fan
- Multicomp MC36031
  - 5V
  - 115mA
  - 600 mW
  - Pushes 3cu.ft/min

- Pulse Width Modulation for variable fan speed (0V = 0 PWM and 5V = 255 PWM)

Duty Cycle	Voltage	Temperature Range	PWM Value	Fan Speed
0	23mV	Less than 70 F °	0	0
30%	.778 V	70 F °	72	30%
40%	1.123 V	74 F °	102	40%
60%	2.553 V	78 F °	153	60%
80%	3.753V	82 F °	204	80%
100%	4.42 V	86 F °	255	100%

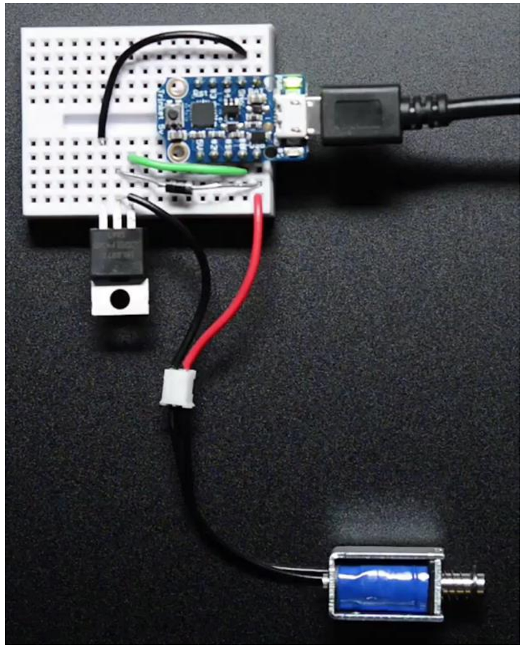


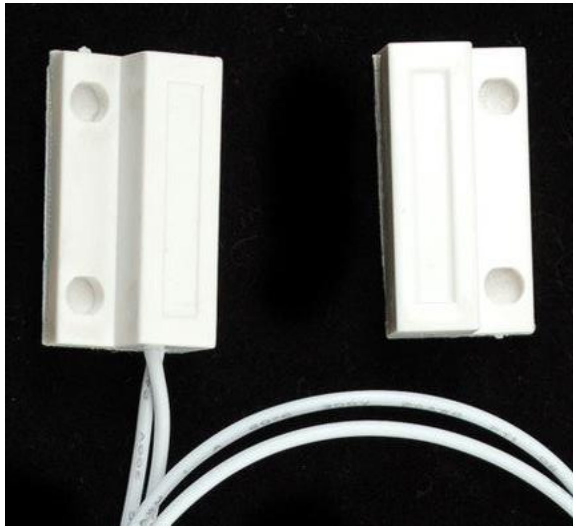
Laser Blocking

- Needed to block the laser while a sample was being loaded on to the sampling stage
- Must be quick

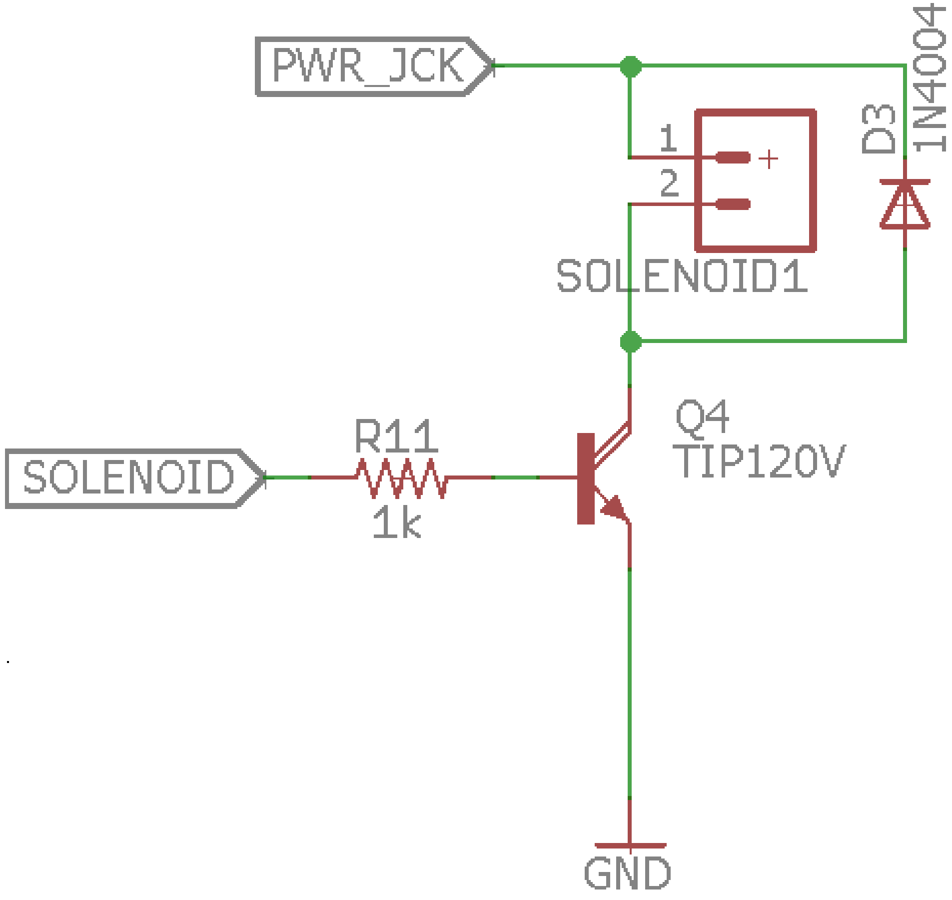
Mini Push-Pull 5V Solenoid

- Faster than a motor for our application
- Small and cheap - $4.95





Circuit Diagram



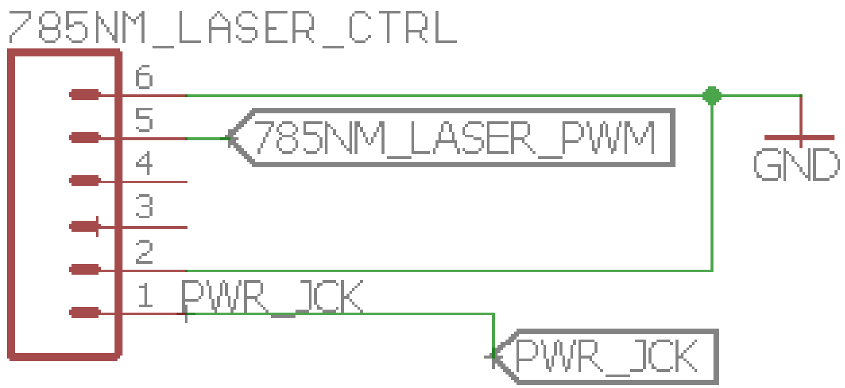
Laser Power Control

- Display Laser Power (Software) & Control Laser Power.

- Laser uses 100mW and runs on a 5V source.
- Pulse Width Modulation to modulate the power.

Duty Cycle	Voltage	Power Prior to Calibration	PWM Value
10%	.5	10 mW	26
20%	1	20 mW	51
30%	1.5	30 mW	77
40%	2	40 mW	102
50	2.5	50 mW	128
60	3	60 mW	153
70	3.5	70 mW	179
80	4	80 mW	204
90	4.5	90 mW	230
100%	5 V	100 mW	255

- Circuit Diagram

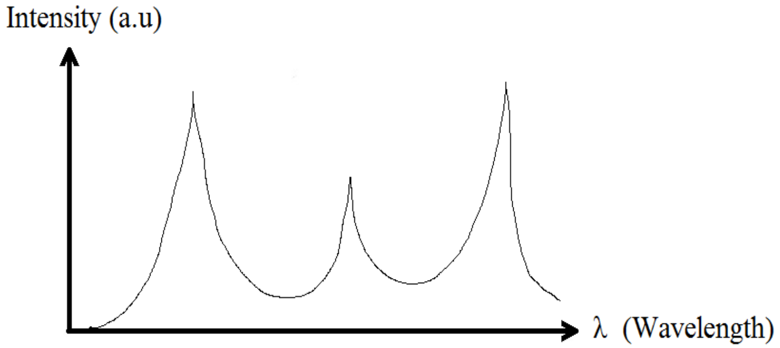


Backlight Control

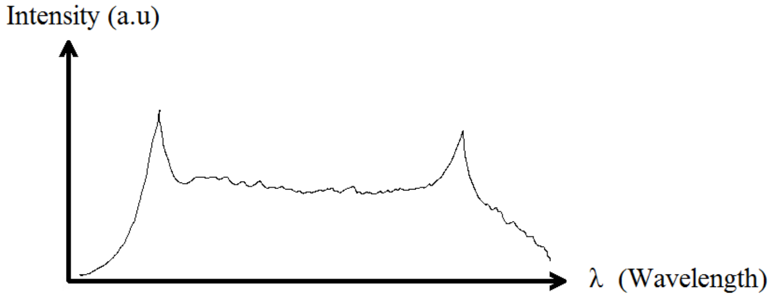
- Control Microscope backlight
  - Turn on when a sample is on the sample stage
  - Turn off when taking a spectrum

- Backlight Specifications:
  - 24V
  - 1.5A
  - Runs on separate power supply
  - Optional - Plan to integrate power supply into the system

- Why Backlight Control is Needed:

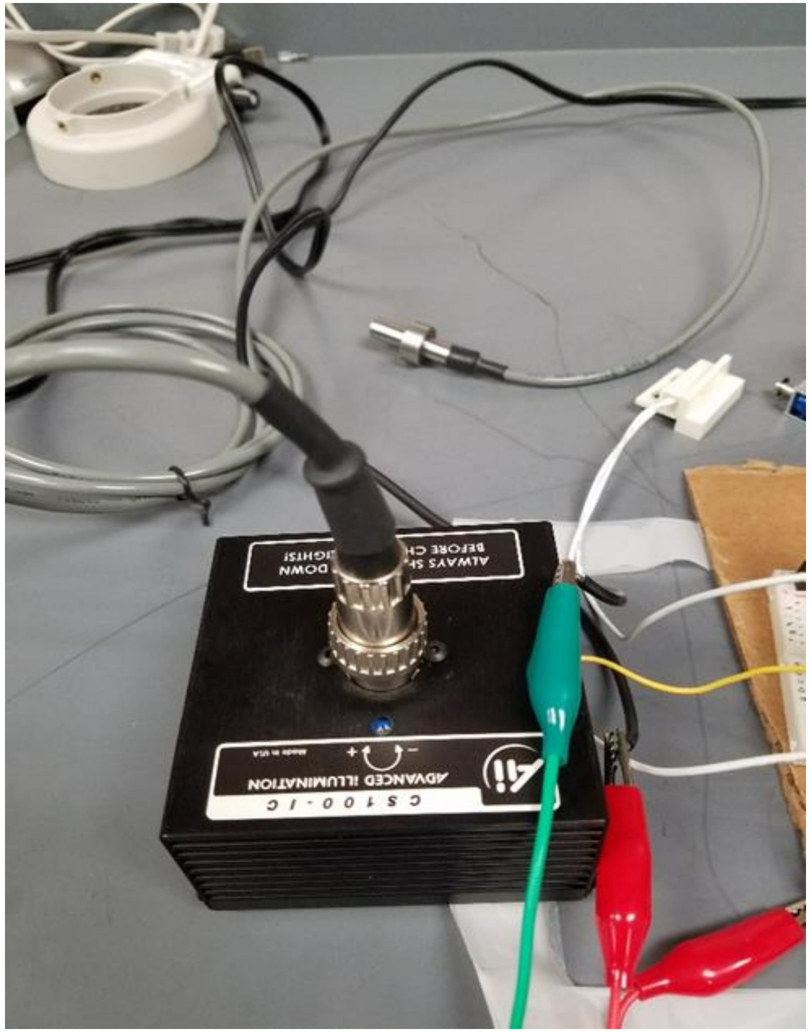


Spectrum with the use of a backlight

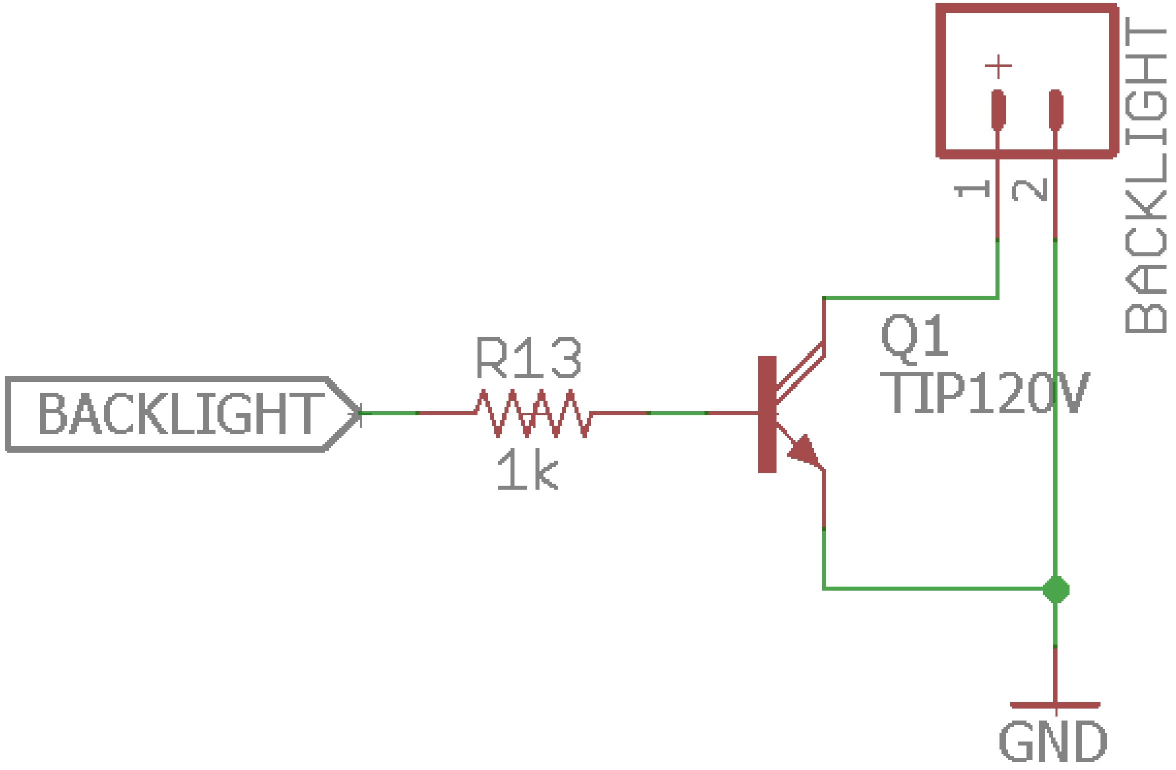


Spectrum without the use of a backlight

Backlight Control



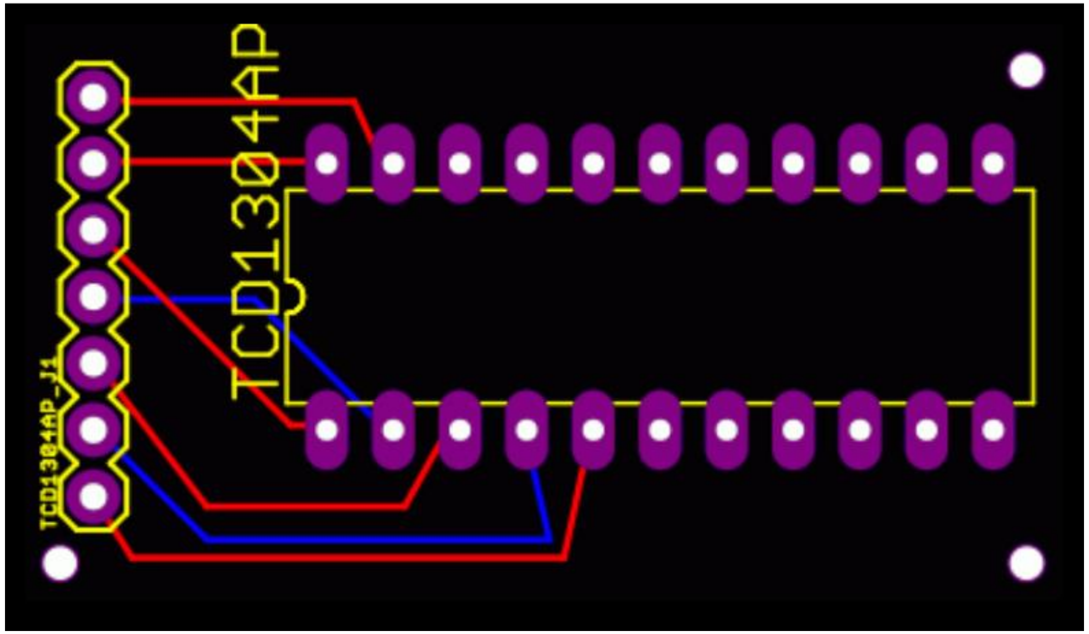
- Circuit Diagram



Spectrometer CCD Circuit

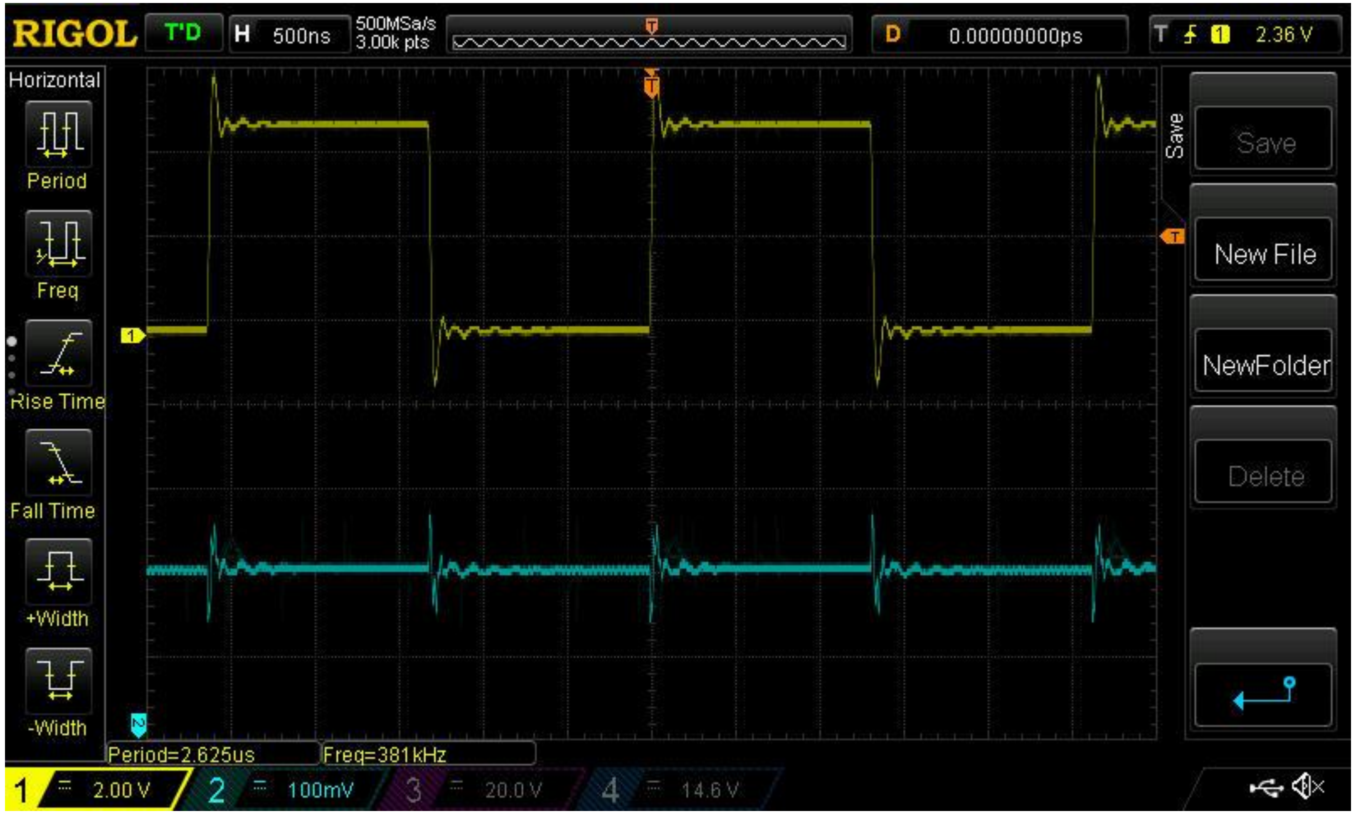
- Converts the intensity of light to an associated voltage
- This is done by "shifting" signals between stages

- Toshiba TCD1304AP
  - 3648 Pixels
  - Load Resistance of 100 kOhm
  - 3.0 V(min)
  - 22 DIP Package



Spectrometer CCD Circuit

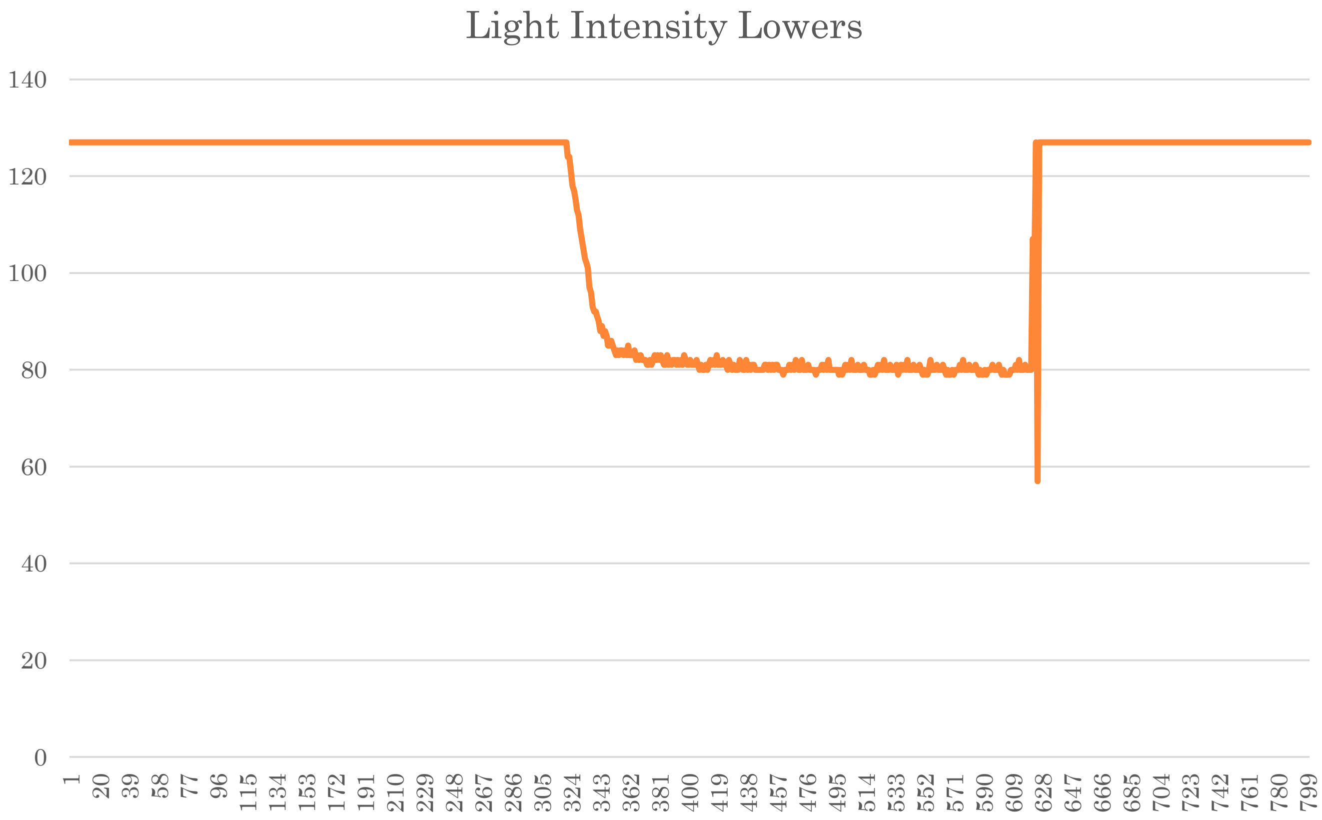
- The CCD requires 3 driving pulses.
  - The Master Clock, the Shift Gate, and the Integration Clear Gate.
- Master Clock Frequency requirement is .8Mhz to 4Mhz



- To generate the pulses, the ATmega328p timers were used.
- The figure on the right shows the Master clock and the Integration clear gate.

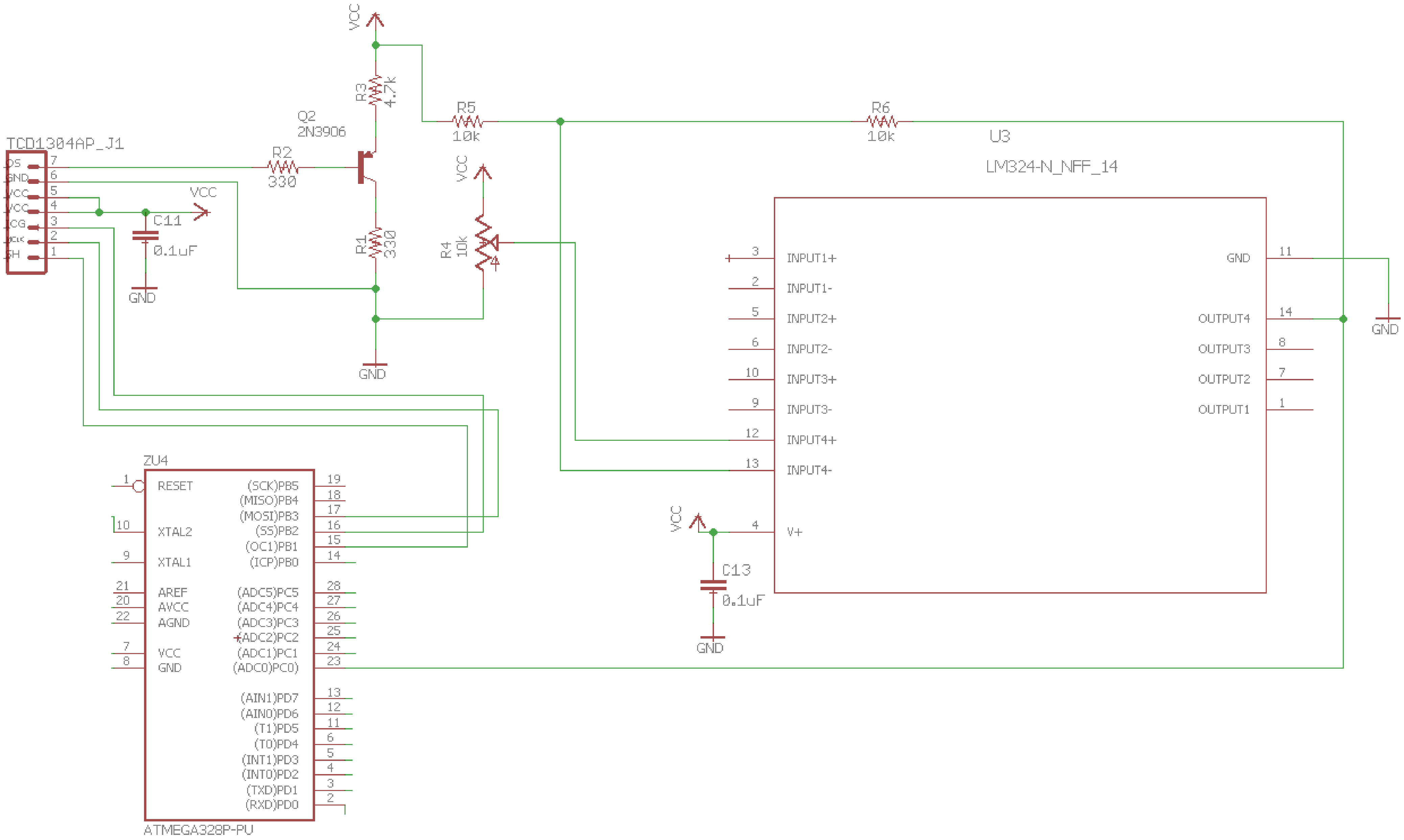
Spectrometer CCD Circuit

- When the CCD is dark, the voltage out of the CCD is at its highest (close to 2.5V).
- When Light is shown on the ccd, the voltage drops. Higher intensity, lower the voltage.



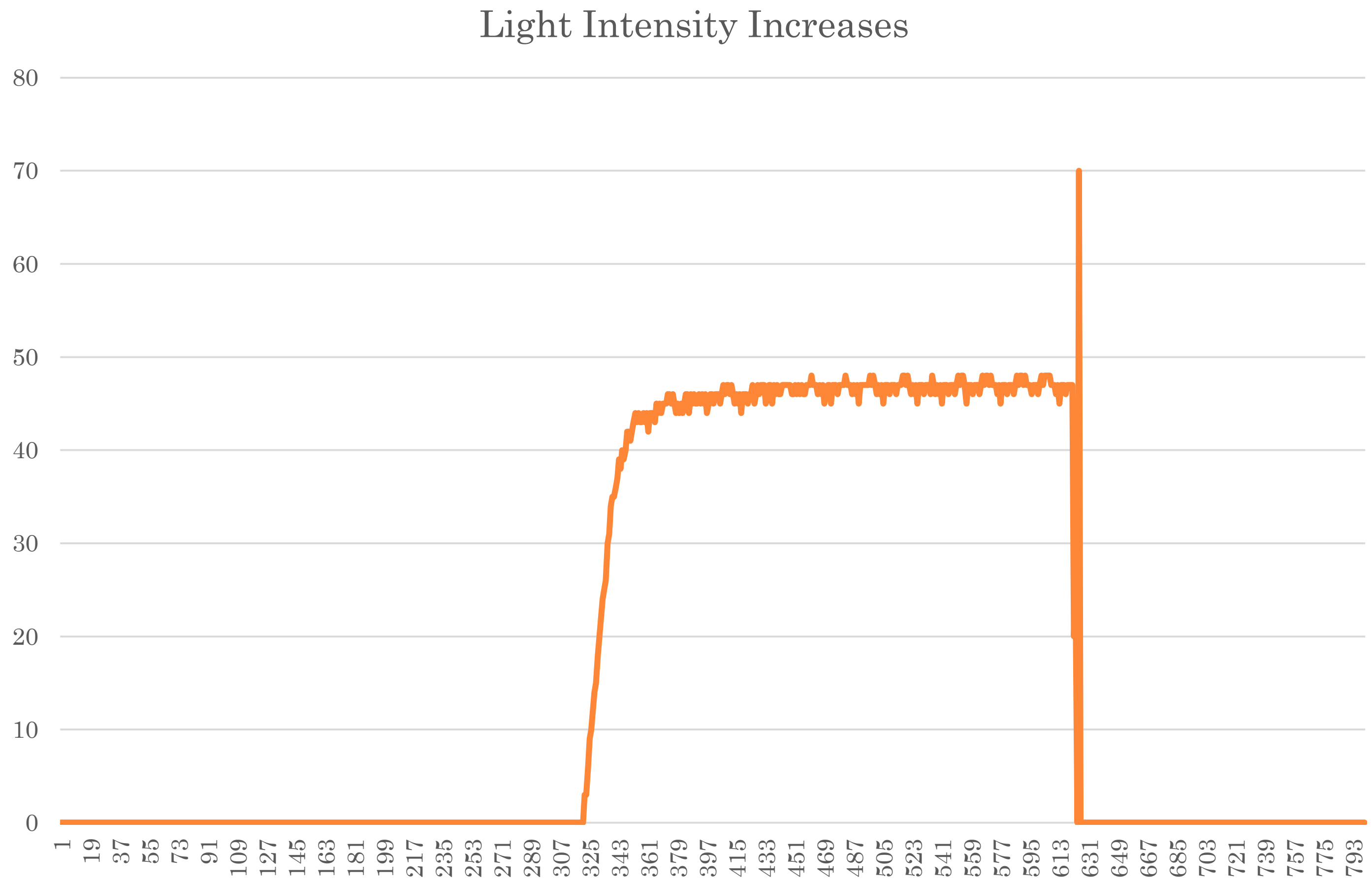
- Though this works, this is the opposite of what we wanted

Spectrometer CCD Circuit



SPECTROMETER CCD CIRCUIT

- Using the potentiometer to change your offset, now when the CCD is dark, the voltage out of the CCD is at its lowest (close to .6V)
- When Light is shown on the ccd, the voltage increases. Higher intensity, higher voltage.



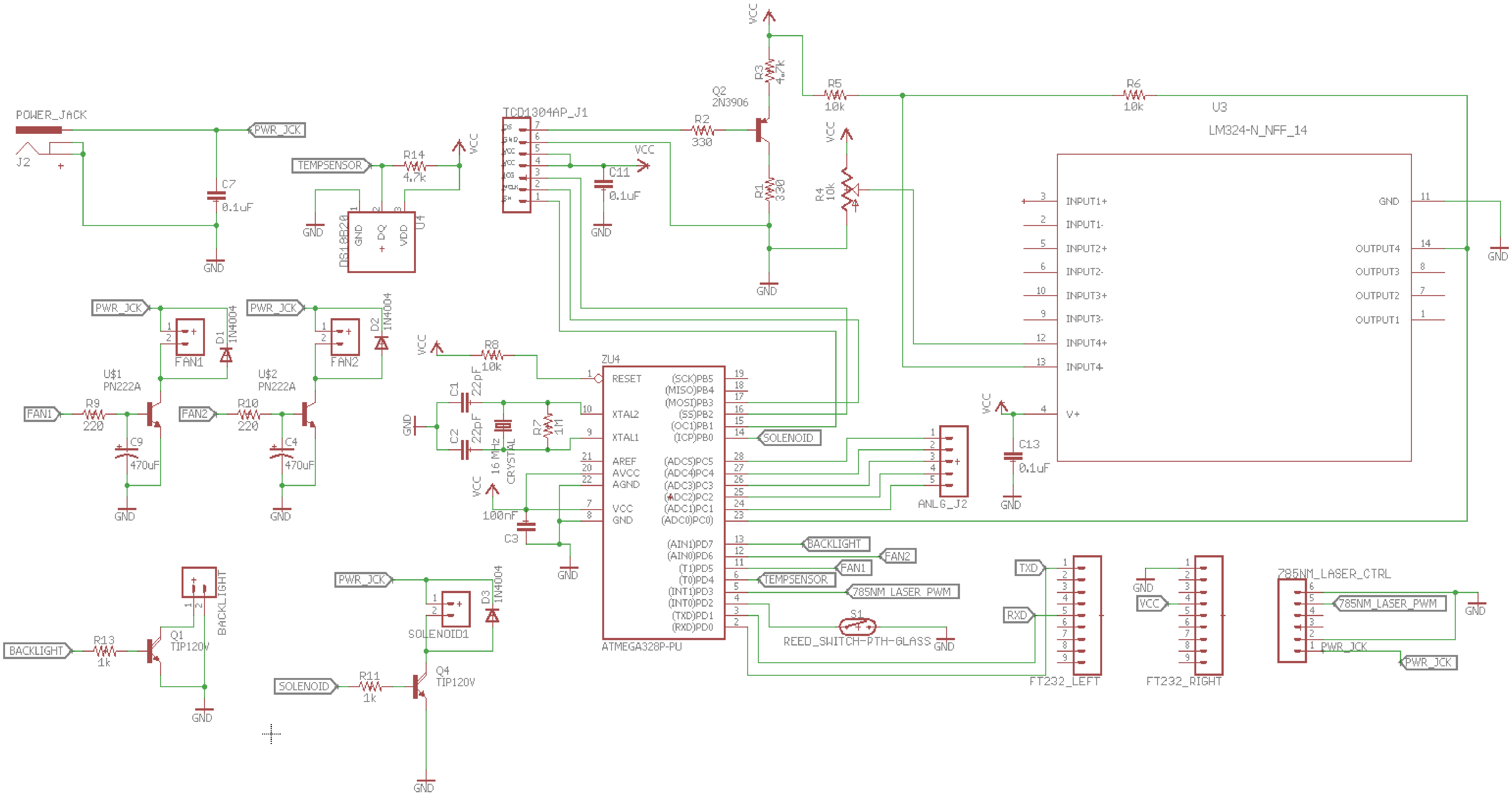
Issues – Spectrometer CCD

- Even though the Arduino Uno can drive the CCD, the internal ADC is not fast enough to continuously read all 3684 pixels.
- Only 800 pixels are being used.
- Only 8-bit resolution.
- 2k Memory

- How this is achieved:
- 1) Slowing down the Master clock speed to 380 KHz
- 2) Speeding up the internal ADC to 500 kHz.

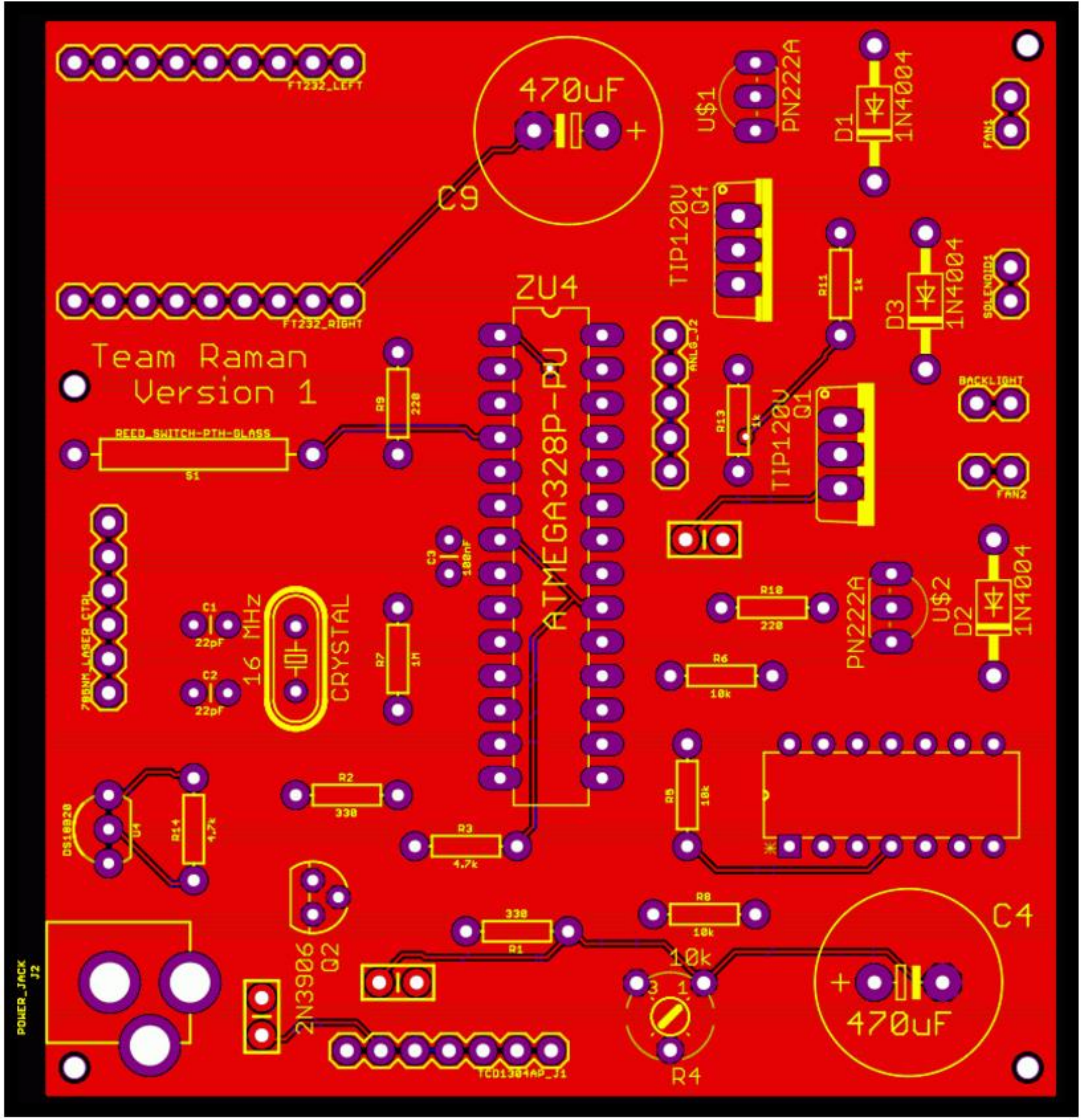
- Atmega328p lose 10-bit accuracy over 200 KHz
- 8-bit accuracy is at 500 kHz.

Full Schematic



PCB

- Manufacturer: 4PCB
- Cheap for Students
- #3 PCB Manufacturer in North America



Graphical User Interface

- MATLAB
- Used to Control
  - Laser Power
  - Fan Speeds
  - Temperature
  - Door Sensor
  - Graph Wavenumber vs Intensity
  - Camera

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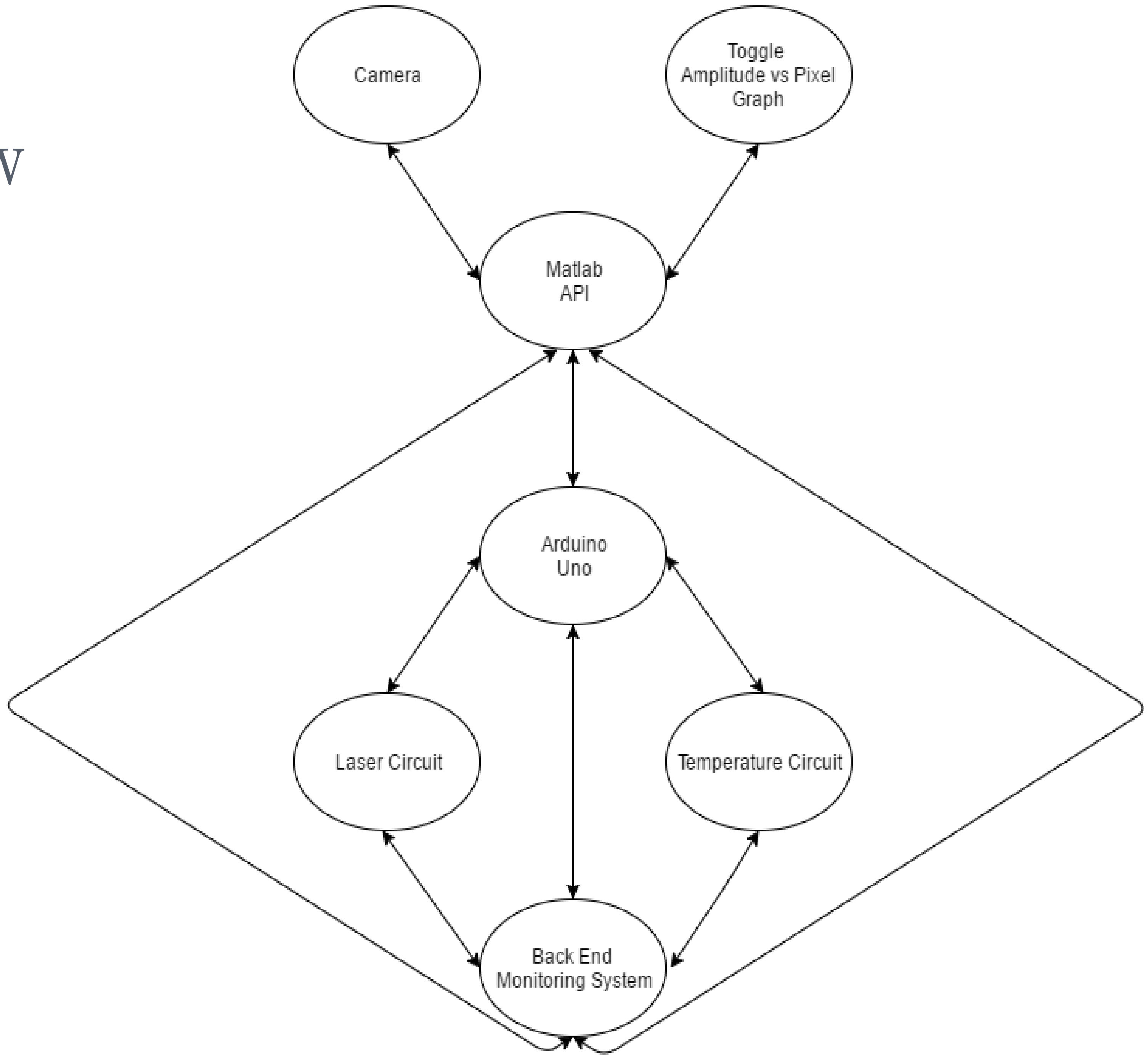
GUI Flow



Camera
Toggle Amplitude vs Pixel Graph
Matlab API
Arduino Uno
Laser Circuit
Temperature Circuit
Back End Monitoring System

Ramen Spectroscopy

Update Nov 10, 2016 10:45:56 am

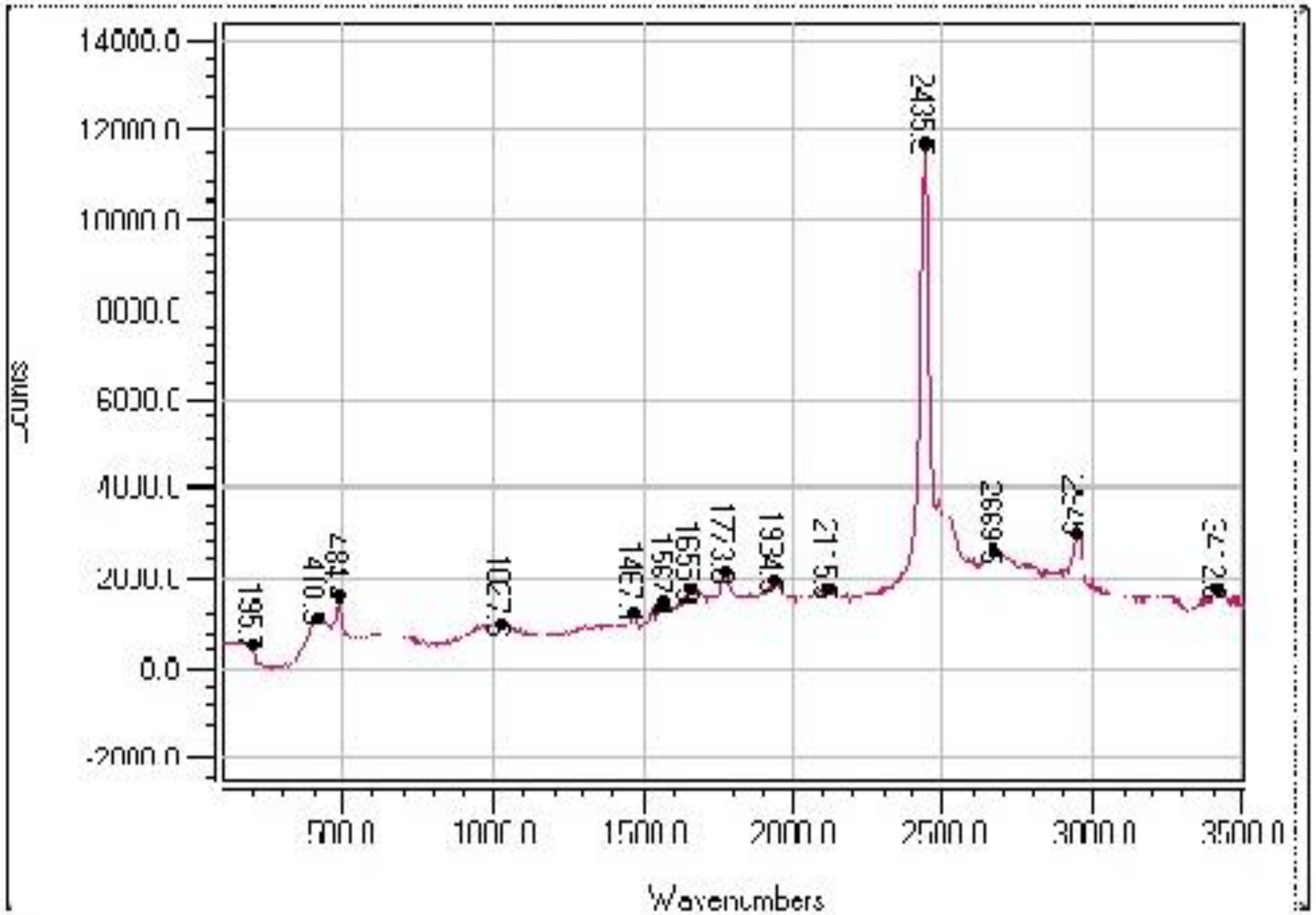
Power

Disabled Toggle

Fan	Current Temp (F)
Disabled	97

Event Log

Power flag successfully checked
Temperature retrieval failed: Object reference not
Fan flag successfully checked
Current temperature successfully retrieved
Fan turned on successfully



Software Design Issues

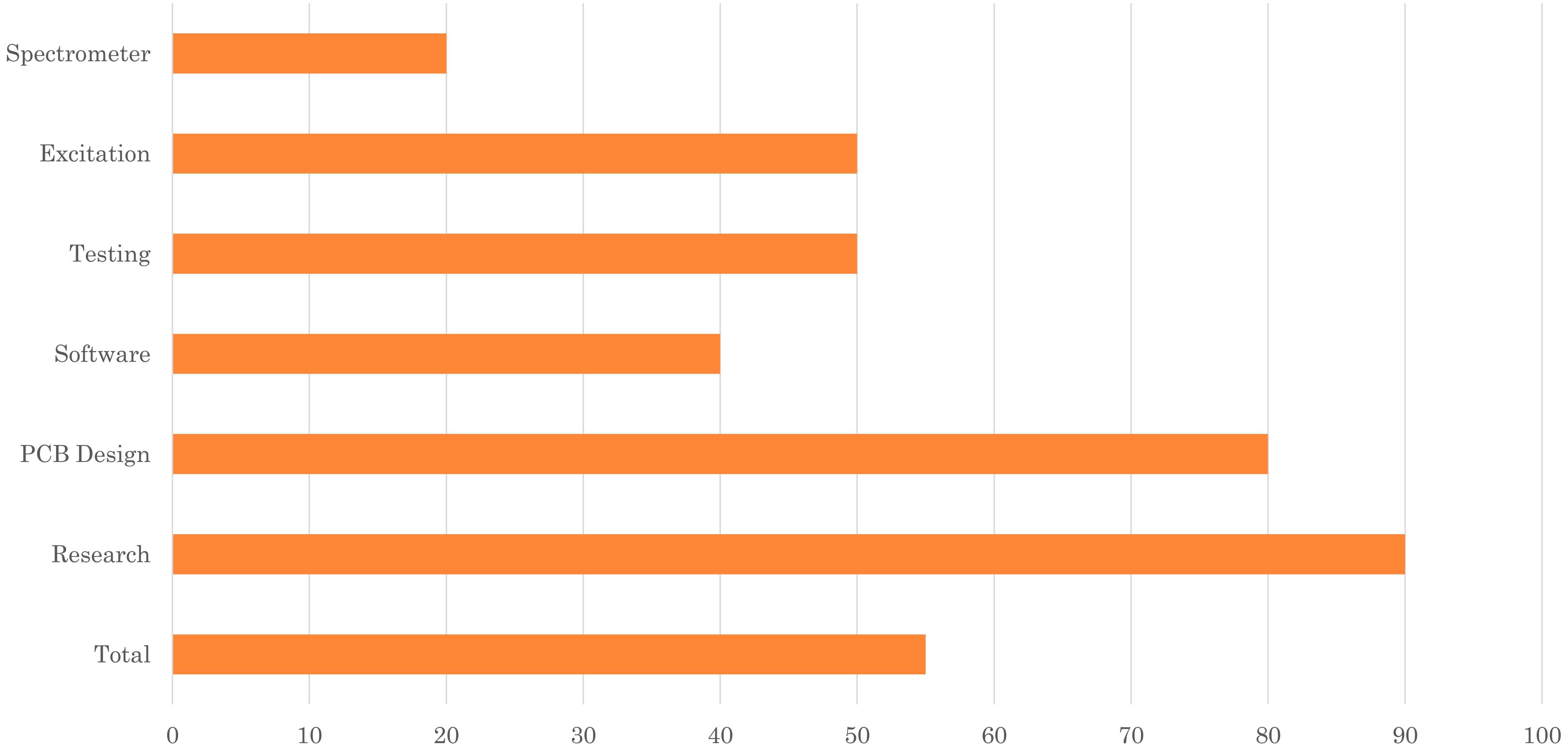
- MATLAB-Arduino protocols for high amounts of parallel communication via Serial.

Budget

Electronics Parts	Price
Arduino Uno	24.95
5V 2A Power Supply	7.95
Magnetic Contact Switch	3.95
DS18B20	3.95
Solenoid	4.95
TO-220 Heatsink	0.75
Diode Kit	5.99
Transistor Kit	20
Capacitor kit	20
Resistor Kit	10.99
5V DC Fan	7.99
TCD1304	3.5
LM324 Op Amp	0.58
break-away pin stip male	4.95
FT232RL	14.95
PCB-Team Raman	$ 33
PCB -TCD1304	$ 33
Total	$ 201.45

Optics Parts	Price
Grating	64.40
Grating Mount	65.90
Focusing Mirror	179.00
Focusing Mirror Mount	185.00
1st Lens	41.21
1st Lens Mount	16.00
2nd Lens	33.10
2nd Lens Mount	34.70
Cage 4pack	26.37
2" 5-pack Post Holders	38.50
2" 5-pack Posts	23.36
Notch Filter Mounts	38.70
Mount for Detector	59.20
Kinetic Mirror Mount with a 1" BB1-E03 Mirror	103.50
Semrock Beamsplitter	255.00
Total	$ 1,163.94

Project Progress



QUESTIONS?