Low-Shift Raman Microscope Attachment

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Senior Design 1

Group 17

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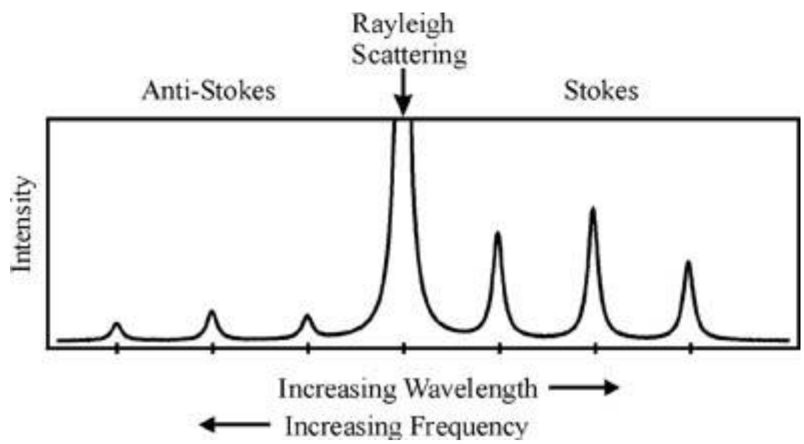
Sponsor/Customer - Dr. Matthieu Baudelet (baudelet@ucf.edu)

Narrative and Motivation

Spectroscopy is a branch of science that involves the creation and collection of a spectrum that acts as the "fingerprint" of a sample. Raman spectroscopy is a spectroscopic technique used to obtain a spectrum induced from molecular vibrations, which can be used for sample identification and quantification. When a laser is incident on a sample, Rayleigh scattering or elastic scattering is a dominant process and is the same wavelength as the excitation source. However, inelastic scattering is of interest in Raman spectroscopy and is caused when the vibrational states of a molecule causes the scattered wavelength to shift from the excitation wavelength. A Raman spectrum is shown below with the Stokes and Anti-stokes scattering or shifts from the excitation wavelength. The spectrum is plotted in intensity of the light signal vs. wavenumber (cm^{-3}).



A microscope is a convenient device used to observe a sample with high-resolution imaging. Furthermore, sending a laser light through the objective lens of the microscope allows for strong focusing of the laser light onto a sample. Utilizing the strong focusing of a microscope can be useful for spectroscopy, especially for Raman. The customer and sponsor Dr. Matthieu Baudelet wants a Raman spectroscopy setup to be built as an attachment for his microscope to detect low Raman shifts.

In summary, this project involves a laser and filters to create a laser signal with a narrow line width for the microscope. The Raman scattering created from the narrow line width laser is the output light signal that will be analyzed using a spectrometer. The excitation and spectrometer serves as the attachment for the microscope and must be rugged, compact, and controlled from a user interface. Companies that currently make expensive Raman microscope attachments are Ondax and Renishaw, and our customer wants a similar design that is affordable and deliverable.

Specifications

Excitation Section

- Laser: λ = 785 nm
- Excitation Signal with a narrow line width
- Filters: 2 Volume Bragg Gratings (VBG)
- Power Sensor: Detect and Measure Power of λ = 785 nm
- Laser Power must be controlled
- Temperature of excitation section needs to be constant for the VGBs

Microscope

- Stage movement x,y,z
- Imaging device for sample
- Alignment of Raman excitation and imaging should work for any available microscope objective.
- Safety (Class 1)

Spectrometer

- Filter out laser line λ = 785 nm
- Resolve Stokes and Anti-stokes Raman Scattering
- Spectral Range: Detect low-shift Stokes and Anti-stokes ($\pm$ 200 cm^{-1})
- Resolution < 5 cm^{-1}
- Detector for λ ≈ 785 nm

Graphic User Interface (GUI)

- Display temperature
- Display/Control Laser Power
- Display live feed of sample image
- Display spectral results
- Go button

Overall System

- Box to enclose excitation, spectrometer, and microscope section: Rugged and Compact
- Class 1
- Safety Feature

Device Functionality

The entire system, which includes the excitation, spectrometer, and microscope sections, must be rugged, compact, enclosed in a box, and achieve class 1 restriction. The following defines each device functionality.

Laser - Source of excitation

Volume Bragg Grating (VBG) - Functions as a filter for the laser. The spectrum of the laser beam is filtered using the VBG so that a narrow line width is achieved.

Temperature Sensor - Monitor temperature within the system.

Laser Power Sensor - Measures the power of the laser beam.

Dispersive Optic - Disperses the Raman scattering signal to be captured by a detector.

Detector - Reads the Raman scattering signal so that it can be processed and displayed in a spectrum.

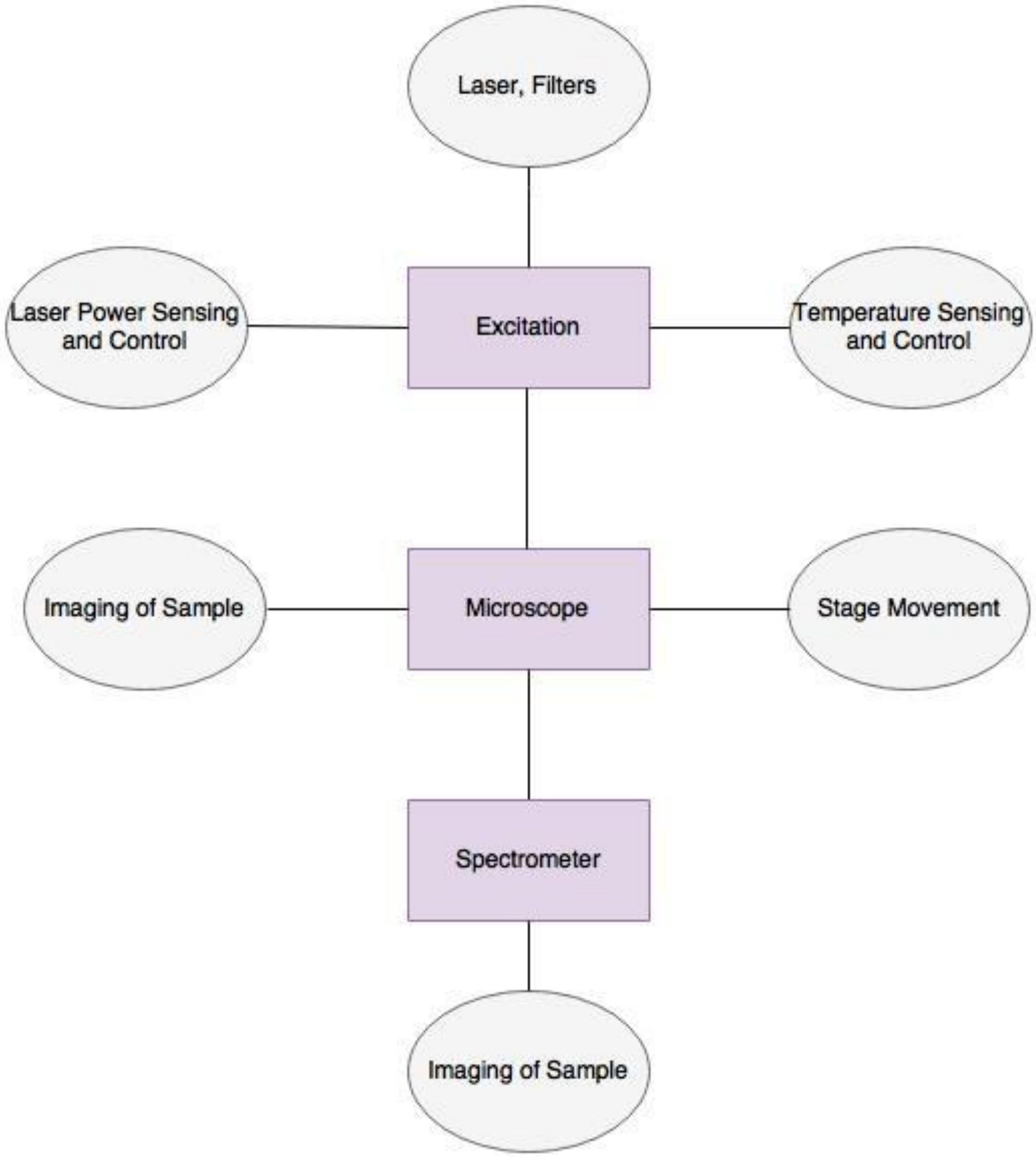
Microcontroller - Controls various aspects of each section, which includes temperature sensing and control, laser power sensing and control, and spectral acquisition.

House of Quality

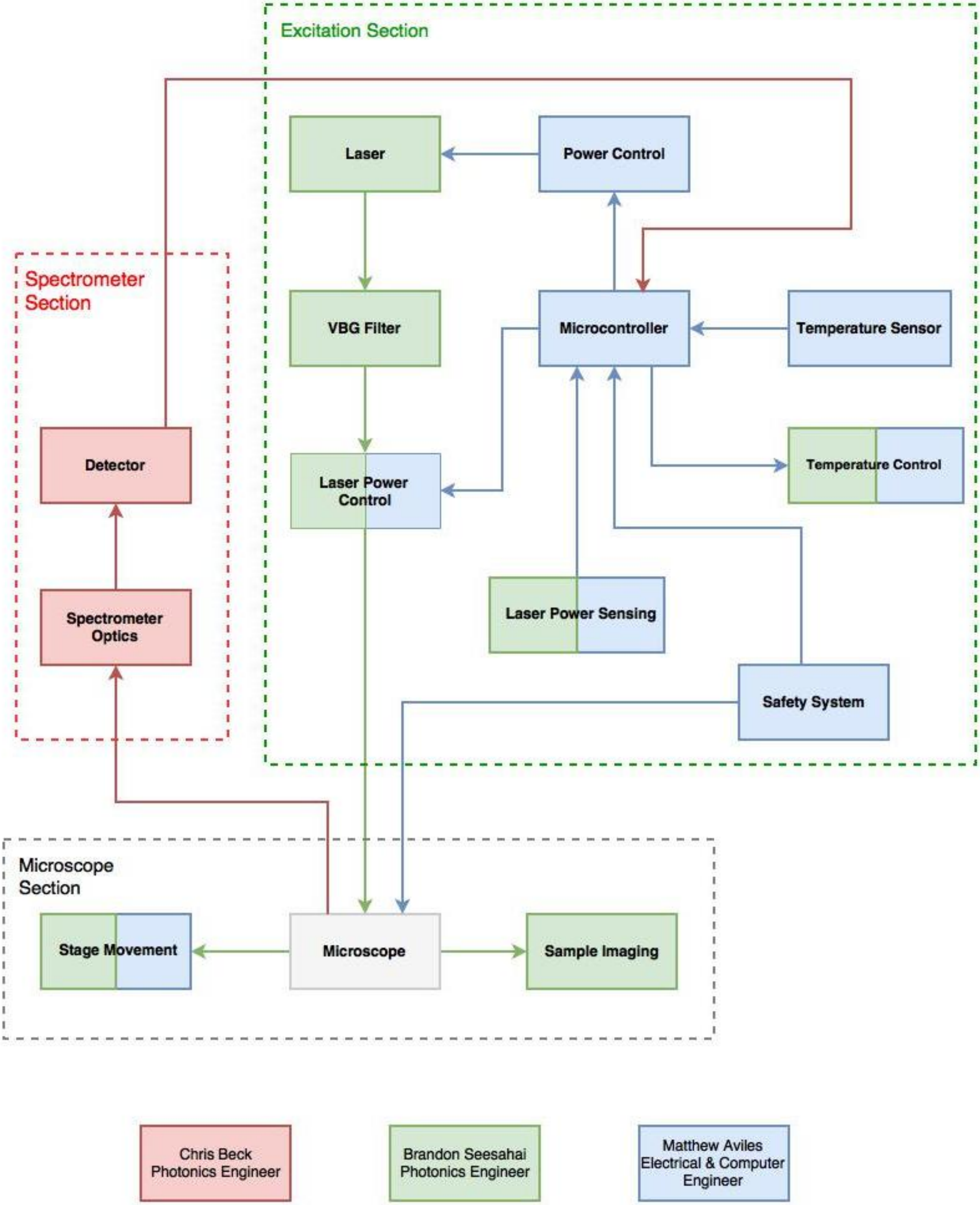
			Marketing Requirements							
			Laser Power	Filtering	Spectral Range	Resolution	Sensitivity	Ease of Use	Ease of Implementation	Cost
			+	+	+	+	+	+	+	-
Engineering Requirements	Laser Power	-					↑			↑
	Filtering	-	↓			↑	↓	↑	↓	↑
	Spectral Range	-				↓			↓	↑
	Resolution	-			↓		↑	↑	↓	↑
	Sensitivity	-						↑	↓	↑
	Ease of Use	-							↓	↑
	Ease of Implementation	+			↓	↓	↓	↓		↓
	Cost	-	↑	↑	↑	↑	↑	↑		

Block Diagrams

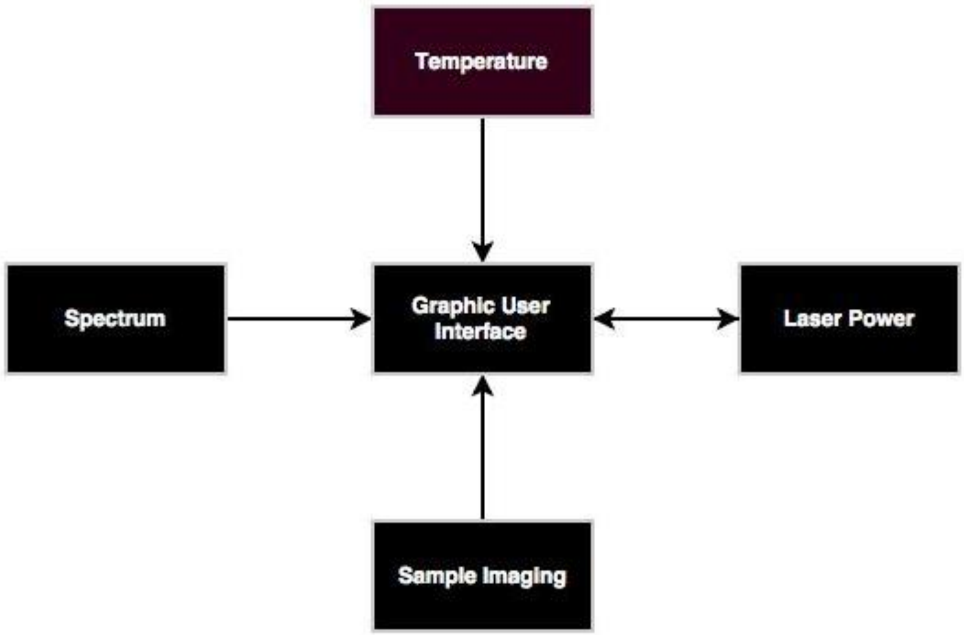
General Block Diagram

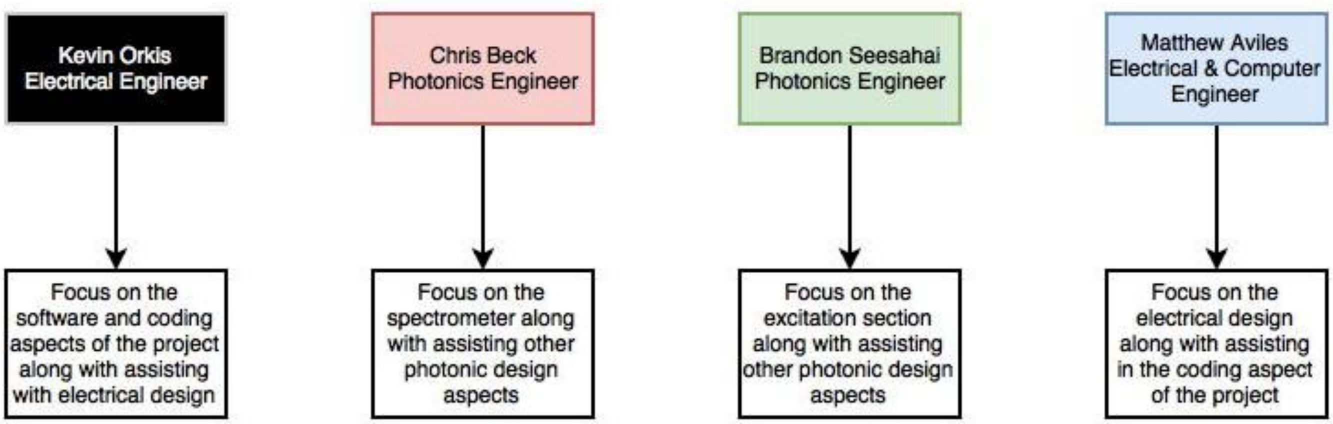


Hardware Diagram



Software Diagram





Estimated Project Budget and Financing

Parts to Purchase	
Excitation Stage	
Parts	**Price**
Microcontroller	$25.00
Sensors & Control	$25.00
Option 1 - Temperature Sensor	
Option 2 - Power Sensor	
Temperature Control	
Option 1 - Fan	
Laser Power Control	$50.00
Option 1 - 2 Polarizers + 1 motor	
Option 2 - Control Current	
Beam splitter	$15.00
Power Control	
Option 1 - Switch	$1.00
Total Estimate	**$116.00**
Sampling Stage	
Parts	**Price**
xyz stage	
Option 1 - Pre-motorized	$1,000.00
Option 2 - Manual, may need to motorize	N/A
Safety	
Option 1 - Contact Switch	$1.00
Option 2 - Different Camera Mount	N/A
Total Estimate	**$1,001**
Spectrometer Stage	
Parts	**Price**
Detector	
Option 1 - CCD	$10.00
Option 2 - CMOS	$6.00
Grating	$10.00
Pinhole	$30.00
Collimating lenses/mirrors	$70 - $100
Need 2 of them	$140 - $200
Total Estimate	**$186 - $256**

Total Final Estimate	**$303 - $1,373**

Parts Already Owned
Excitation Stage
Parts
785nm laser
2 VBG's
Photometer
Sampling Stage
Parts
Microscope
Camera?
Spectrometer Stage
none

Initial Project Milestone for Both Semesters

Fall 2016		
Task	Duration	Dates
Ideas	1 Week	Aug 22th –Aug 26th
Project Selection & Role Assignment	1 Week	Aug 29th –Sep 2th
Initial Document	1 Week	Sep 5th- Sep 9th
Divide and Conquer Paper		Sep 9th
Research ideas	2 week	Sep 12th- 23th
Begin Writing	2 week	Sep 26th – Oct 7th
Begin Design(Optics, Software, PCB)	2 week	Oct 10th-Oct 21th
Table of Contents	1 week	Oct 24th-Oct 28th
Research Parts	1 week	Oct 31th- Nov4th
Final prototype review	2 week	Nov 7th- Nov 18th
Draft		Nov 11th
Order Parts	1 week	Nov 21th – Nov 25th
Finalize Documentation	1 week	Nov 28th-Dec 2th
Review Documentation	2 days	Dec 5,6th

Spring 2017		
Description	Duration	Dates
Test Parts	1 week	Jan17th- Jan 20th
Build Test Model	7 weeks	Jan 23th- Feb 10th
Test Model	4 weeks	Feb 13–March 10th
Finish Model	2 weeks	March 12th – March 24th
Prepare Final Presentation	1 week	May 1st