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

[Diagram showing the components of a spectrometer: Light Source, Collimating Lens, Grating, Focusing Lens, Detector]

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

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

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
Experiment Procedure

• SpinView camera software
  • Change camera exposure

• Start/Stop Data collection

• See and save images

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

FREI Flame

Raman Shift

Intensity

Raman Shift [cm⁻¹]
Calibration

• Use sample data in place of actual spectrometer image

Neon spectrum (SMA mode)

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

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
## Raman Spectrometer Project

### Schedule

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<th>ACTIVITY</th>
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<th>ACTUAL START</th>
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All items not given an Actual Start or Actual Duration value were unable to be completed due to lab closures resulting from the COVID-19 virus. These closures started after spring break and are illustrated by the two dark bars in the schedule as seen to the right.
## Budget

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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.*

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
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

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

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

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

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

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**Base Total:** $1,047.10