Laser Instrument Development for Planetary Surfaces Characterization

ECE 487 Senior Design Project

Group 7

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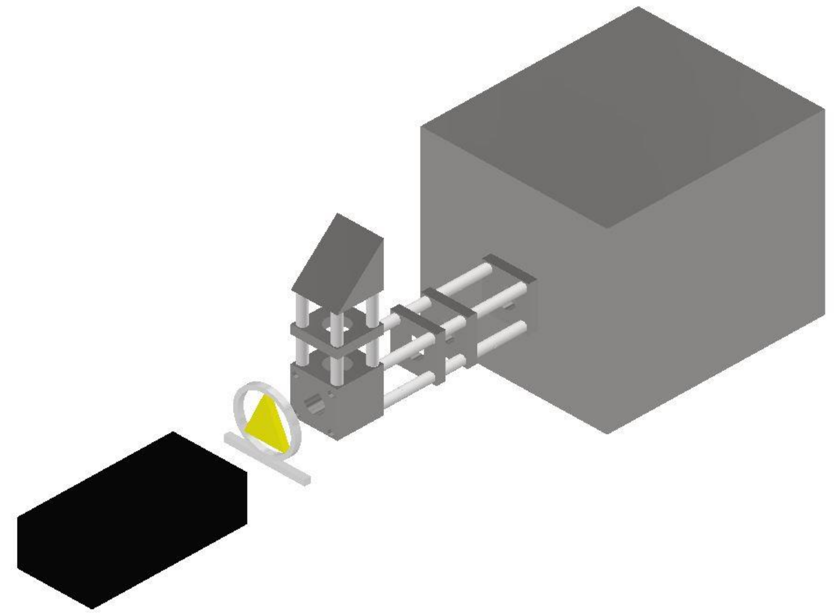
Key Points

- ★ Design Problem
  - Problem Statement/Proposal
  - Design Methods
  - Alternative Designs
- ★ Realistic Constraints
  - Three Constraint Model
- ★ Analysis/Results
  - Testing and Results
  - Analysis
- ★ Engineering Standards



Design Problem

<u>Original Problem</u>:

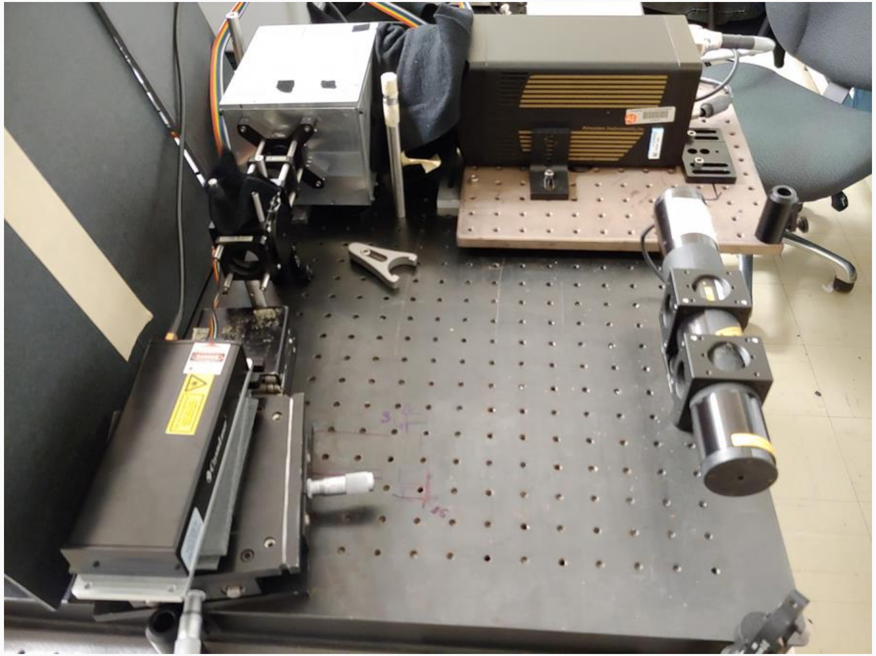
The 785 nm Raman spectrometer is assembled but generates low-accuracy results

<u>Original Proposal</u>:

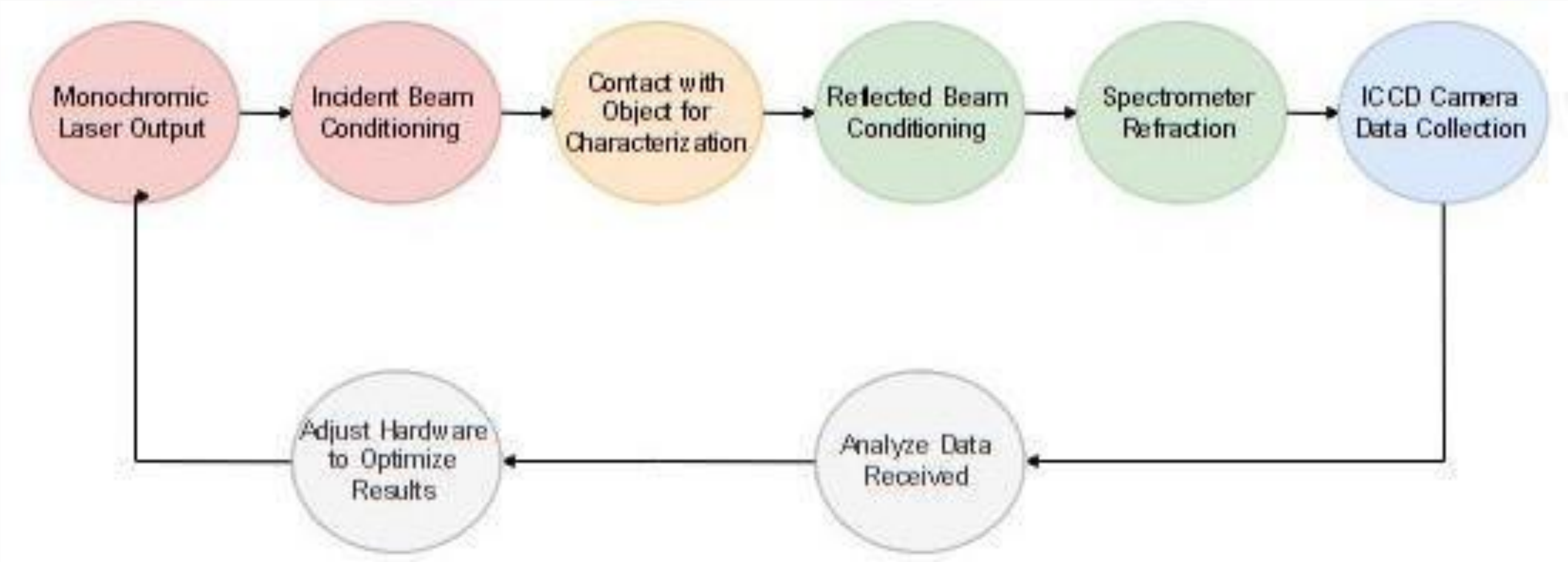
Optimize the spectrometer through calibration, and comparison to known values, to achieve an SNR of >= 25 and stable Raman data

Design Methods

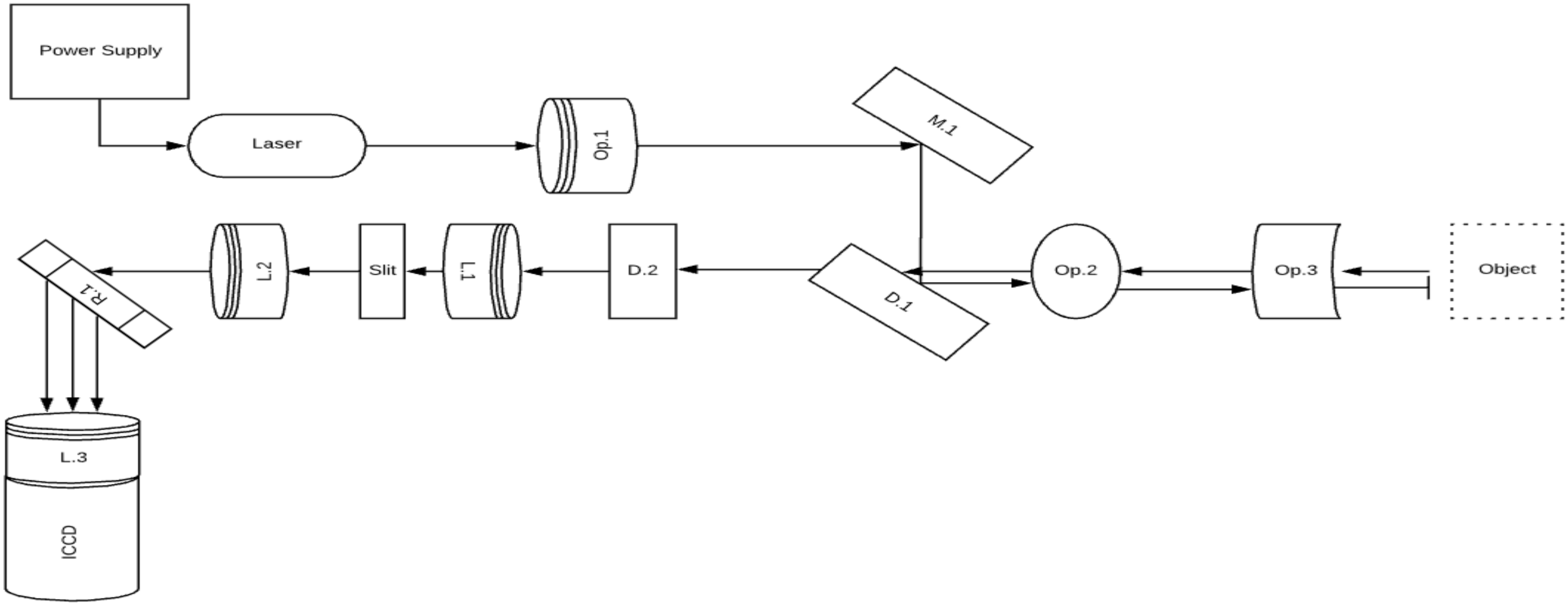
- **<u>Design Features</u>**
  - Compact, mission-capable Raman spectrometer
  - Uses Raman Effect to determine composition of materials without physical interaction



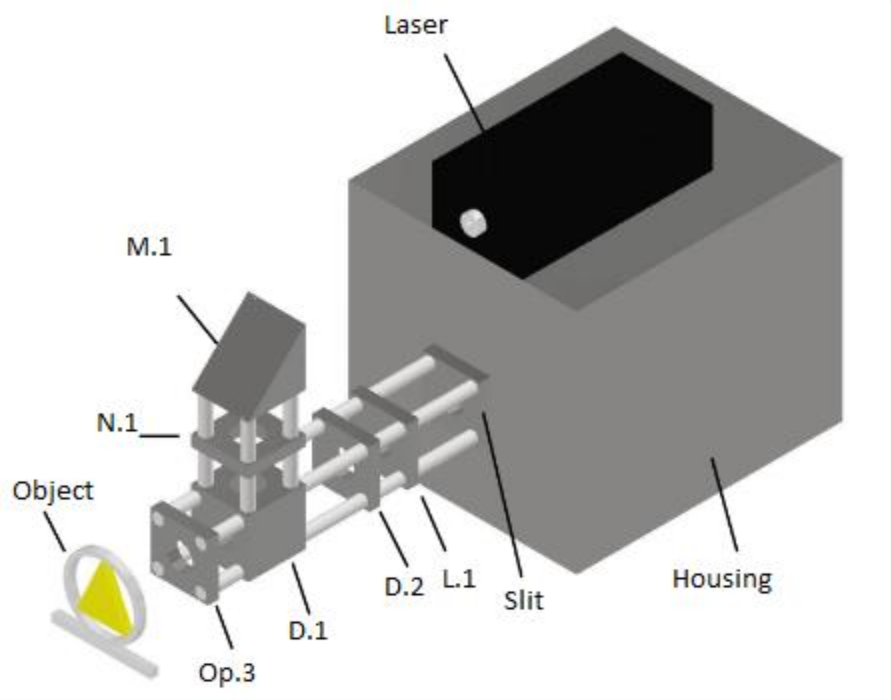
Design Approach

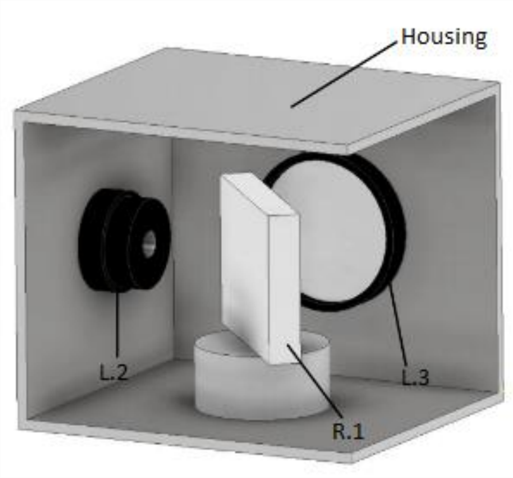


Initial Design



Initial Design





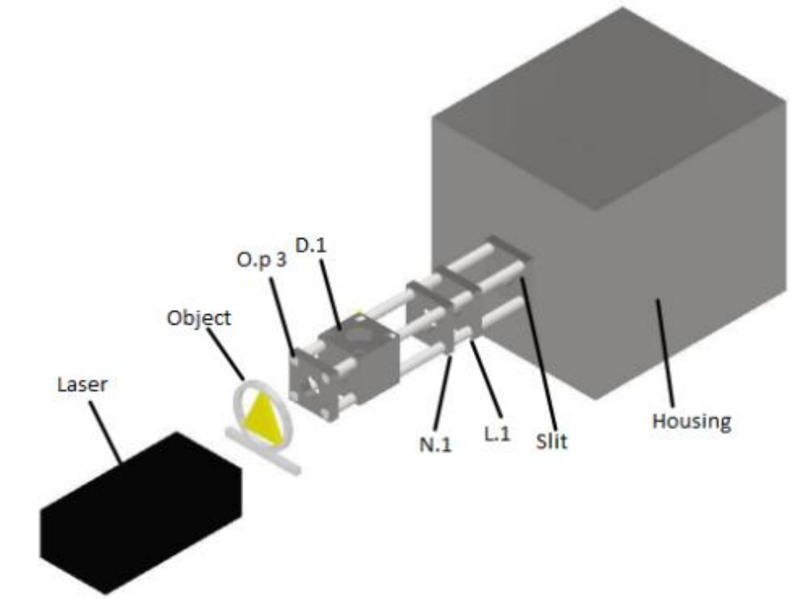
Design Approach

Alternative Designs:

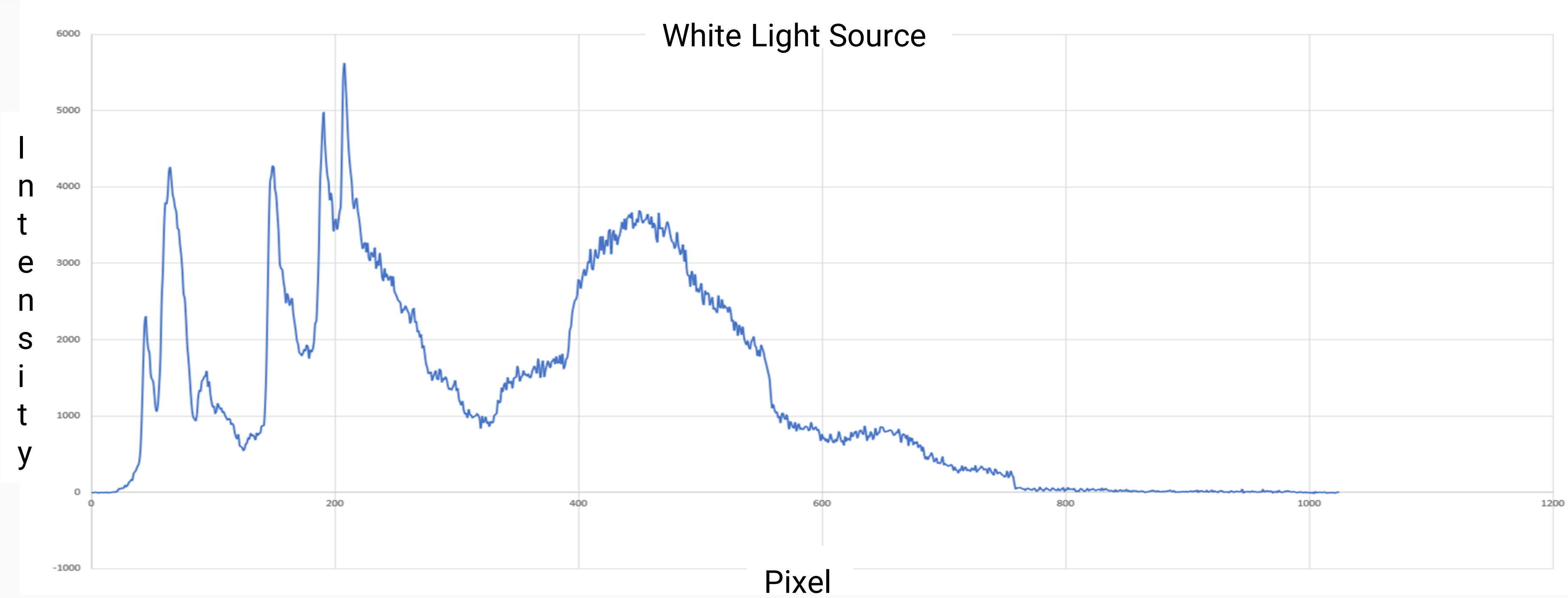
- Additional optic filters
  - Placed in line with dichroic lenses to better filter 785nm laser
- Newer camera/software
  - Improved functionality and vendor support
  - Very expensive
- Different laser source
  - 532 nm
    - Higher intensity
      - Stronger Raman signals
      - Stronger fluorescence
    - No additional wavelength bleed-through
- Transmission vs. backscattered system
  - Transmission
    - Less optical losses
    - Weaker Raman signal
  - Backscattered
    - More complicated optics
    - Better Raman peaks

Design Solution

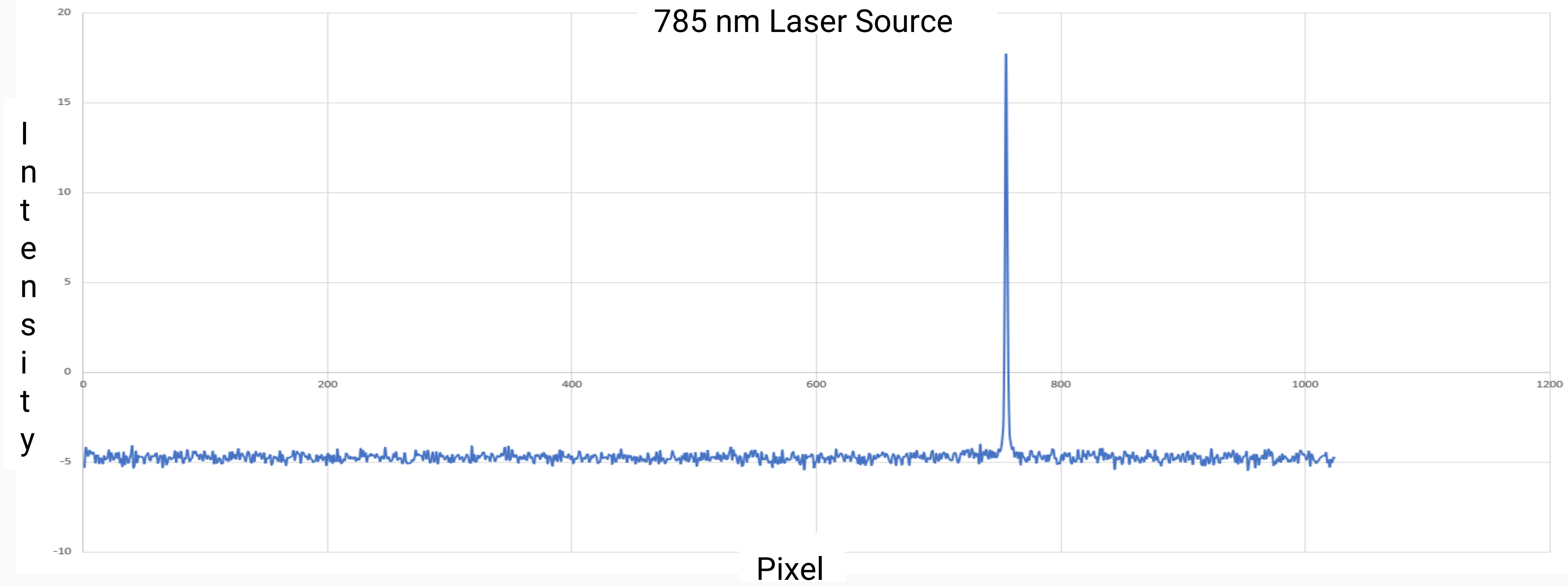
- ➔ Transmission Model
  - ➔ Weaker Raman Signal
  - ➔ Fewer optical components
  - ➔ Less optical losses
- ➔ Additional notch filter
- ➔ Shorter optical track



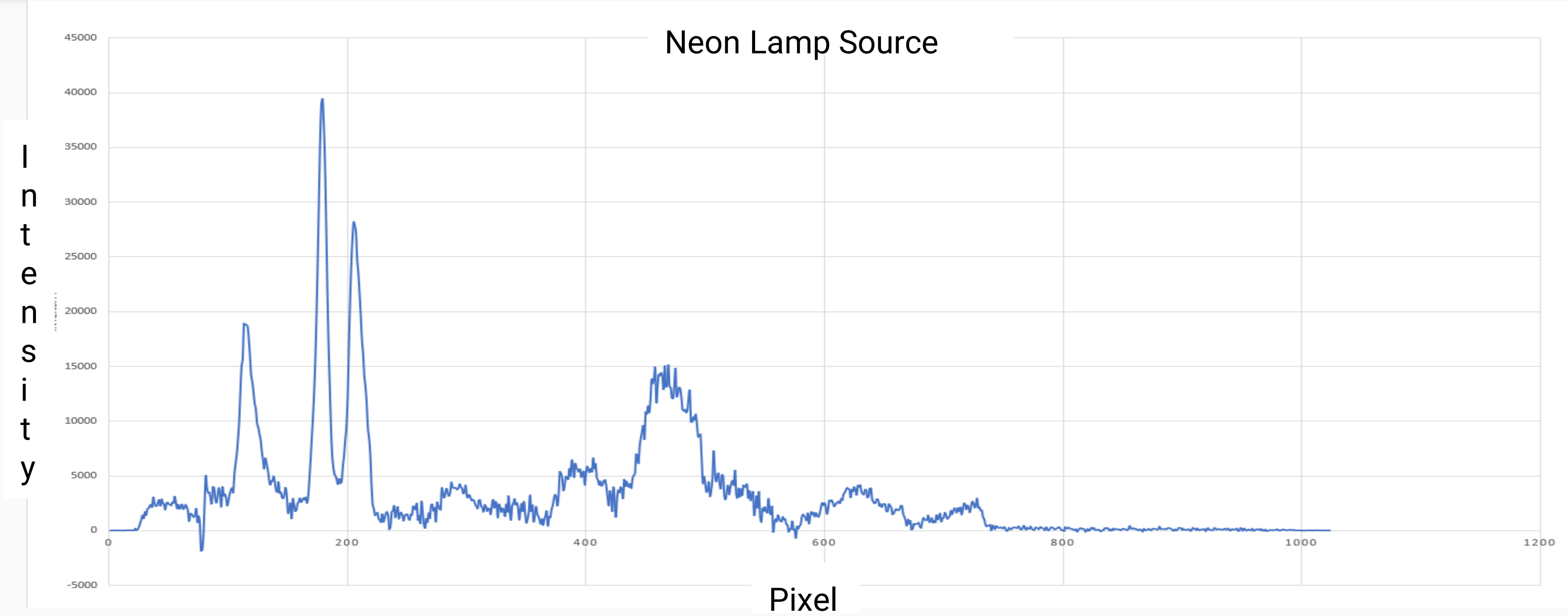
White Light Calibration



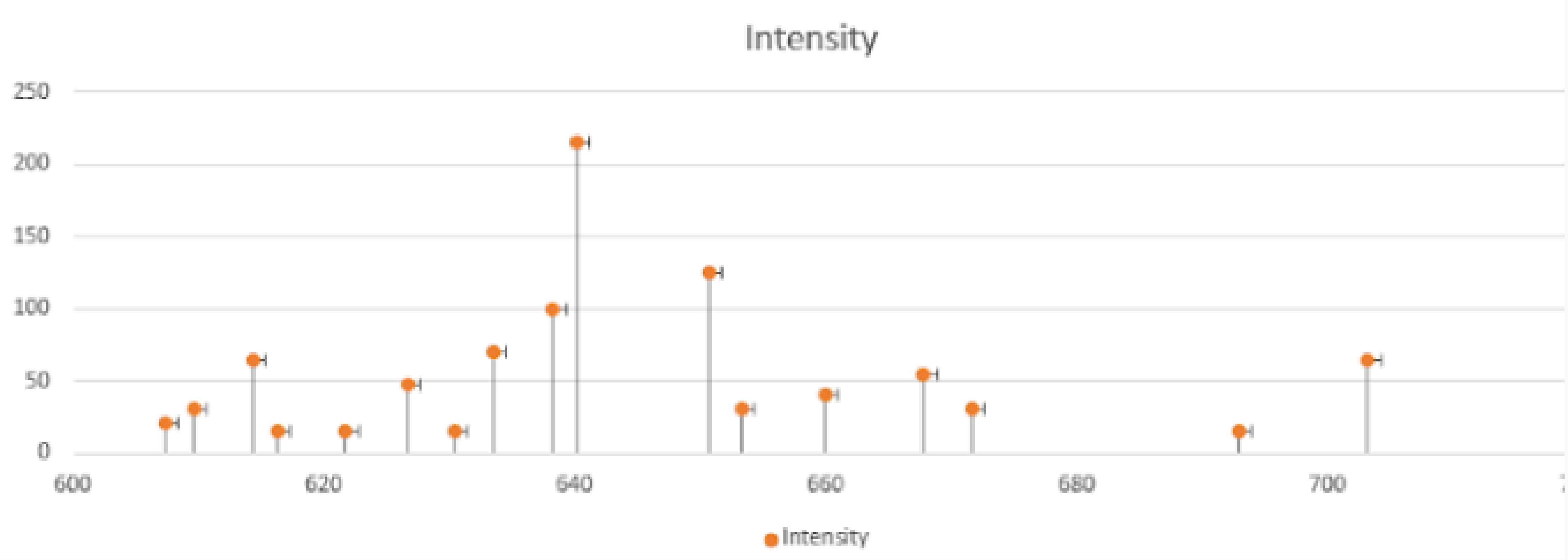
Laser Source Calibration



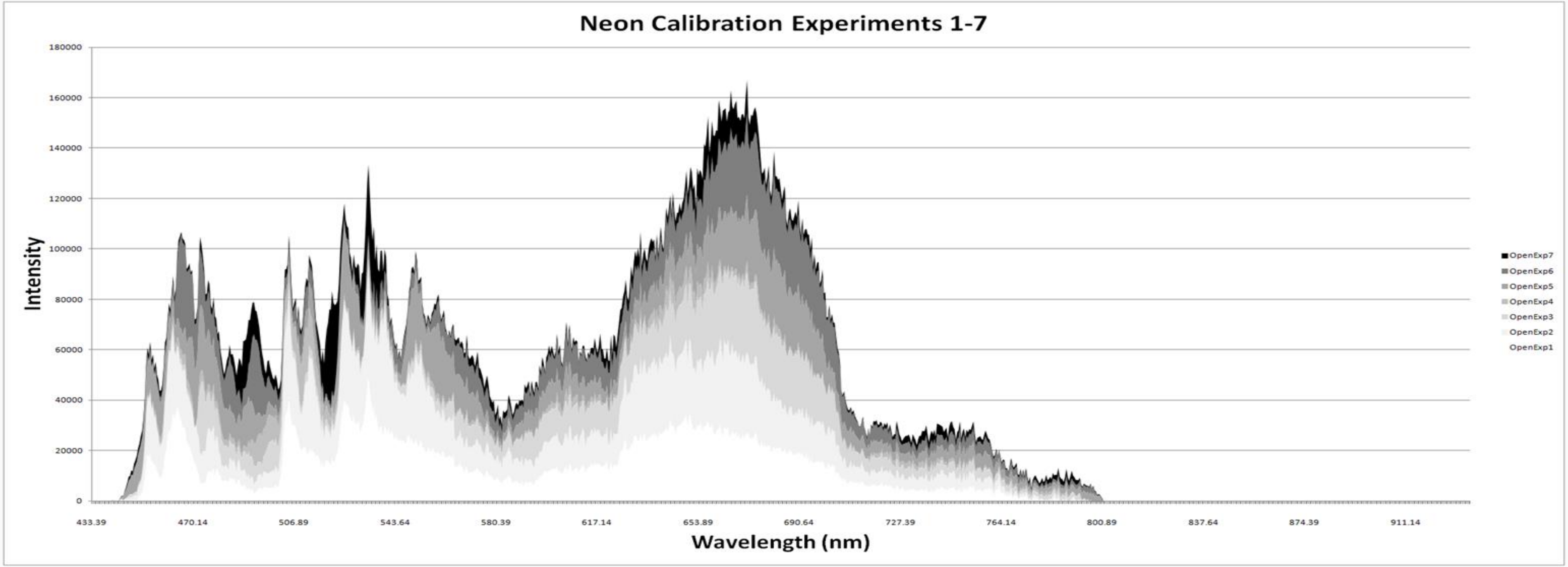
Neon Lamp Calibration



Neon Lamp Calibration



Neon Lamp Calibration



Data Interpretation

- Pixel-to-Wavelength Conversion
  - First-order linear relationship between 785 nm and 632 nm laser source intensity peaks

$$wavelength(nm) = 0.49(nm/pixel)\,(pixel) + 432.9nm$$

- WinSpec32 software
  - Uses pixel grid to produce intensity vs. pixel data
  - Wavelength conversion equation to generate spectrometry data
  - Microsoft Excel to generate cumulative results graphs and compare

Results/Analysis

- Calibration tests
  - SNR of 37.76 (Avg intensity: 53529, StDev: 1417.5)
  - Acceptable comparison to expected neon
- Raman data
  - Trials over two-week span
  - Failed to acquire any Raman data
- Analysis of goals
  - Exceeded SNR goal of 25
  - Failed to produce reliable, consistent Raman data

$$SNR = \frac{Average\ Intensity}{Noise\ (Standard\ Deviation)}$$

Average Peak	Standard Deviation	SNR
53,529.40	1,417.52	37.76

Design Analysis

- Holographic grating angle
  - Initial: 45 degrees
  - Final: 50 degrees
- L.2 settings
  - Initial: x1 magnification, 10mm focal length
  - Final: x1.5 magnification, ∞ focal length
- Possible upgrades
  - More-secure spectrometer housing
  - Shorter optics track
  - Additional holographic material

Realistic Constraints

- Time
  - Delays
  - May 2020 end date
- Cost
  - NASA funded
- Scope
  - Compact
  - Accurate
  - Versatile

Realistic Constraints

- Time
  - Months spent without operational access to spectrometer data
  - COVID-19 lockdown
- Cost
  - Limited project budget to find new hardware (ICCD)
- Scope
  - System size constraints
  - Limitations in signal amplification

Engineering Standards

- ASNI Z136.3-2018: Safe Use of Lasers in Health Care
- NASA-STD-(I)-007 NASA Computer-Aided Design Interoperability
- NASA-STD 8739.6 Implementation Requirements for NASA Workmanship Standards
- IEEE 1394-2008 IEEE Standard for a High-Performance Serial Bus
- ISO 11254-2:2011: Lasers and laser-related equipment
- ASTM E1840 - 96(2014): Standard Guide for Raman Shift Standards for Spectrometer Calibration

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Thank you!