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Analysis of Aluminum Monoxide Emission Spectra in a Simulated Solid Rocket Propellant Flame

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Overview

- Motivation/Rocket Propellant Background
- Simulated Propellant Flames
- Aluminum Monoxide Emissions
- Thermal Emissions
- Summary/ Future Considerations

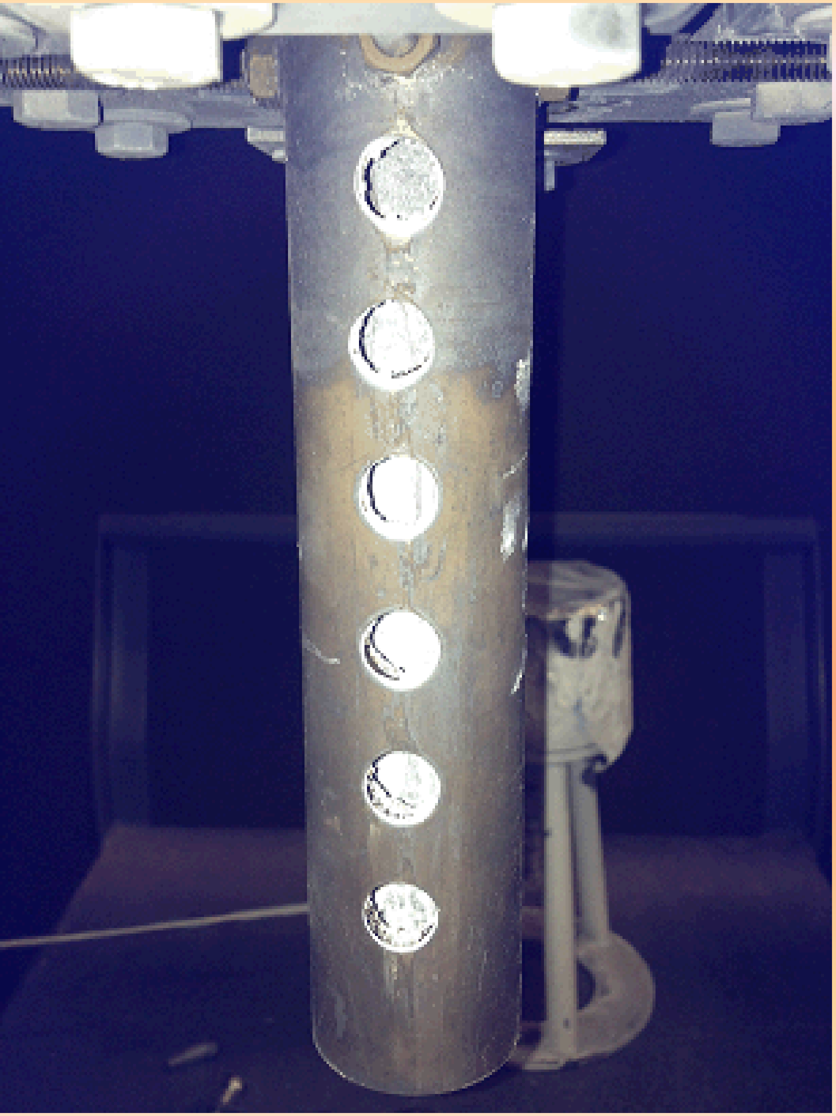
Rocket Propellant Background

- Aluminum particles are often added to solid rocket propellants
- Combustion dynamics of aluminum particles (fuel) and ammonium perchlorate (oxidizer) are of interest
- Desire to understand what happens in accident scenarios

Simulated Propellant Flame

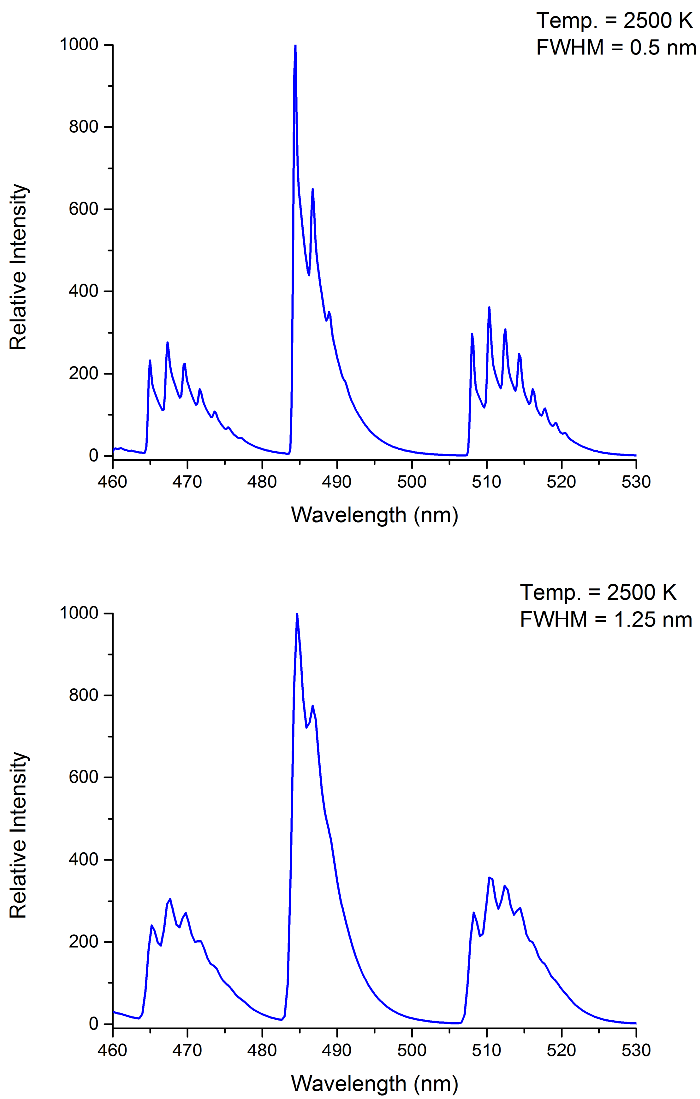
- Large scale (10's of meters) testing is expensive and hazardous, thus small scale, repeatable experiments are advantageous
- Use an aluminum powder fed oxyacetylene torch to simulate the propellant flame
- Collect spectral measurements along the height of the simulated flame

Simulated Propellant Flame



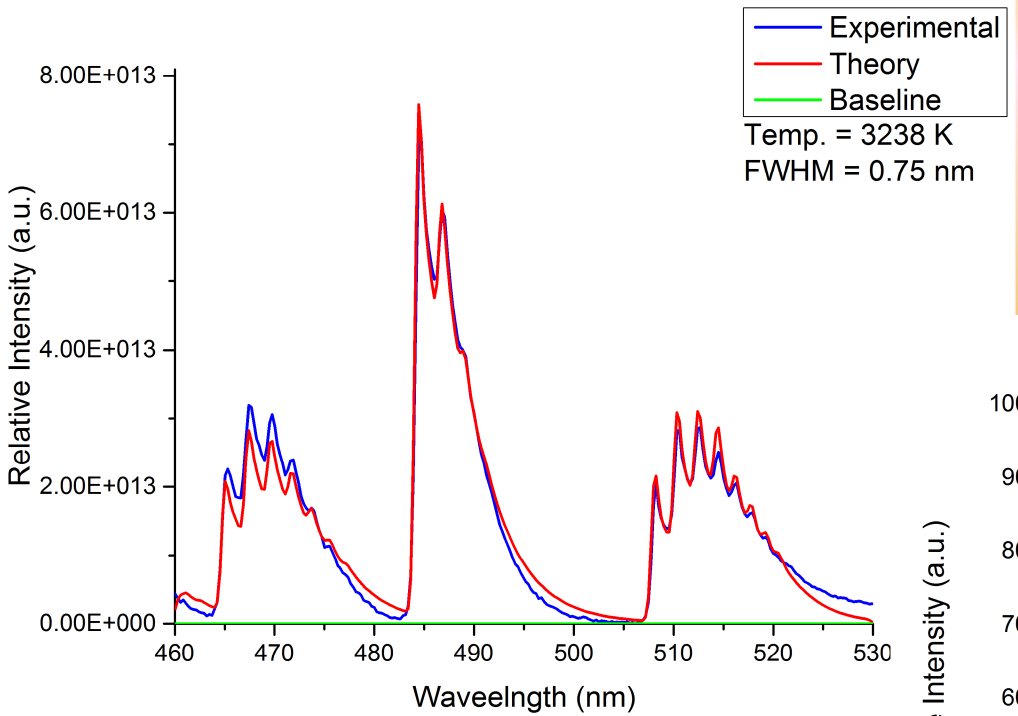
- Variable aluminum powder size and feed rate, Oxidizer to Fuel Ratio, integration time
- Ocean Optics HR2000 and HR4000 fiber coupled spectrometers
- Coupled with a stepper motor

Spectral Fitting for AlO Emission

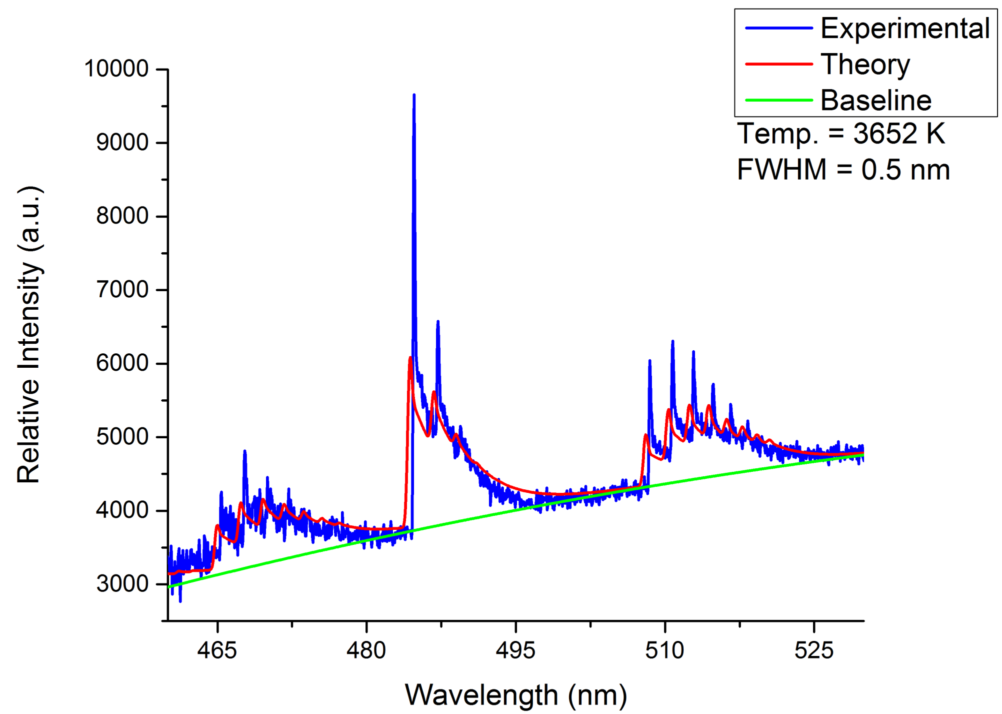


- Prior to fitting, spectrometers are properly calibrated
- Experimental spectra are fitted to accurate line strengths to determine flame temperature using a Nelder-Mead algorithm
- Used Nelder-Mead for its ability to incorporate multiple fit parameters as well as baseline offset

Spectral Fitting for AlO Emission



OFR = 8/10
Aluminum Feed Rate = 320 rpm
Height = 4 Inches



OFR = 8/10
Aluminum Feed Rate = 320 rpm
Height = 13 Inches

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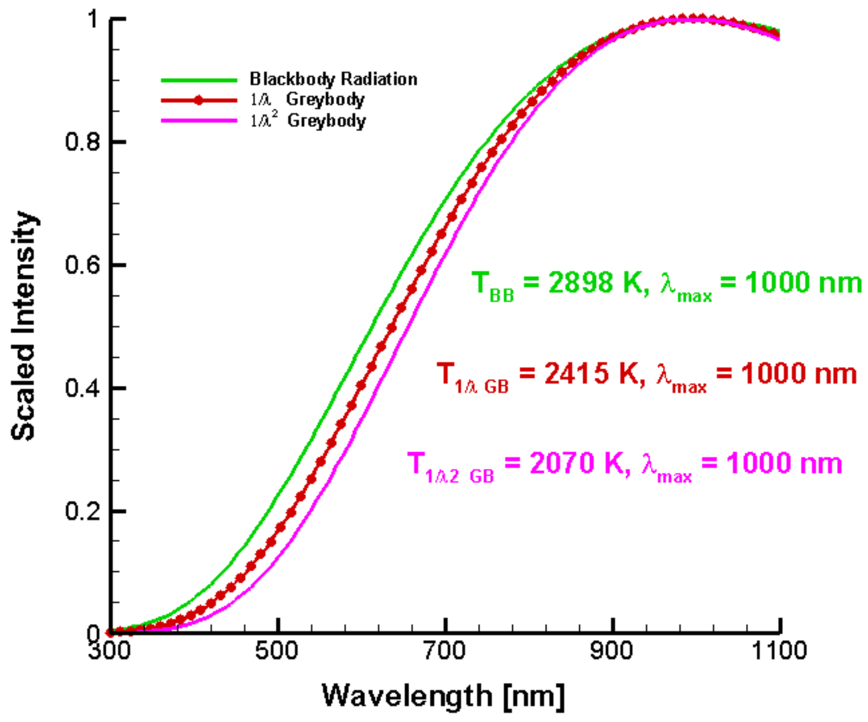
Flame Thermal Emissions



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- Thermal emissions are determined with Planck's radiation law for varying emissivity

$$\ln\left(C\frac{I_{\lambda,T} * \lambda^5}{\epsilon(\lambda,T)}\right) = -\ln\left(\mathrm{Exp}\left(\frac{hc}{k_B}\frac{1}{\lambda T}\right) - 1\right)$$

$$\cong -\frac{hc}{k_B}\frac{1}{\lambda T}$$

- Consider wavelength dependent emissivity
- $\varepsilon(\lambda,T) = 1, \,{}^{1}\!/_{\lambda}, \,{}^{1}\!/_{\lambda^2}$

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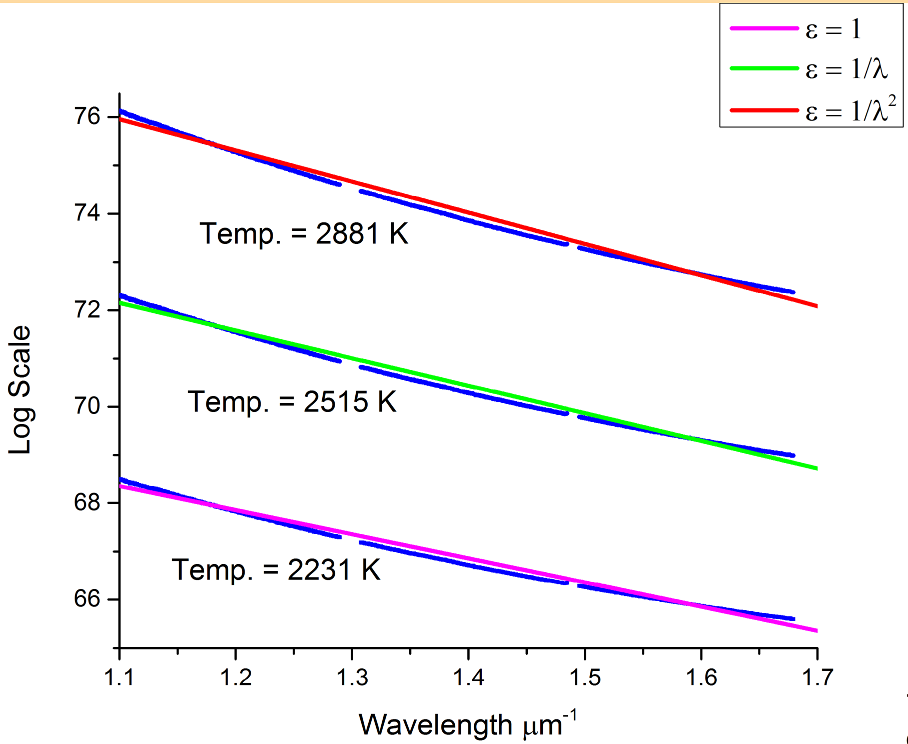
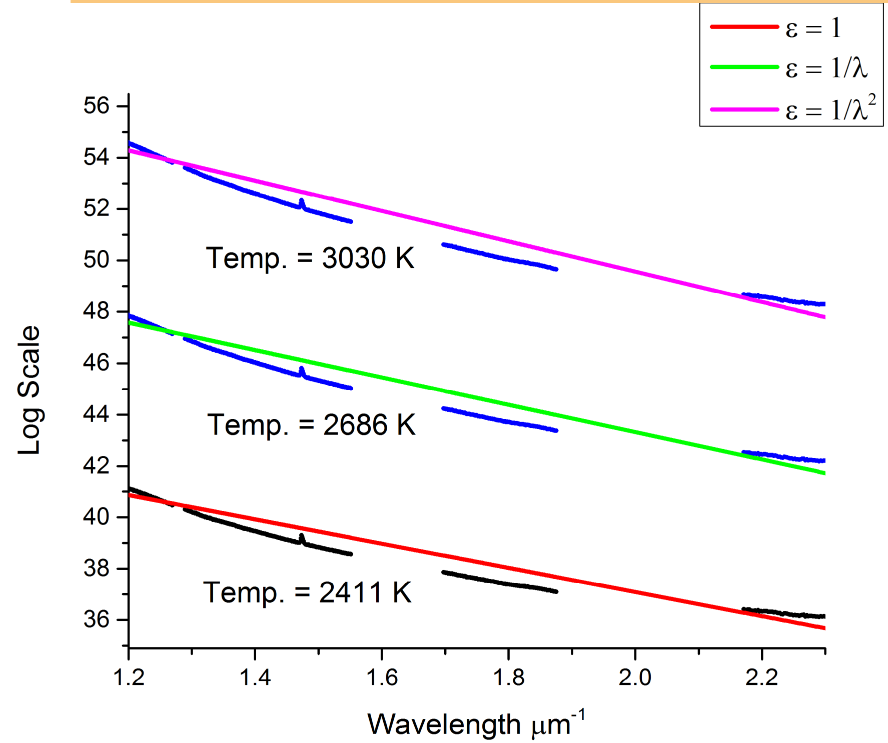
Planck Fitting Results for Thermal Emissions

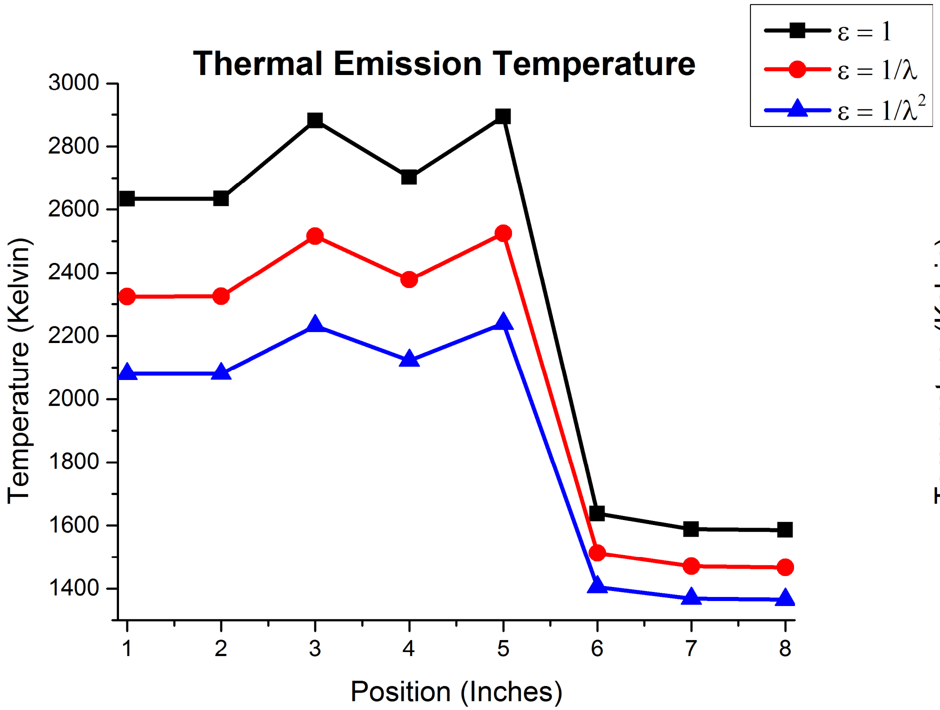


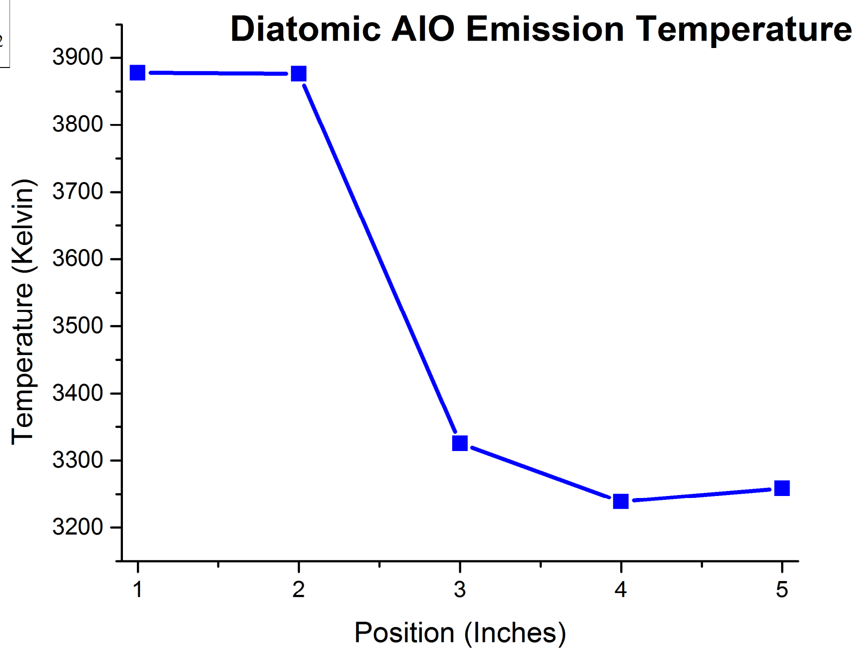
OFR = 8/10
Aluminum Feed Rate = 320 rpm
Height = 3 Inches



OFR = 8/10
Aluminum Feed Rate = 160 rpm
Height = 13 Inches

Temperature Summary





OFR = 8/10

Aluminum Feed Rate = 320 rpm

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Summary

- Used an oxyacetylene with aluminum powder feed to simulate a propellant flame
- Used AlO spectra to determine diatomic AlO emission temperature
- Used thermal emissions to determine the thermal temperature

Acknowledgments

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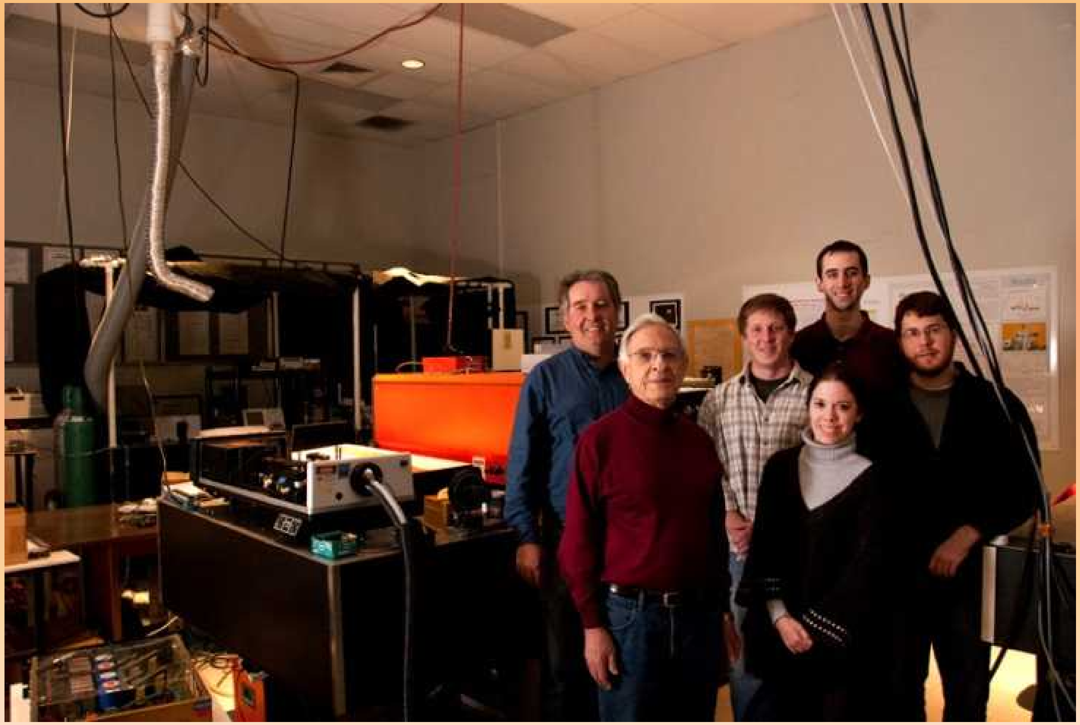

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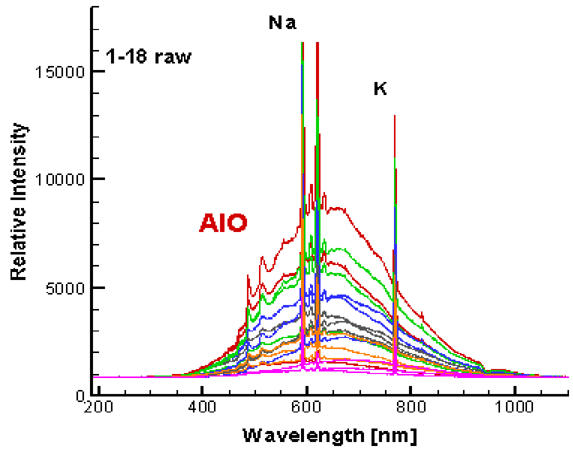
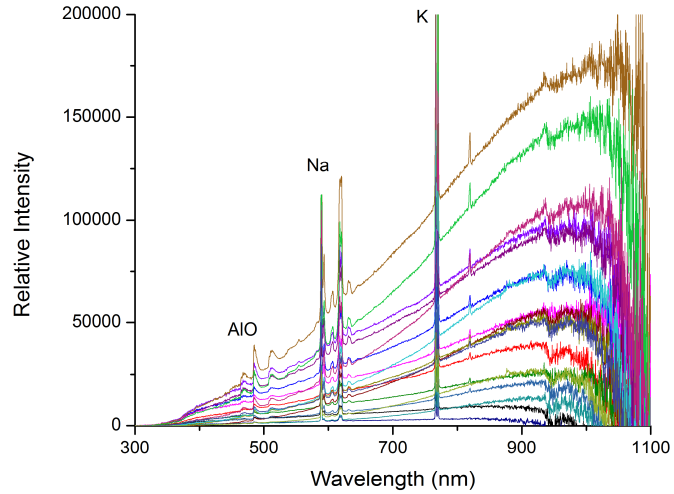
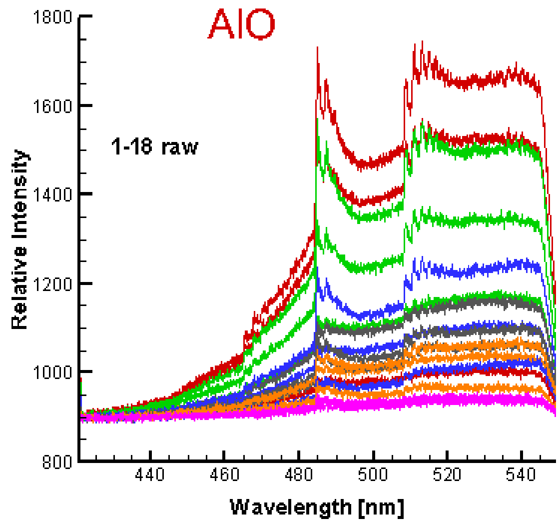
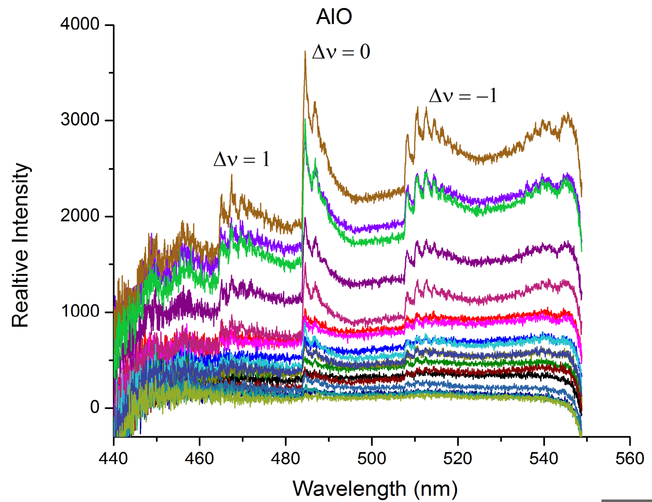
Solid Rocket Propellant

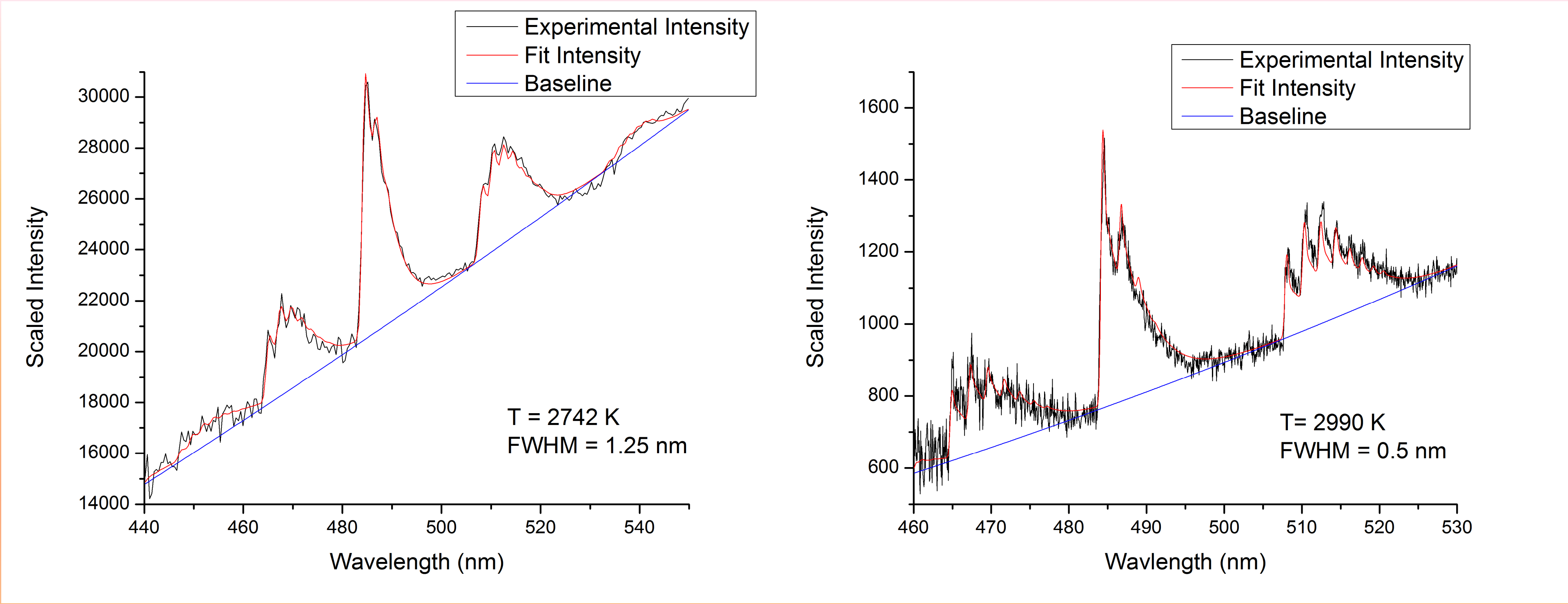








Solid Rocket Propellant



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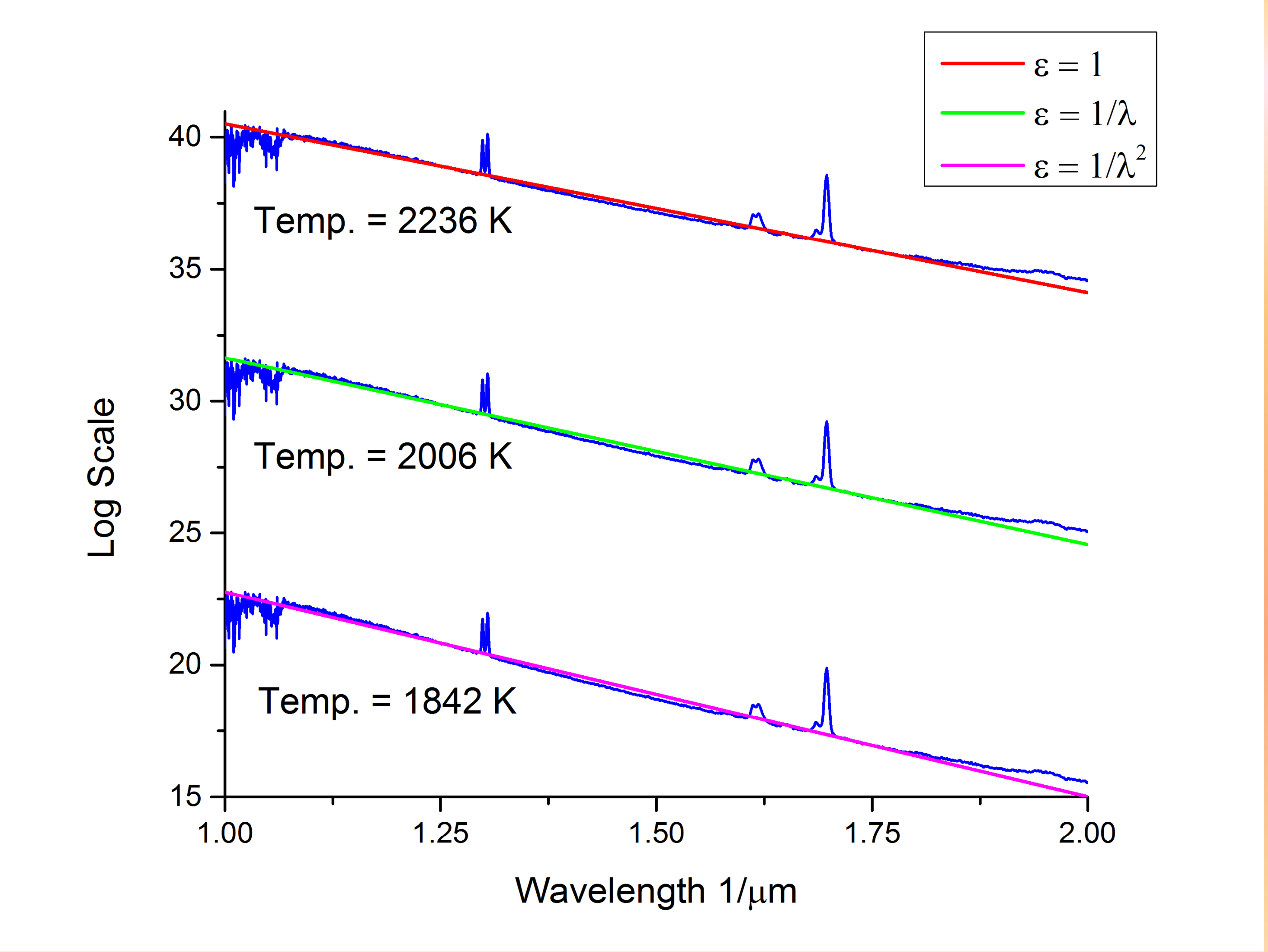
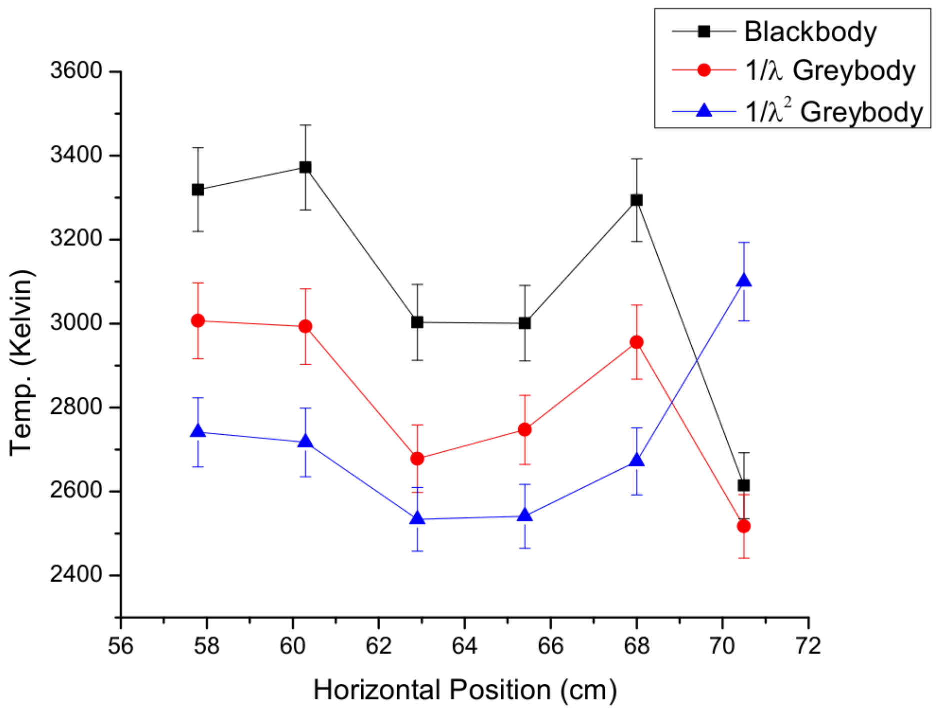
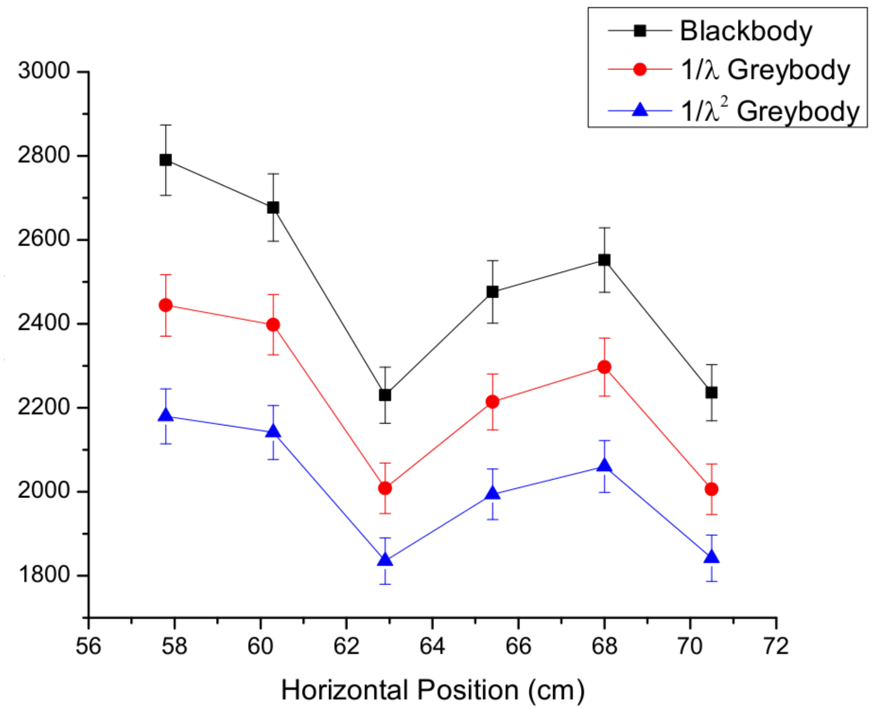
Solid Rocket Propellant



- **Na, K, and Al (second order 308 and 309 nm) lines present**

Solid Rocket Propellant





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Narrowband
Height = 508 mm

Broadband
Height = 305 mm