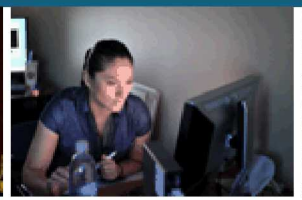
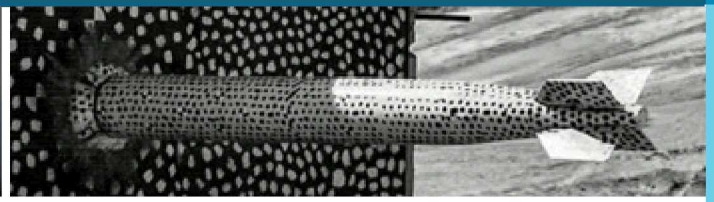
SAND2019-3385C

X-ray Excitation of Thermographic Phosphors





PRESENTED BY

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PERC Purdue Energetics Research Center

NASA

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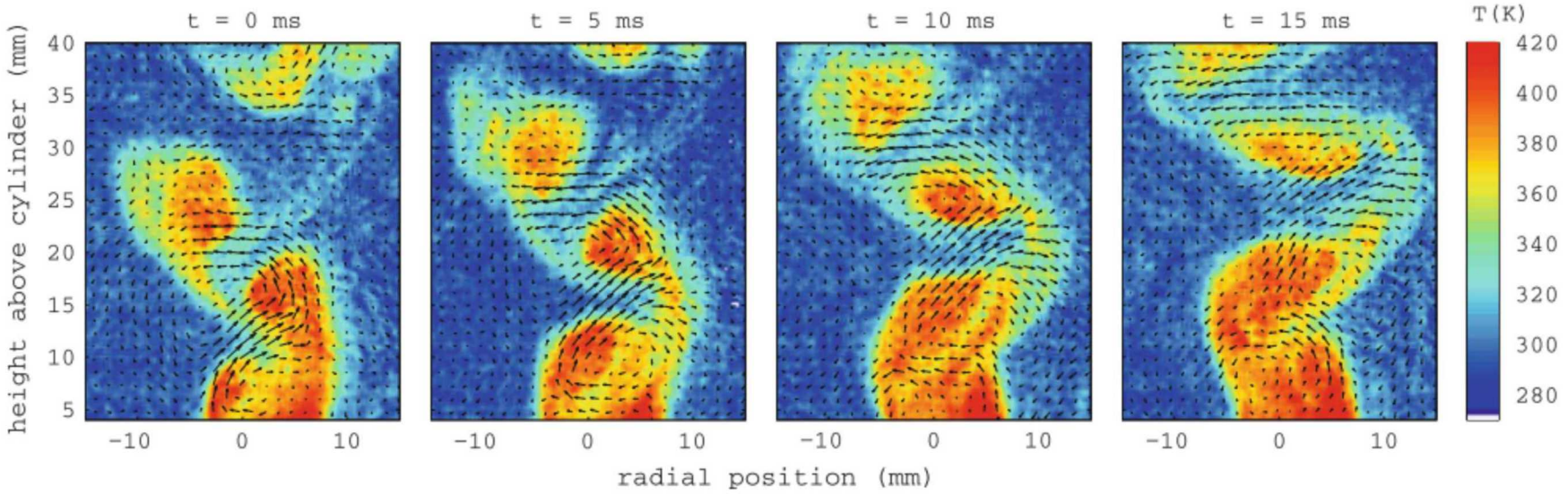
Introduction

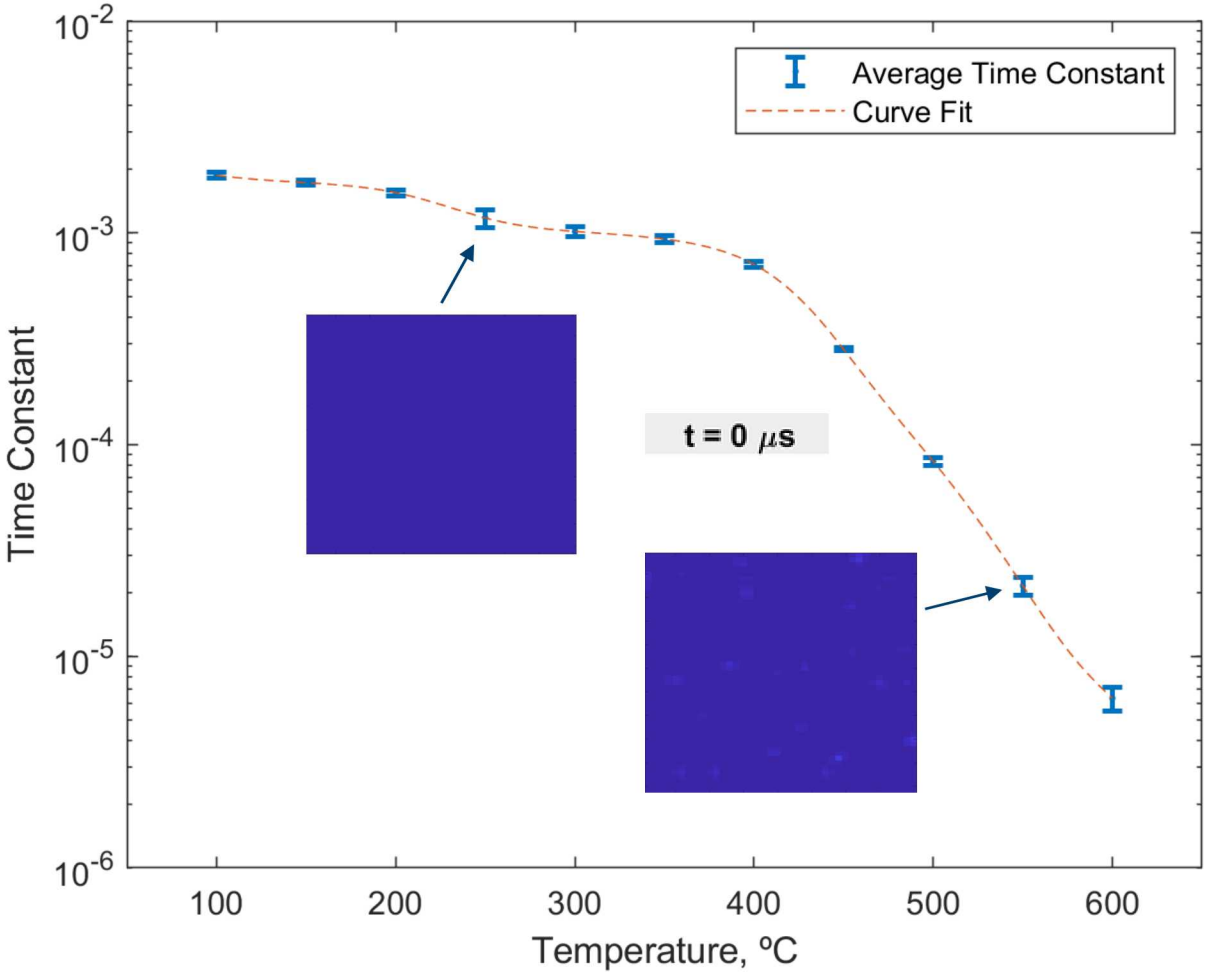
- Temperature measurements can be challenging within combustion environments.
  - Thermocouple: invasive, suffers from thermal lag, point measurement.
  - Pyrometry: non-invasive, but requires knowledge of emissivity.
- Phosphor thermometry has been successfully applied to such environments.
  - Involves imaging the temperature-dependent phosphorescence emitted by thermographic phosphors.



C. Abram, B. Fond, A.L. Heyes, F. Beyrau, High-speed Planar Thermometry and Velocimetry using Thermographic Phosphor Particles, Appl. Phys. B Lasers Opt. 111 (2013) 155–160.

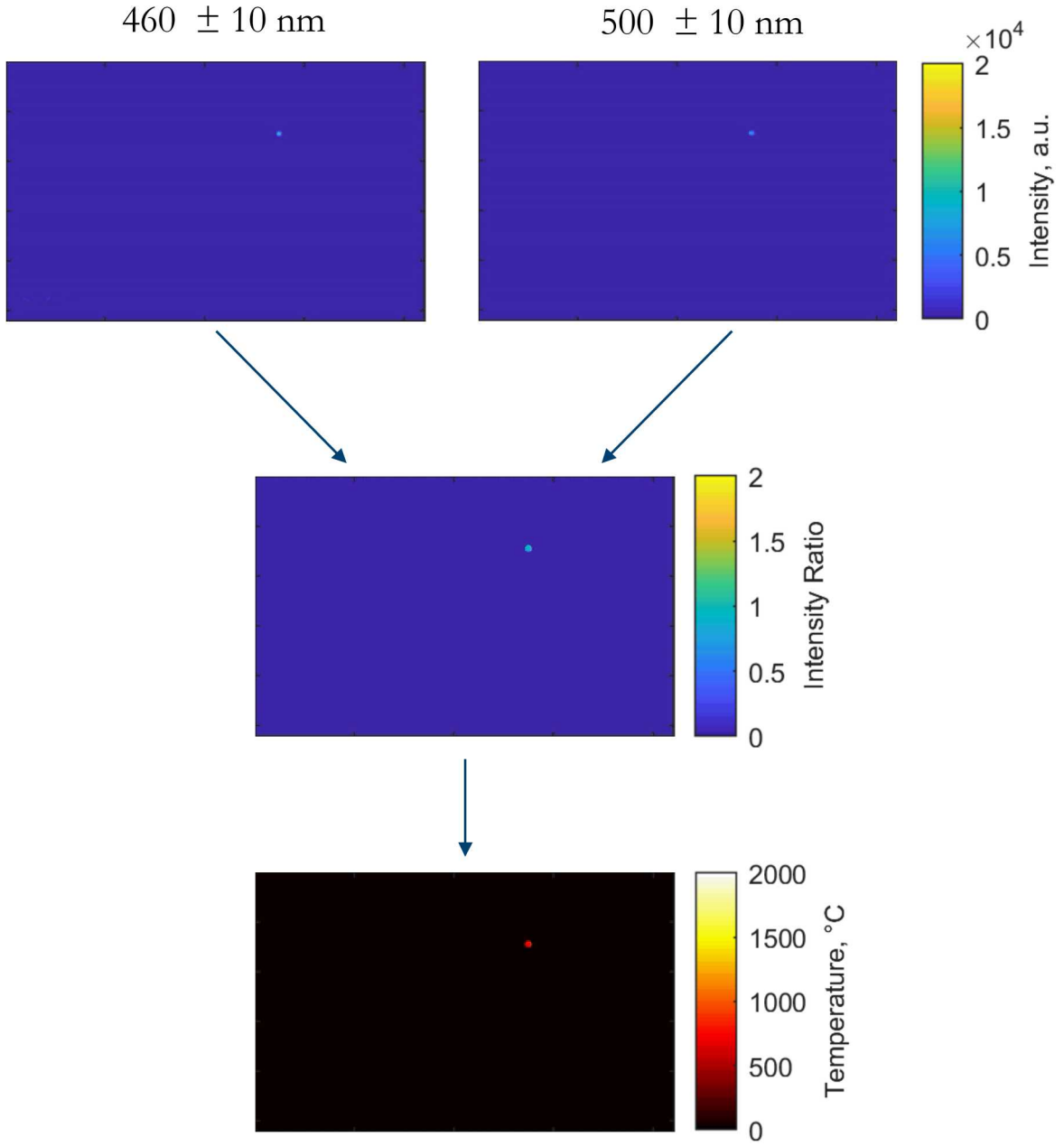
Introduction

- Thermographic phosphors: ceramic matrix doped with a transition or rare-earth metal.
- Typically excited via laser.
  - LED excitation recently explored.
- Two characteristics of the phosphorescence are temperature dependent:
- Lifetime
  - Plot shows the time constant of Mg_4FGeO_6:Mn as a function of temperature.
  - Frames captured at 125 kHz.



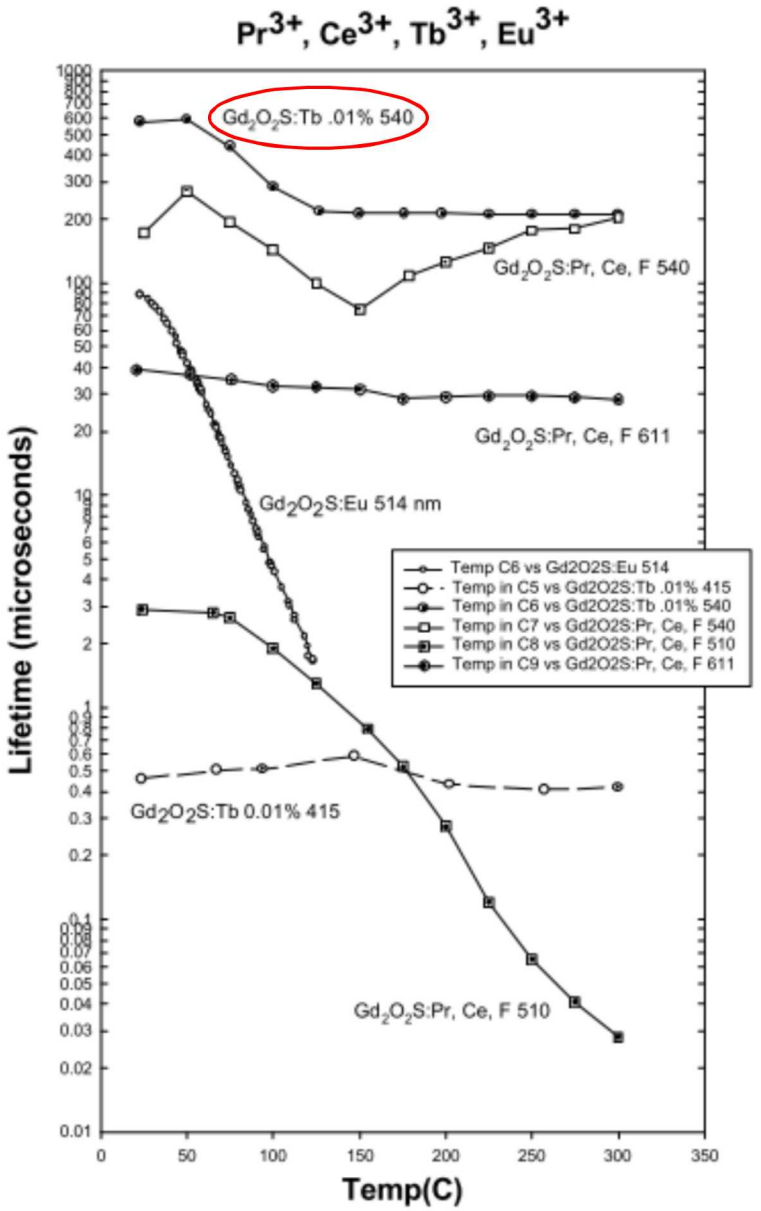
Introduction

- Thermographic phosphors: ceramic matrix doped with a transition or rare-earth metal.
- Typically excited via laser or LED.
- Two characteristics of the phosphorescence are temperature dependent:
- Intensity Ratio
  - Top images show signal captured from a YAG:Dy sample from different optical filters.
  - Temperature found using calibration curve.
  - Camera frame rate set to 10 Hz.



Introduction

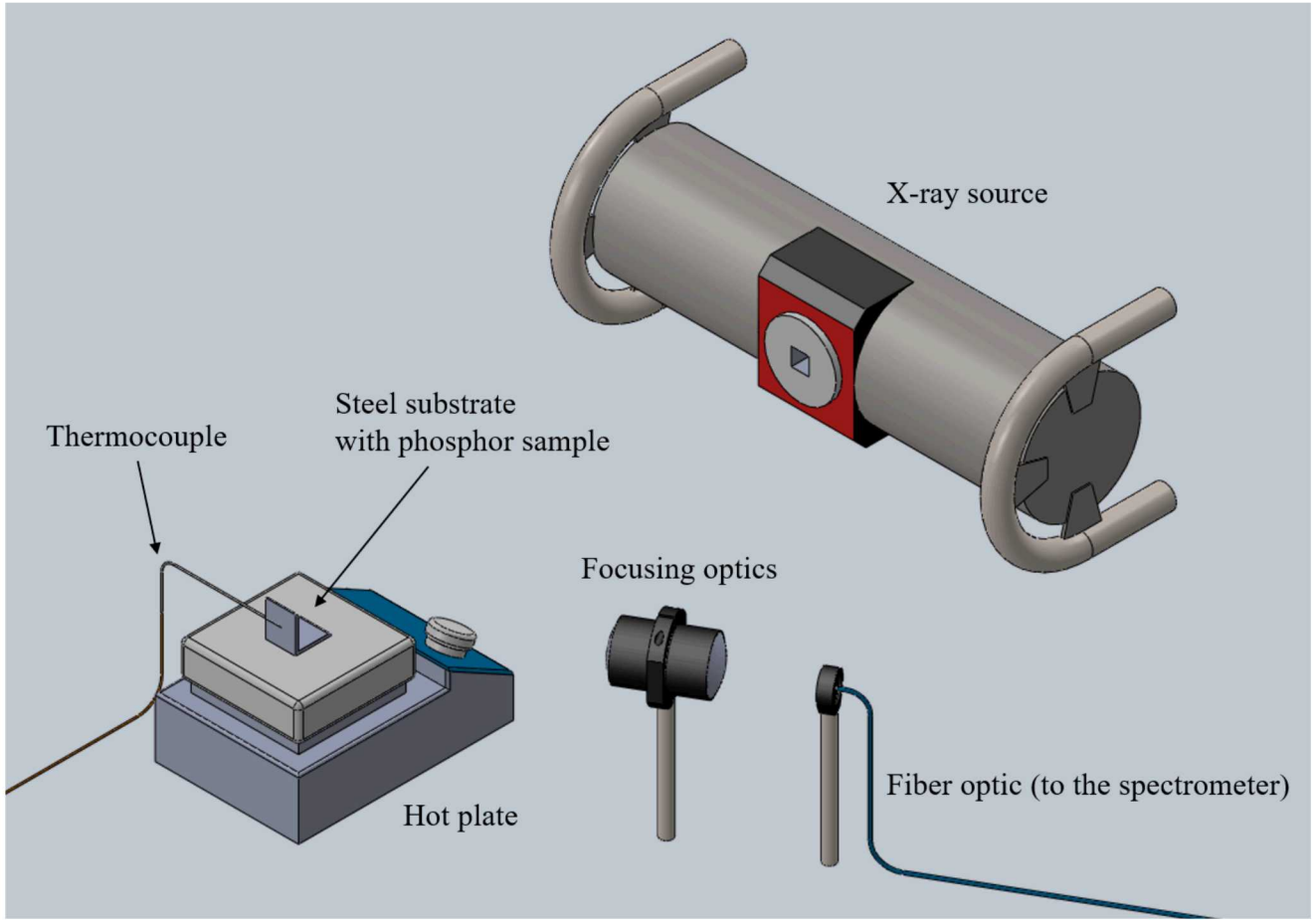
- Would like to use X-rays as the excitation source.
  - This would allow for simultaneous X-ray probing and surface temperature measurements of a reacting sample.
- Several phosphors exist which are known X-ray scintillators and have thermographic properties when excited by laser.
- Goal: Determine if the induced emission of one such phosphor remains thermographic under X-ray excitation.
  - Gd_2O_2S:Tb used in this study.



S. Allison, M. Cates, D. Beshears, A Survey of Thermally Sensitive Phosphors for Pressure Sensitive Paint Applications, Instrum. Aerosp. Ind. Proc. Int. Symp. 397 (2000) 29–37.

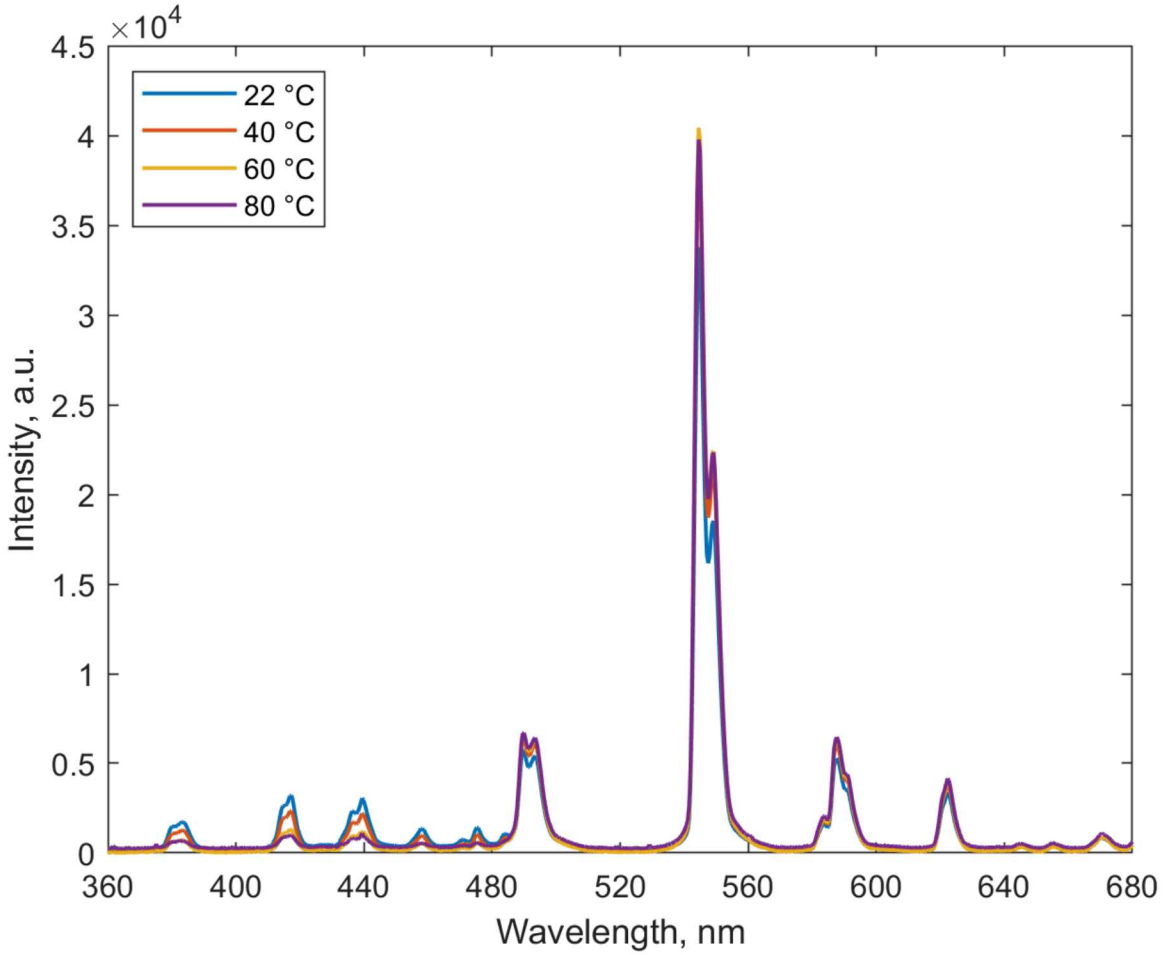
Experimental Methods

- Sample excited using a Comet MXR-451HP/11 X-ray source.
- Phosphorescence collected and imaged using a spectrometer (Ocean Optics FX-XR1-ES).
- Hot plate heated the sample.
  - Temperature monitored using handheld thermocouple reader (Omega Engineering).
- Spectrometer calibrated using a Hg-Ne pencil style calibration lamp (Newport, model 6034)



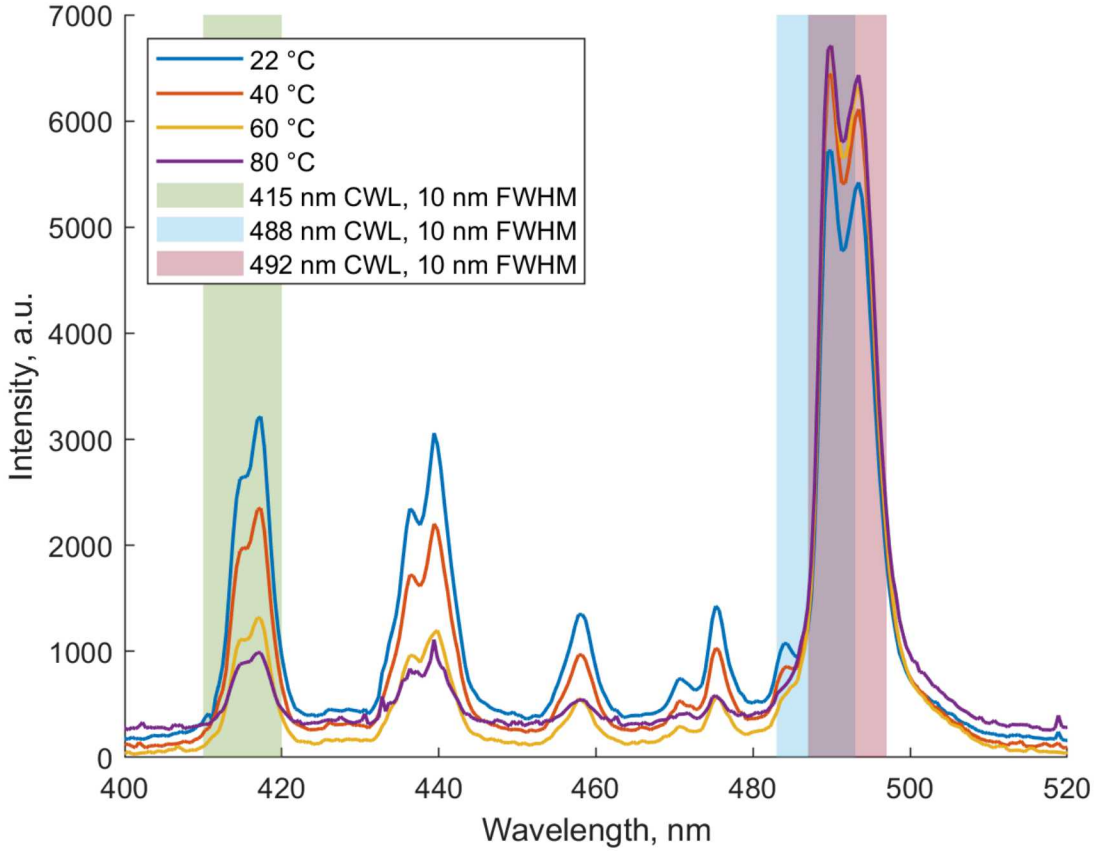
Results

- Average Gd_2O_2S:Tb phosphorescence spectra at several temperatures.
  - 15 spectra averaged at 22 °C, 5 spectra at all other temperatures.



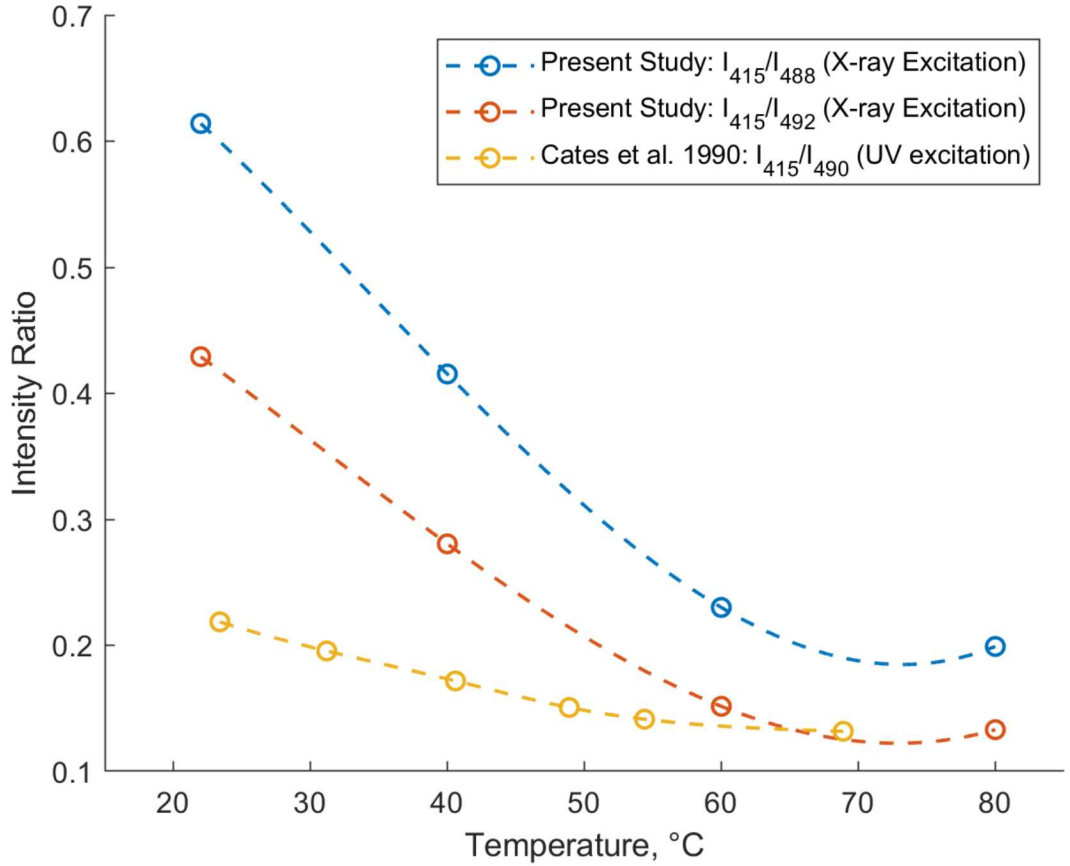
Results

- Section of the spectra showing more detail.
- Shaded areas show spectral bands used when calculating intensity ratios (based on filters available from Edmund Optics).



Results

- Intensity ratio calibration
  - Results for X-ray excitation compared to those for UV excitation from Cates et al. 1990.



Data taken from: M.R. Cates, K.W. Tobin, D. Barton Smith, Evaluation of Thermographic Phosphor Technology for Aerodynamic Model Testing, 1990.

Conclusions

- Induced phosphorescence from Gd_2O_2S:Tb remains thermographic under X-ray excitation.
- Spectrum shifts as temperature is varied.
  - Opposite trends seen for some peaks in the spectra
  - Taking the ratio between two such peaks increases the sensitivity of the intensity ratio calibration.
- Intensity ratio calibrations created using spectrometer data.
  - Compared to previously published results for UV excitation.
  - Similar trends seen for both excitation sources.
  - The differences in these calibrations are most likely due to variations in the experimental setups between the two studies.
- These results serve as a first step towards simultaneous X-ray probing and surface temperature measurements.

Acknowledgements

NASA Space Technology Research Fellowship grant No. 80NSSC17K0190 (E. R. Westphal)

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Questions?