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Thermographic Sensitivity of Lanthanide-doped Phosphors under X-ray Excited Optical Luminescence

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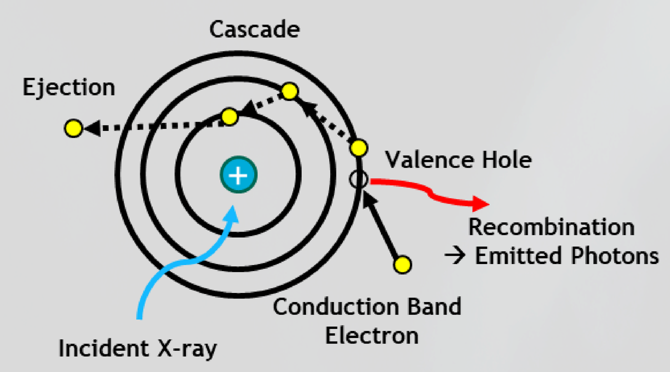
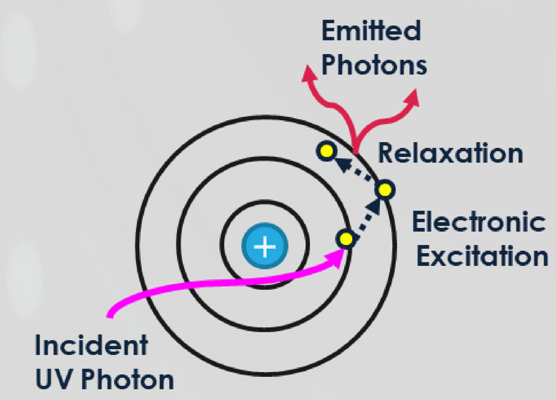
X-ray Excited Optical Luminescence (XEOL)



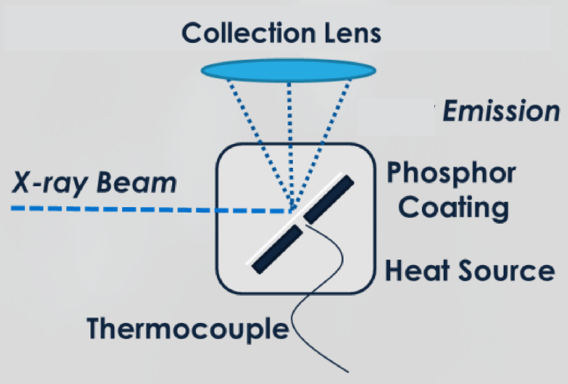
- Incident x-rays generate holes in core-electron shells
- Upper shell electrons cascade downward to fill vacancies, emitting characteristic x-rays
- Leaving a hole in the outermost (valence) shell, electrons from the conduction band can recombine
- Recombination leads to visible photon emission

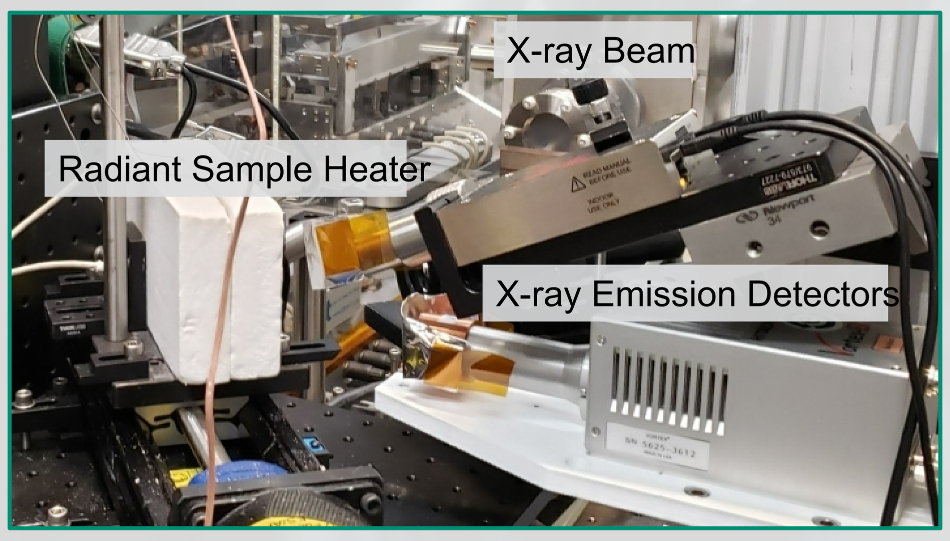
UV-excited Phosphorescence



- Incident UV photons electronically excite valence shell electrons
- The excited electrons can relax down to lower energy levels
- Visible phosphorescence is the radiative relaxation
- Non-radiative processes compete: thermographic behavior

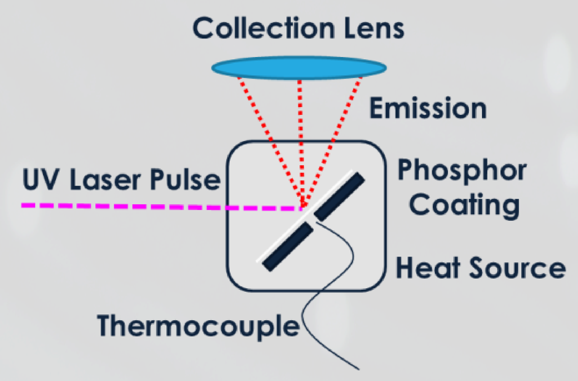
Advanced Photon Source Setup

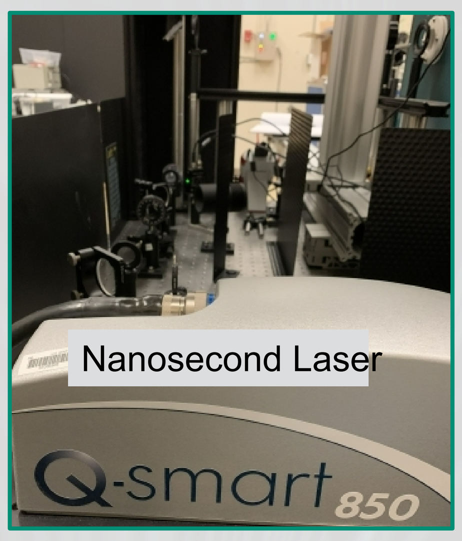


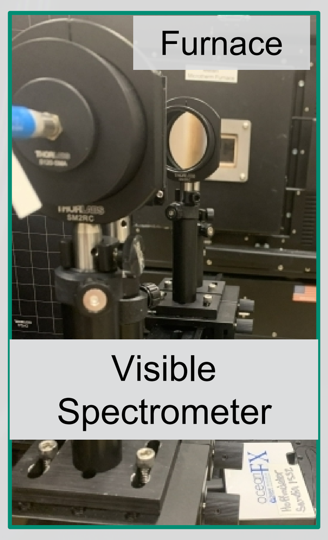


- Excitation Source: Monochromatic beam from 7-BM-B, $E_{incident}$ = 60.5 ± 0.5 keV
- Visible detection: Ocean Optics OCEAN-FX-XR1-ES, 60 spectra for each set, $\Delta t_{integration}$ = 1 s
- Heater: In-house built radiant sample heater, (Thermcraft PL1000 cast plate heaters & Omega Autotune Temperature/Process Dual Setpoint Controller)
- Sample temperature measured from K-type thermocouple

Sandia National Laboratories Setup



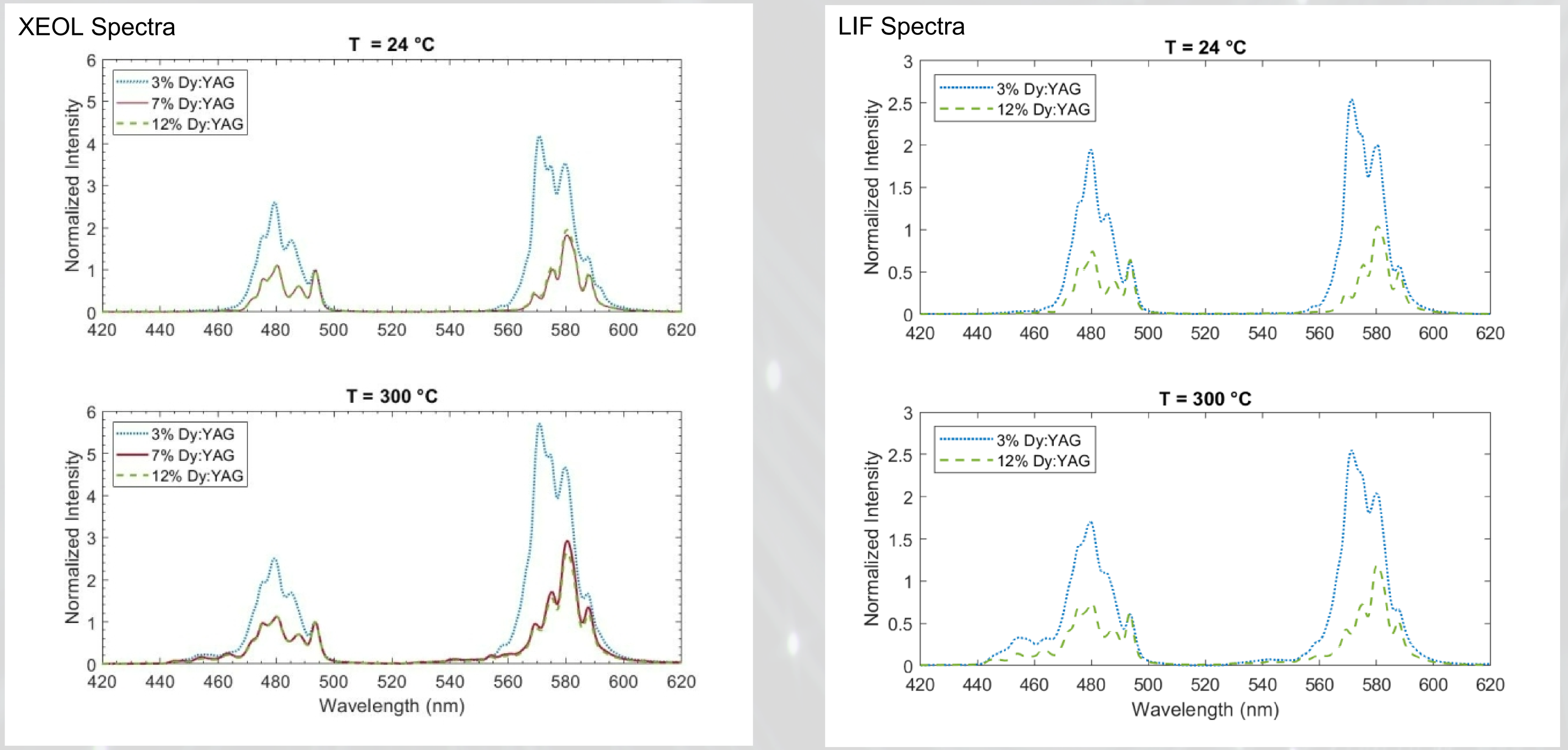




- Excitation Source: Quantel Q-smart 850 Nd:YAG laser, λ = 355 nm, Δt_{pulse} = 6 ns
- Visible detection: Ocean Optics OCEAN-FX-XR1-ES, 60 spectra for each set
- Heater: Mellen Microtherm Furnace
- Sample temperature measured from K-type thermocouple

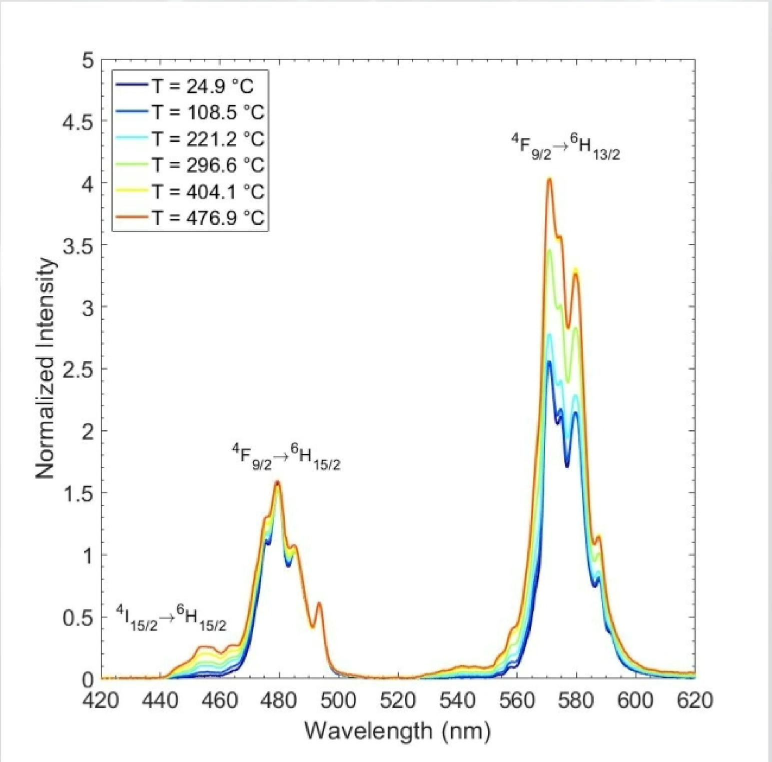
XEOL vs. UV-excitation Results

Effect of Dopant Concentration on the Emission of YAG:Dy

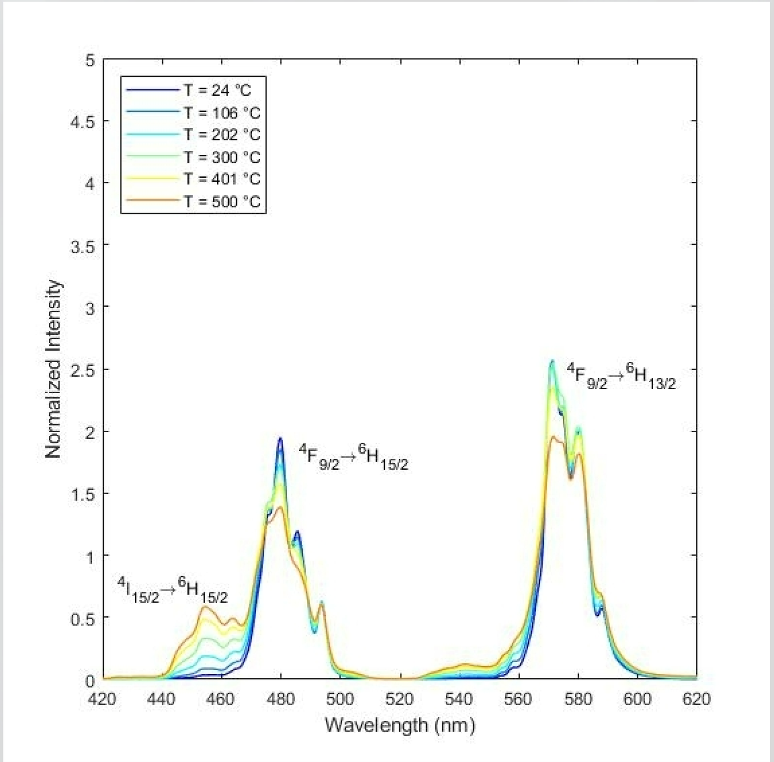


- Spectra normalized to the peak centered near 490 nm
- Structure of emission line manifolds varies with Dy dopant concentration
  - 3% varies greatly from 7% and 12% dopant concentrations
  - Suggests dopant concentration influences the probability of pumping certain vibrational states in the excited electronic state of each manifold

3% Dy:YAG XEOL Spectra

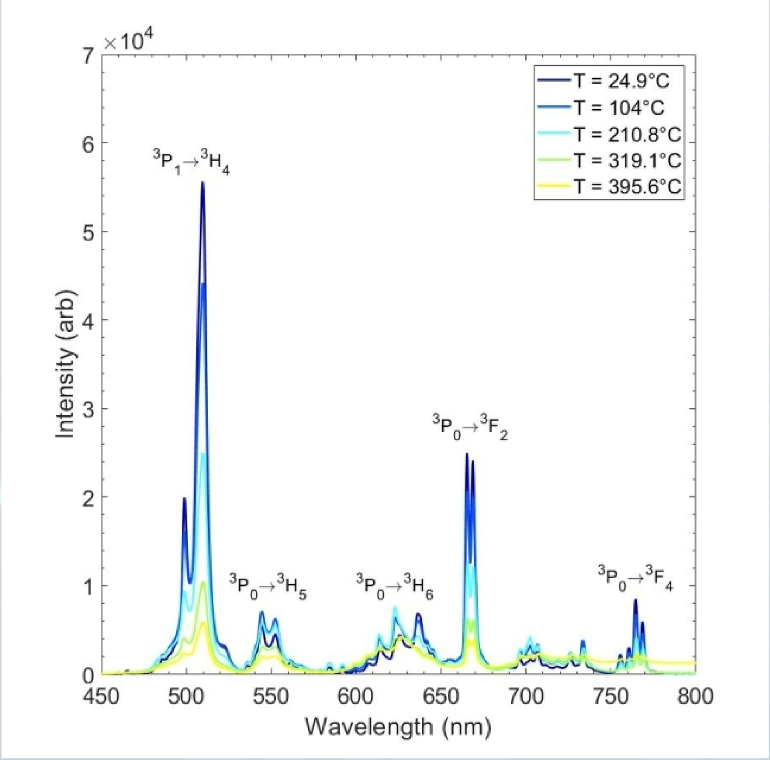


3% Dy:YAG LIF Spectra

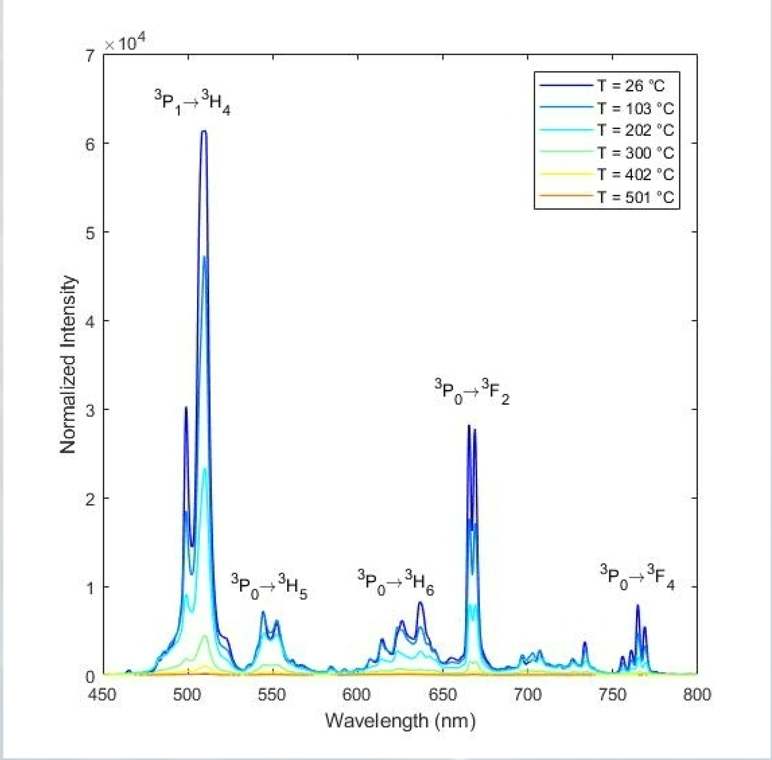


- Spectra normalized to the peak centered near 490 nm
- Larger amount of pumping of the $^4I_{15/2} \rightarrow {}^6H_{15/2}$ transition observed under UV excitation (this transition is commonly using in intensity ratio calibrations with YAG:Dy)
- Variations in the relative shifts in intensity seen in the $^4F_{9/2} \rightarrow {}^6H_{15/2}$ and $^4F_{9/2} \rightarrow {}^6H_{13/2}$ transitions between the two excitation sources.

3% Pr:Gd_2O_2S XEOL Spectra

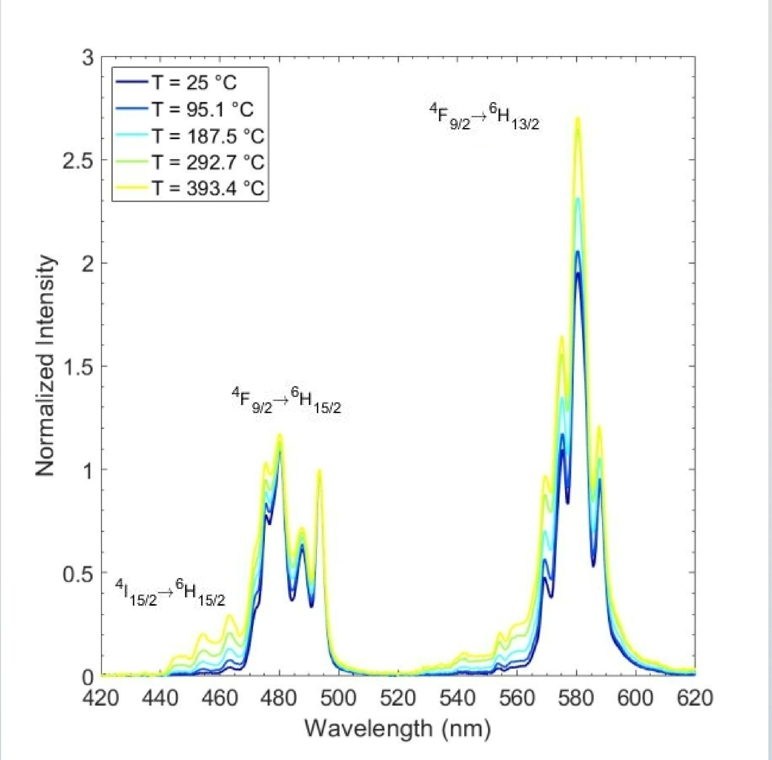


3% Pr:Gd_2O_2S LIF Spectra

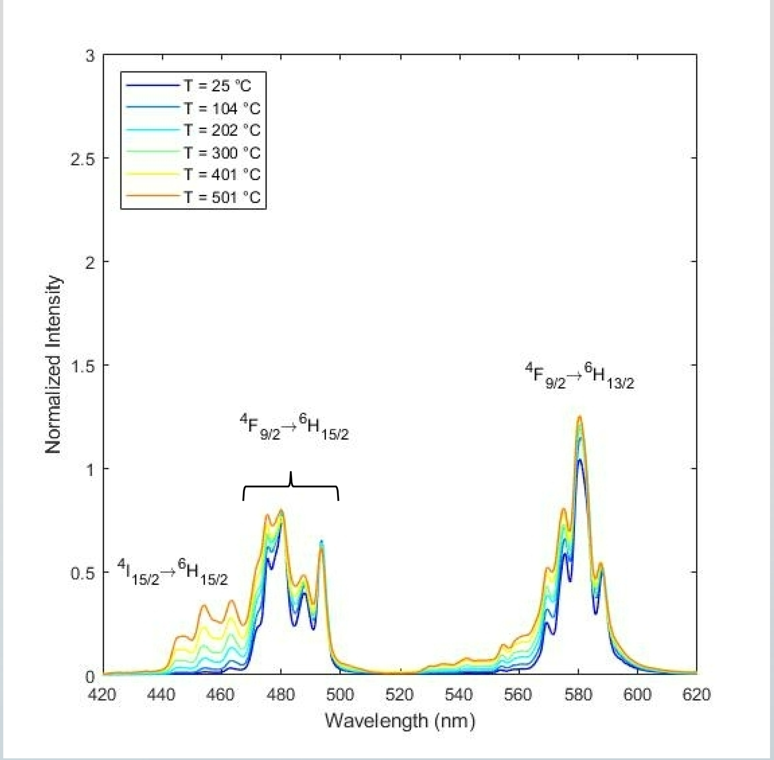


- Visible emission attenuates with increasing temperature
- Larger amount of relative attenuation observed under UV excitation
- Suggests the physical processes of XEOL pump the excited states of the observed transitions to higher populations at elevated temperatures compared to UV excitation

12% Dy:YAG XEOL Spectra



12% Dy:YAG LIF Spectra



- Spectra normalized to the peak centered near 490 nm
- Trends seen in the emission line manifolds with varying temperature more comparable between the two excitation sources for this Dy dopant concentration compared to 3% Dy:YAG
- Higher relative peaks for the $^4F_{9/2} \rightarrow {}^6H_{13/2}$ transition implies relaxation more probable through this process

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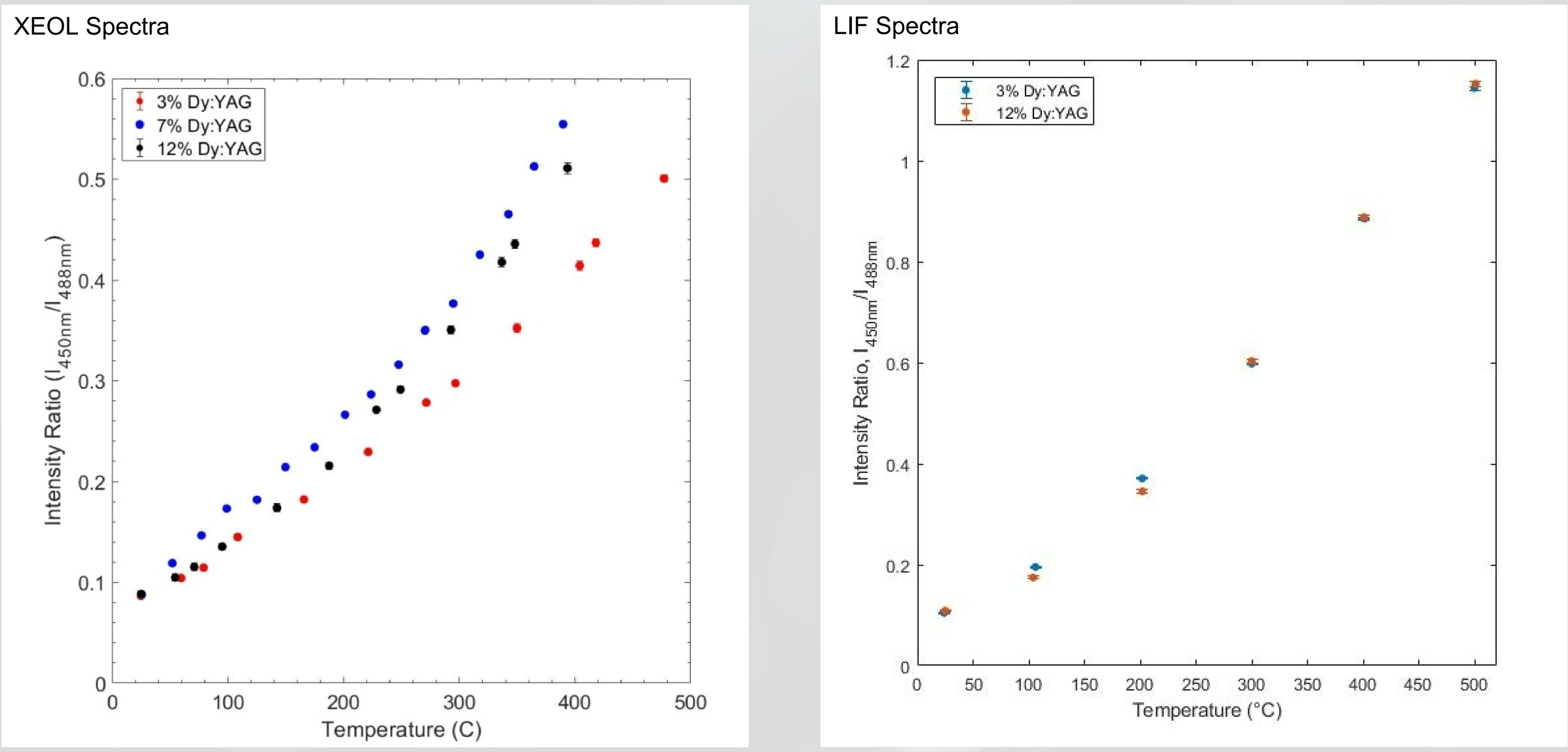
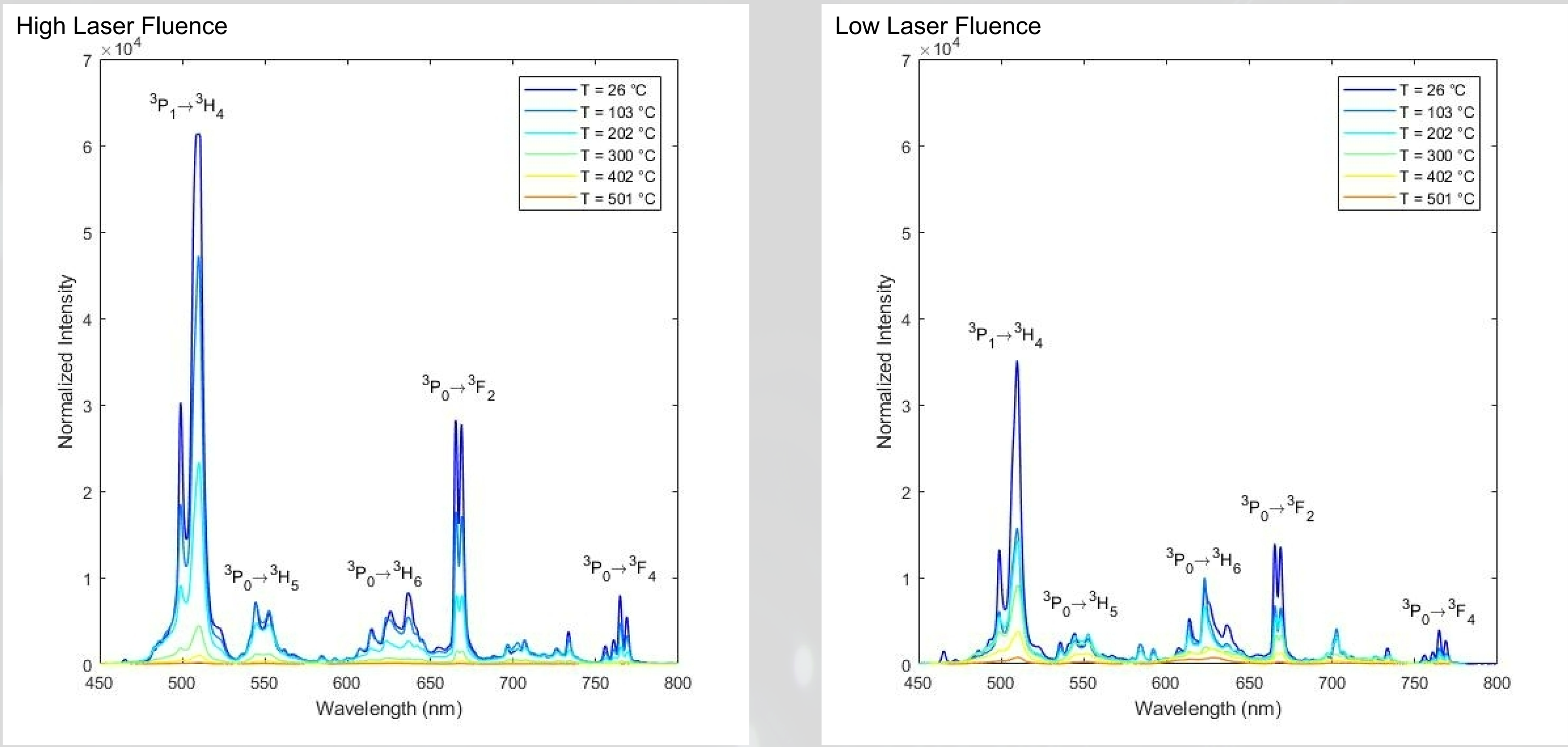
Additional Content

Effect of Dopant Concentration on an Intensity Ratio of YAG:Dy



- The temperature sensitivity of XEOL has a stronger dependence on dopant concentration than LIF
- XEOL is less sensitive to temperature than LIF

Effect of Laser Fluence on 3% Pr:Gd_2O_2S LIF Spectra



- The manifold behavior of $^3P_0 \rightarrow {}^3H_6$, $^3P_0 \rightarrow {}^3H_5$, and less densely populated states are effected by laser fluence
- XEOL spectra more closely resemble the high-fluence LIF spectra, implying XEOL data may be within the saturation regime

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