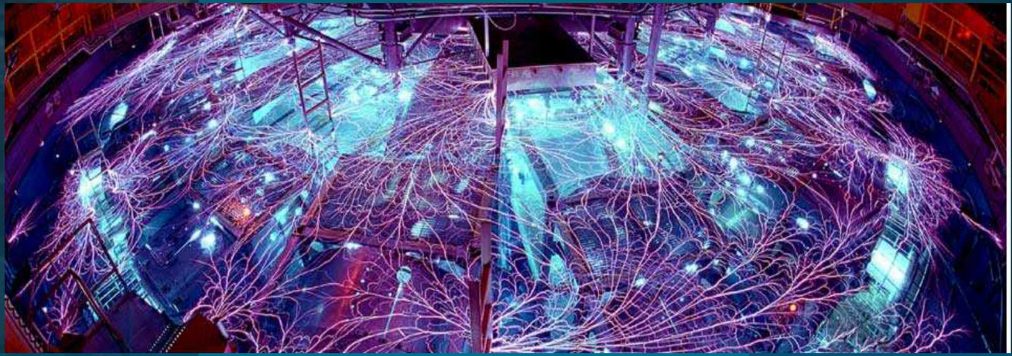
SAND2020-2692C

An Optical Thermometer for Sandia's Z-Machine:



High-Pressure, High-temperature Reflectivity in Diamond Anvil Cell

PRESENTED BY

Kaleb Burrage, Patricia Kalita, Richard Hacking, Chris Seagle and Dan Dolan

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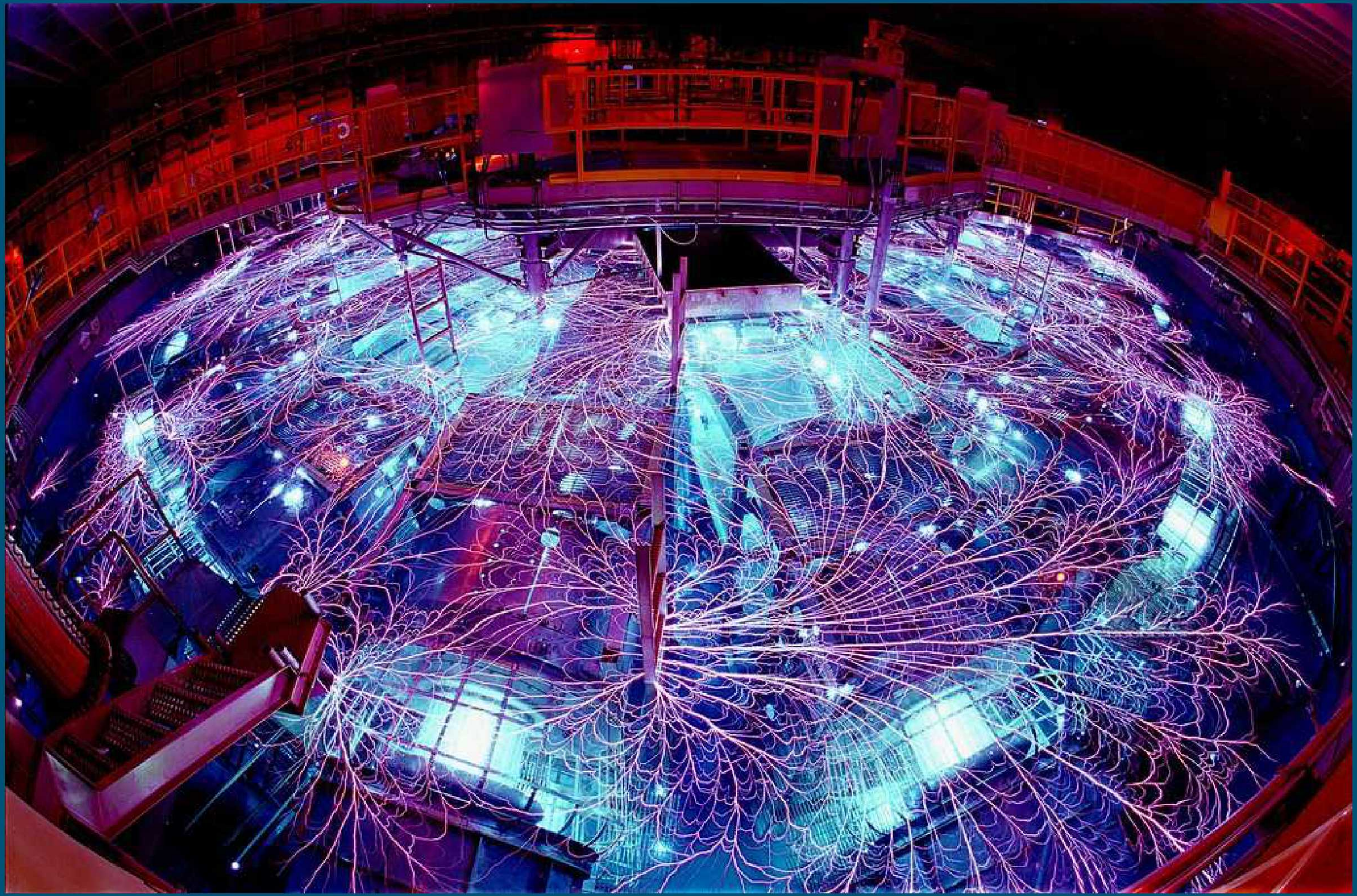
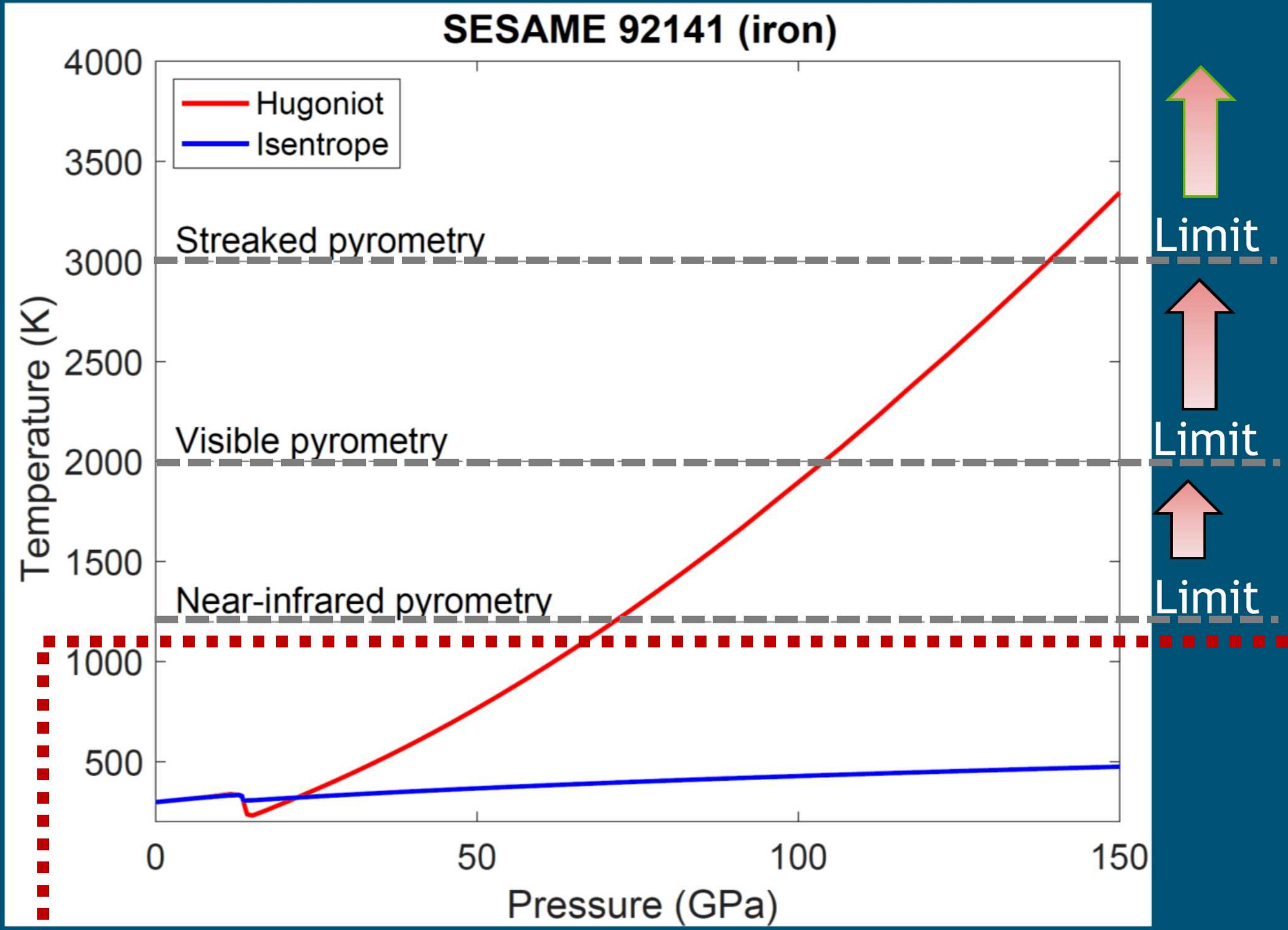
Sandia's Z Machine for High Precision Dynamic Compression Studies



- The core capability of SNL Z-Machine is dynamic material compression
- World's most powerful laboratory radiation source
- Inertial confinement fusion
- Weapon's effects, weapons physics, and other applications of high energy density physics

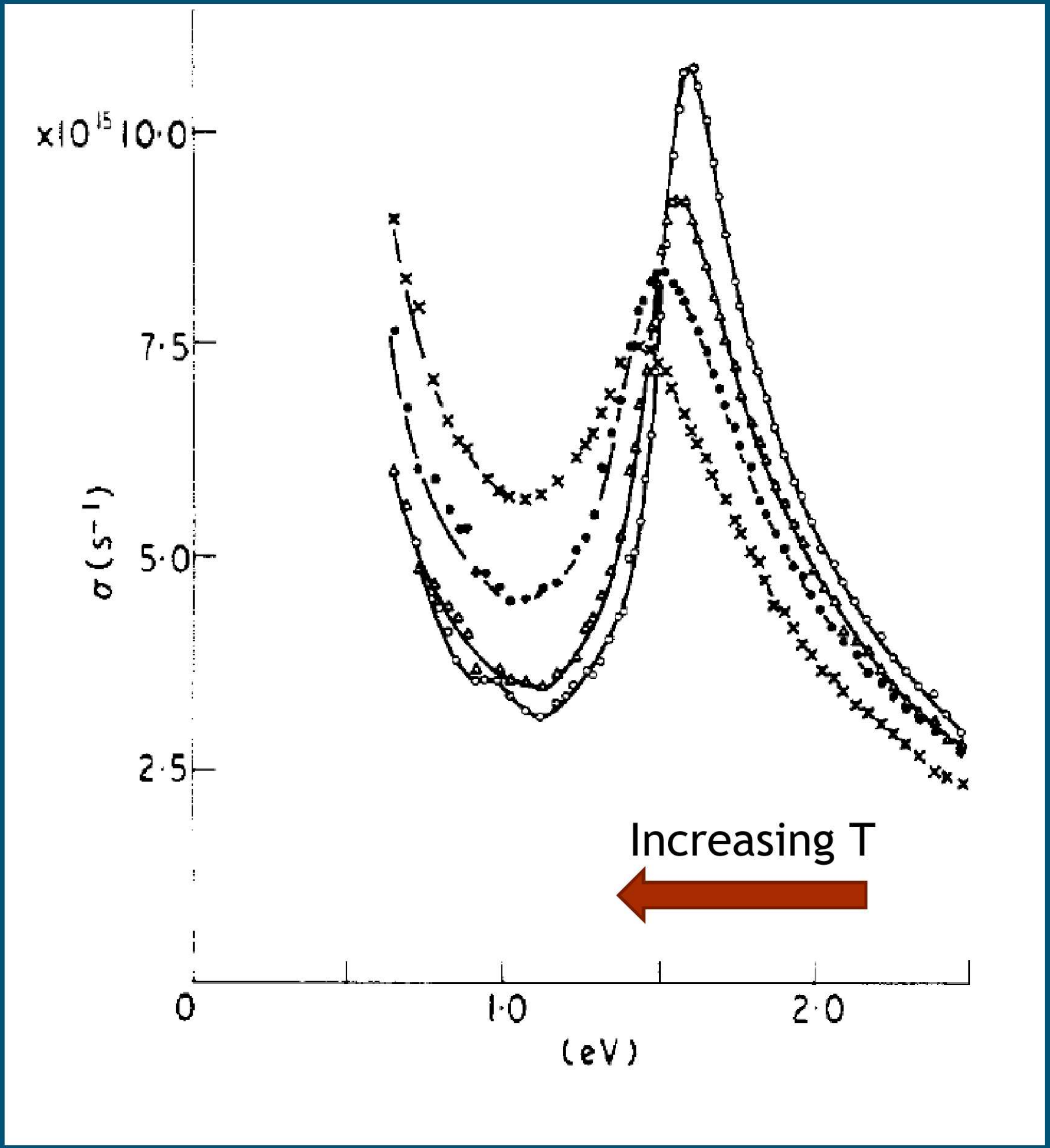
What are the limits of current T diagnostics on SNL's Z?



- Currently on Z shots there is **no T diagnostic** working **below 1200 K** (926^{o}C)
- example: cannot distinguish between shocked and ramped iron at 50 GPa, even though the temperatures are quite different!

Optical Thermo-reflectance is a possible enabling diagnostic for the 300-1200 K and 0-100 GPa range

Temperature Effect on Aluminum Optical Conductivity



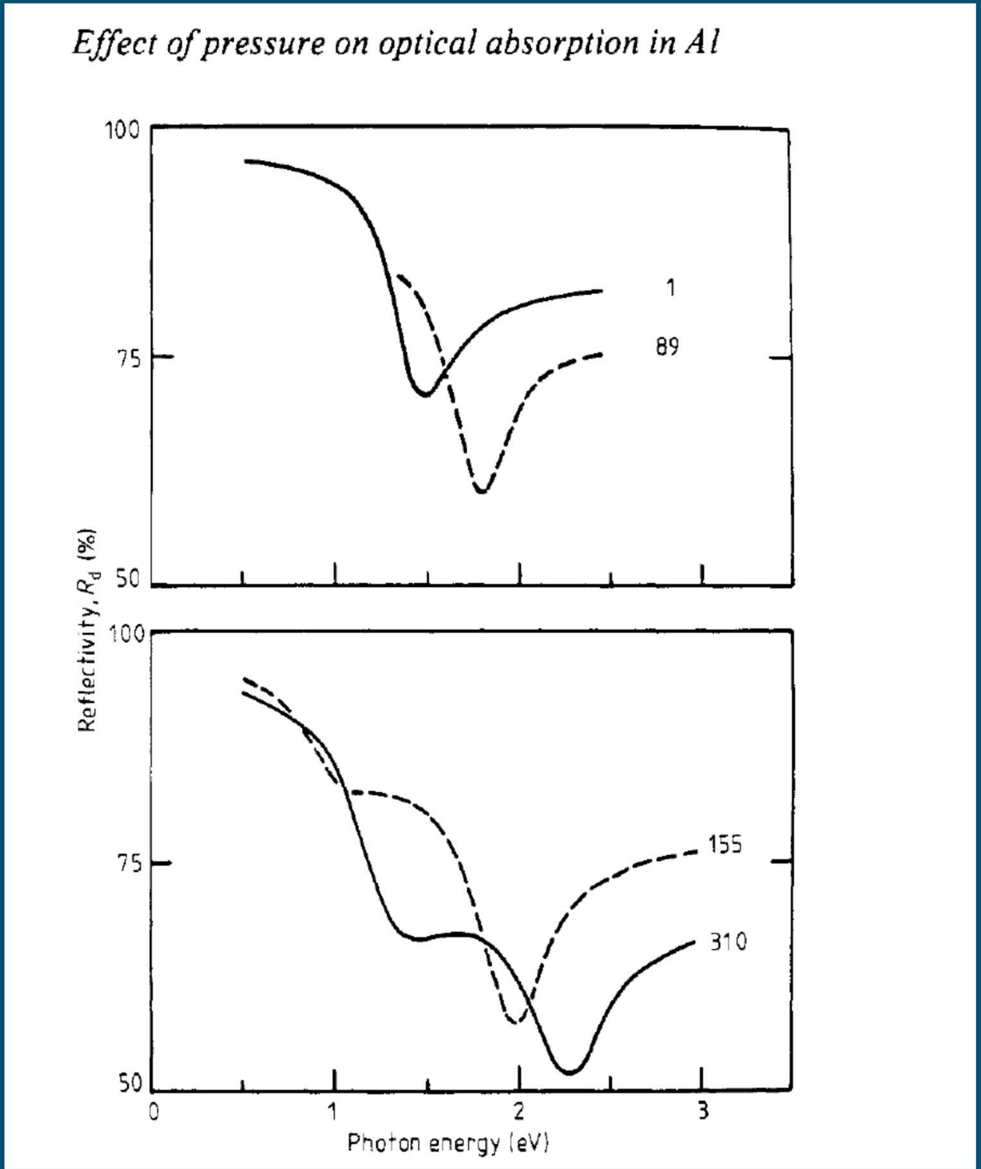
Aluminum has an absorption feature around 1.5 eV

This absorption feature is related to interband transitions

Increasing temperature shifts absorption to lower energy

Mathewson et al *Journal of Physics*, 1973

Pressure Effect on Aluminum Reflectivity



Increasing Energy

Tups et al *Journal of Physics*, 1984

Aluminum has an absorption feature around 1.5 eV

Absorption is interpreted as mainly interband transitions

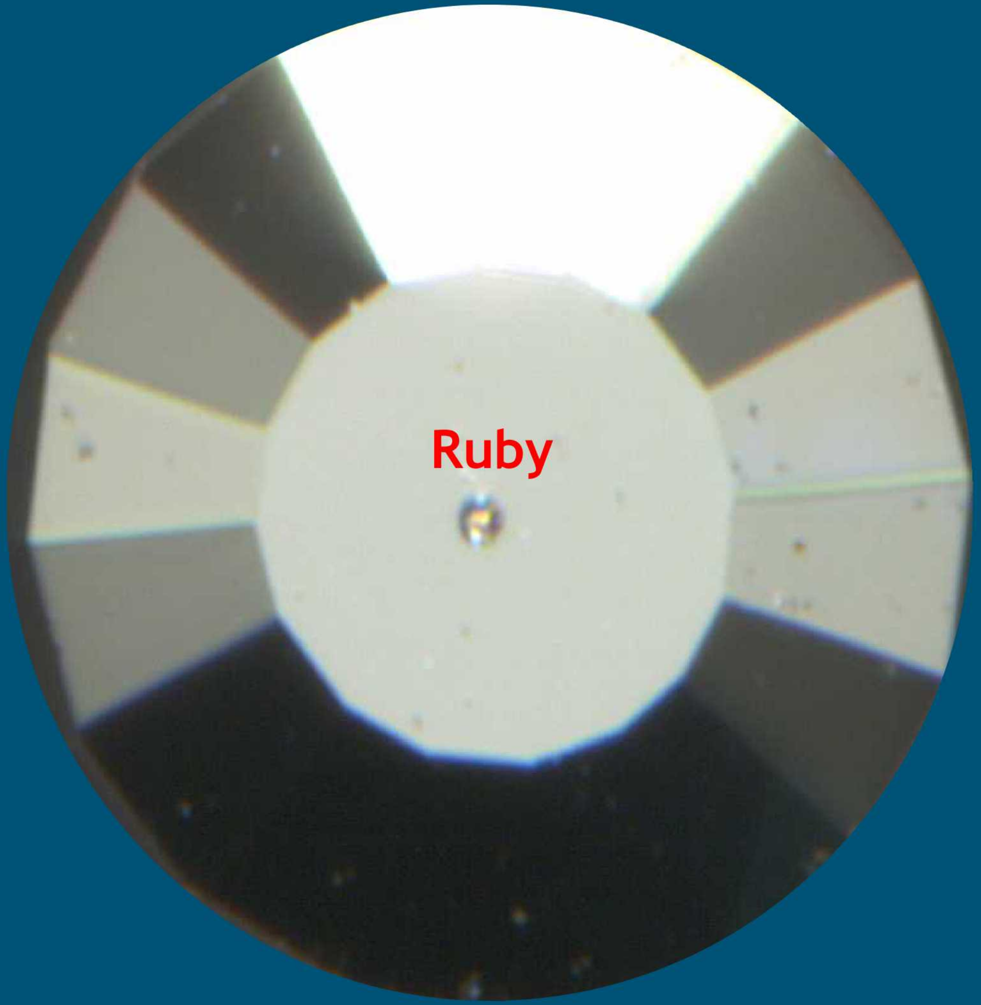
Increasing pressure shifts absorption to higher energy

Simultaneous Pressure and Temperature Phenomena

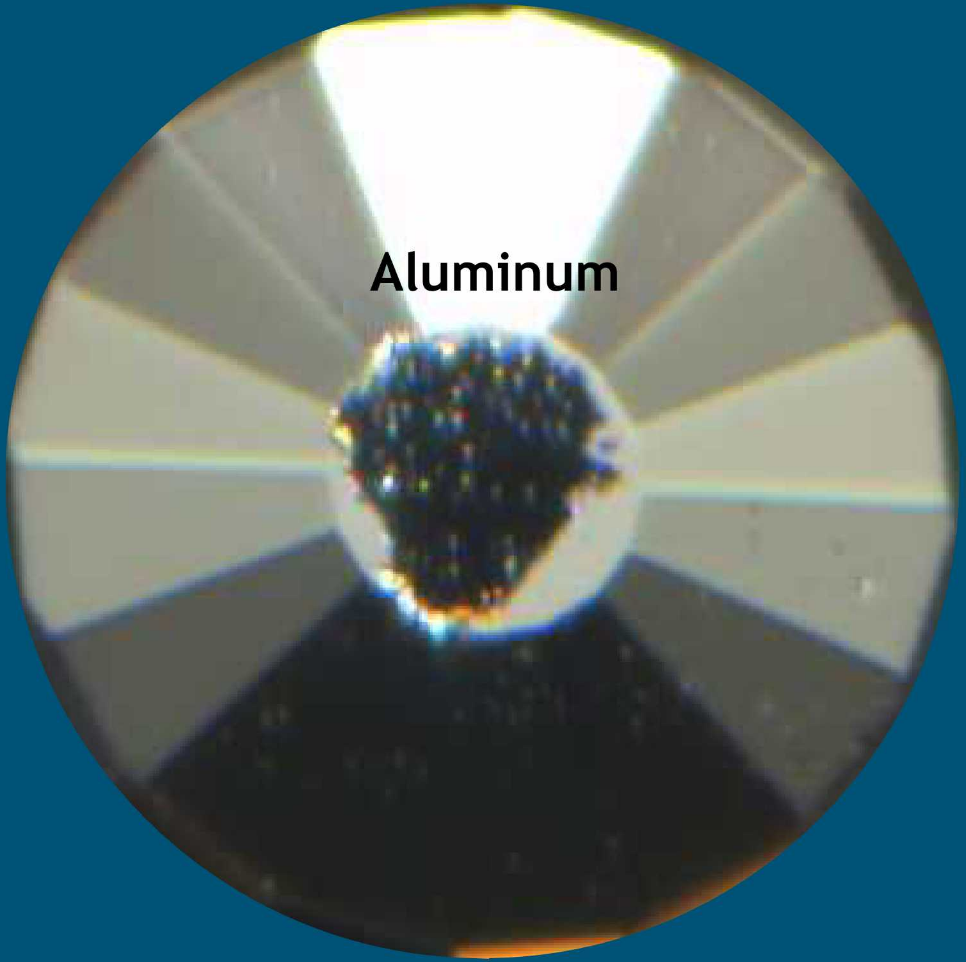
- Goal : Calibrating simultaneous Pressure and Temperature shifts in Aluminum
- Spectral shape of absorption shift with Pressure and Temperature effects can be used as an optical thermometer
- Pressure causes a greater shift in energy than temperature; it is expected that temperature effect will hinder the shift to higher energy

The Diamond Anvil Cell (DAC)

- Ruby used as pressure calibrant

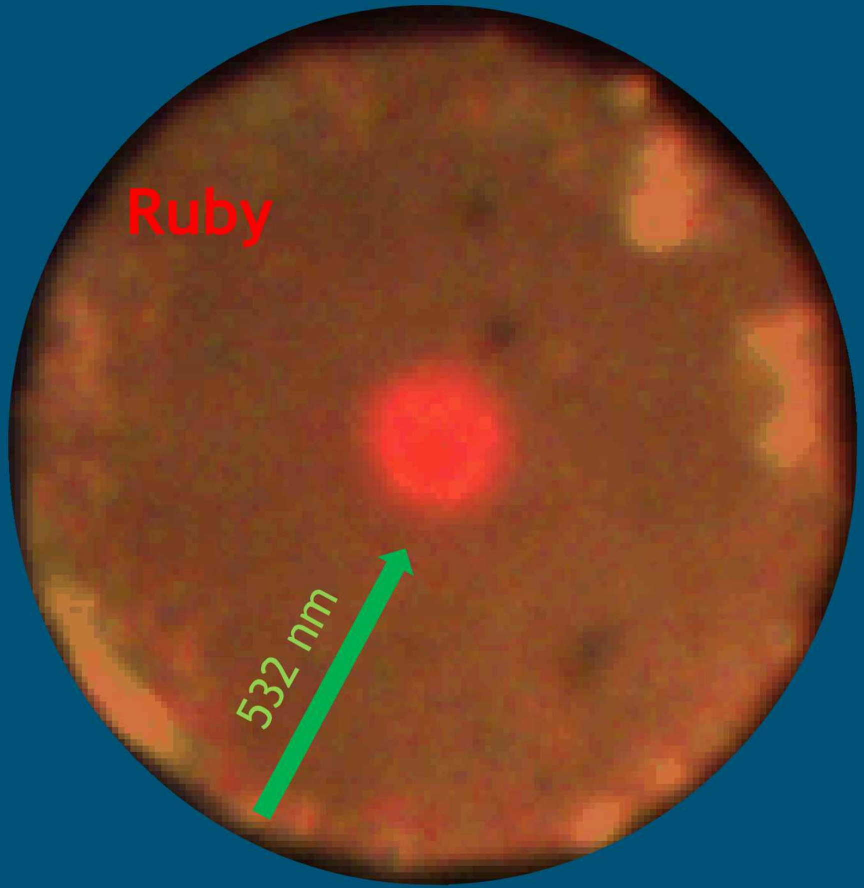


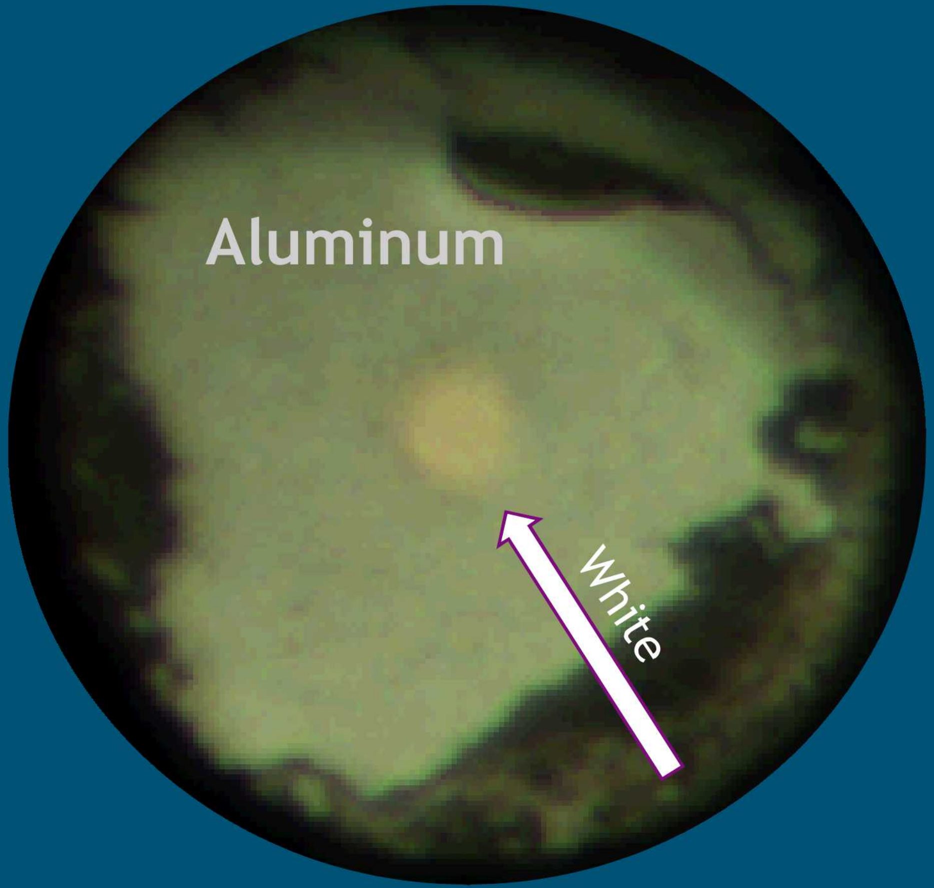
- 532 nm Laser is focused onto Ruby
- White light from Laser Driven Light Source (LDLS) is shown onto foil



Taking Measurements Within the DAC

- 532 nm Laser is focused onto Ruby
- White light from LDLS is shown onto foil





Taking Measurements Within the DAC

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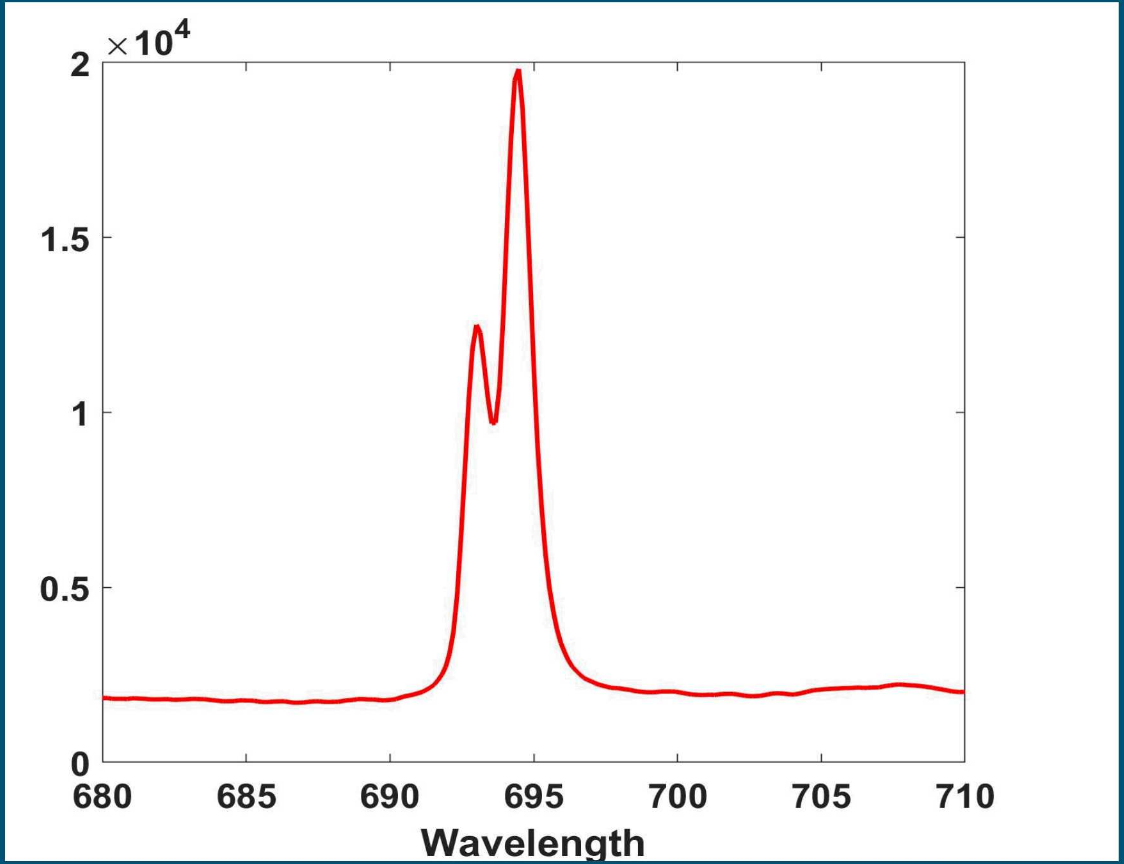
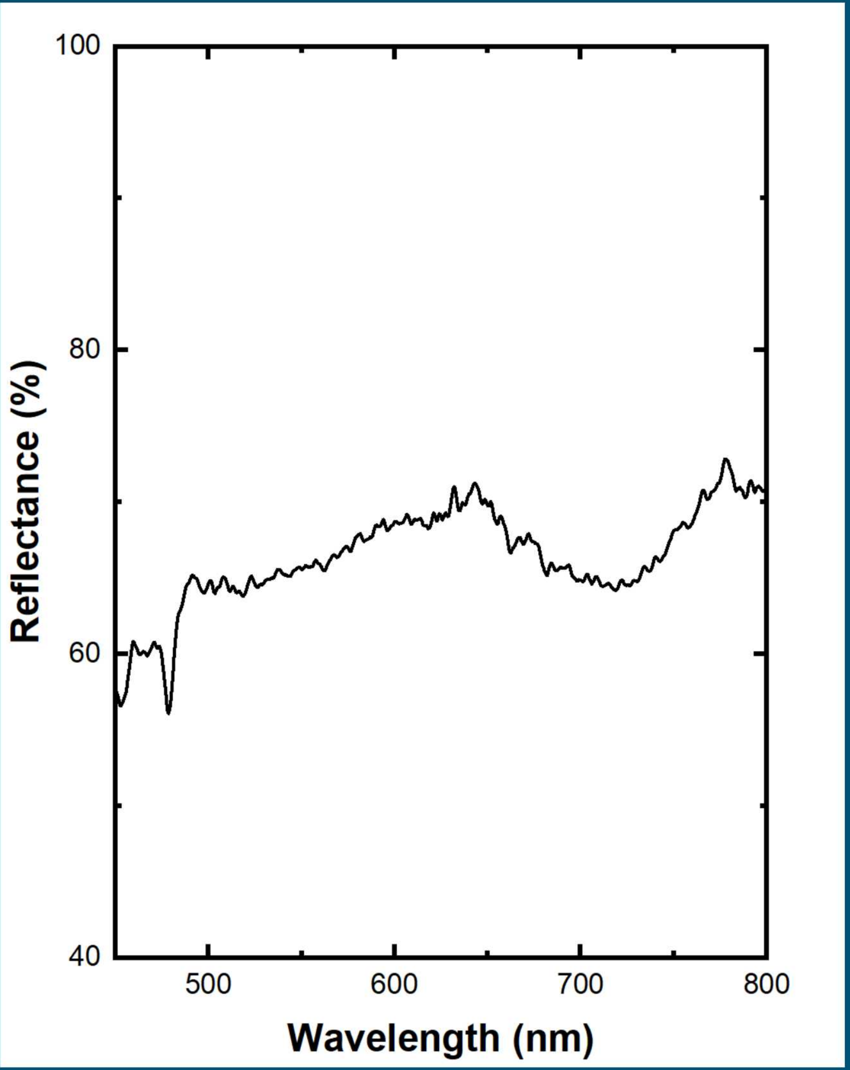
Ruby Fluorescence



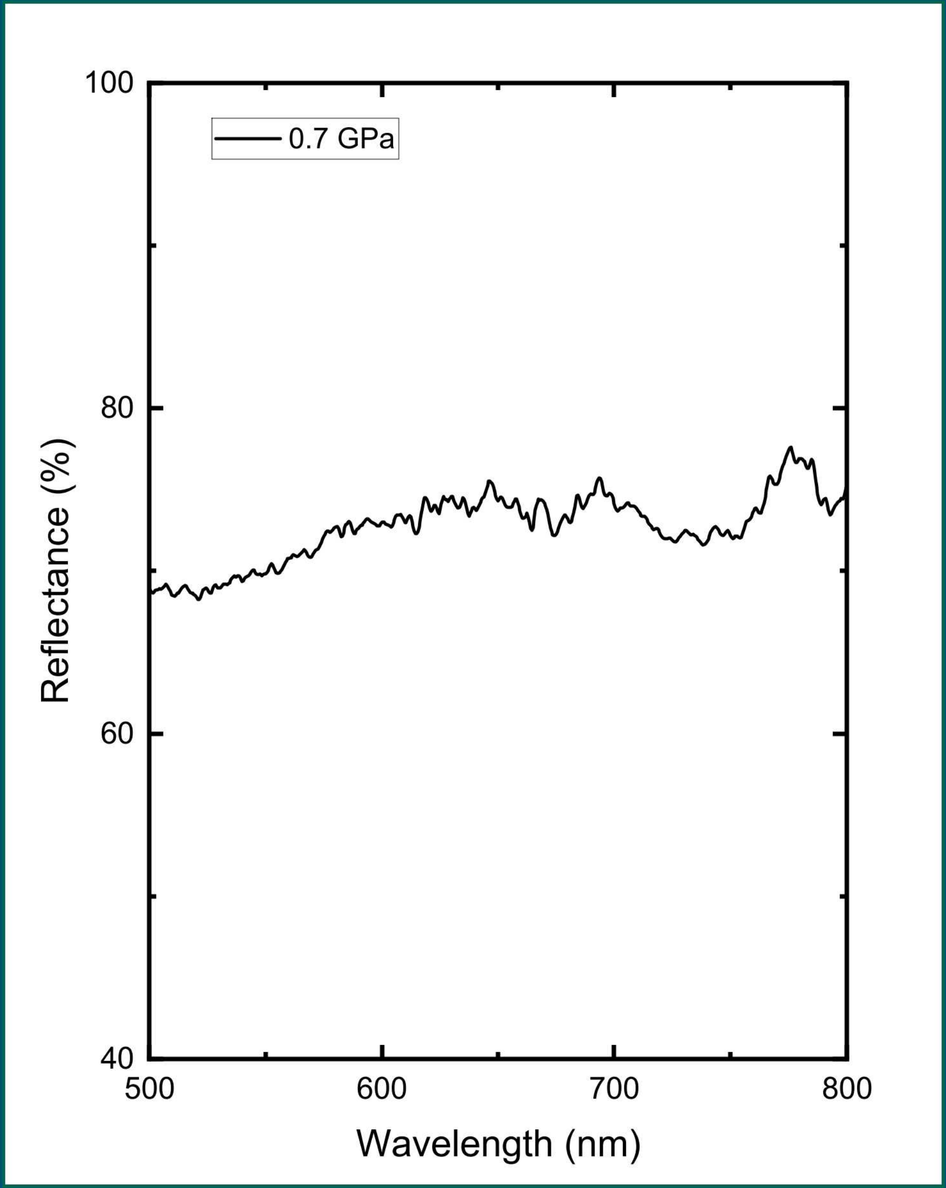
Aluminum Reflectance



Experimental Setup

- Left side measures shift in ruby fluorescence for pressure marker
- Right side measures shift in Aluminum absorption feature

Results – Room Temperature (25°C)



- Observed dip in reflectance at 732.6nm

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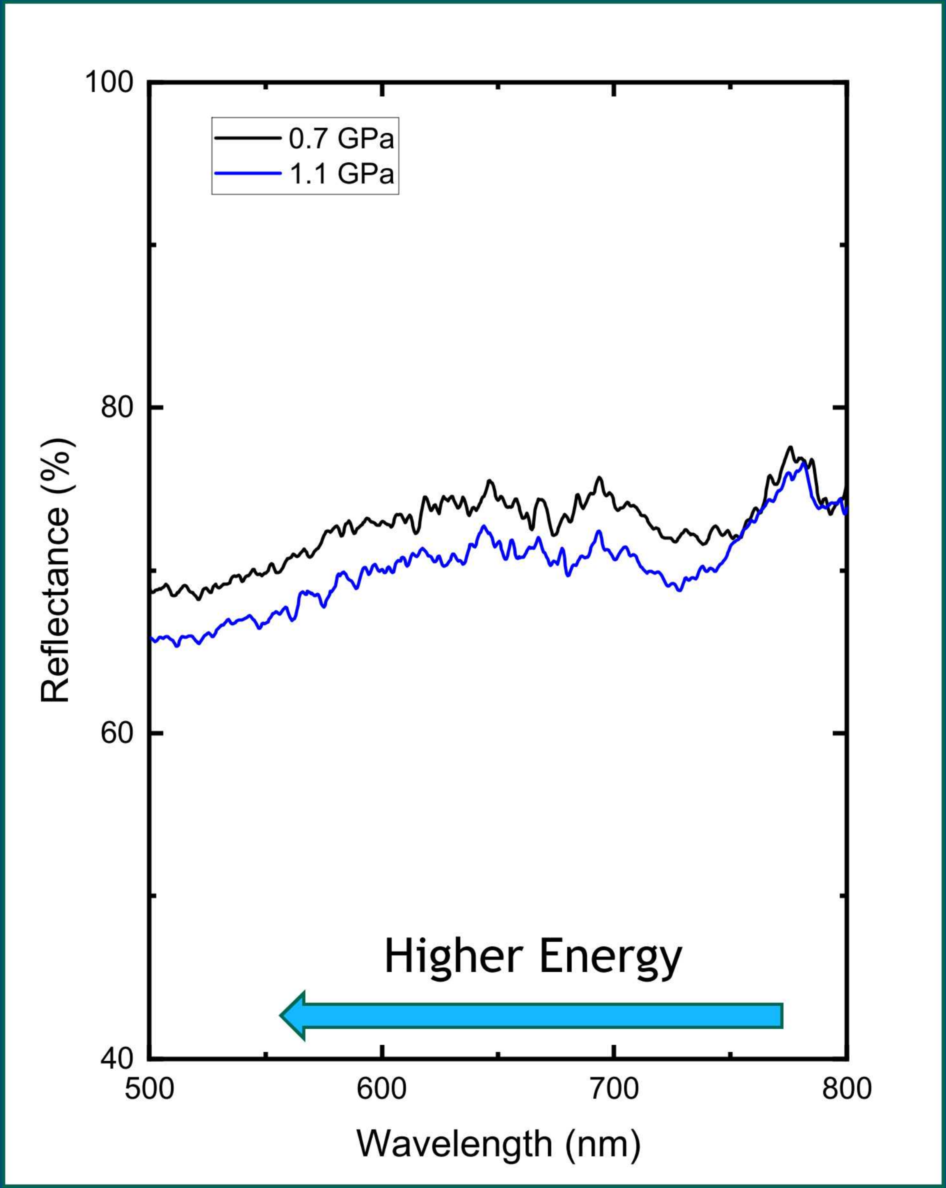

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- Increasing pressure begins to shift dip to higher energy

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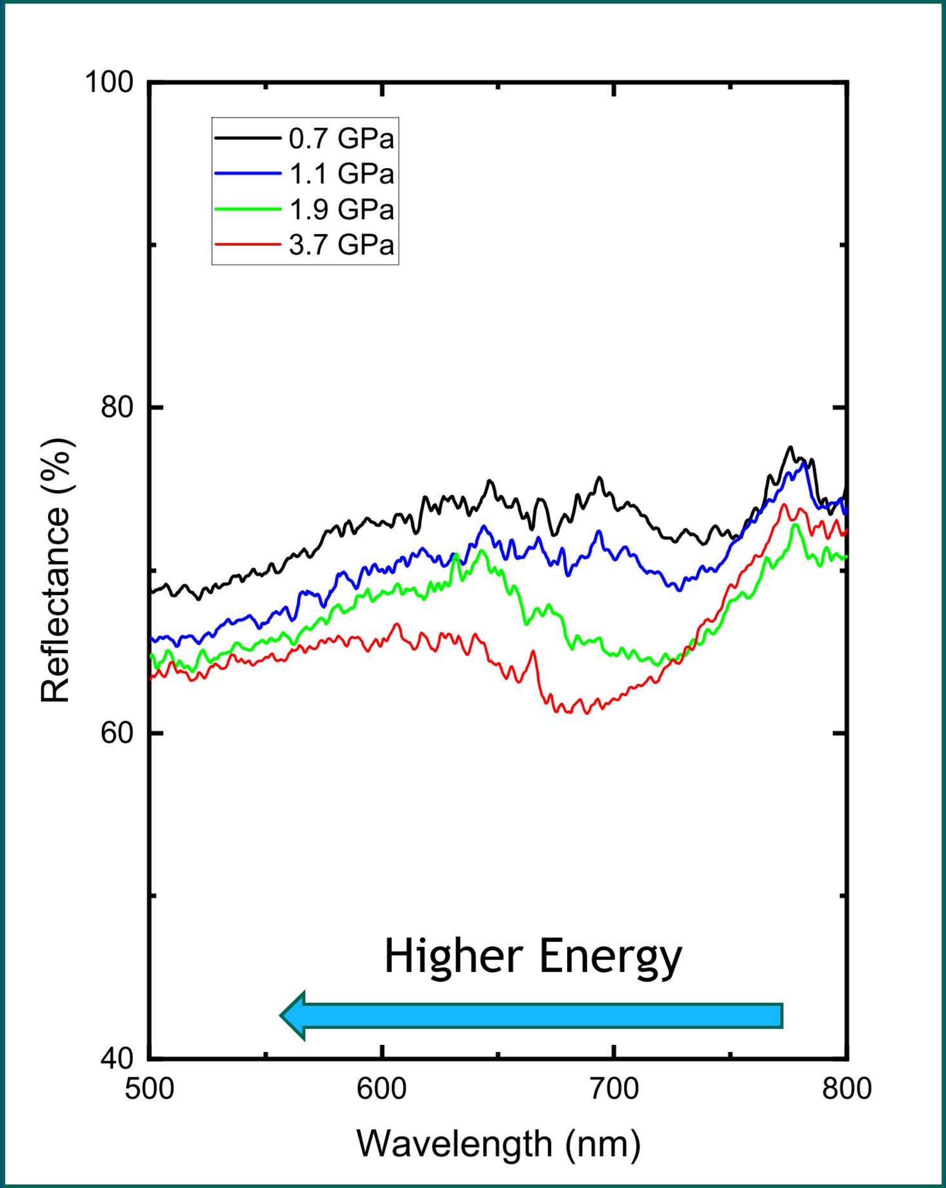

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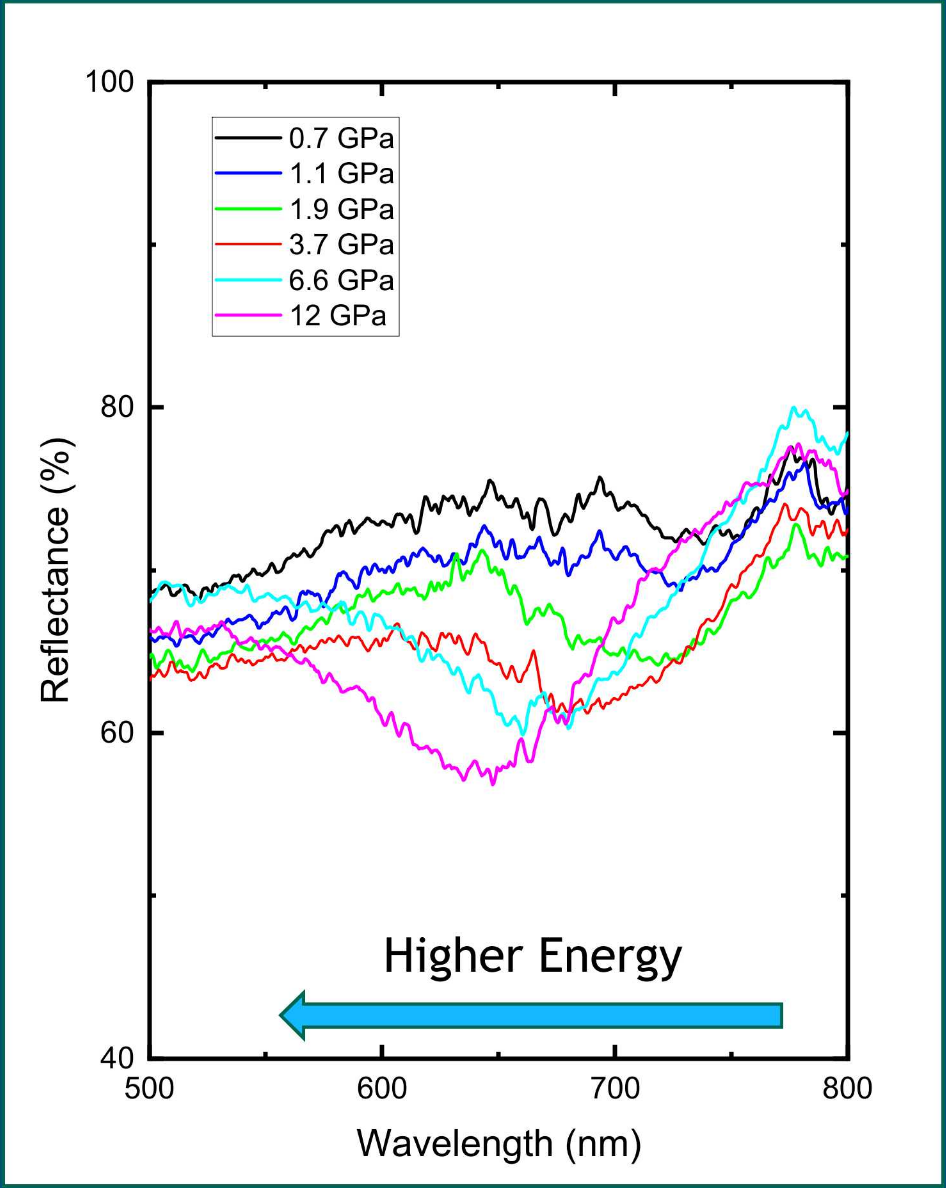

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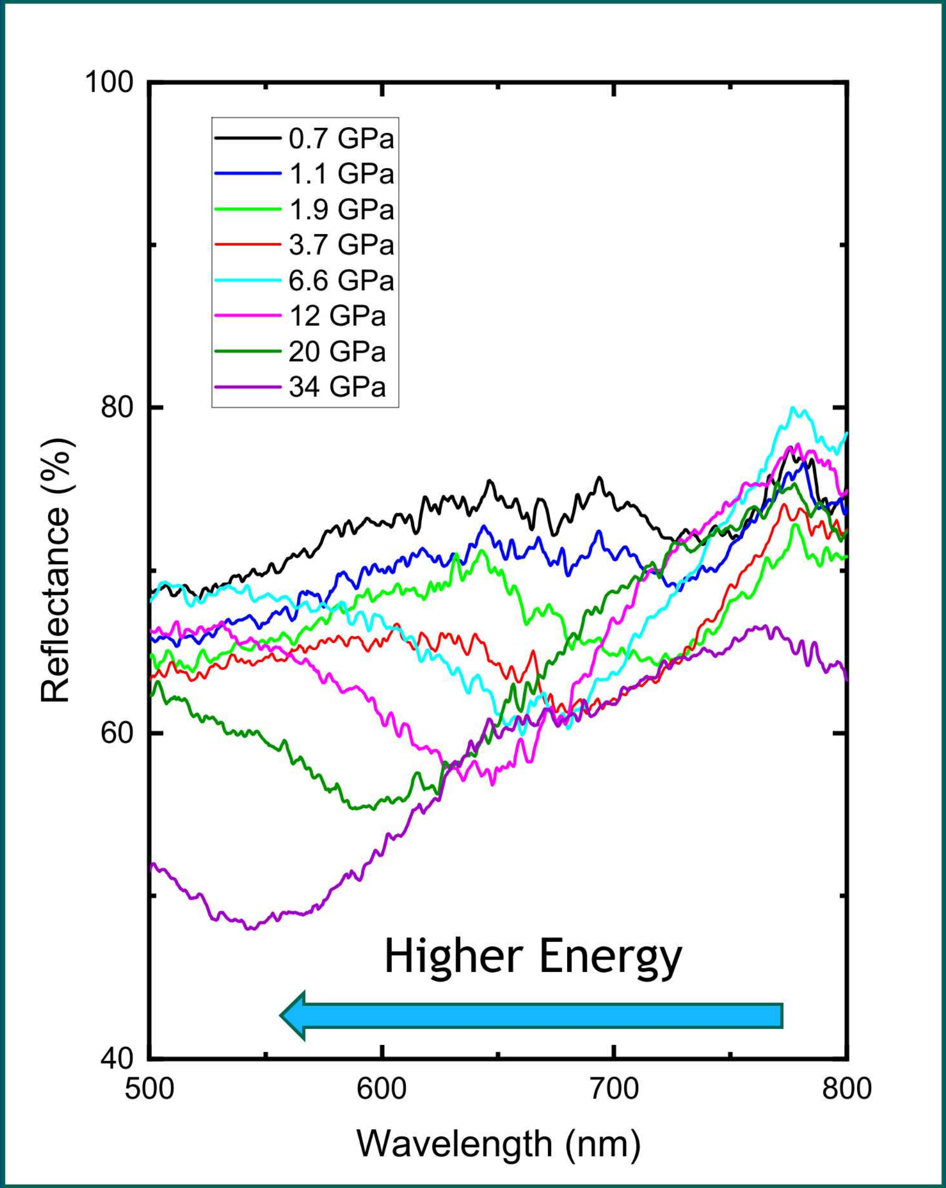
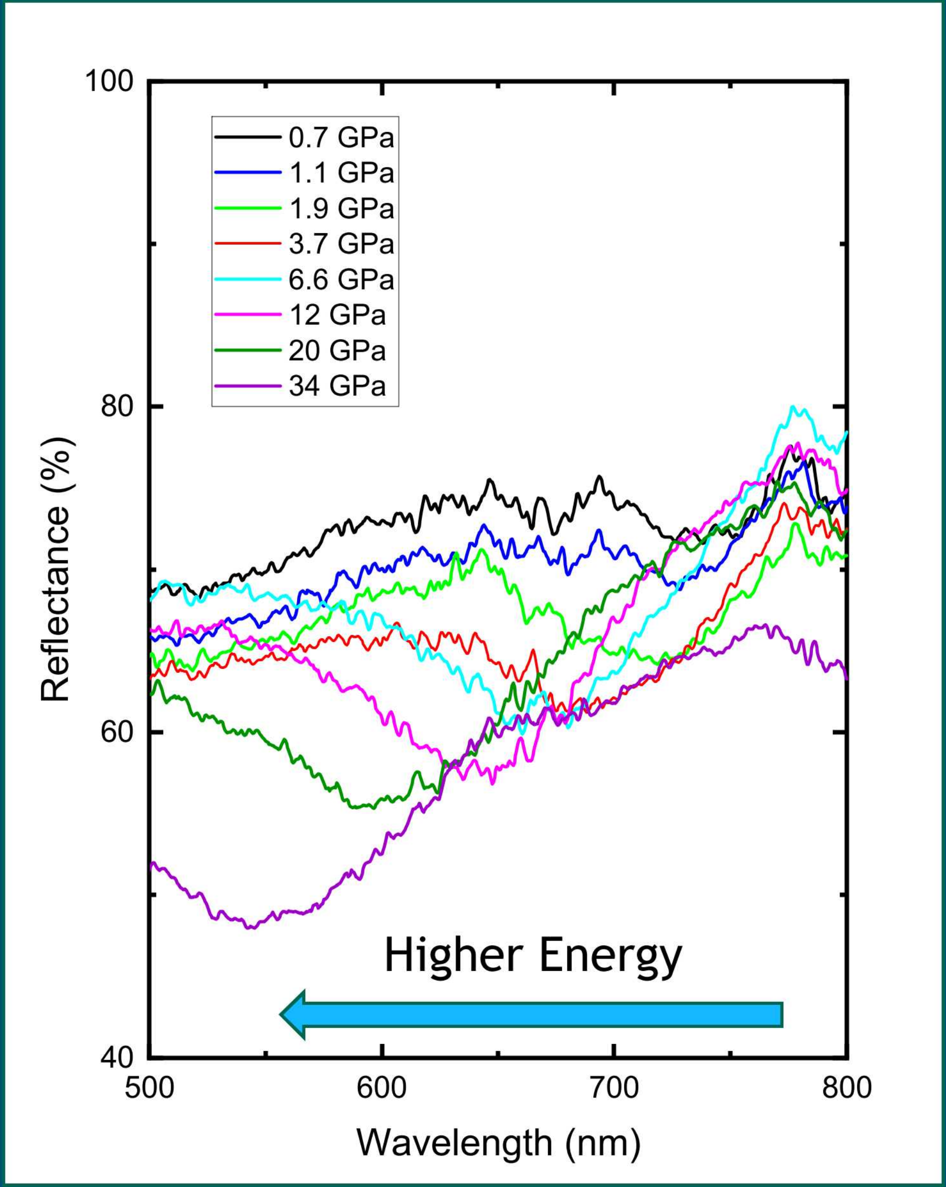
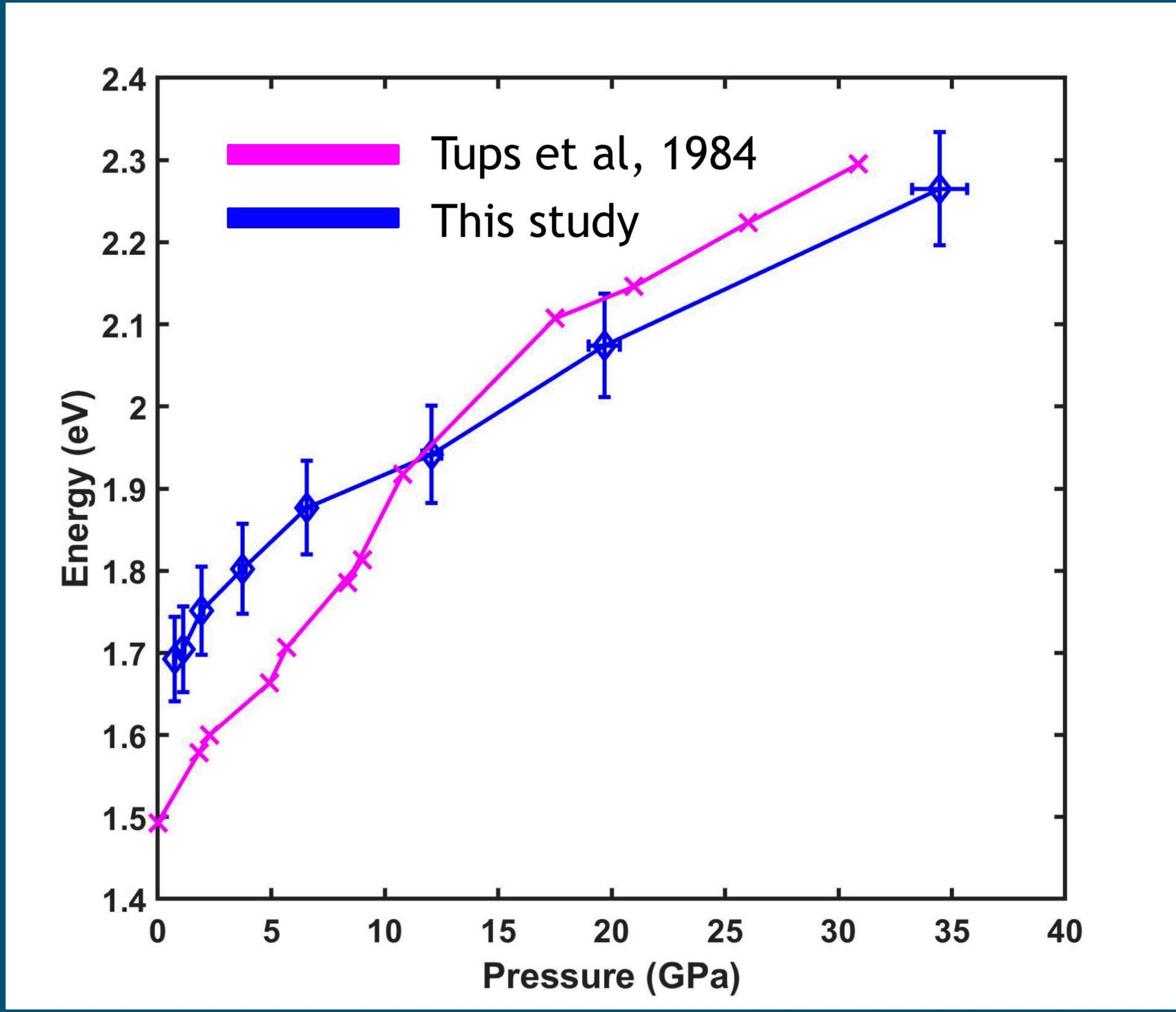


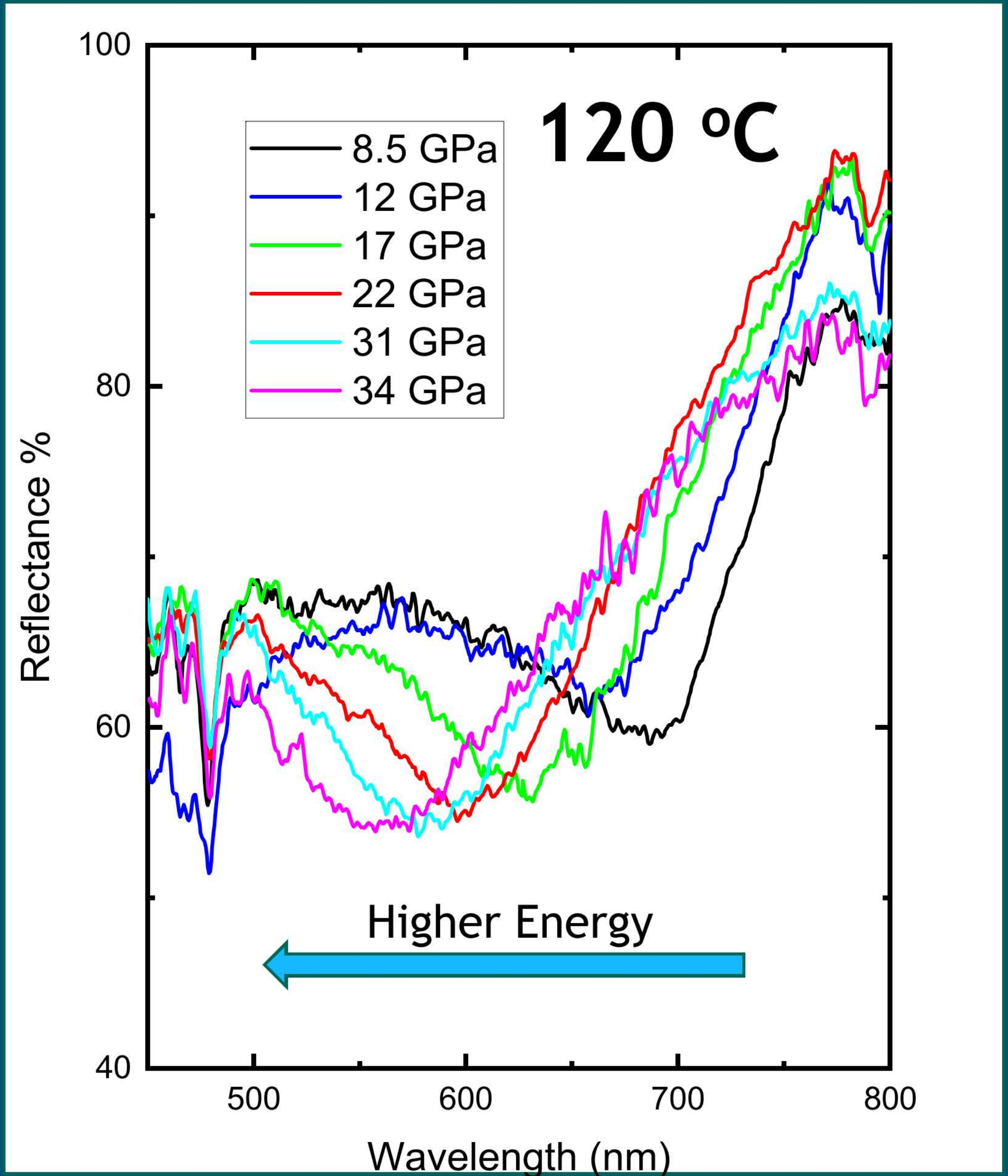
- Observed dip in reflectance at 732.6nm
- Increasing pressure begins to shift dip to higher energy
- Reflectance decreases as pressure increases
- Absorption well

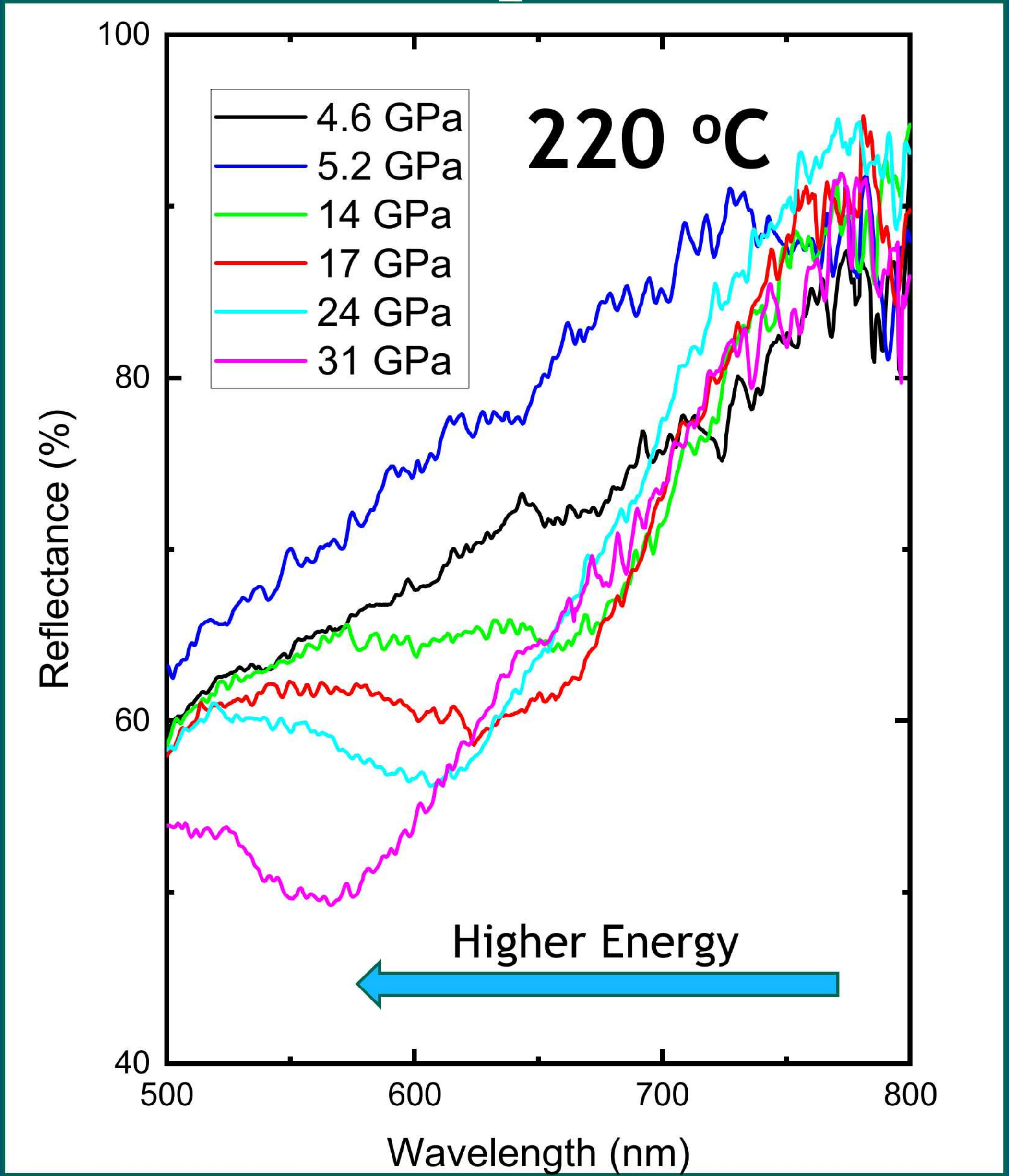
Results – Room Temperature (25°C)



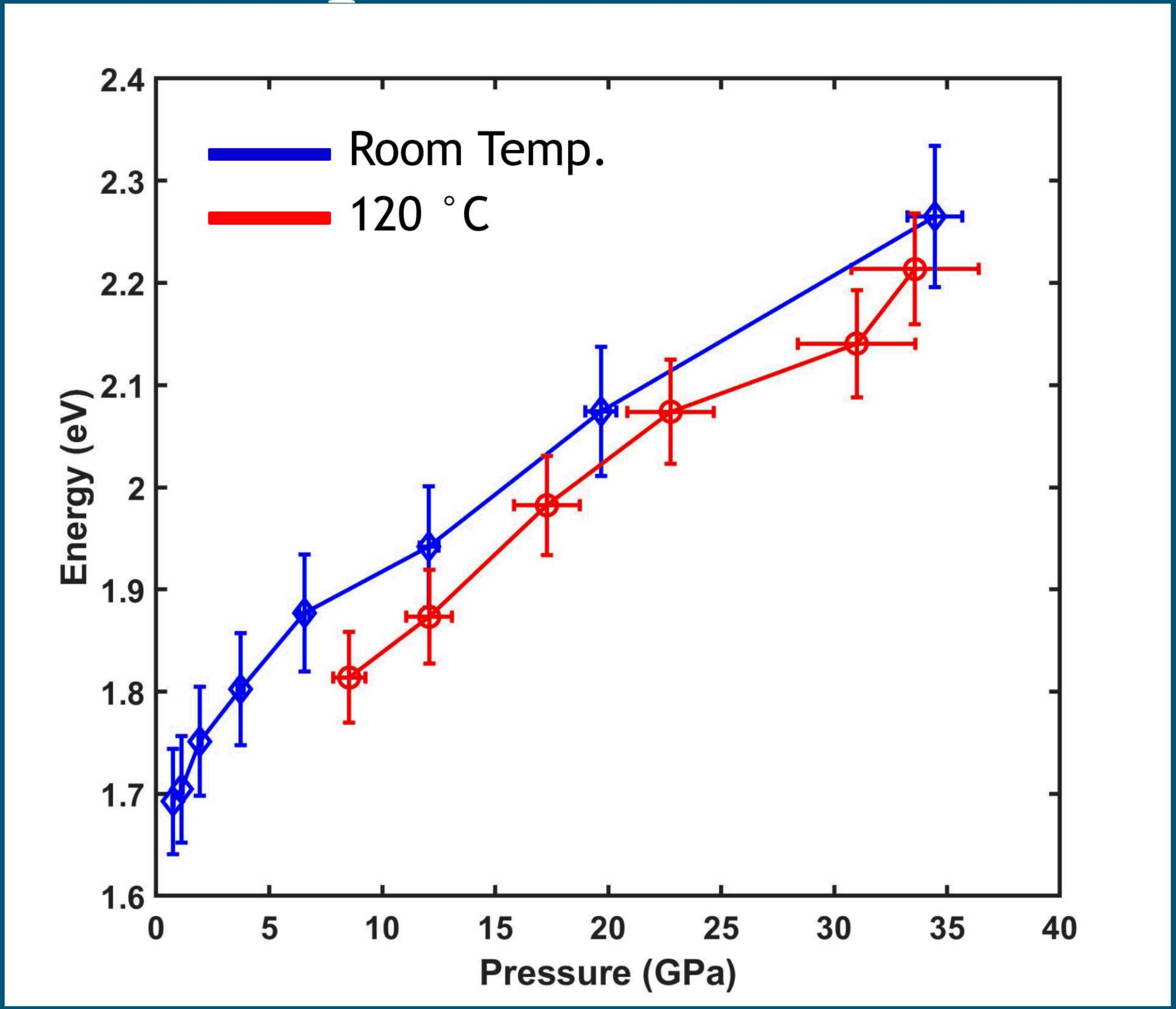


Reflectance Results at Different Temperatures



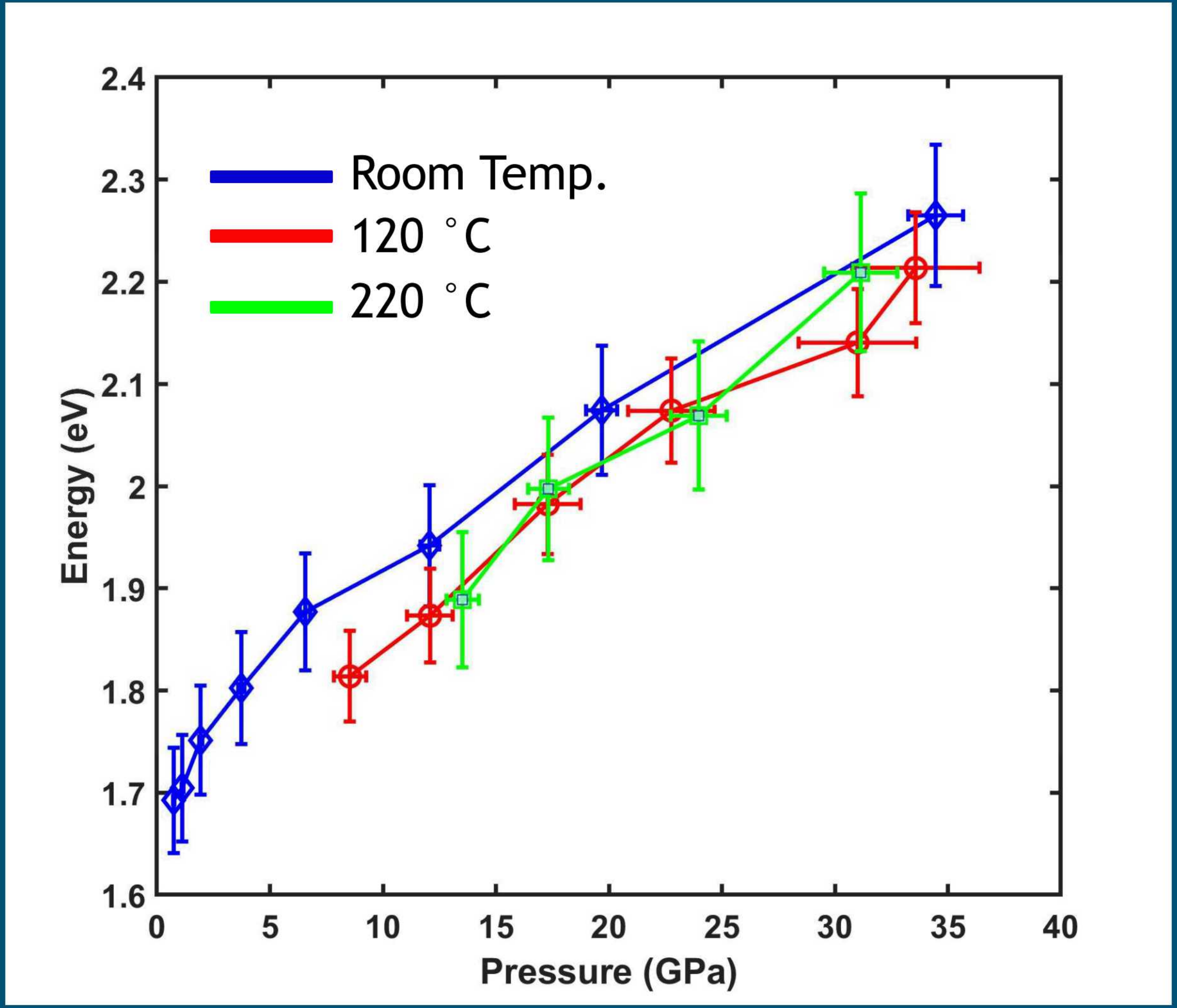


Relationship Between Energy, Pressure, and Temperature



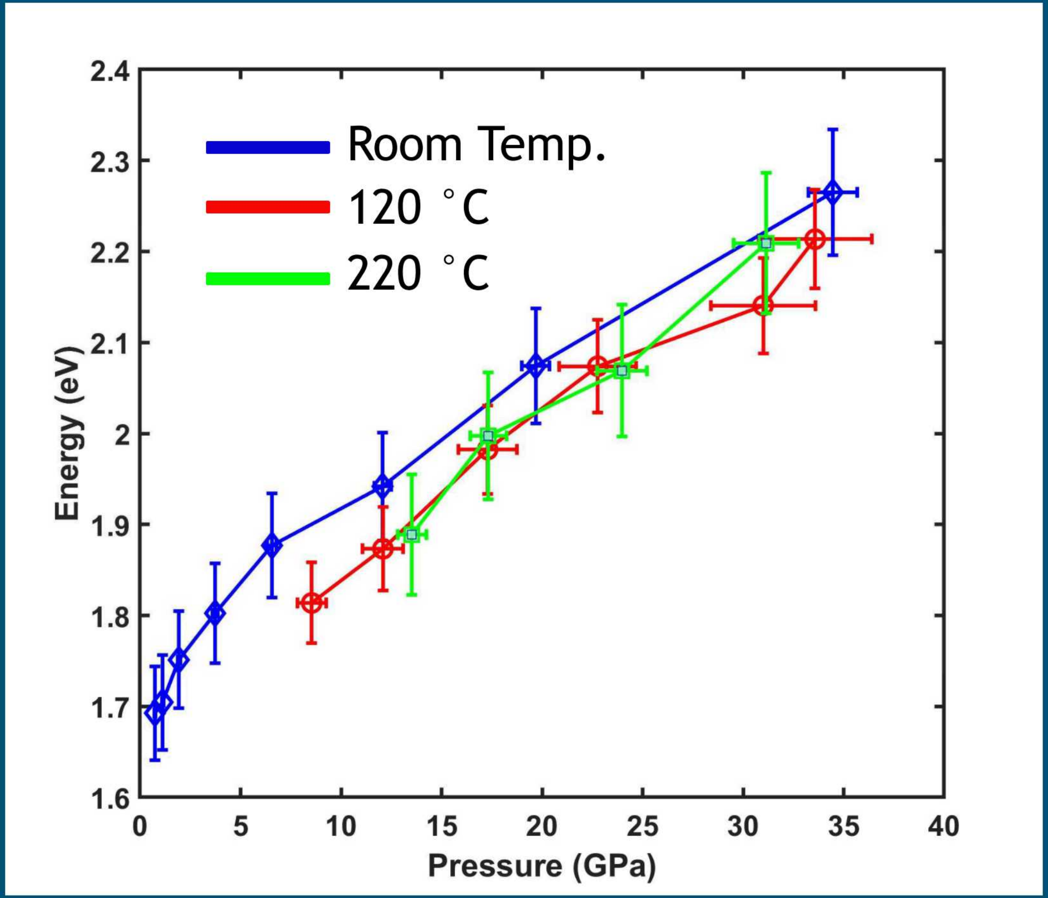
- Increasing sample temperature shows a decrease in absorption energy at any given pressure
- Clearly distinguishable trend between room temperature and 120 °C

Relationship Between Energy, Pressure, and Temperature



- Increasing sample temperature shows a decrease in absorption energy at any given pressure
- Clearly distinguishable trend between room temperature and 120 °C
- However, 220 °C measurements are not distinguishable; spectrometer limits and stronger temperature effect may be causes for ambiguity

Summary



- Absorption feature of Aluminum could lead to creation of an optical thermometer by calibrating temperature and pressure effects
- Results are promising: more calibration is needed for lower pressure (<20 GPa) and higher temperature (>300 °C)
- Means of simultaneous temperature-pressure calibration combined with reflectivity inside a DAC

Acknowledgements

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- Patricia Kalita, Chris Seagle, and Dan Dolan.
- Construction and alignment of DAC laser table was made possible with the help of Richard Hacking and the mechanic shop at DICE.