Light Storage and Thermal-Assisted-Switching of $SrAl_2O_4$:Eu,Dy

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Introduction

$SrAl_2O_4$:Eu^{2+}, Dy^{3+} crystals exhibit one of the most pronounced phosphorescence that is appealing for alternative lighting technologies that are independent, rechargeable, and energy efficient. The Strontium aluminate phosphor possesses advantages over sulfide-based phosphors such as ZnS:Cu, as its afterglow can be observed by the (dark-adapted) eye for 18-24 hours [1]. Efforts to improve its performance include the optimization of the synthesis method [1], understanding the phosphorescence mechanism, [2] and studying thermoluminescence effects [3] in this material. For technological applications, it is also important to be able to manipulate the emission intensities and decay rates, ideally so that the light emission can be switched on and off on-demand. In this work, we present the characterization of the phosphorescence decay rate at various temperatures from room temperature up to 120 °C and phenomenological studies of the optical charging/discharging effects from ~80 K up to ~670 K. Cyclic optical charging/discharging curves are obtained using custom-built automated systems. The data obtained was

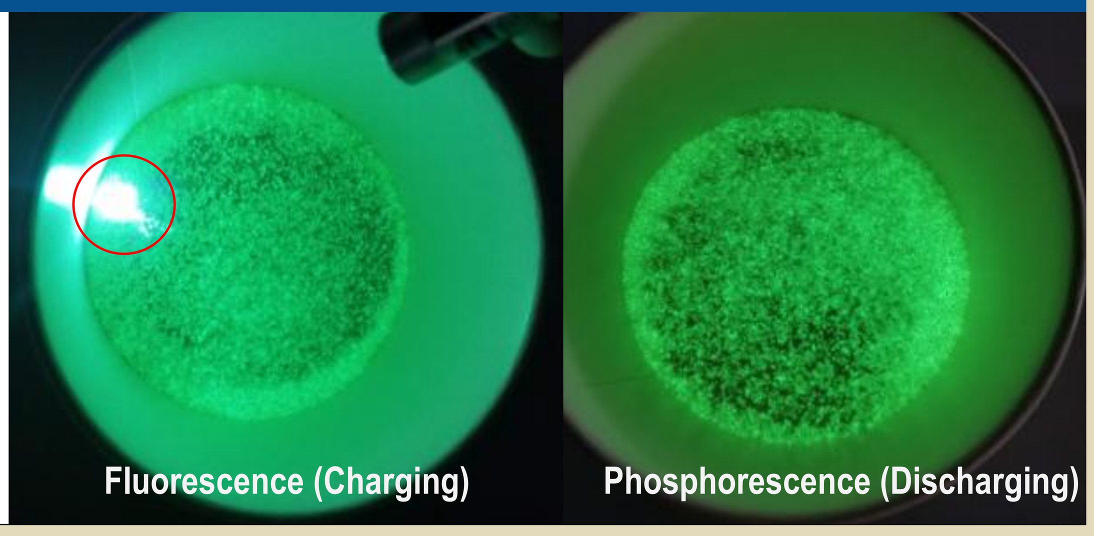
programmatically analyzed in Igor Pro to extract the time constants of the phosphorescence decay. The temperature dependent decay rates and interplay between fluorescence and phosphorescence are discussed. Finally, we demonstrate the ability for the strontium aluminate phosphor to act as a long-term light storage at low temperatures that can be activated at higher temperatures for on-demand lighting applications. Although this phosphor has potential for application, the observable emitting length decreases the smaller the particle size.

Phosphorescence – Fluorescence – Thermoluminescence

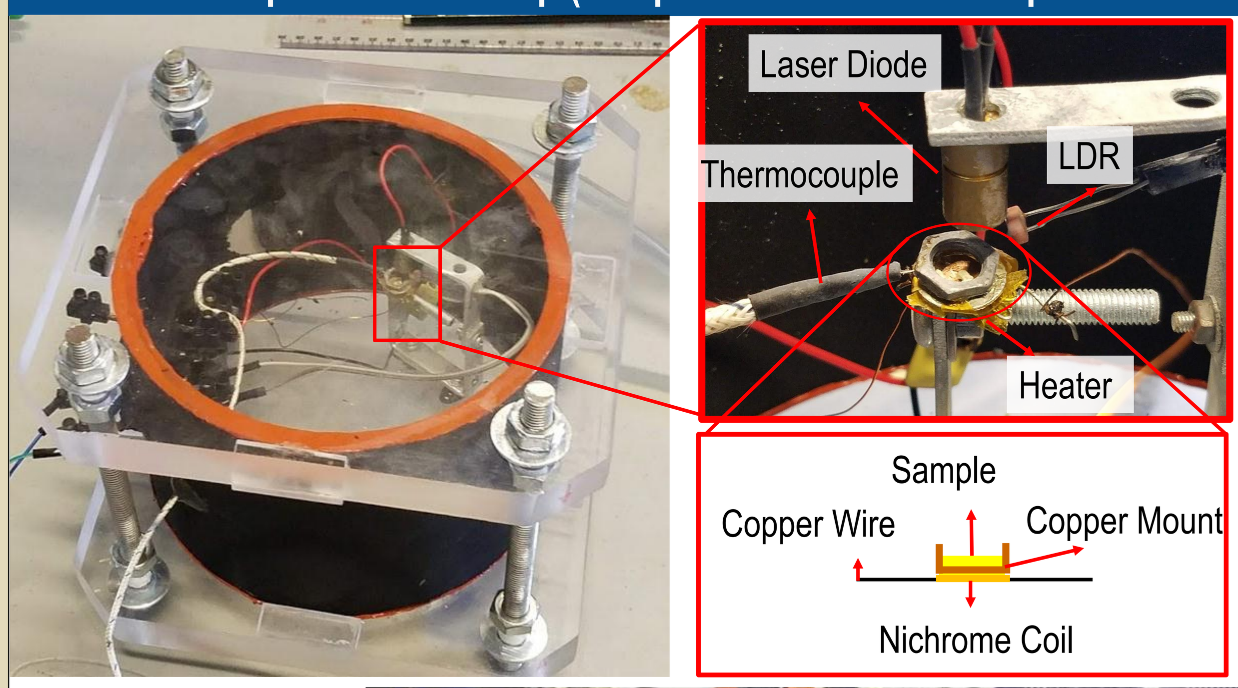
Phosphorescence: re-emission of absorbed light over a period of time.

Fluorescence: instant re-emission of light, changing the frequency or intensity of light.

Thermoluminescence: emission of stored energy through light, due to increase in temperature.

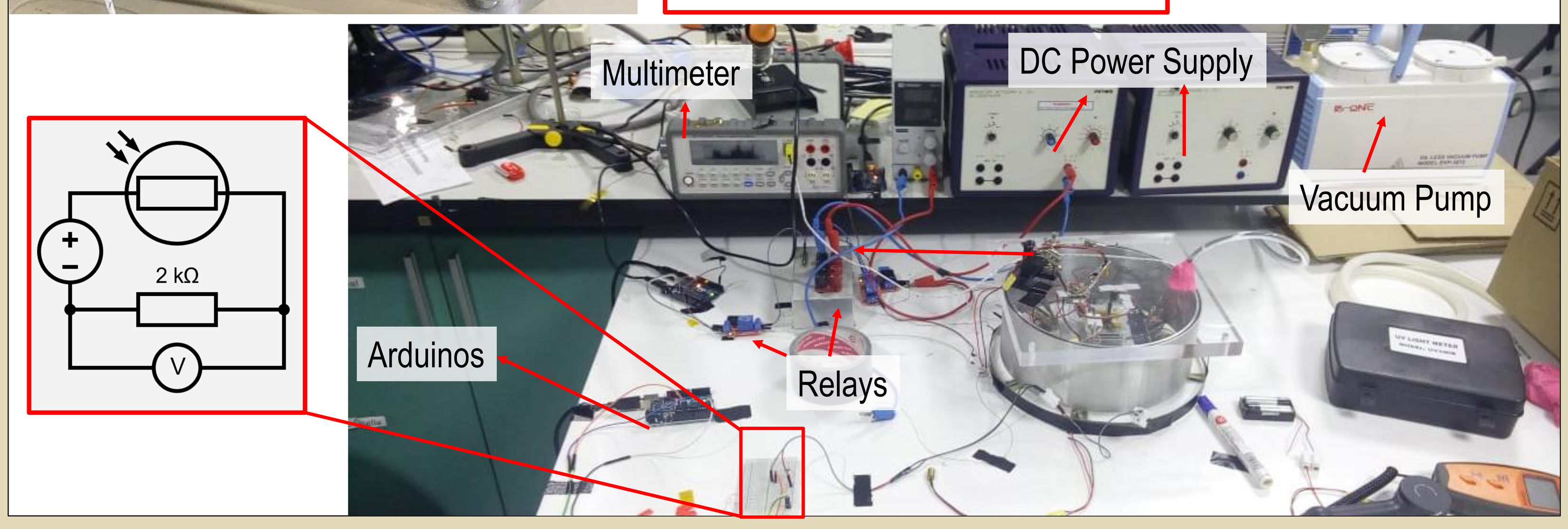


Experimental Setup (Temperature Controlled Optical Characterization)

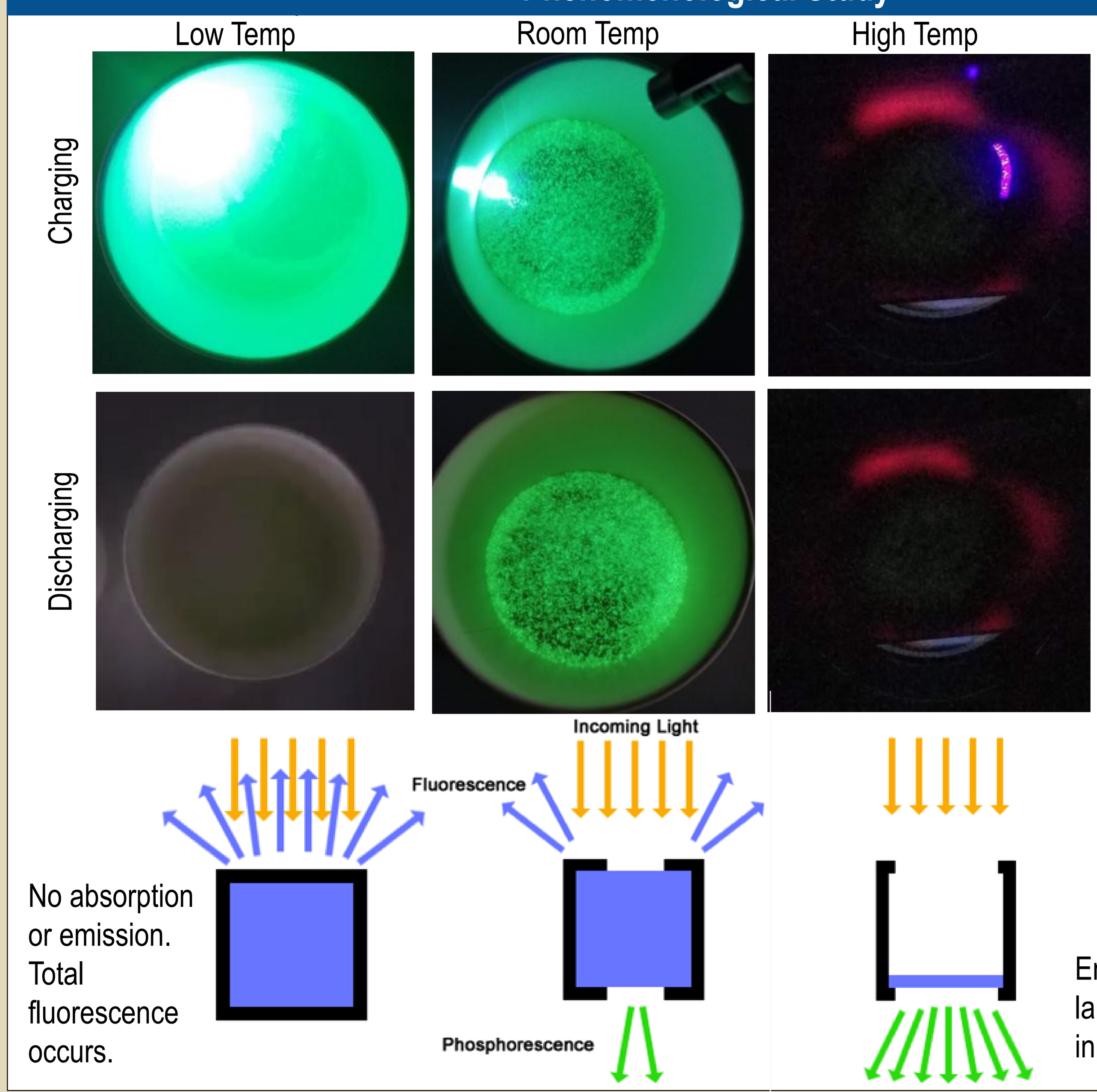


Capabilities:

- Vacuum Compatibility
- Light Intensity vs Time
- Light Intensity vs Temperature
- Automated Laser Excitation
- Temperature Stabilization



Phenomenological Study



At low temp:

- Charging cannot be done.
- Fluorescence is enhanced.
- No Phosphorescence.

At room temp:

- Charging can be done.
- Both fluorescence and phosphorescence are observed.

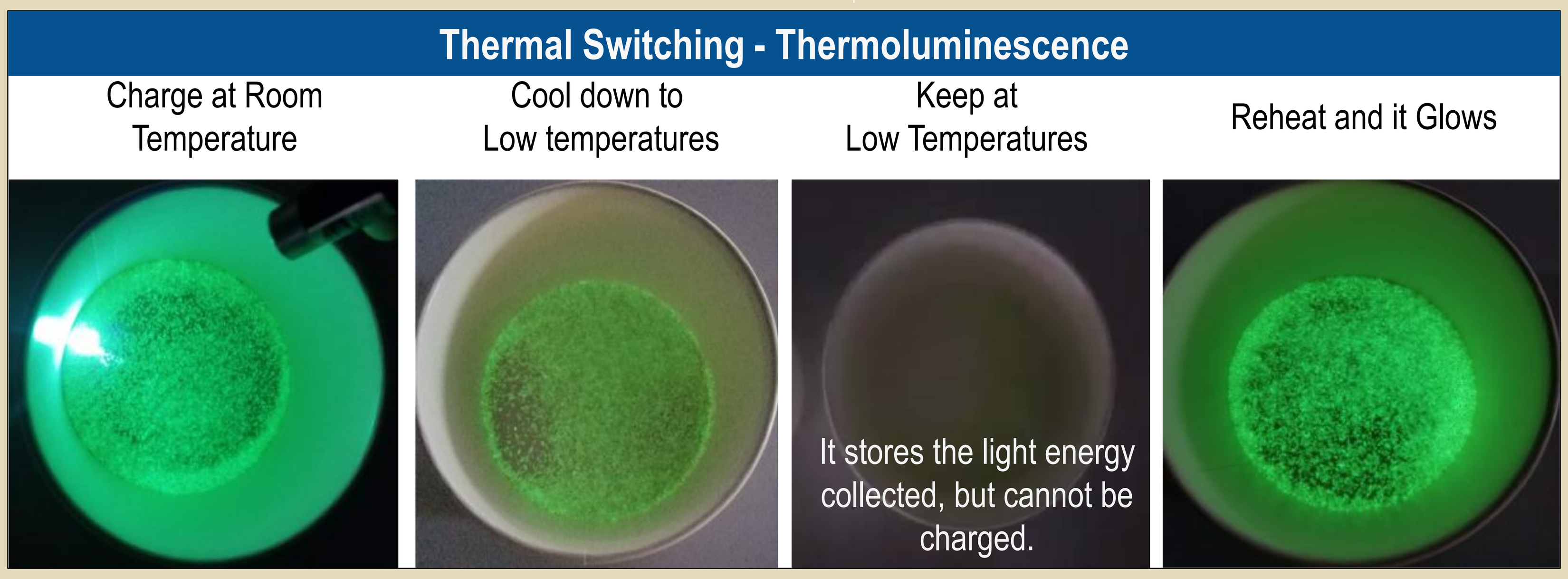
At high temp:

- Charging cannot be done.
- No fluorescence and phosphorescence observed.

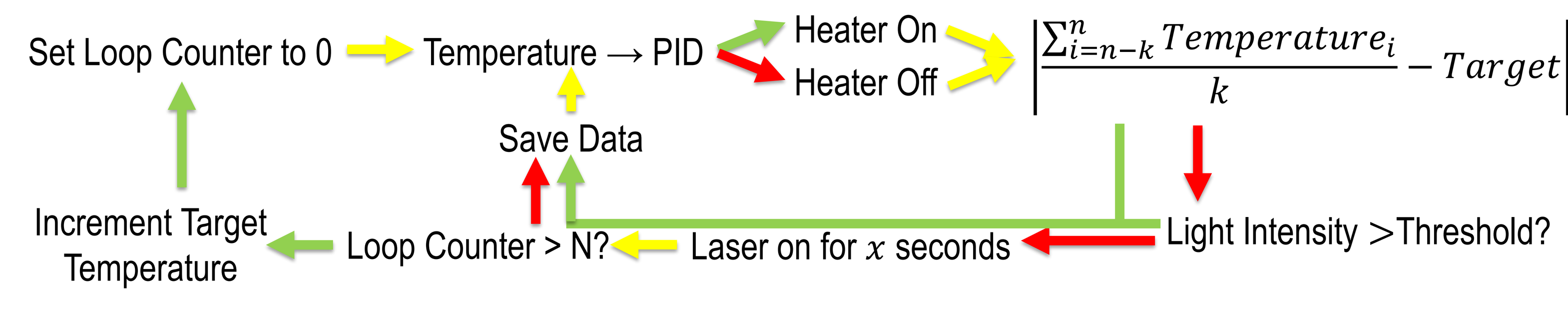
No absorption or emission. Total fluorescence occurs.

Energy drain is larger than energy input.

Thermal Switching - Thermoluminescence



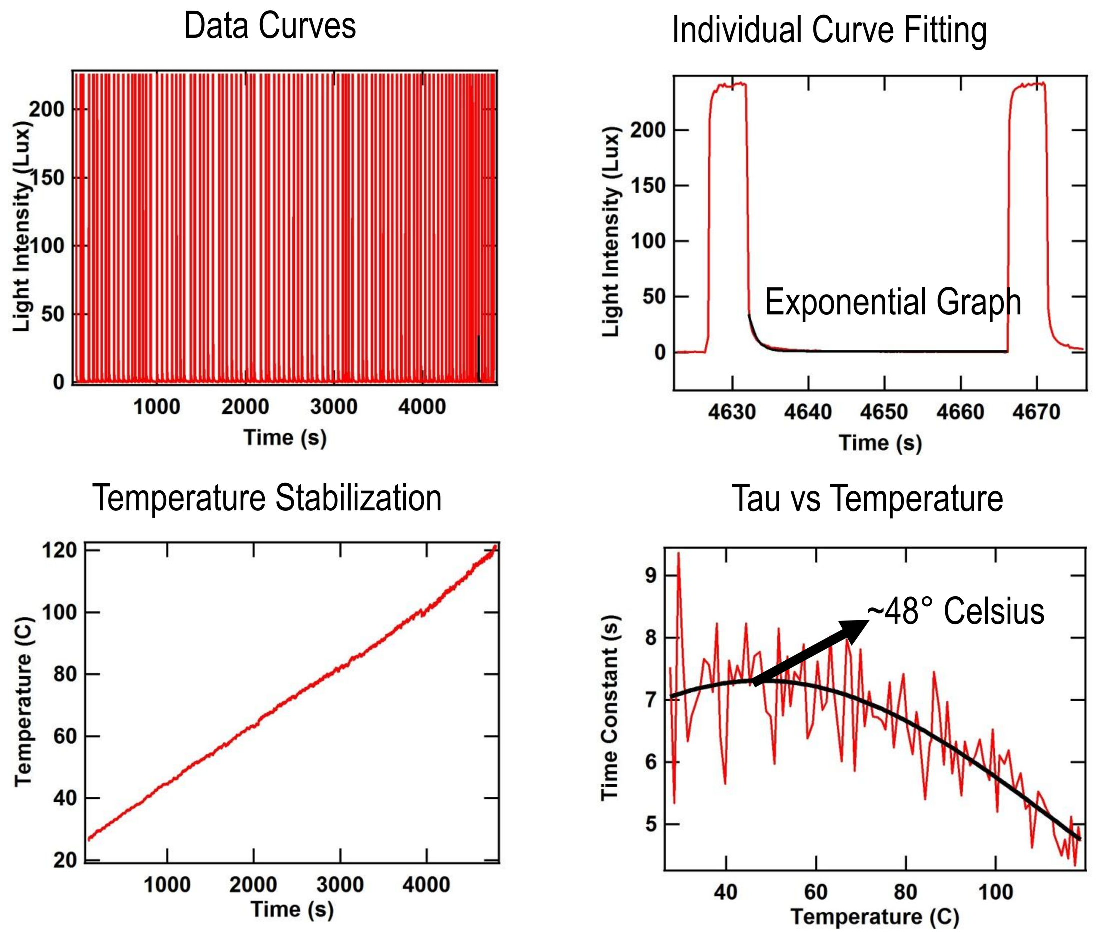
Control System and Data Acquisition via LabView



$$\left|\frac{\sum_{i=n-k}^{n} Temperature_i}{k} - Target\right| > Threshold?$$

Let n be number of datapoints
Let k be number of datapoints to consider for stabilization

Light Decay Time Constant vs Temperature

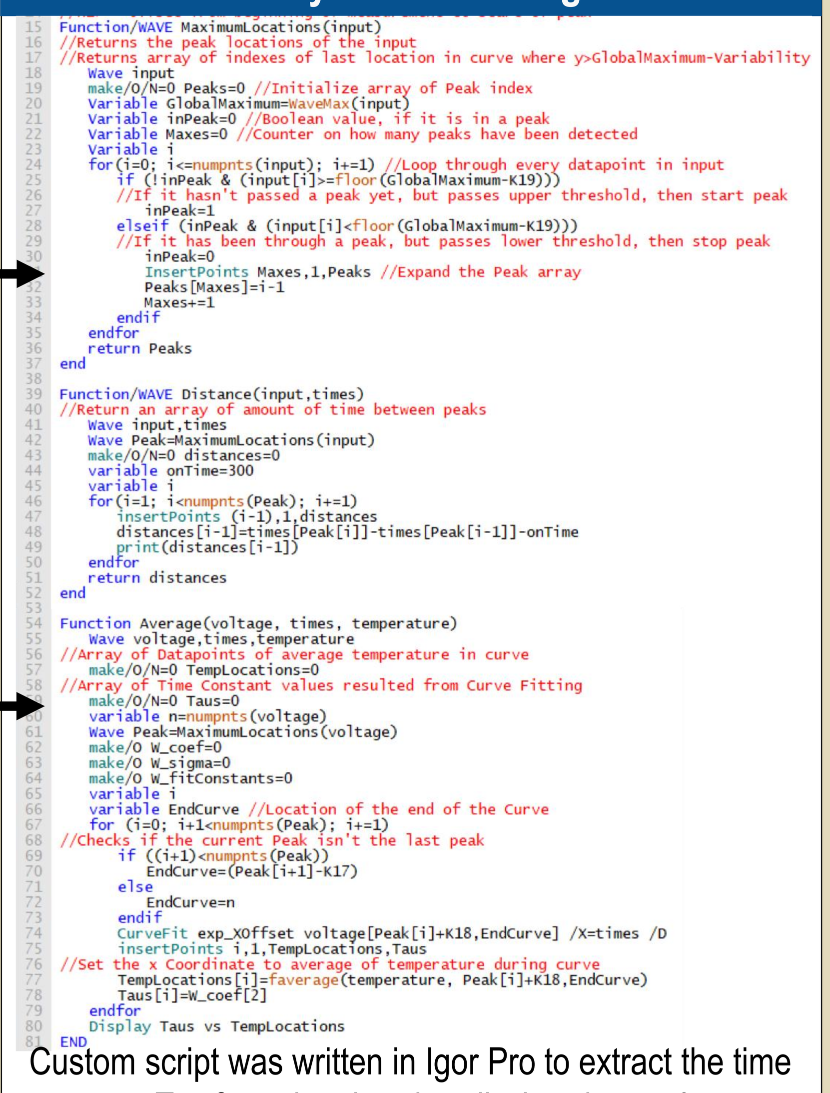


$$Lux = \frac{10^4}{\left(\left(\frac{10Vk\Omega}{V_{input}} - 2k\Omega\right)10^4\right)^{\frac{4}{3}}}$$

Exponential Graph:

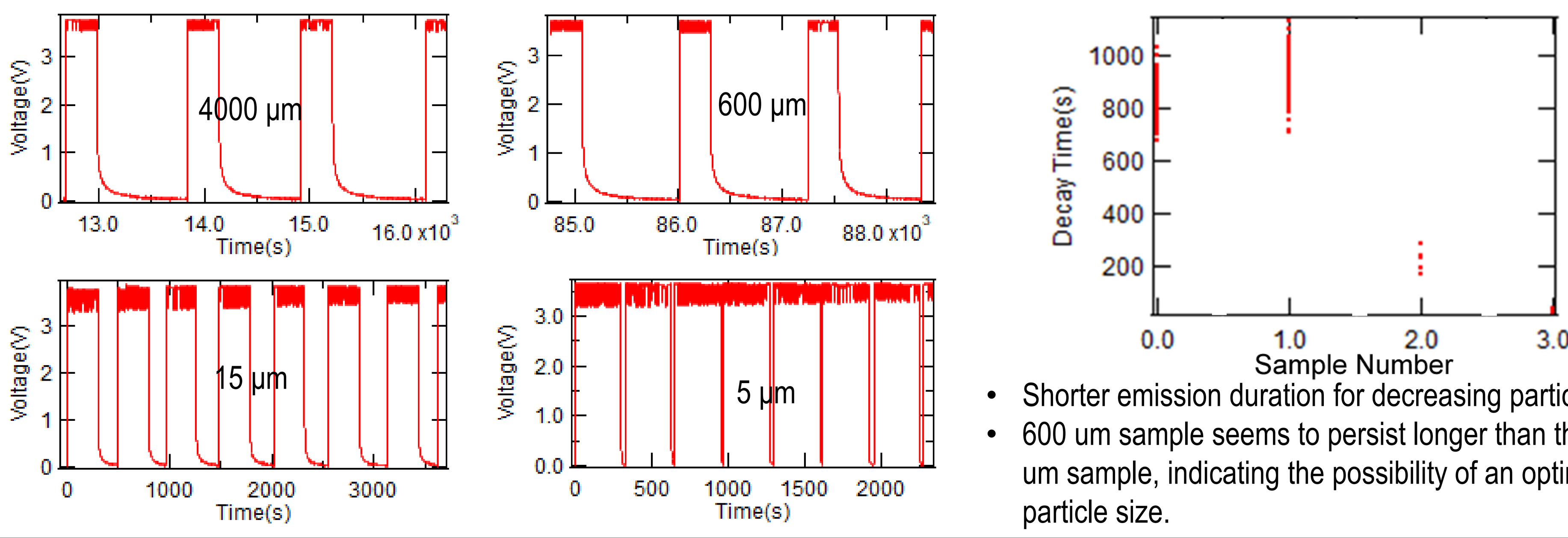
$$y = y_0 + Ae^{\frac{-(x-x_0)}{\tau}}$$

Data Analysis Code via IgorPro



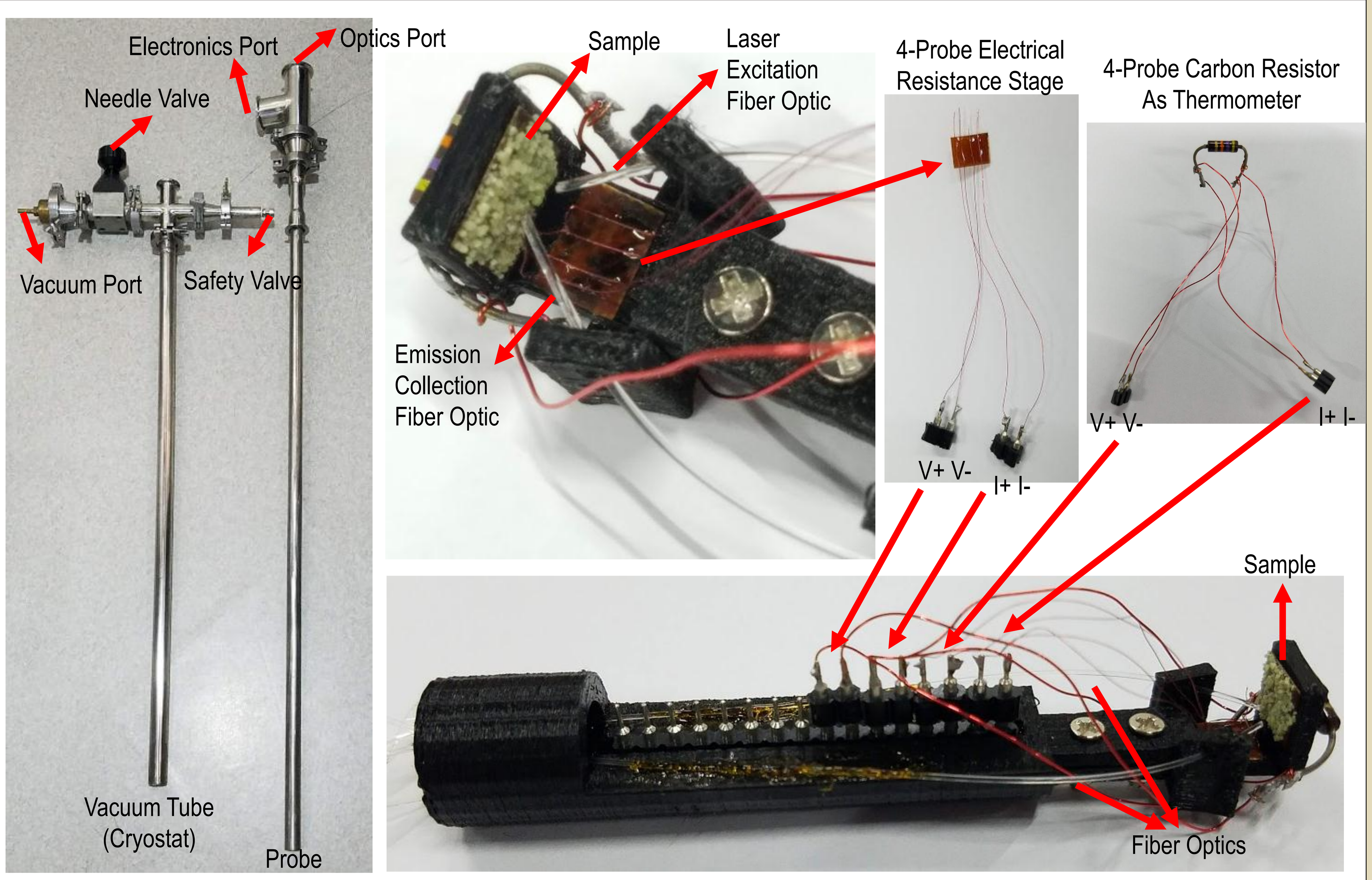
Custom script was written in Igor Pro to extract the time constant Tau from the charging-discharging cycles at various temperatures automatically.

Particle Size Dependent Emission Duration



- Shorter emission duration for decreasing particle size.
- 600 um sample seems to persist longer than the 4000 um sample, indicating the possibility of an optimal particle size.

Future Improvements: Cryogenics Compatible Optoelectrical Measurement Probe



Conclusion

This work demonstrates the basic mechanism of storing light energy in strontium aluminate phosphors in a long-term fashion by cooling it down to low temperatures. At such low temperatures, the phosphorescence effects are not observable rather, we see an enhancement in the fluorescence. Higher temperature accelerates the release of energy and at very high temperatures, both the fluorescence and phosphorescence are not observable. Charging of the crystal can only be done near the room temperatures. In particular, a peak in the light decay time constant at ~ 48 °C may correlate to an optimal temperature for light charging. Future works into the particle size dependence and their effects to the observed phenomena are underway. Experimental setup improvements using fiber optics, power meter, and monochromator down to cryogenics temperatures are also in progress.

References

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