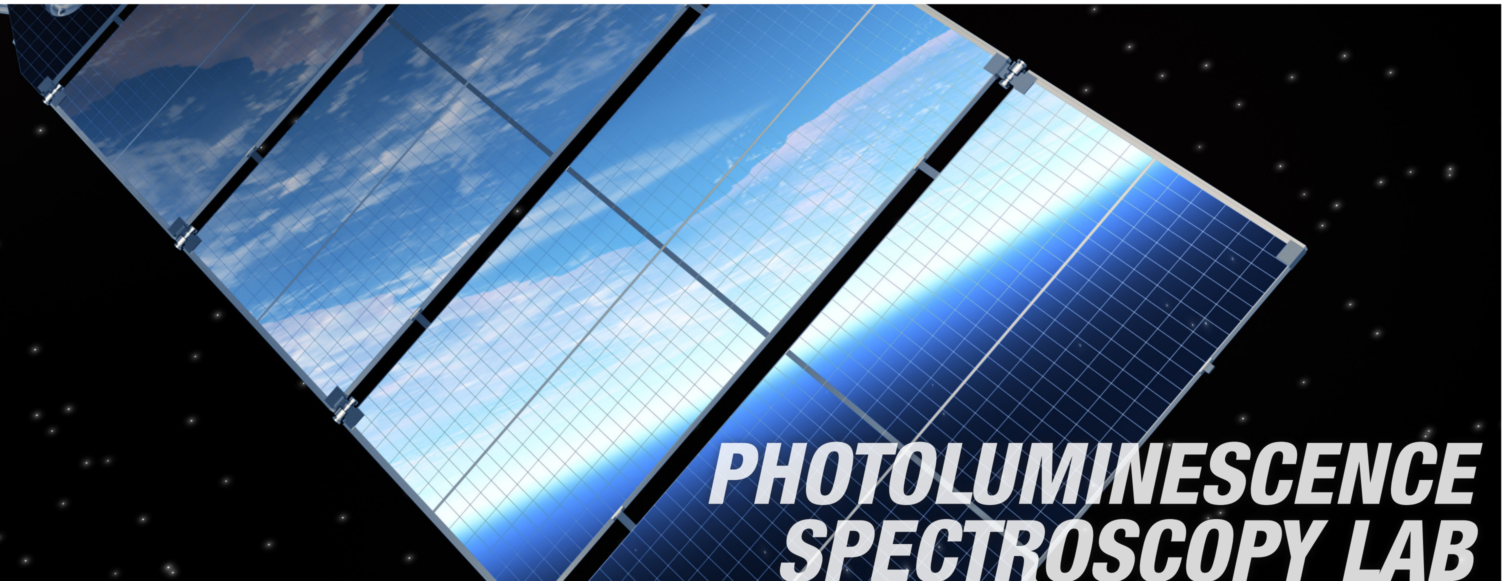
AEROSPACE

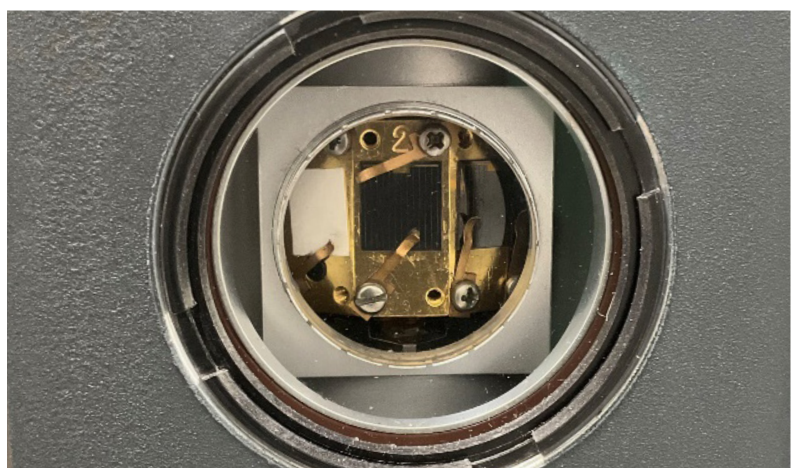


PHOTOLUMINESCENCE SPECTROSCOPY LAB

Spectroscopic Materials Diagnostics

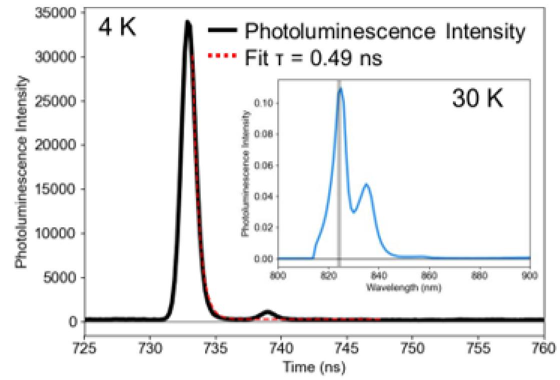
The reliability of semiconductor optoelectronic devices, such as photovoltaics, detectors, and emitters, is critical to the space enterprise. Factors such as application environment (including space radiation environment and temperature variation), manufacturing processes, and material structure affect semiconductor device performance by altering the physical behavior of charge carriers in the semiconducting material. As next-generation materials and devices are developed rapidly, nondestructive techniques for evaluating their performance in appropriate physical regimes become increasingly necessary.

Aerospace's Photonics Technology Department has developed and utilized a photoluminescence spectroscopy laboratory with a suite of experimental techniques, including time- and energy-resolved photoluminescence spectroscopies, to characterize semiconductor material and device performance. Time-resolved photoluminescence (TRPL) and steady-state photoluminescence (SSPL) respectively provide time- and energy-resolved information about radiative recombination of carriers in semiconductor materials. These parameters can be used to provide quantitative and qualitative information about the material's performance and demonstrate the presence and effects of material defects on device performance. These spectroscopies can be used on a wide variety of materials and devices to understand device failure mechanisms, quantify how specific defects are formed and how they affect device performance, and provide information to educate theoretical models with physics-based values for carrier recombination lifetimes.



A single-junction GaAs solar cell mounted in one of two variable temperature cryostats.

Aerospace's excitation sources include two tunable ultrafast (femtosecond) lasers with excitation wavelengths ranging from 700 to 900 nm and detection capabilities ranging from UV wavelengths to 1700 nm. TRPL can be performed using analog detection or via time-correlated single-photon counting (TCSPC) with a time resolution of roughly one nanosecond. Aerospace utilizes two closed-cycle cryostats with feedthroughs for electrical and thermal components to control and monitor test article temperatures ranging from 4 K to 350 K, allowing for spectroscopic investigation at a wide range of temperature values. Sample size for either devices or bulk material may range from 0.5 cm × 0.5 cm to up to 7.5 cm × 19.6 cm, and positioning stages allow for spectroscopic probing in multiple sample locations. In addition to standard TRPL and SSPL, a custom software program allows for automated acquisition of combined time- and energy-dependent data that simulates a “streak camera” and provides spectra demonstrating differences in emission intensity and lifetime as a function of energy. Researchers in the Photonics Technology Department will continue using these testbeds to characterize photovoltaics, bulk semiconductor materials, and other semiconductor devices and materials of interest to our government customers.



TRPL transient and carrier recombination lifetime acquired for non-irradiated GaAs single-junction solar cell. Inset: SSPL spectrum of a non-irradiated GaAs single-junction solar cell.

Photoluminescence Spectroscopy Techniques

Technique	Excitation	Detection	Time Resolution	Sample Size	Sample Temperature	Basic Information
Grating spectrometer steady state photoluminescence (SSPL)	CW lasers (800 nm, 1480 nm), pulsed fs laser, tunable (pseudo-steady state or CW operation, 785 to 900 nm)	300 to 1700nm NIR enhanced photomultiplier	Not applicable	Up to 7.5 cm × 19.6 cm	4 K to 350 K	• Provides energy-resolved information about band edge and defect recombination in semiconductor materials
Time-resolved photoluminescence (TRPL) via time correlated single photon counting (TCSPC)	Pulsed fs laser, tunable (785 to 900 nm)	300 to 1700nm NIR enhanced photomultiplier	1 ns	Up to 7.5 cm × 19.6 cm	4 K to 350 K	• Provides time-resolved information about carrier recombination in semiconductor materials • Determines carrier lifetimes • High sensitivity; Can access very low injection regime

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