# Development of a PL Emission Spectrometer

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## Introduction

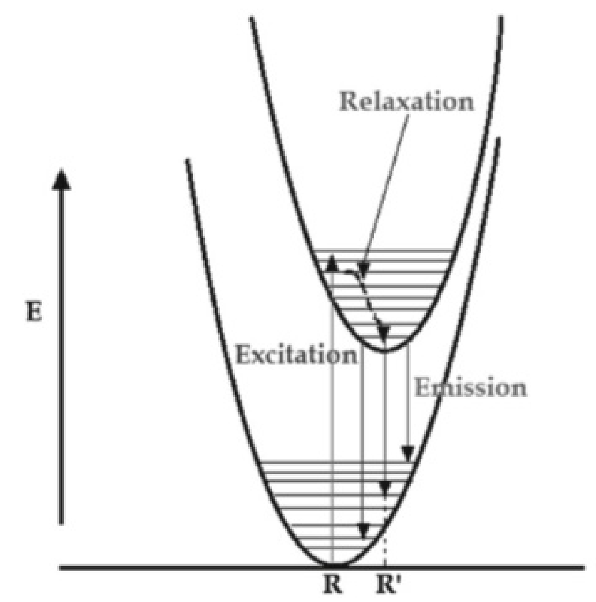



Figure 1

### Photoluminscence

Photoluminescence (PL) is the process by which materials will absorb a photon, exciting an electron to a higher-energy excited state, then emit a photon as the electron relaxes back to a lower-energy state. Measuring PL in various different ways is a common method for characterizing materials, especially semiconductors.

Basic PL measurements are emission and excitation, and differ only by their independent variables. Emission measurements use one wavelength to excite the material, and measure the intensity of light emitted across a spectrum. Excitation measurements use many wavelengths to excite the material, and measure the intensity of light emitted at a particular wavelength. This project is centered around PL emission measurements.

### Motivation

The Micro-Femto Energetics (ufE) Lab has a system capable of measuring both PL emission and excitation of materials. While the system has a diverse set of uses and is scientifically valuable to have, it has certain drawbacks that make it challenging to use.

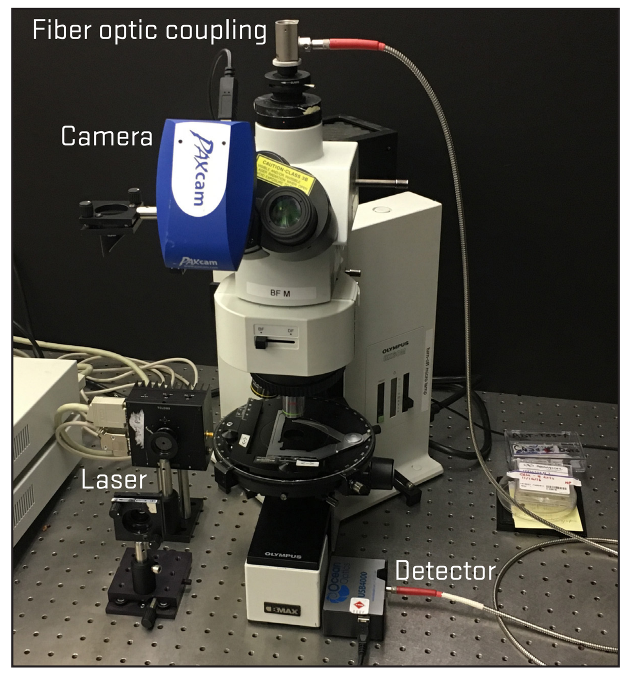
Researchers taking measurements with this system have to invest up to 90 minutes of time into starting-up and shutting-down the system, which makes cursory measurement of samples impractical. Because the system has a wide variety of uses, optical equipment often has to be reconfigured around it. The system uses a xenon-arc lamp and monochromator as its light source, leading to wide-field illumination on samples. This is significant for crystalline structures and nanomaterials, which often require illumination of a single molecular domain.

This project aimed to resolve these issues by designing a system that could measure PL emission of samples accurately, quickly, and with the potential for single-domain illumination.

## Design

### Microscope

This system is built around an Olympus BX60M metallurgical microscope with linear sample stage, filter cube attachment, and trinoculars. The microscope has a built-in white lamp which is useful for general illumination of samples when identifying a domain to excite.




### Laser Illumination

This design uses a laser light source to achive single-domain illumination. A diode laser system from ThorLabs was coupled into a side port of the microscope, and directed toward the sample using a filter cube with dichroic mirror.

### Filters

The filter cube fits inside the microscope at the intersection of the laser beam and light reflected from the sample. It can hold as many as two filters, and one mirror mounted at 45 degrees.

The filter cube is critical because it directs the laser beam onto the sample, and separates light emitted by the sample from light reflected off of the sample. A mirror and emission filter that block the wavelength of the laser beam must be chosen to prevent illumination from reaching detectors, and allow through only emitted light.

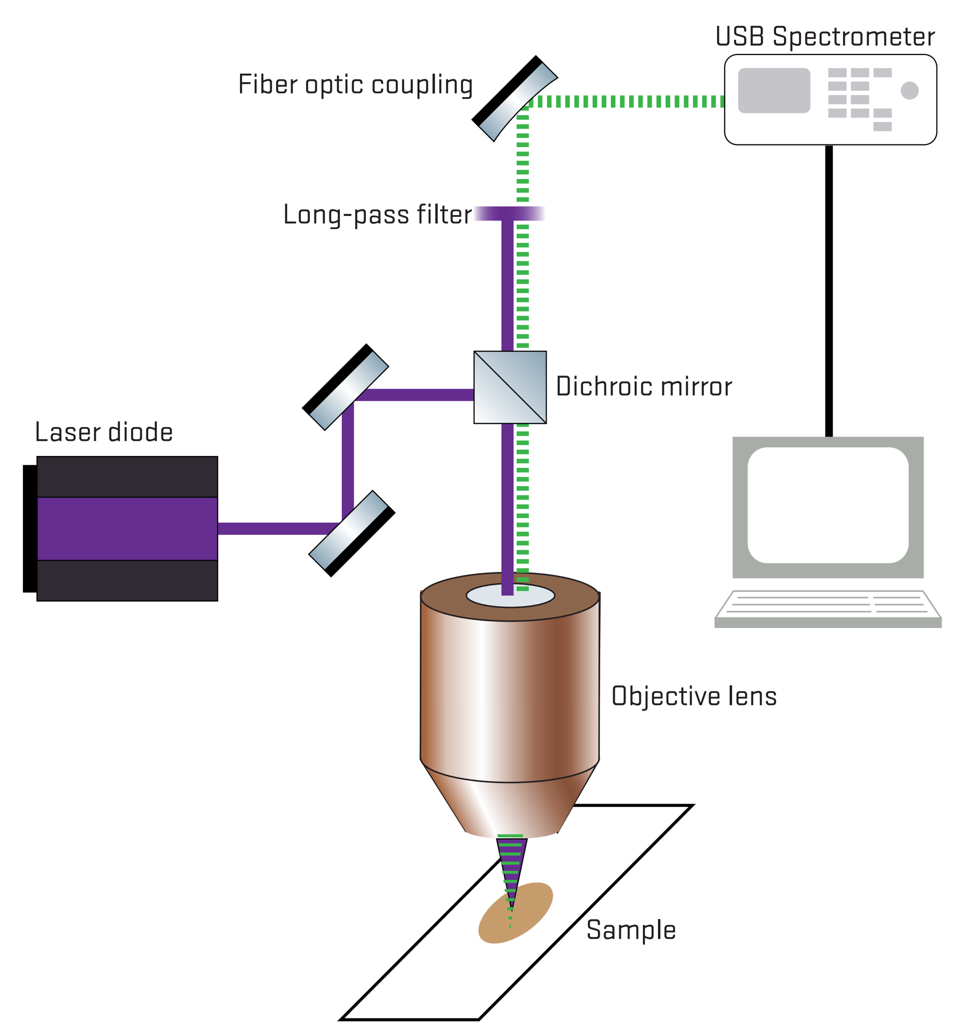
### Objective Lens

The microscope's objective lens serves a dual-purpose. It takes the laser beam, which may be as wide as 3-5mm, and focuses it down to a point on the same order of magnitude as the sample (this ultimately makes single-domain illumination possible). It also collects light from the sample and directs it back up through the microscope.

### Detectors

The trinocular optic allows multiple detectors to be connected to the system. In this case, we use a digital microscope camera for general imaging of samples, and an Ocean Optics USB spectrometer for measuring emission spectra.

The camera is connected to the trinocular directly, but the spectrometer must be coupled to the system using a fiber optic.




## Results

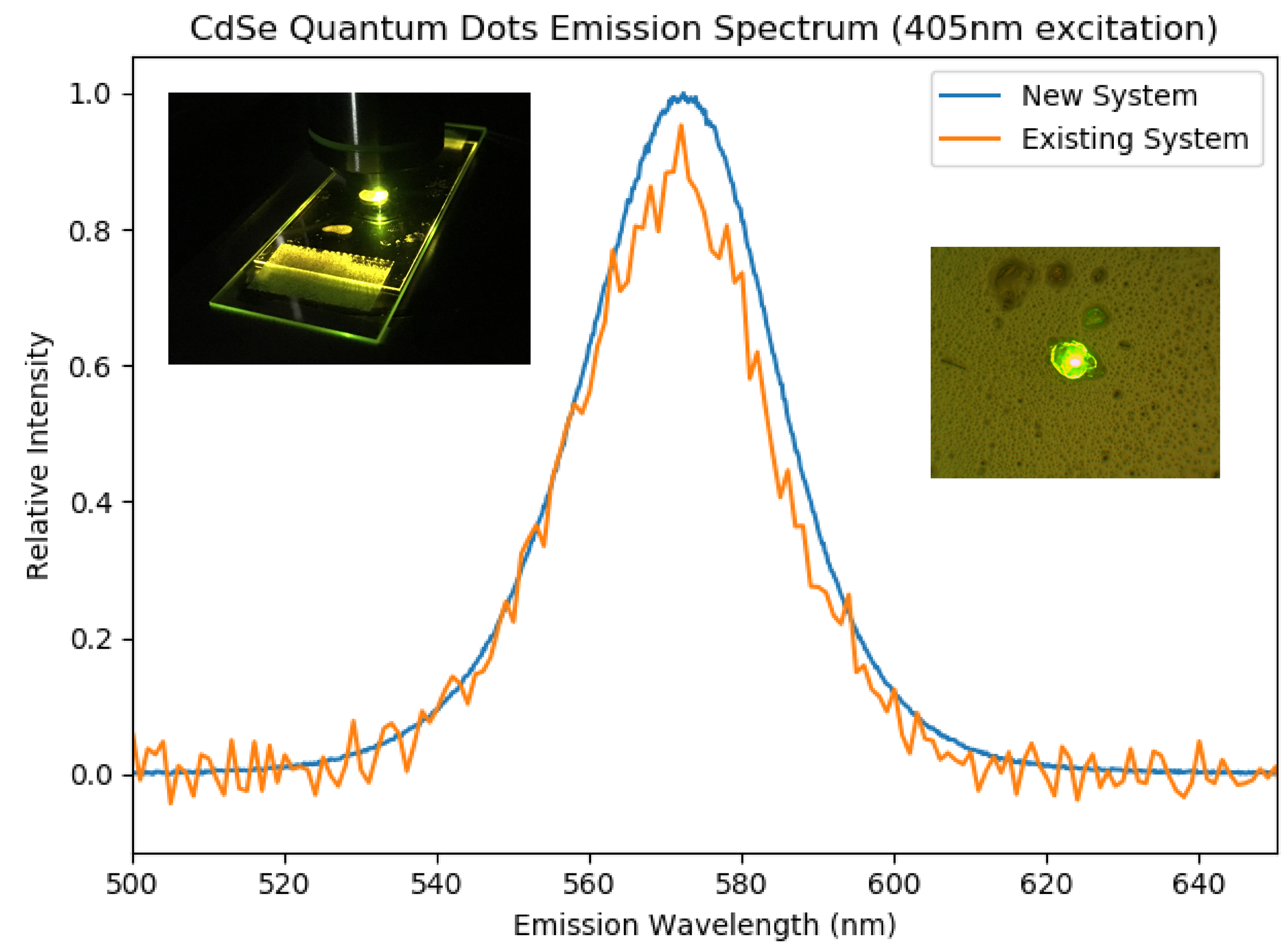



Figure 2

The cadmium selenide nanoparticles measured for Figure 2 emit strongly between 520nm and 620nm. Figure 2 shows normalized emission spectra measured by the existing (commercial) system and the new system. The alignment of the emission peaks indicates that the new system is measuring the emission spectrum of the material accurately.

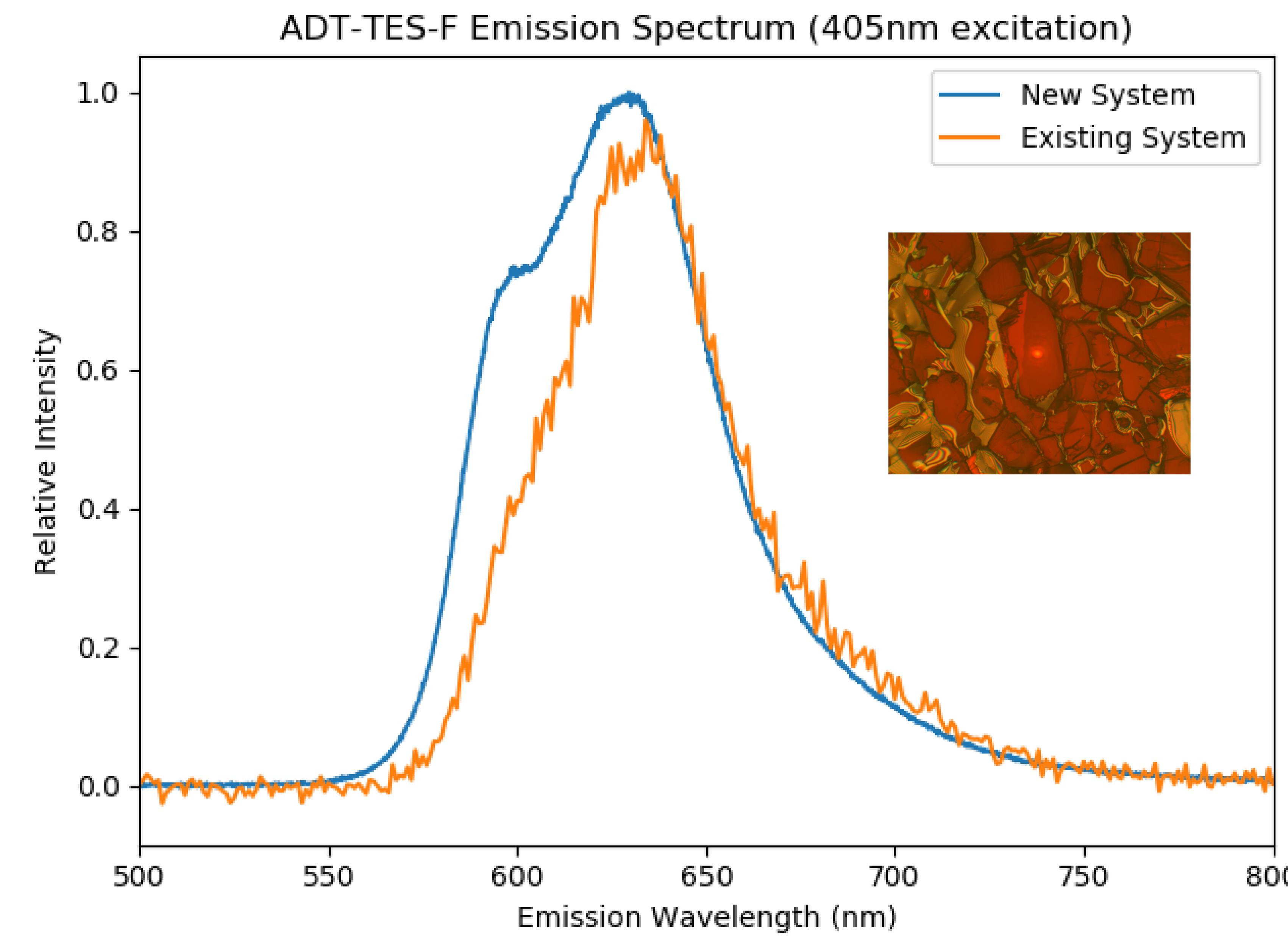



Figure 3

ADT-TES-F is a crystalline structure, and doesn't emit as strongly as the cadmium selenide particles in Figure 2. The normalized spectra in Figure 3 have similar features, but don't trend together as strongly as Figure 2.

It's possible that the wide-field illumination of the existing system, by exciting many of the adjacent crystal domains, is not exciting the secondary peak in this spectrum as strongly as the laser illumination.

## Future Work

The existing system in the ufE Lab has the capability of measuring emission spectra in both the visible and near-infrared (NIR) ranges. However, the detector used to measure NIR light must be cooled with liquid nitrogen, which makes those measurements quite costly.

Future work on this project will attempt to expand the new system's sensitivity into the NIR range by using a reflective grating and linear InGaAs array camera (sensitive in the NIR region) to measure sample emissions.

## Acknowledgements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Thanks to Kyle Vogt and Gina Mayonado for making themselves available to answer questions give guidance throughout the project.

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**Fig. 1:** Shinde, K. N., et al (2012). Basic Mechanisms of Photoluminescence. *Phosphate Phosphors for Solid-State Lighting* (pp. 41-59). Berlin: Springer.