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EXPERIMENT



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| SPECTROMETERS |

| ACCESSORIES |

| SUBSYSTEMS |

| COMPLETE SOLUTIONS |



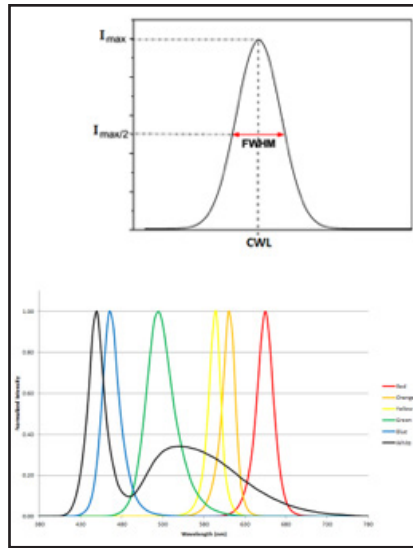
## Radiometric Characterization of LEDs

### Introduction

LEDs are used for all sorts of applications from lighting to horticulture. By using LEDs to provide greenhouse lighting, farmers and growers have the power to control crop illumination to impact growth characteristics and yield. Horticulturists are interested in the effects of light on the growth of their crops, with much analysis of how the intensity of blue and red light affects both the growth rate and blossoming of various floral crops. Until now farmers and horticulturists were limited in their options to control and measure the illumination of their crops. But recently the horticultural industry has been experimenting with the addition of red, blue and white LEDs to existing illumination systems. The idea is to better tune the spectral content to match the needs of the crops. Continuously monitoring the LED emission spectrum with a miniature spectrometer enables growth patterns to be correlated with the illumination spectra.

Thanks to the evolution of small, handheld spectrometers, LED based applications are more easily managed than with previous instruments. Indeed, spectrometers can be deployed to measure LED emission wavelengths as well as brightness and power output. To appreciate why miniature spectrometers are viable tools for LED measurement, it helps to understand the typical performance parameters being measured.

LEDs are often defined by their CWL (center wavelength) and FWHM (full width at half maximum), as well as their power (obtained by integrating the intensity under the spectral curve in irradiance mode). CWL and FWHM measurements can be made in either relative irradiance or



absolute irradiance mode, but power measurements are only possible in absolute irradiance mode, which requires a system that has been radiometrically calibrated to provide absolute values.

It is important to note that not all LEDs are a single peak. White light LEDs have 2 peaks – one from a blue LED that excites a phosphor coating inside the LED package, and a less intense, broader peak at longer wavelengths from the phosphor emission. White light LEDs are more often characterized using correlated color temperature (CCT), which fits the LED's spectral output to a blackbody curve (essentially comparing it to the sun or a tungsten halogen bulb) and reports the corresponding color temperature.

In this experiment, you will use a calibration light source and integrating sphere to radiometrically calibrate an Ocean Optics spectrometer system configured for measuring LED emission. You will then use your calibrated system to measure absolute spectral intensity values and peak characteristics including the center wavelength (CWL) and full width at half maximum (FWHM) for different LEDs.

## Materials

- FLAME-S-VIS-NIR spectrometer
- HL-3-INT-CAL calibration light source calibrated for use with an integrating sphere
- QP400-2-VIS-NIR fiber
- FOIS-1 integrating sphere designed to collect light from emission sources like LEDs

- LED-PS LED power supply and controller
- Computer with OceanView software installed
- Bare LED bulbs that are 9.52-mm diameter or smaller with 2.77-mm lead spacing including one white LED if available


## Safety

Wear safety goggles and other appropriate safety gear during the experiment. Take all proper safety precautions when handling solutions and wear proper eye protection when working with UV light sources.

## Procedure

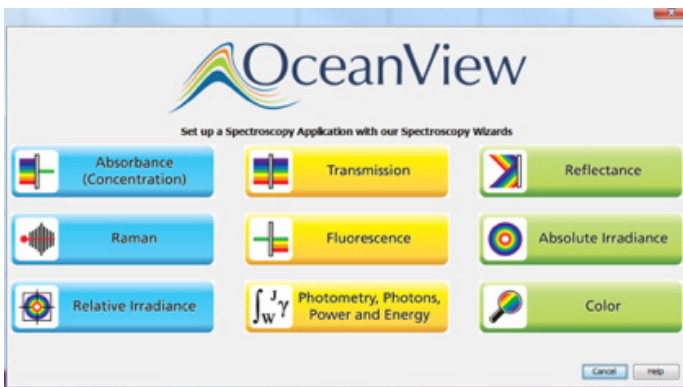
1. Connect the power cord to the HL-3-INT-CAL calibration lamp. Turn the lamp on and allow it to warm up at least 15 minutes.
2. Connect the spectrometer to your computer using the USB cable and allow the spectrometer to warm up for at least 15 minutes.
3. Use the fiber to connect the spectrometer to the SMA-terminated output port of the integrating sphere.
4. Connect the power cord to the LED-PS, insert a test LED into the electrical connector and turn the LED-PS on.

**NOTE:** The leads coming from the LED have different polarity. If the LED does not light up when the LED-PS is turned on, remove the LED from the connector, rotate it 180 degrees and reinsert it into the connector.

5. Place the LED-PS on the integrating sphere so the LED is inserted into the sample port of the integrating sphere.
6. Start OceanView. Click the **Start** button, then select **All Programs | Ocean Optics | OceanView | OceanView** or use the **Desktop shortcut**  created when you installed the software.
7. Select the **Spectroscopy Application Wizards** option on the **Welcome Screen**.



8. Select the **Photometry, Photons, Power and Energy** option in the **Spectroscopy Wizards** window to start the Photometry Wizard.



9. Select the **New Absolute Irradiance Processing** option.


10. Set your acquisition parameters in the **Set Acquisition Parameters** window.


a. Click the **Automatic button**  to automatically adjust the Integration Time to the optimum value.

b. Set **Scans to Average** to 10 and **Boxcar Width** to 5 to reduce measurement noise and improve the measurement. You can set **Scans to Average** to a higher value but this will slow down your acquisitions (total measurement time equals the number of averages multiplied by the integration time).

c. Place a checkmark in the **Nonlinearity Correction** box if this feature is available for your spectrometer. Click **Next**.

11. Select the **New Calibration** option to radiometrically calibrate the spectrometer using the HL-3-INT-CAL lamp with the integrating sphere.

12. Click the **Store Reference**  button to store a reference spectrum. Click **Next**.

13. Close the shutter on the light source or block the light from entering the spectrometer. **Do not turn your light source off**. Click the **Store Background**  button to store a background spectrum. Open the shutter or unblock the light source and click **Next**.

14. Click **Browse** to navigate to the location of the calibration file that came with the calibration lamp and click **Open** to load it. Click **Next**.

15. Select the **Use Integrating Sphere** option for the **Collection Area** and save the calibration file for future use by clicking the **Save to File...** button. Click **Next**.

**NOTE:** The radiometric calibration file saved for your system is valid as long as the fiber remains connected to the integrating sphere and spectrometer. If the fiber is disconnected from the spectrometer or integrating sphere, a new radiometric calibration must be done.


16. Select **Integrated Intensities** option and click **Next**.

17. Specify the wavelength range over which you want to integrate your power values. For these measurements, you can specify the wavelength range where your LED emission occurs. Click **Finish**.

18. You are now ready to radiometrically characterize your LEDs.

19. The Absolute Irradiance spectrum for your LED will be displayed in the **AbsoluteIrradianceView** window. You can adjust the graph appearance using the graph tools  above the graph. For example, click the **Scale Graph Height to Fill Window** button  to zoom in on the spectrum.


20. A range of integrated intensity values for the LED will be displayed in the **Table** window.


21. Configure peak finding to characterize your LED peak characteristics using the **View Spectrum Peaks**  button in the **Absolute Irradiance window**.

- a. Select the data source for the peak metrics calculations from the options in the table. Click **Next**.
- b. Use the **Configure Baseline** options to subtract any underlying spectral structures that may obscure the peaks you are trying to identify. Select **None** for these LED measurements. See the OceanView manual at [OceanOptics.com](http://OceanOptics.com) for more details on these settings. Click **Next**.
- c. Use the **Determine Peaks** options to set different methods of peak analysis and filtering to reduce unwanted noise effects. Use the default **Controls** settings and select **None** under **Smoothing** for these LED measurements. See the OceanView manual for more details on these settings. Click **Next**.
- d. Select the parameters you would like to measure for the LED. Make sure to include the Center Wavelength (CWL) by selecting **Center** and the optical resolution as full width at half maximum (FWHM) by selecting **FWHM**. Select **Show Table of Values** to display your peak parameters in a table. Click **Finish**.

22. Your peak characteristics will be shown in the **Peak Table** window.

23. Record the LED peak characteristics including CWL, FWHM and total power in  $\mu\text{W}$  in the **Data and Analysis** section.


24. Click the **Convert Active Spectrum to Overlay** button  to overlay the spectrum so you can compare it to the spectra for other LEDs in the same graph view. If you want to remove an overlaid spectrum, click the **Delete Overlay Spectrum** button . Highlight the spectrum you want deleted and click **OK**.

25. Save your LED spectrum by clicking the **Configure Graph Saving** button  to configure the **File Writer**.

- a. Select the directory where you want to save the file.


- b. Enter a filename for your spectrum.

- c. Click **Apply** and then **Exit** to close the dialog box.

26. Click the **Save Graph to Files** button  to save your spectrum.

27. Change the LED bulb and repeat steps 23-26 for the other LEDs.

**NOTE:** When working with LEDs of different intensities, you can change the integration time and scans to average values after the spectrometer has been calibrated to optimize the acquisition and avoid saturation, but you must store a new dark spectrum with the new acquisition parameters before making any measurements. **Do not change the boxcar smoothing value after it is set during calibration.**

28. Before exiting OceanView, print a copy of the graph showing the LED spectra by clicking the **Print** button .

## Data and Analysis

LED #	CWL (nm)	FWHM (nm)	Total Power $\mu\text{W}$
A			
B			
C			

If you had a white LED available for the measurements, what CWL and FWHM value does OceanView report for the white light LED? Does this make sense?

## Additional Tasks

1. Change the drive current on the LED-PS.

- a. How does the CWL change?

- b. Does the peak shape change?

2. Customize the **Schematic** to display the integrated power and other photometry values in separate Scalar views in OceanView.

a. Click the **Schematic Window** tab to open the **Schematic View**.

b. Right click on an empty part of the **Schematic** and select **Advanced Math | Filtering | Selector** to add a **Selector** node to the **Schematic**.

c. CTRL+click and drag to connect the **EPP** node generated by the Absolute Irradiance wizard to the **Select** node.

d. Double-click the **Select** node and use the drop down menu to select the LED parameter you would like to display. For integrated power, you can select uWatt. Click **Apply** and then click **Exit** to close the dialog box.

e. Right click on an empty part of the **Schematic** and select **View | Add Scalar View**.

f. CTRL+click and drag to connect the **Select** node to the **Scalar** node.

Save a screenshot of your OceanView software displaying the LED absolute irradiance spectrum, LED peak parameters and integrated power value.

3. Run the Color wizard in OceanView and determine the color parameters for the LEDs.

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on setting up your spectroscopy  
system from Ocean Optics.**



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