

Introduction to the Spectrometer

I. Introduction

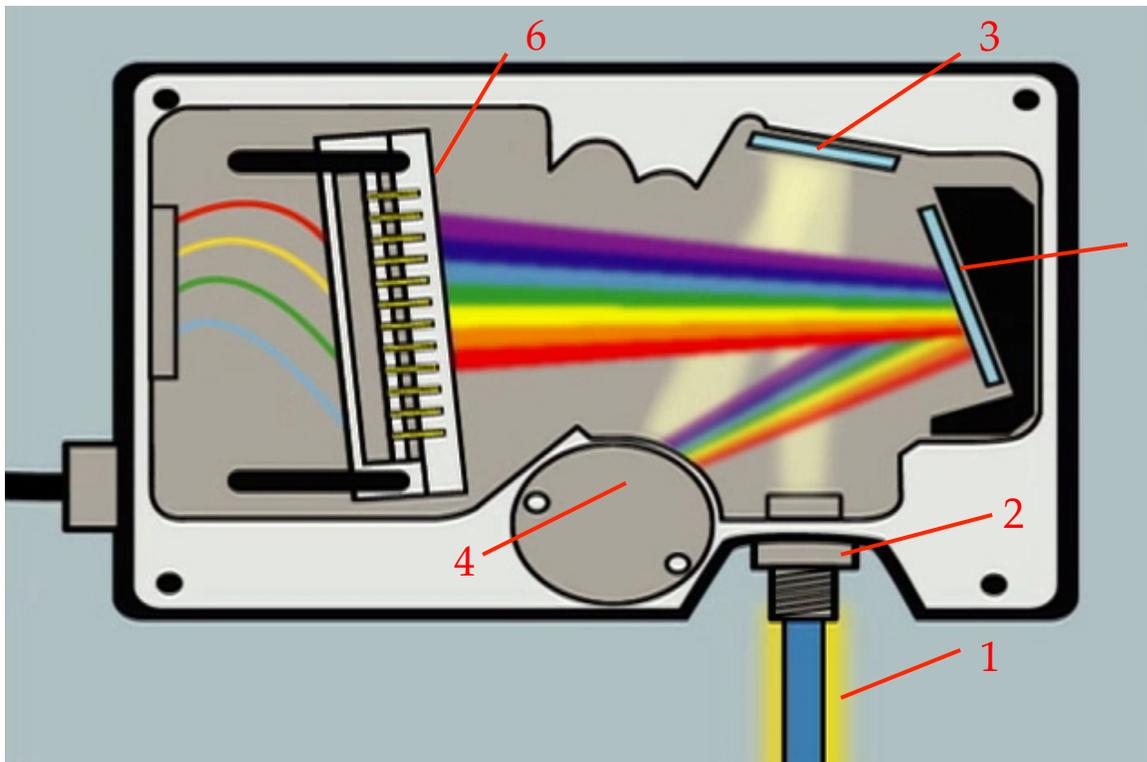
Spectroscopy is the study of the interaction between light and matter and how this interaction affects the intensity of light as a function of its energy or wavelength. Historically spectroscopy was used to discover many of the elements, and today it is used to learn about the electronic or mechanical structure of materials among other things. Physicists, chemists, biologists and geologists use spectroscopy to learn about the materials, chemicals and cells that make up our world.

There are many types of spectroscopy. Raman, photoluminescence, fluorescence, transmission, absorption, and reflection are some examples. Typically in order to study how light interacts with a material we need to make our sample emit light or interact with light in some way. This can be accomplished using a variety of methods that depend on what you want to learn about the material. Energy such as light or voltage can be used to excite electrons in the material so that they emit light. Or we can bounce light off of a material or through a material and see what light is scattered or reflected or transmitted.

The spectrometer is the primary tool we will use to examine light as a function of its wavelength. Our spectrometers are the USB2000 models made by Ocean Optics.

www.oceanoptics.com

1. Below is an image extracted from a video on Ocean Optics' website.¹ The elements inside the spectrometer are as follows: 1) optical fiber, 2) connector, 3) mirror1, 4) grating, 5) mirror 2, and 6) detector. Find out how the spectrometer works.



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2. Using the spectrometer: There are three types of spectra that we can capture using LoggerPro software to control the USB2000: **%transmittance, Intensity and absorbance**. You can select the specific type by following the path:

Experiment → Change Units → Spectrometer 1 → then select the mode.

- a. **Intensity:** The intensity spectrum captures whatever light is incident on the spectrometer. This mode it typically used for looking at a sample that is emitting light such as a light bulb or gas discharge tube. The units are arbitrary and go from 0 to a maximum of 1. In general, it is important that all of the spectrum has an intensity less than 1. If this is not the case, you could be saturating the detector and missing important information. At the same time, you want the maximum intensity to be close to 1 so that you don't miss any small features. The intensity viewed by the spectrometer can be adjusted by increasing (or decreasing) the distance between the light source and the fiber optic coupling to the spectrometer. Another way to change the light intensity viewed by the spectrometer is to change the sample time. A longer sample time will give a higher signal and vice versa. To change the sample time use the following path:

Experiment → Set Up Sensors → Spectrometer 1. To begin collecting data press the green play button on the top right. Once you have a spectrum you want to keep, you can export it as a CSV (comma separated value) file that can be read and graphed later in excel.

- b. **% Transmittance:** In this mode you are determining how much light gets through a sample, so you typically start with white light source that illuminates a sample. In order to know how much light gets through the sample, you have to know how much light you are starting with, R_λ , and how much background light exists, D_λ . When you use this mode you will be asked to "Calibrate" the spectrometer. It is at this point that the computer determines the light source, which we will call the reference, $R(\lambda)$ and the background, which we will call the dark spectrum $D(\lambda)$. It is very important that you don't move the collection fiber or the light source, or you will destroy this calibration. When you begin to make your measurements, you should never get a %transmission that is greater than 100%. After you calibrate, you can put your sample in place and press the green button to see how much light is transmitted. The computer calculates the Transmittance using the following equation where S_λ is the signal coming through your sample.

$$T_\lambda = \frac{(S_\lambda - D_\lambda)}{(R_\lambda - D_\lambda)} \times 100\%$$

- c. **Absorbance:** Absorbance is like the opposite of transmission. It tells you how much light is NOT getting through your sample. It works in much the same way as the % Transmittance only it is calculated using the following equation:

$$A_\lambda = -\log_{10} \frac{(S_\lambda - D_\lambda)}{(R_\lambda - D_\lambda)}$$

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Physics 317 –Instrumentation Lab

3. Light bulbs

Now let's look at a spectrum that is a little more interesting! We have three light bulbs to look at: incandescent, compact fluorescent, and LED. For each type of bulb do the following:

- Observe what happens when you move the bulb closer to and further from your fiberoptic cable. Describe what is happening and explain.
- Fix the bulb at a particular distance. Capture several spectra of the bulb using different integration times be sure that at least one of your integration times does not cut off any of the peaks by saturating the detector. (You should not have flat peak tops.) What happens to the spectrum when you change the integration times?
- Print the spectra for each lightbulb. Can you explain why the spectra have the shape that they do?
- Find the wavelengths of four or five peaks in the compact fluorescent light bulb spectrum and compare these wavelengths to the mercury spectrum.

4. Transmission and absorption spectra using colored filters

- Pick two colored filters to examine.
- Capture your reference and dark spectra
- You may have noticed that once these spectra are captured there are several letters that turn from gray to blue. The T stands for transmission spectrum, the R for reflection, and the A for absorption. The SpectraSuite software calculates these spectra for you based on the dark spectrum, $D(\lambda)$, the reference spectrum $R(\lambda)$ and the spectrum with the sample in place, $S(\lambda)$.

$$T_{\lambda} = \frac{(S_{\lambda} - D_{\lambda})}{(R_{\lambda} - D_{\lambda})} \times 100\%$$

- Depress the T button with the mouse and insert a colored filter. Save the spectrum. Repeat for one other colored filter.
- Next depress the A button and record the absorption spectrum for your two colored filters where $A_{\lambda} = -\log_{10} \frac{(S_{\lambda} - D_{\lambda})}{(R_{\lambda} - D_{\lambda})}$
- Can you make sense of the appearance of the four spectra and the two colored filters? Qualitatively explain your data.