

# 1 Laboratory #5: Grating Spectrometer

## 1.1 Objective:

To observe and measure the spectra of different light sources.

## 1.2 Materials:

1. OSA optics kit.
2. Nikon digital camera (available from Stockroom)
3. Cardboard box
4. Adhesive tape
5. Scissors
6. *ImageJ* Software (installed on lab PCs and available as a free download from <http://rsb.info.nih.gov/ij/>)

## 1.3 Background:

A transparent diffraction grating is a piece of glass or plastic with a series of parallel lines spaced very close together, as illustrated in Figure 1. The lines can be made in many ways (scratches, strings of plastic, etc.). Regardless of how the lines are made, they act the same way. They cause some of the light to change direction. This is represented by the deviation angle  $\theta$  in Figure 1.

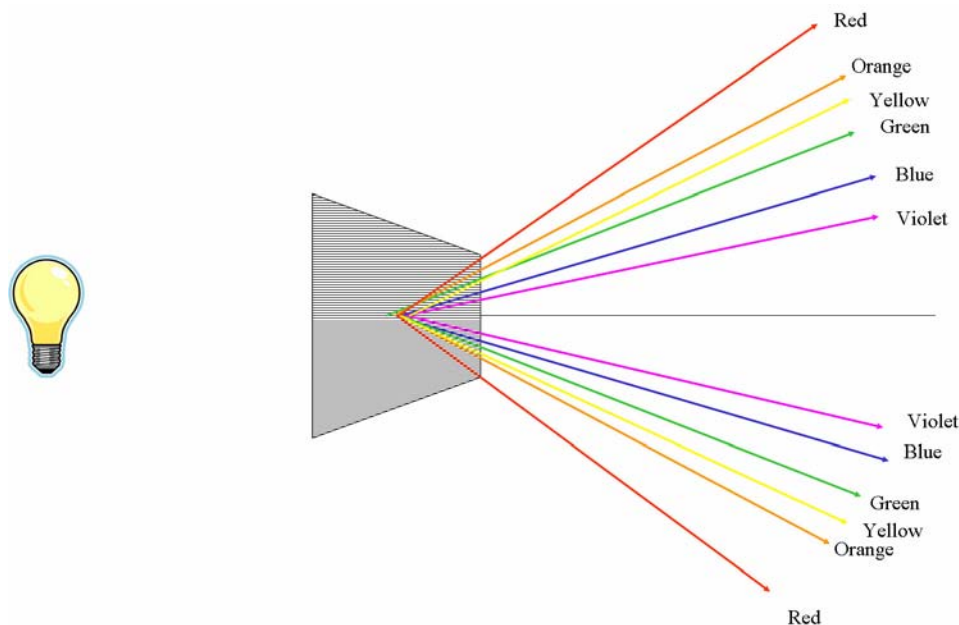


Figure 1: Schematic of diffraction of white light into its spectrum by a grating

The deviation angle  $\theta$  depends on the spacing of the lines and the wavelength of the light. More deviation (larger  $\theta$ ) occurs if the lines of the grating are spaced closer together and/or if the wavelength of the light increases.

The wavelength of light governs its perceived color. Red has the longest wavelength of light that we can see. The longest wavelength of visible light is  $\lambda = 700$  nm. The shortest is violet  $\lambda = 400$  nm. Green is in the middle with  $\lambda = 550$  nm. The familiar spectrum colors are easy to remember with the mnemonic "Roy-GBiv" for **R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **I**ndigo, **V**iolet. Different light sources have different amounts of these colors. In this laboratory exercise, you will use a grating to disperse the light from different light sources and measure the relative amount of the different colors.

#### 1.4 Part I: Visual observation of a spectrometer

A grating is supplied in your OSA optics kit, as shown in Figure 2. Hold the grating up to your eye with the long dimension in the horizontal direction as shown in Figure 3. Look at a light source to see the spectrum of the light source. The spectrum will be on both sides of the source. Look at the spectrum that is on the right side of the source by moving your eye and grating so the source is on the left side of the grating. Examine several different sources of white light. Do the different sources of white light produce different spectra?



Figure 2: Diffraction Grating in OSA Optics Discovery Kit

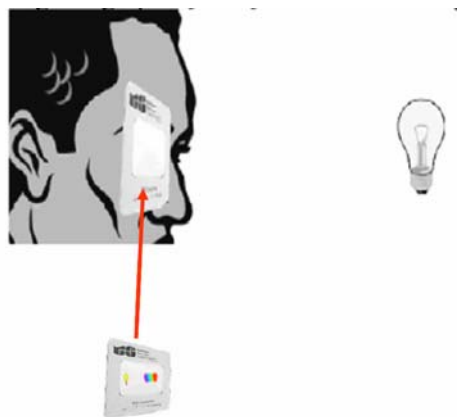


Figure 3: use a diffraction grating to see the spectrum of a light source by holding the grating next to you eye.

## 1.5 Part II: Building a Quantitative Spectrometer

To improve the spectra that you observed in Part I, and to record these spectra quantitatively, you will construct a spectrometer. Place the grating over the digital still camera as illustrated in Figure 4. Hold the grating in place with tape. Now, however, you can press the shutter button and take a picture of the spectrum. (Ideally only the light source you are measuring will be on. You may find that you need to have some other light because the camera will not fire if it is too dark).

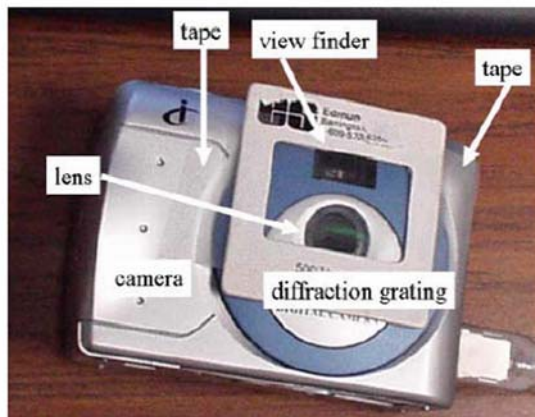


Figure 4: Any camera can be used as a spectrometer (viewfinder, single-lens reflex, or video). For a viewfinder digital camera, the grating should go over both the viewfinder and the lens. For an SLR or video camera, place the grating over the lens only.

An improved spectrum is seen if the size of the light source is very long and very thin. You can achieve this by shining the light from the source onto a long, narrow strip of translucent tape. Construct the spectrometer box as illustrated in Figure 5. The goal is to create a narrow slit less than 1 mm wide. You can use any cardboard box that is at least  $200\text{ mm} \times 200\text{ mm}$  in size. cut a rectangular hole, as shown. The hole should be about  $50\text{ mm} \times 10\text{ mm}$ . Place index cards over the hole to form a narrow slit. The slit should be about 0.5 mm wide. Place a single strip of translucent tape over the slit.

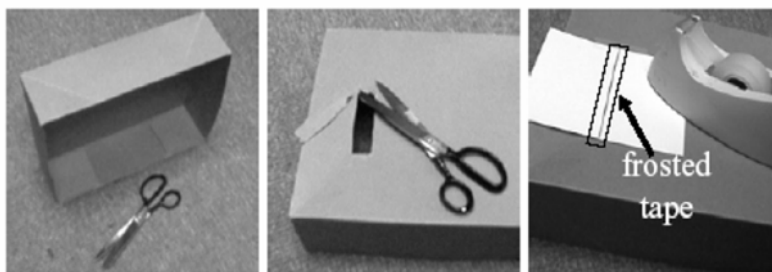


Figure 5: Fabrication of the spectrometer box

Hold the box in front of a light source, as illustrated in Figure 6. The light source can be as close to the slit as you like. The closer the source, the brighter the spectrum.

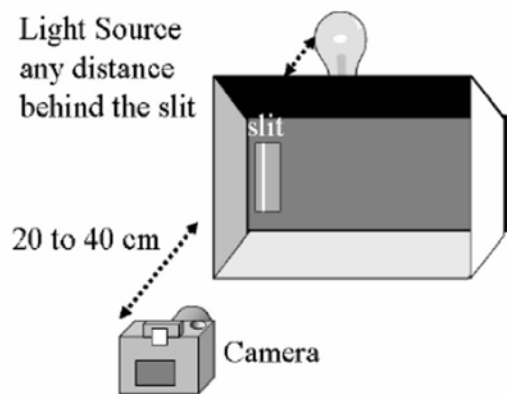


Figure 6: Location of box, light source, and camera.

Hold the camera up to your eye and look at the slit in the box just as you looked at a light source with your eye. You should observe the spectrum as illustrated in Figure 7. Press the shutter button to capture an image of the spectrum.

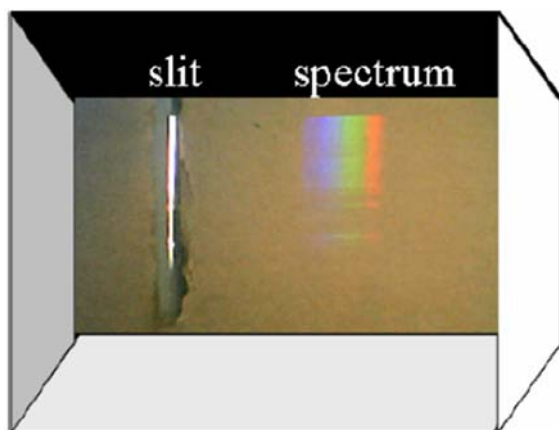


Figure 7: scene through the viewfinder

The computer monitor in the lab is a light source. Open the word processor and use the white background as a light source. Place the spectrometer slit near the screen and take a picture of the monitor spectrum. Capture images of all other light sources made available to you by the instructor.

## 1.6 Part III: Displaying and Plotting Spectra

Download and save the images to a chosen location on the lab computer. Open the image analysis program called *ImageJ* by clicking on its icon. Use the command sequence {File/Open} to open one of your images. Once an image is open, construct a rectangle around the spectrum using the rectangle tool; the right and left sides of the rectangle should be positioned at the extreme left edge of the violet part of the spectrum and extreme right edge of the red part, respectively, as shown in Figure 8. Note the width of the spectrum as shown in the ImageJ window. A width of about 30 to 70 pixels is common, depending on the grating and the camera you are using.



Figure 8: Selection of a region using the “rectangle tool” in *ImageJ*.

Display the spectrum graph with the commands {Analyze/Plot Profile}, as illustrated in Figure 9. Click on the spectrum graph to highlight it. You can copy the data with the copy button, then past them into a document. You can copy the image of the plot by holding down the Alt key and hitting the Print Screen key. You can print the graph with the commands {File/Print} as illustrated in Figure 10. Generate and print a spectrum for each light source.

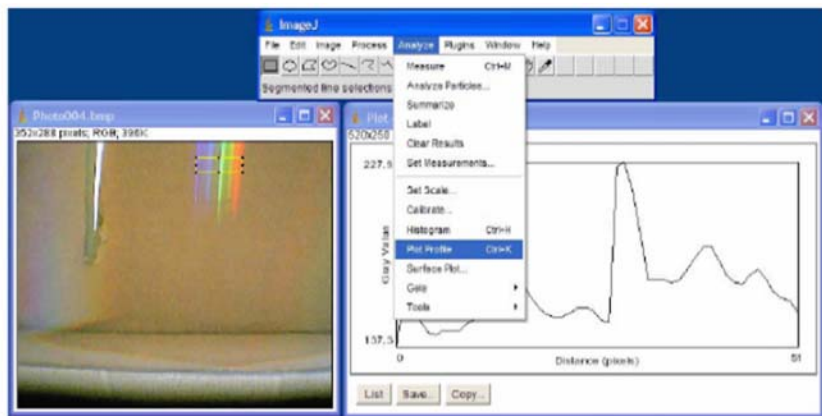


Figure 9: Display the spectrum with the commands {Analyze/Plot Profile}

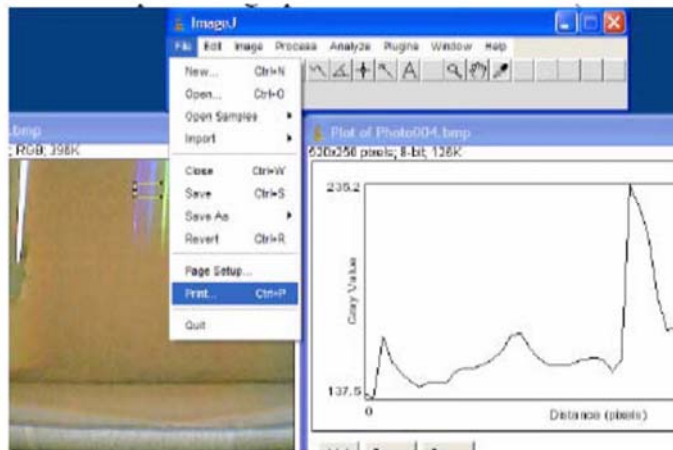


Figure 10: Print the spectrum

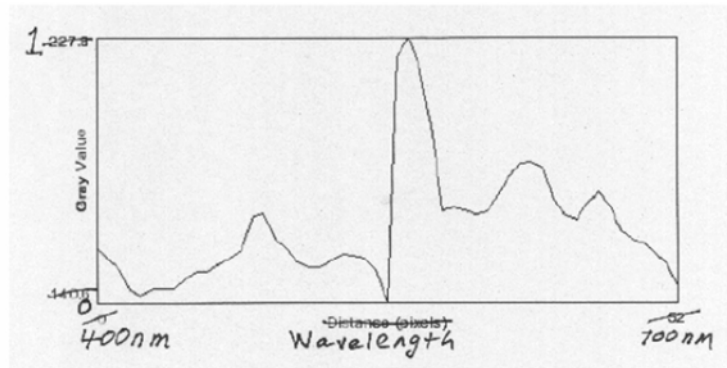


Figure 11: Relabel the axes

## 1.7 Lab Report:

Your Lab report should include one printed spectrum for each light source. Label the axes.

Your lab report should address the following:

1. It is often said that white light is a mixture of all colors in the spectrum. According to the spectra you measured, how would you modify this statement?
2. If you were given a light source of unknown type, could you use the spectrometer to determine whether or not the light source is an ordinary light bulb?
3. The light sources you measured are of two types. One type is the *incandescent source*. This type produces light that is a smooth mix of all wavelengths from 400 nm to 700 nm. The other type is the *line source*, which produces light of three dominant wavelengths, with very little light from intermediate wavelengths. The three dominant wavelengths correspond to red, green, and blue light. Label each spectra to identify whether the source is an incandescent or a line source.

## 1.8 Bonus

In addition to printing the individual spectra, use the copy key to paste all the spectra into a spreadsheet and plot them together on one plot.