

## Lab 10. CHARACTERIZATION OF LIGHT SOURCES Scanning Spectrometer Version

### I. Introduction

Monochromators isolate a small wavelength band from a broad spectral source. They consist of a dispersive element (prism or grating) and an image transfer system (entrance slit, mirrors and/or lenses, and exit slit). Within the monochromator, an image of the entrance slit is transferred to the exit slit while dispersing the wavelengths components of the incident radiation. A grating monochromator based on a Czerny-Turner configuration similar to the one used for this lab is shown in Figure 1:

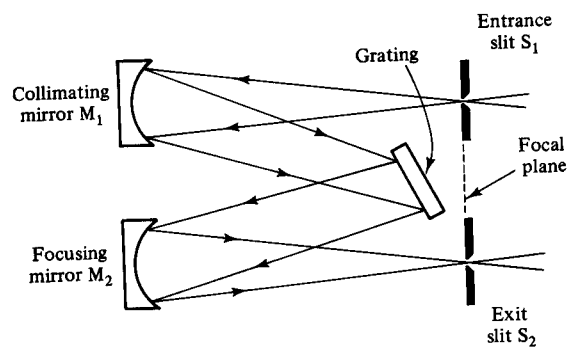
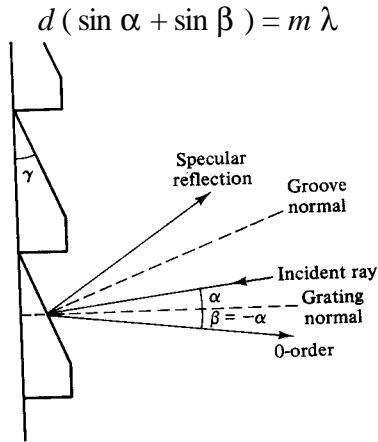


Figure 1. Czerny-Turner plane grating monochromator.

Incident radiation passes through the entrance slit  $S_1$  and strikes the collimating mirror  $M_1$ . The entrance slit acts as a point source at the focal point of spherical mirror  $M_1$  that collimates the radiation incident on the grating. The grating disperses the wavelengths spatially into collimated beams, spectrally separated by angle, that are incident on the focusing mirror  $M_2$ . Mirror  $M_2$  focuses these beams in the plane of the exit slit as spectrally separated images of the entrance slit. Because the parallel rays of a given wavelength are incident on the focusing element at a specific angle, each wavelength is focused to a slit image at a different center position. As the angle of the grating is scanned, these images are swept across the exit slit that transmits spectrally separated light.

A diffraction grating is a plate that is ruled with closely spaced grooves. The grating acts like a multi-slit source when collimated radiation strikes it. Different wavelengths are diffracted and constructively interfere at different angles. The grating that you will use is a reflection grating with 1200 lines/mm. The surface of a typical reflection grating is shown in Figure 2. The angles of incidence and diffraction are measured with respect to the grating normal, not the groove normal. By convention, the angle of incidence is always taken as a positive angle. The diffraction angle is defined to be positive if the diffracted ray is on the same side of the grating normal as the incident ray (labeled specular reflection in the figure), and negative if it is on the opposite side. The condition for constructive interference by a grating is given by:



**Figure 2. Diffraction from a blazed reflection grating**

Here  $m$  is the order of diffraction and assumes the values  $0, \pm 1, \pm 2, \pm 3$ , and so on. The order  $m$ , like the diffraction angle, is defined as positive for diffraction on the same side of the grating normal as the incident ray and negative on the opposite side. The groove density (grooves per mm) is related to the groove spacing  $d$ . The grating that you will use has 1200 grooves per mm so the  $d$  spacing is

$$d = \left( \frac{10^6 \text{ nm}}{\text{mm}} \right) \left( \frac{1 \text{ mm}}{1200 \text{ grooves}} \right) = 833.3 \text{ nm/groove}$$

Consider monochromatic light with a 600 nm wavelength incident on the grating at an incident angle of  $10^\circ$ . In the first order, the 600 nm radiation is diffracted at an angle  $\beta = 33.1^\circ$ .

For a given  $d$  spacing and angle of incidence,  $\alpha$ , additional wavelengths satisfy the grating equation at an angle of diffraction  $\beta$  for higher values of  $m$ , a phenomenon known as overlapping orders. This is a problem only if the source covers a broad spectral range.

## **II. Objectives**

- Calibrate a grating monochromator with known wavelength light source (HeNe laser).
- Measure line width of He-Ne laser
- Measure emission from "unknown" light source
- Measure emission from broadband light source

## **III. Procedure**

The suggested overall layout for this experiment is given in the figure. The major components include: monochromator and He-Ne laser.

NOTE: Always remember to check for linearity of your detector with an appropriate neutral density filter (NDF). If needed, attenuate the light entering the monochromator with a NDF.

### **III.1 Monochromator Calibration (Laser)**

- 1) Assemble the basic system layout as per Figure 3.

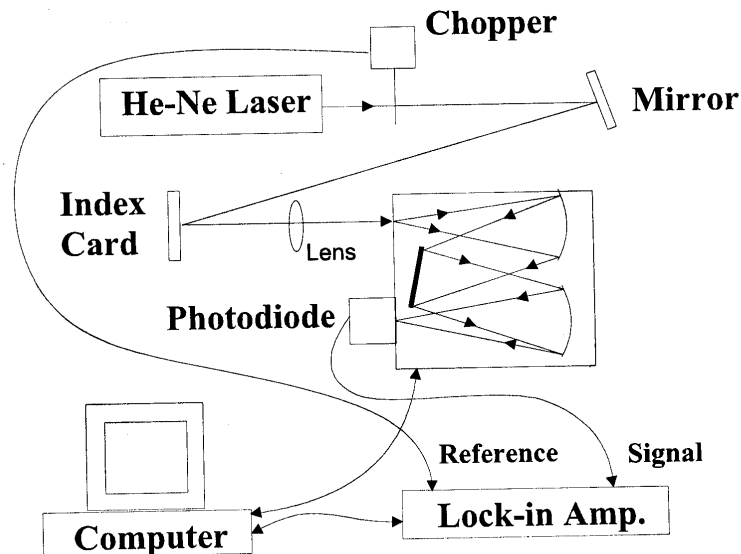


Figure 3. Instrumental set up.

- 2) Direct a He-Ne laser beam onto the spectralon. It is important that you use SCATTERED light into the monochromator. If one used the direct laser light, the wavelength calibration of the monochromator would depend upon the incident ANGLE of the laser light. In addition, the spectral resolution of the monochromator would be very poor because only a small part of the grating would be illuminated.

- 3) Place a mirror next to the lens as shown in Figure 5. Now direct the beam reflected from the first mirror to the mirror next to the lens. Direct this beam onto the spectralon cube. The spectralon cube will scatter the light so that the slit will be evenly illuminated. Check the entrance slit to see if the focused beam from the lens is centered on the slit. You may want to close the slit down to a couple hundred microns. By using a white note card, check to see if the small round mirror in the monochromator is fully illuminated. If it isn't, adjust the beam on the spectralon so that it becomes fully illuminated. Place the cover on the monochromator and turn out the room lights.

- 4) Connect the diode output to the Lock-in amplifier.

- 5) Scan the HeNe laser spectrum.

Since the intensity of the focused beam on the slit is relatively high and may saturate the detector, you will need to check the photodetector for linearity. Now you are ready to scan the wavelengths of the HeNe laser with the monochromator. Open the program C:\WINDOWS\Desktop\Monochromato Lab View\Spex270M Simple Control\ SCANNING for Physics 2. This program will scan through a user defined range of wavelengths by adjusting

the angle of the diffraction grating in the monochromator and plotting the intensity of the light on the low power detector as a function of the wavelength of light. You will need to enter a range of wavelengths to scan. This is the “Starting Position” and the “End Position” on the SCANNING for Physics 2 window. For HeNe the center wavelength is 632.8 nm, so you should scan around this. Try 631 to 635. Set the “Increment” to 0.1. The scan may reveal that the center wavelength is not 632.8 nm. If this is off by a few nanometers the monochromator data will need to be shifted to the actual center wavelength. You can fix this on a Microsoft Excel spreadsheet. Once you have found the line for HeNe you may want to narrow in on the wavelength of interest by decreasing the range around the line and also setting the increments to a lower value. If you notice that the scan plot is missing some data points due to saturation of the detector, you will have to set the power meter to a less sensitive setting and run the scan again.

The SCANNING for Physics 2 program records data and stores it into a two column format; the first column is the wavelength and the second column is the power recorded by the power detector. You can use Matlab, Excel and many other programs to work with these data sets. However, you may find it more convenient to use Excel on the computers in the lab. To do this just open the file you saved in Excel and let the Text Import Wizard configure the data so that it can be loaded into a spreadsheet format. Save all of your data to a disk and/or to the hard drive of the computer. Make sure to label your data sets with slit widths and the light source.

Repeat the scan over the same range but with a different slit width. Take data for a total of 5 different slit widths. Be sure to include the SMALLEST slit width , 6  $\mu\text{m}$  for your monochromator. Since the peak transmission intensity will decrease with decreasing slit size, the sensitivity on the power meter may need to be adjusted. Make sure that the input and exit slits of the monochromator are the same size. Measure the peak intensity at its maximum and the spectral width at the half maximum.

Slit-width	Intensity	Spectral width

Scan the monochromator in the 1200-1300 nm range. In this range you should observe the second order diffraction peak corresponding to 1265.6 nm (twice the HeNe laser wavelength). The intensity of this peak will be smaller , so adjust the lock-in sensitivity as needed. Record the monochromator setting for the second diffraction peak.

Scan the "unknown" source

Scan the flashlight bulb.

#### **IV. Questions for Discussion**

1) Based on the He-Ne calibration, determine the wavelength correction for the monochromator. Use this calibration in the rest of your lab to report spectral intensity versus wavelength.

2) For you data measuring the line width of the He-Ne laser, plot the data for all the different slit sizes on the same graph. Clearly, the peak intensity of the transmitted light DECREASES with decreasing slit width. WHY?

3) Now investigate whether the SPECTRAL WIDTH of the measured laser light is changing. Re-plot your data but normalize it such that the peak intensities of each spectrum is the same. Does the measured width of the laser light change with decreasing slit width?

#### References

Moore, J. H., Davis, C. C., and Coplan, M. A., *Building Scientific Apparatus: A Practical Guide to Design and Construction*, Addison-Wesley (1983).  
Jenkins, F. A. and White, H. E., *Fundamentals of Optics*, McGraw-Hill.