LAB 12 -- CHARACTERIZATION OF LIGHT SOURCES
CCD Spectometer Version

I. Introduction

Light sources can be characterized according to their wavelength spectrum as either narrow or broad-banded. For example, atomic resonance lamps such as sodium or mercury emit light only at certain wavelengths. The spectral bandwidth of the light at each atomic line is generally very narrow. Lasers, of course, are effectively monochromatic (i.e. single wavelength). Conversely, arc lamps, such as xenon, emit over a very broad wavelength range with few spectral features. The choice of source type depends on the particular application as well as the availability of optical components such as filters and spectrometers.

In this experiment, you will verify the wavelength calibration of a spectrometer with a known narrow wavelength source (Mercury Arc Lamp). Then, you will characterize the laser wavelength linewidth of the He-Ne laser and an "unknown" light source by analyzing their emission wavelength spectra with a spectrometer.

II. Objectives

- Calibrate a grating spectrometer with known wavelength light sources.
- Measure line width of He-Ne laser
- Measure emission from "unknown" light source.

III. Procedure

The suggested overall layout for this experiment is given in the figure. The major components include: spectrometer, He-Ne laser, "unknown" source, corresponding lamp sockets as needed, lamp power supplies as needed.

III.1 Spectrometer Calibration (Atomic Emission Lamp)

1) Assemble the basic system layout as per the figure.

2) Place the calibration lamp in an x-y-z translation stage. Your goal is to collect some of the light with a lens and direct it into the spectrometer. Initially, make sure that the diode array detector is not electrically connected to the rest of the electronics while the top of the spectrometer is off.

3) Collect as much of the lamp light as you can with the lens (a 35mm lens is sufficient) and direct it into the grating spectrometer through the entrance slit. Use initially a slit width of about 1mm or less. The image should be focused at the slit. In your alignment, place the lens roughly a distance of 2f (where f is the focal length of the lens) in from of the entrance slit. Align the slit, lens, and calibration so that they are collinear and at the same height. Open the top of the spectrometer. Using another index card, follow the light beam around in the spectrometer. The system is properly aligned when the light through the entrance slit is centered on the first curved mirror. If you have difficulty seeing the lamp light in the spectrometer, you can replace this source with a He-Ne laser beam diffusively scattering from an index card. The diffusively scattered light mimics a point source of light. Adjust the center detected wavelength of the spectroscopy such that you get at least three calibration lines from the lamp emerging from the spectrometer opening where the CCD array will be.

4) Close and seal the top of the spectrometer.

5) Connect CCD array to the driver box (and install it on the spectrometer if you removed it to observe the mercury lines). Connect the driver box to the PC and power supply.

6) Initiate a spectrometer scan via the computer from roughly the maximum wavelength range and record as many peaks as possible.

7) Using the calibration chart, identify for the computer the wavelength values for several of the peaks. The computer will use these values to calibrate the spectrometer.

III.2 Laser Line Width

1) Replace the calibration lamp with a He-Ne laser beam diffusivily scattering from an index card. Place the index card and the He-Ne laser beam spot so that the image of the spot is focussed and centered on the input slit. Scan the spectrometer from around 625-645nm covering the first diffraction peak. Use the LARGEST entrance slit width possible.

2) 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 available for your spectrometer. Since the peak transmission intensity will decrease with decreasing slit size, the sensitivity on CCD array may need to be adjusted by the computer.

III.3 Unknown Sources - Laser pointer

NOTE: Your instructor will provide you with the "unknowns".

1) Replace the narrow source with the unknown which you have been assigned; eg. a laser pointer.

2) Keep the lens fixed. Use a 1mm (or something close) slit. Focus the light onto the entrance slit of the spectrometer by moving only the lamp.

3) Initiate a spectrometer scan over a wavelength range suggested by your instructor. (Nominally 450- 800nm). Adjust your scan to cover just the laser pointer source.

4) Repeat your scan for the SMALLEST slit size available.

<u>IV. Questions for Discussion</u>

1. 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?

2. Now investigate whether the SPECTRAL WIDTH of the measured laser light is changing. Replot your data but normalize it such that the peak intensities of each spectra is the same. Does the measured width of the laser light change with decreasing slit width?

3. For the smallest slit width, is the measured spectra width instrument limited? In other words, are you measuring the physical spectral width of the He-Ne laser or is the measured width broader because the spectrometer can't resolve it?

4. Describe the observed spectrum of your unknown. What is the peak (center) wavelength and what is the approximate spectral width? Based on the results of Discussion question 3, are you measuring the true spectral shape or it instrument limited?

References

Moore, J. H., Davis, C. C., and Coplan, M. A., Building Scientific Apparatus: A Practical Guide to Design and Construction, Addison-Wesley (1983).
Hecht, *Optics*, Addison-Wesley.

Figure 1.