

LAB 12 -- CHARACTERIZATION OF LIGHT SOURCES

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 monochromators.

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

II. Objectives

- Calibrate a grating monochromator 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: monochromator, He-Ne laser, "unknown" source, corresponding lamp sockets as needed, lamp power supplies as needed.

NOTE: Always remember to check for linearity of your detector, especially when you change light sources, with an appropriate neutral density filter (NDF). If needed, attenuate the light entering the monochromator with a NDF. Alternatively, reduce the entrance slit opening.

III.1 Monochromator Calibration (Laser)

NOTE: The monochromators are all different. Your instructor will provide individual guidance as to their operation.

- 1) Assemble the basic system layout as per the figure.
- 2) Direct a He-Ne laser beam onto the index card. 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) Collect as much of the scattered light as you can with the lens (a 35mm lens is sufficient) and direct it into the grating monochromator 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 front of the entrance slit. Align the slit, lens, and He-Ne laser spot so that they are collinear. Open the top of the monochromator. Using another index card, follow the laser beam around in the monochromator. The system is properly aligned when the light through the entrance slit is centered on the first curved mirror. Scan the monochromator in the

range of 620-640nm. Observe the diffracted light as it sweeps across the output slit. Generally, there are several diffracted beams corresponding to the zeroth, first, second, etc. orders of diffraction.

- 4) Position a x-z translation stage with photodiode assembly until it is flush (i.e. no ambient light leaking in) with the exit slit. Use black tape as needed to "seal" the diode to the monochromator AFTER you have optimized the detector position.
- 5) Connect the diode output to the Lock-in amplifier.
- 6) Initiate a monochromator scan from 600 - 650 nm - locate the laser beam wavelength. Note the rate of the scan.
- 7) Once located, set the monochromator at the peak transmission. Optimize the position of the photodiode detector. Record the monochromator setting for the first diffraction peak which corresponds to 632.8nm (He-Ne).
- 8) Scan the monochromator in the 1200-1300nm range. In this range you should observe the second order diffraction peak corresponding to 1265.6nm (twice the He-Ne laser wavelength). The intensity of this peak will be smaller, so adjust the lockin sensitivity as needed. (If you monochromator can not scan to this larger range, skip this step.) Record the monochromator setting for the second diffraction peak.

III.2 Laser Line Width

- 1) Scan the monochromator from around 625-645nm covering the first diffraction peak. Use the LARGEST 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 for your monochromator. Since the peak transmission intensity will decrease with decreasing slit size, the sensitivity on the lock-in may need to be adjusted. Make sure that the input and exit slits of the monochromator are the same size.

III.3 Unknown Sources

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

- 1) Replace the narrow source with the unknown which you have been assigned; e.g. fluorescent lamp.
- 2) Keep the lens fixed. Use a 1mm (or something close) slit. Focus the light onto the entrance slit of the monochromator by moving only the lamp.
- 3) Initiate a monochromator scan over a wavelength range suggested by your instructor. (Nominally 450-800nm)

IV. Questions for Discussion

- 1) Based on the He-Ne calibration, derive a formula which relates the monochromator reading to the actual wavelength. The formula should be of the following form:

$$\lambda = m \lambda_c + b$$

where λ is the wavelength, λ_c is the monochromator reading, m and b are constants (slope and offset to a linear fit). Use this calibration in the rest of your lab to report spectral intensity versus wavelength.

- 2) Describe what is happening to the light inside the monochromator. For a monochromatic source such as the He-Ne laser, did you observe any spots inside the monochromator which were hitting a wall in addition to the exiting light? If so, what is this light?
- 3) 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?**
- 4) 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?
- 5) 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?
- 6) Describe the observed spectrum of your unknown. Based on the results of Discussion question 5, are you measuring the true spectral shape or it instrument limited? Is only part of it instrument limited? What is the actual source of the emission inside the lamp; i.e., what is the active component generating the light? (to answer this consider sharp intensity peaks... do you correspond to known emission from any atoms? Consult table in OPSE lab.).

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.

