Astronomy 351 – Instrumentation in Astronomy
Course Project: Scanning Monochromator

1. Overall Goals and Procedure

The overall goal of your team's project is to construct a scanning grating monochromator. It will measure signal strength versus wavelength over some portion of the visible spectrum. This device should be able to determine the wavelength of a red HeNe laser using a discharge lamp as a calibrator. You need to be able to take and display a spectrum of the lamp automatically. You also will need to determine the efficiency of your instrument.

Your designing should be an iterative process. Gather together design ideas and alternatives. Put together a strawman design for your whole system and your measurement process. Go through each aspect of the performance requirements. Examine the impact of design decisions in one area (say, mechanics) on the design in another area (e.g. software). Go back and work through your design again to reflect what you learned in the first pass. You will interact with us during one of the early iterations and also during a later iteration (see schedule below).

1.1. Performance Specifications

Resolution: Your instrument must have a resolution ≤ 0.6 nm.

Sensitivity: Your instrument must be able to detect the orange lines from the mercury lamp with a signal-to-noise ratio of 5.

AΩ: Your instrument must accept radiation from an AΩ product $\geq 5 \times 10^{-6}\ cm^2 sr$.

Goals: It would be desirable to beat the sensitivity and AΩ requirements by as large a factor as possible. It would also be desirable to be able to change the spectral resolution (e.g., by changing a slit width), making it either larger or smaller. No specification is placed on scan rate or fraction of time spent taking data during the scan, but you will only have 1/2 hour to demonstrate the capabilities of your instrument. The sensitivity of your instrument depends both on the efficiency of your optics and the noise in your electronics. You should make both as good as possible.

2. Optical Design

You are limited to the optics we have on hand. These include 1-in^2 600 line/mm diffraction gratings, 3-in dia 17.5-in focal length mirrors, and a variety of lenses, flat mirrors, and optics holders.

1. What optical arrangement will you use? Will you use a mirror or lenses? Are the aberrations small enough to meet the resolution specification?

2. What is the dispersion of your spectrometer (nm/mm)? What entrance and exit slit widths do you need to meet the resolution specification?

3. How closely spaced in wavelength do the samples of your spectrum have to be, given the resolution requirement?

4. Do you need baffling to prevent stray light (either from the source you are measuring or from the room) from reaching your detector?

3. Electronics

1. What are the levels of the signals put out by the detector? Are these appropriately matched to the allowable input range of the A/D converter? Can the signal level be suitably adjusted by using the variable gain on the A/D board or is additional gain or attenuation necessary?

2. Does the detector produce a DC voltage offset across its output? Is it necessary for dynamic range reasons to null this offset? Does the normal operating background produce such an offset?

3. Is the output impedance of the system low enough?

4. Given the way you plan to take data, what kind of bandwidth do you need for the output from the detector? What kind of analog filtering do you need?

5. Are you going to have a shutter or switch the lamp or laser on and off under computer control? Do you need some interface electronics for this?

6. Are you going to move whatever you move "open loop", or do you want to devise an electronic circuit to measure the motion?

7. Can any of the functions you have assigned to electronics be performed more easily by software?

8. How well does your design avoid electrical pickup?

4. Mechanical Design

We have optical breadboards and some optics holders that you can use, but we do not have holders for the gratings or devices to rotate or translate optics or detectors to scan the spectrum. You will have to either build them or buy them. If you plan to buy them, you will have to consider delivery times and our (very limited) budget. Note that some parts are available from previous incarnations of the instrument. You can use these in addition to any parts you purchase.

1. How will you hold your diffraction grating and mirror if you use one?

2. How will you lay out and mount your optical components on a breadboard?

3. What light baffling, if any, will you use?

4. What will move in your system to scan the spectrum? How will you make it move? (If you plan to scan the grating angle, you might incorporate the rotation mechanism into you grating holder.) How precisely and accurately does it have to move to meet the resolution requirement?

5. If you have to build components for your spectrometer, you will have to sketch the concept, make proper shop drawings, and go to the shop and make it. (Different people might do different ones of these jobs.)

5. Software

1. How will you carry out your observations and measure the quantities required to answer the questions we have posed?

2. You have a monochromator. What will you scan to make a spectrum: the grating or the detector?

3. How fast will you scan? Step and integrate? Rapid scan?

4. How fast will you sample?

5. Does the A/D have adequate dynamic range for the signal, the offsets, and the noise?

6. How will you average the data to reduce noise and systematics?

7. What does a basic flowchart of your software look like?

8. What is your strategy for using the software to reduce offsets? Deal with different finds of noise? Compensate for imperfections in the mechanical implementation?

6. Things to Measure

1. Once you have built your spectrometer, measure its spectral resolution.

2. Using the available lamps, estimate the wavelength accuracy of your measurement of the HeNe line.

7. Milestones

March 2: First project team meetings

March 23: Conceptual Design Review meetings (discuss ideas)

April 6-8: Preliminary Design Review meetings (present plans)

April 27-29: Critical Project Review meetings (instrument trial run)

May 4-6: Project Demos and evaluation