# Phys 4910 Spectroscopy
# Introduction to the Photomultiplier

## Introduction

Our monochromator has two modes of operation
- using a diode array detector
- using a photomultiplier tube (PMT) detector

After looking at the first mode last week we will look at the second this week. As an example of using a PMT we will again take the helium spectrum. You should notice that the blue and green lines which were so weak last week (because of the response of the diode detector) will now be as strong as the yellow and red lines.

## Using the PMT

Although the PMT is superior to the diode detector both in terms of its signal to noise ratio, and its wider spectral response, it does have two drawbacks
- Since it is a single detector, rather than an array you will need to scan through the spectrum, rather than taking a series of snapshots of the spectrum. That takes time. A full scan over the visible region can easily take 20 minutes, sometimes longer.
- The sensitivity of the PMT is very much a function of the operating voltage. If the voltage is too low then the apparent intensity of your spectrum will appear vanishingly small. Make the voltage too high and the spectrum becomes overwhelmingly high. It can sometimes take a few attempts to get the voltage just right.

## Operating the monochromator

When using the PMT, the monochromator is computer controlled using only the program "Monochromator Control". It must first be used to set the diverter to "side", and is then used to either set the wavelength to some fixed number, or to scan between two set wavelengths.

The spectrum itself is recorded by the program "PMT Data Acquisition". This program acts like a strip chart, recording the electrical current from the PMT as a function of time. (Note: when you first start the program thee is a piece of nagware that shows up. It will go away in about 30 seconds.)

## Lab procedure

### Preliminaries

1. If you need to log on to the computer, then use the account Student for which the password is physics.

2. On the desktop there is a folder labeled "Spectroscopy". Open this folder
3. Open the program "Monochromator Control". (Note: Ignore the warnings. Simply use the "OK" button to proceed.)
4. Select the option "Diverter" and make sure that the "Exit Mirror" option is "Side".
5. Click on "Return" to get the main menu.

**PMT characteristics**

1. Place the helium lamp in front of the slit but close to the edge of the table.
2. Turn on the power supply to the PMT, and set the voltage to -500 V.
3. Set the electrometer scale to 100 nA. (Note: you might need to change this setting as you make the adjustments below.)
4. Select "Operation" in the "Monochromator Control" program.
5. Enter the wavelength of any of the strong helium lines (see last week's lab) in the box labeled "Wavelength" (top left of window) and press "Goto". The monochromator will then rotate the grating so that light of that wavelength is directed to the exit slit. (This does depend on the calibration of the monochromator. If is poorly calibrated and you cannot get a signal then please see me.)
6. You should now get a reading on the electrometer. By making small changes to the wavelength that you entered (I would suggest a change of no more than 0.1 nm at a time) try to maximize this signal. Alternatively, you can use the jog control with the option set to "Singe Step". (You may have to change ranges on the electrometer as you do either of these.)
7. The signal is also quite sensitive to the position of the lamp. Try moving it sideways to see if you can get a larger signal.
8. The width of the slit controls the amount of light entering the monochromator, and hence also the amount of light falling on the photomultiplier, and in turn its output current. When you have the largest signal you can find adjust the entrance slit width to make the current about 50 nA.
9. Without changing anything except the applied photomultiplier voltage, measure the current using the electrometer as a function of the applied voltage between -200 V and -800 V. (You may have to change ranges on the electrometer as you do so.) **Note: Do not exceed 1000 V**
10. Plot the signal current as a function of voltage.

**Helium spectrum**

1. Set the PMT voltage such that the strength of the signal that you see is between 50 nA and 100 nA.

2. The output of the electrometer can be recorded by the computer using the Labjack interface. The signal is recorded by the program "PMT Data Acquisition" which turns the computer into a strip recorder. Start this program.

3. The aim is to record the helium spectrum between 350 nm and 720 nm in a reasonable time (say 20 minutes). Note: you can do this in one go, there is no need to split the spectrum into two. There are some parameters that you need to decide on

   a) The rate at which the monochromator is going to scan through the spectrum, from the total scan width (in nm) and the time you want to the measurement to take. Note: pay careful attention to this. If you enter a number which is too small then your scan will take a very long time, and you cannot stop it until it reaches the end. Enter the following

      i. Start wavelength, in nm. In this case 350
      ii. End wavelength, in nm. In this case 720
      iii. Scan speed, in nm/min. Enter the number that you have decided on.
      iv. Number of scans. Set equal to 1.
      v. Scan delay.  Set equal to 0
      vi. **Do not start the scan yet.**

   b) The rate at which the computer (using the program "PMT Data Acquisition") will take data. There are a number of selections available. The higher the rate you choose the better the resolution and the smoother the spectrum will look, but also the higher the total number of data points you will have to collect. Note: you cannot take more than 10,000. If you do the program crashes and you will have to start again. Aim for a **total** number less than 10,000 with some margin for error. Make the selection that is closest to the rate you want.

   c) There are some options for changing the display (the options below the display). You can select anything here, as your selection can be changed at any time during the scan without affecting the results.

4. Once you have decided on your parameters, and entered them appropriately, first start taking data using the button labeled "Acquire" in recording program "PMT Data Acquisition", and then set the monochromator scanning using the button "Start Scan" in the "Monochromator Control" program.

5. Sit back and relax. You have nothing to do (except perhaps change the display) until the scan finishes.

6. When all the data has been taken, and the monochromator reading is 720 nm, the "Monochromator Control" program will automatically stop. However, you need to **manually** stop the "PMT Data Acquisition" program using the button labeled "Pause/Stop". If you don't it will continue taking data until it reaches 10,000 data points and crashes. If this happens you will need to start all over again.

7. You can save your data as a text file for importing into a spreadsheet program. In the recording program "PMT Data Acquisition" click on "Write to file" and save the file in your own directory with a file name that you choose. This is a text file which you can import into a spreadsheet program.

If you obtained a reasonable spectrum then you are finished. On the other hand if the spectrum appears weak you will need to run it again with a higher PMT voltage. However, if your peaks are too large (that is, off the scale) then run a scan again using a lower PMT voltage.

**Keithley Electrometer**

The diagram to the right shows the Keithley electrometer. The sensitivity of the electrometer is controlled by the two central dials. The larger one sets the order of magnitude of the instrument, and the smaller one is a multiplier. For example, if the large dial reads $10^{-7}$ A and the small dial reads 0.3, then the electrometer has a full scale reading of 0.3 x $10^{-7}$ A = 3 x $10^{-8}$ A = 30 nA.

The only other control of interest is the one on the top right. The small dot on the dial should be opposite the '-' symbol, indicating that we are measuring a negative current[1]. The other settings are

- Power Off – power of completely off
- Off – the electrometer is on, but the input is disconnected, so no readings are being taken
- + – for measuring positive currents
- Center zero – for measuring currents of either polarity.

**Hamamatsu C9525 Power Supply**

The diagram to the right shows the power supply which supplies the negative voltage required for the PMT. Its voltage is controlled by the four arrows to the right of the display. The display itself shows the current voltage, with one of the digits underlined. Using the left and right arrows you can select any one of the three digits to be underlined. The up and down arrows then either increase or decrease the underlined digit.

Note the voltage is not actually applied until the green button to the right of the arrows is pressed in.

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1 Remember that the photomultiplier produces electrons, and since electrons are negatively charged that corresponds to a current going *into* the photomultiplier (negative), not *out of* it (positive).