Phys 4910 Spectroscopy
PMT Characteristics

Introduction

This lab focuses on two properties of the photomultiplier:

1. The gain of the photomultiplier as a function of the applied voltage. This relates directly to the operating behavior of the PMT
2. The limiting factor in the ability of a photomultiplier to detect very weak signals, which is governed is its dark current. For light signals low enough that the PMT current is lower than its dark current special techniques, principally photon counting, have to be employed.

Assignment – Gain of the PMT

1. Open the Monochromator Control program, and set the Diverter to the side (the position of the photomultiplier).
2. Turn on the power supply to the photomultiplier with a voltage of 700 V.
3. Select any line from the spectrum of the lamp. Literally any line will do, although you will find it easiest to use a good strong line. You can use the spectrum from last week to make an appropriate choice. (Note: you don't need to know its wavelength.)
4. Adjust for maximum intensity (that is, maximum current from the PMT, as shown on the electrometer) by adjusting the position of the lamp, and as you slowly change ('jog') the wavelength.
5. Adjust the slit width to get a current reading of about 100 nA (10^{-7} A). The actual value is immaterial at this stage.
6. Measure the current for a PMT voltage from 200 V to 1000 V. (This is a relative measure of the gain of the photomultiplier as a function of applied voltage, although you cannot assign absolute numbers as you do not know how many electrons are being emitted from the cathode.)

Assignment – Dark Current of the PMT

The dark current is the small current that is still detected even when no light falls on the cathode. It has a number of sources, which you can read about in the online Hamamatsu catalog, and in other source.

7. Turn off the lamp, and block the input to the monochromator to prevent stray light entering the monochromator.
8. Measure the dark current for the same range of applied voltage. (You will need to change the sensitivity of the electrometer to at least the 10^{-8} A range (f.s.d.) as the dark current is very small.

Report - Discussion

The report for this laboratory exercise has two parts:

1. Analysis and discussion of your gain measurements

a. The dependence of the relative gain on the PMT voltage (V). If we assume the the gain varies as V^n, then what is the power, n? (Hint: think logarithms.)
b. How does this relate to the PMT being used, and what physical property does it tell you? Two hints:
   i. Think about the basic design and operation of a PMT[(1)]
   ii. The number of electrons being emitted from the cathode is a constant, since you are not changing the light intensity.

2. A review of the nature of the dark current. The Hamamatsu Photomultiplier Handbook is a good comprehensive place to start, although a little long (see the class lecture notes for a link to the handbook.) You should be able to find other online resources[(2,3)] also.
   a. The dependence of the dark current on the PMT voltage (V). Can you identify the different regions corresponding to different regions of the dark current?
   b. If you take the ratio of signal to dark current, this is the signal to noise ratio. What is its dependence on PMT voltage? Does that tell you anything about the optimal choice of parameters for operating your PMT?

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1 http://www.hamamatsu.com/us/en/community/optical_sensors/tutorials/guide_to_detector_selection/index.html
2 http://sites.fas.harvard.edu/~phys191r/Bench_Notes/B4/PMT_prop.pdf
3 http://www.et-enterprises.com/files/file/Understanding-photomultipliers.pdf