OPTICS 380A
DETECTORS

Introduction

This lab deals with a variety of photo detectors. A photo detector converts optical energy into observable signal and is used in numerous scientific and technical applications. There are two general categories of photo detectors: thermal and photoelectric. Thermal detectors convert light energy into heat energy and are generally slow and inefficient. Photoelectric detectors convert light into current. In this lab you will be familiarized with four types of detectors: photomultiplier, photodiode (p-n junction), photoconductor and pyroelectric detector.

Some of the important parameters of photo detectors are (1) quantum efficiency, probability of generating a pair of photo carriers by a single photon, (2) responsivity, relation between the electric current and optical power, and (3) response time. All parameters depend on the wavelength of incident light and on the amount of power. All detectors have a finite dynamic range which is defined by their minimal detectable power and saturation power.

The signal output of photo detectors is current. The current signal is usually converted to voltage signal using a transimpedance amplifier. A transimpedance amplifier is an op-amp with a feedback resistor, and you can think of it as a circuit that converts current to voltage.

For this lab, you need to answer all the questions in section A to D, including the plots.

A. THE PHOTOMULTIPLIER TUBE (PMT)

1. Read the data sheets for the Burle 931A PMT and its power supply PF1042. Connect the PMT to the 12 volt main power supply and program it for –1000V with a programming power supply voltage of 8V or programming resistance of 2 kΩ. Connect the output of the PMT to a transimpedance amplifier and measure the voltage output with an oscilloscope (Channel 1).

2. Hook up a green LED to a function generator operating at 25Hz. The LED drive current/voltage should be variable.

3. Place the anode opening of the PMT next to the green LED.

4. Hook up a large-area Si photodiode next to the green LED and use a similar transimpedance amplifier to observe the voltage output on the oscilloscope (Channel 2).

5. Cover the PMT, LED and Si photodiode assembly with several layers of black cloth.

6. Set both transimpedance amplifiers to a gain of 6 decades (#6 on the selectable switch), and observe the outputs on the oscilloscope. Adjust the oscilloscope so that a 25Hz signal from both detectors is shown in the screen. Describe similarities and differences between the two signals. Note gain settings (V/div) on the oscilloscope.

7. Now reduce the LED drive current/voltage so that the photodiode signal has an SNR of about 1. You may need to adjust the oscilloscope gain and offset. Is the PMT signal still visible? If so, estimate the SNR of the PMT signal. Why do you still observe a PMT signal when the signal can't be reliably observed with the photodiode?

B. TEMPORAL CHARACTERISTICS OF A SLOW AND A FAST PV DETECTOR TO A SHORT LIGHT PULSE

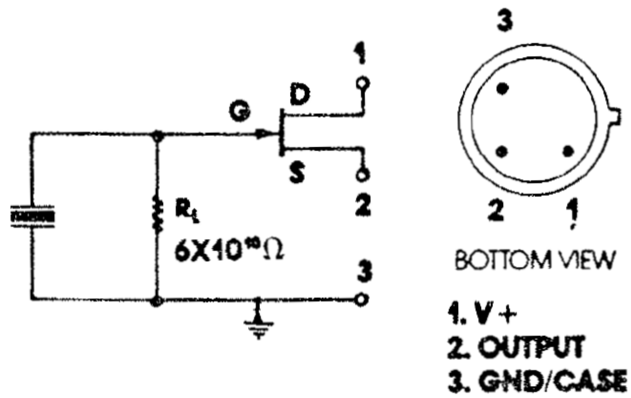
1. We use a xenon flashlamp (an emergency alarm light) to provide a bright, fast source. The xenon discharge has a plasma temperature approximating sunlight (6000K) in the visible spectra, and several strong pressure-broadened (Lorentzian) spectral lines in the near infrared. It is also characterized by a rather short flash duration (tens of microseconds). Characterization of this source is a challenge. This source is also used for flash photography. Use it with a slow repetition rate so that you can capture just a single pulse.
2. Connect the large area silicon photodiode directly into the digital oscilloscope Channel 1, start the source, and find the scope settings that will display a single pulse. Press Single Seq on the scope to save and display the response for a single flash. Press Run to perform a continuous trace. Adjust the voltage and time scale to display the response of a single pulse. You should see a sharp rise (or drop depending on polarity) followed by an exponential decay. Estimate the decay time from the trace. For a fixed signal current I (i.e. fixed intensity of light), the output voltage of the detector is directly proportional to the load resistance, R and is given by V=IR. The input impedance of the oscilloscope is 1MΩ. Estimate the peak current from the trace.
3. Place a 50 ohm resistor across the oscilloscope input terminals and repeat step 1. The input impedance is now approximately 50 ohm. This should reduce the RC time constant. Look at the trace at high power and lower power. Note the response at high power, the detector is saturated. Compare the low power response and the previous traces, and explain why they are different (which has a faster response?).
4. Connect a large area silicon photodiode to a transimpedance amplifier. Connect the output of the transimpedance amplifier to the scope. The transimpedance amplifier is a box called VERSA-350. There is a switch to adjust the resistor and gain for the output signal. Set the switch to lowest gain (10^3V/A). Measure the response using the scope, and compare with the results (peak voltage, shape and decay time) obtained with the 50 ohm resistor in step B.3. Note that even though the gain can be high, the output of the transimpedance amplifier is limited by the power supply. You can see that by setting the switch to highest gain and see the clipping of the pulse response.
5. Set up ***RÁPIDO***, the New Focus 1621 visible nanosecond photo detector in front of the strobe and connect the output to the oscilloscope. Typical detector capacitance is 3pF. What is the typical rise time for a 50Ω load? Use T=RC. In practice, you will see a slower rise time because of parasitic capacitance of the BNC cable. Obtain traces for the three switch positions on the photodiode (10kΩ, OPEN & 50Ω) at fixed input intensity and compare. The switch position determines the load of the detector. When you select OPEN, the total resistance is just the input resistance of the oscilloscope, which is 1MΩ. The output of the detector is limited to 9V, because of the battery. Estimate the pulse width. Explain what happened when you switch to OPEN.

C. TEMPORAL CHARACTERISTICS OF A PHOTOCONDUCTOR

1. Use the strobe light again for this step. Connect the small CdS photoconductor directly to the input of the scope. Look carefully at the CdS photoconductor. Draw a picture of what you observe. There should be two interdigitized electrodes to collect carriers generated by incident radiation. Apply 12 volts bias to the detector and look at the output. Set the voltage and time scale so you can see the temporal response of the photoconductor to the strobe light. Again use single sequence. Compare the results with the silicon photodiode responses.

D. THE PYROELECTRIC DETECTOR

1. Connect the pyroelectric detector per the data sheet in the lab. Measure and plot the voltage response (V_{max}-V_{min}) as a function of chopper speed over the frequency range from 5 Hz to 100 Hz. Use a soldering iron as the source and place a chopper between the iron and the detector. Fix the position of the soldering iron when you do the measurement.



2. Your body is warm and emits infrared radiation. Is the pyroelectric detector able to respond to any other warm bodies in the lab? Try waving at it with no chopper.