Photodiode, Avalanche and Geiger-Mode

Experiment 1

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1 Objectives

The objectives of this experiment are as follows:

- To establish the differences between the 3 modes of photodiode operation; photodiode (linear), avalanche and Geiger.

2 Equipment

- 1 Power supply (not supplied)
- 1 Ammeter (not supplied)
- 1 Integrating sphere (supplied)
- 1 Oscilloscope
- 1 SensL Passive Quench Circuit (PQC) (supplied)
- 1 PIN Photodiode (supplied)
- 1 White light source (supplied)
- 1 SMA to BNC lead (supplied)

3 Photodiode Mode

When the photodiode is unbiased or biased sufficiently low as not to undergo multiplication, the reverse current flowing will be proportional to the light intensity falling on the device. To illustrate photodiode or linear mode the dark current versus reverse bias and photocurrent versus light intensity are examined.

3.1 Dark Current

- Set up the equipment as shown in Fig. 1. This places the photon counting detector, contained within the SensL PQC, in the dark. The room lights may be turned off when making measurements as this increases the darkness.
- Place the $0\ \Omega$ resistor in series with the detector by switching the first PQC switch (brown switch) on and the other switches off.
- Set the voltage on the power supply to -1 V. This places a 1 V reverse bias on the diode.
- Read and record the current flowing through the diode. This is the dark current.
- Decrease the bias to -5 V. Read and record the current again.
- Observe the variation in dark current with reverse bias.

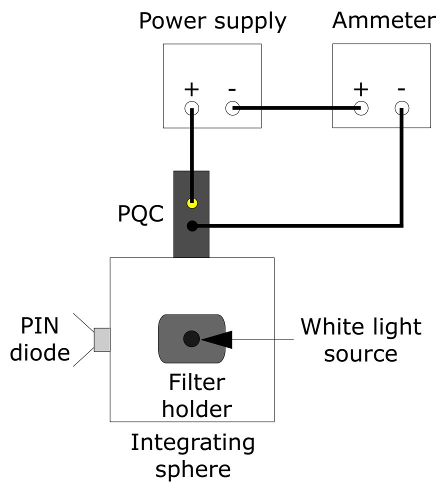

Figure 1: Experimental setup for photodiode and avalanche mode illustration.

3.2 Photocurrent Versus Light Intensity

- Set up the equipment as shown in Fig. 1. Switch the first PQC switch (brown switch) on, which places the $0\ \Omega$ resistor in series with the diode.

- Set the voltage on the power supply to -1 V.
- Place the 600 nm bandpass filter into its holder and place it into the main filter holder.
- Place the OD 2.0 neutral density filter into its holder and then into the main filter holder. Insert the second (empty) neutral density filter holder into the main filter holder to aid with alignment. Place the lid on the filter holder.
- Turn on the white light source.
- Read and record the current flowing through the diode.
- Repeat the procedure with a lower value neutral density filter. Continue repeating the procedure for each neutral density filter, reading and recording the current at each stage. Observe the variation in photodiode current with increasing light intensity.
- Repeat the full procedure with a bias of -5 V on the photodiode.

4 Avalanche Mode

When a photodiode is operated in avalanche mode the bias voltage is brought closer to the breakdown voltage. Here impact ionisation occurs and the closer the bias voltage is to breakdown the larger the multiplication gain will be. This part of the experiment describes how to measure the multiplication gain of the diode.

4.1 Measuring Multiplication Gain

- Set up the equipment as shown in Fig. 1. Switch the first PQC switch (brown switch) on, placing the $0\ \Omega$ resistor in series with the diode.

- Set the voltage on the power supply to -1 V. Turn the room lights off and read and record the current flowing through the diode. This is the unmultiplied dark current, I_{dark}.

- Place the 600 nm bandpass filter in its holder and put it in the main filter holder. Switch on the white light source. Read and record the current flowing through the diode. This is the unmultiplied photocurrent, I_{photo}.

- Decrease the bias to -15 V and repeat the procedure. The currents obtained are the multiplied dark current, $I_{dark\ multiplied}$, and the multiplied photocurrent, $I_{photo\ multiplied}$, at -15 V.

- Repeat the last step decreasing the bias in steps of 1 V until a voltage of -30 V has been reached.

- Calculate the multiplication gain at each bias using:

$$Multiplication\ gain = \frac{I_{photo\ multiplied} - I_{dark\ multiplied}}{I_{photo} - I_{dark}} \tag{1}$$

  Note: the unmultiplied photocurrent and unmultiplied dark current, measured at -1 V, need only be measured once and are used for each calculation.

5 Geiger-Mode

Using the PQC, this part of the experiment illustrates both dark count and photon counting operation.

- Set up the equipment as shown in Fig. 2.

- Set the load resistor of the PQC to 100 kΩ. To do this switch the second switch (red switch) on and the others off.

- Set the current limit on the power supply to 10 μA. Set the PQC voltage to 3 V above the breakdown voltage (the breakdown voltage is supplied by the manufacturer).

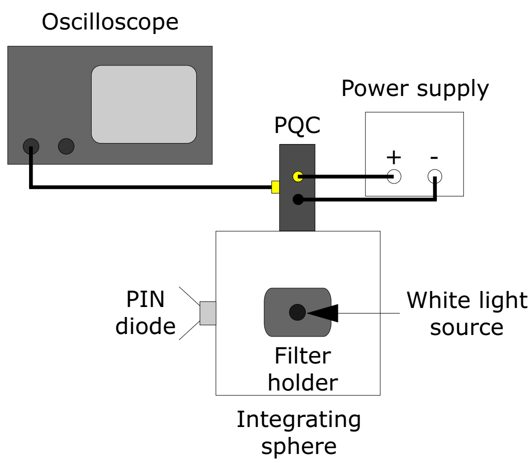

Figure 2: Experimental setup for dark count and photon counting observation.

- Connect the SMA to BNC lead to the SMA connector on the PQC and in turn to the scope. This probes across the load resistor of the PQC.
- Turn off the room lights.
- Set the oscilloscope to 1 V per division on the vertical axis and to 20 μs per division on the horizontal axis. Set the trigger level of the oscilloscope to -500 mV (with the baseline of the waveform at 0). Set up the oscilloscope so that it displays the frequency of the pulses that cross the trigger. Record the frequency, this is the dark count rate of the detector at -30 V. Notice that the amplitude of the pulse is ≈ 3 V corresponding to the excess bias, the dead time is ≈ 40 μs and the dark count rate is ≈ 120 cps (or 120 Hz). Fig. 3 shows what should typically be observed.
- Place the 600 nm bandpass into its filter holder and place it in the main filter holder.
- Insert the OD 2.0 neutral density filter into its filter holder and place into the main filter holder. Place the second neutral density filter holder into the main filter holder to aid with alignment. Place the lid on the filter holder.
- Turn on the white light source.

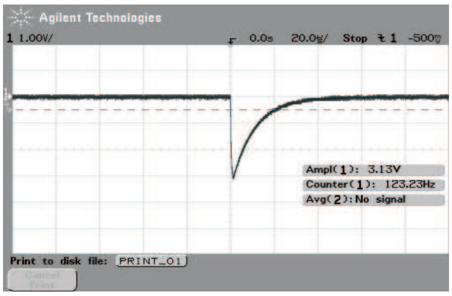

Figure 3: Waveform from PQC biased 3 V above the breakdown voltage and placed in the dark.

- Again bias the PQC 3 V above the breakdown voltage.
- turn on the white light source and turn off the room lights.
- Read the count rate from the oscilloscope. The count rate should have increased (see Fig. 4 for a typical result) as the PQC is now photon counting. Record the bias applied, the count rate and the neutral density filter used.
- Repeat the photon counting procedure for various neutral density filters and compare the results.

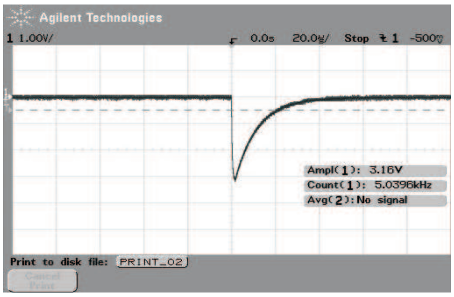

Figure 4: Waveform from PQC biased 3 V above the breakdown voltage and placed in the light.

6 Summary

After completing Experiment 1, the reader should be able to answer the following questions:

1. Does dark current increase or decrease with increasing reverse bias?
2. What affect does reverse bias have on multiplication gain?
3. How does the dark count rate compare to the photon counting rate?

7 Acknowledgements

SensL Technologies Ltd. would like to acknowledge Dr. Aoife M. Moloney of the School of Electronic and Communications Engineering in the Dublin Institute of Technology and Dr. Alan P. Morrison of the Department of Electrical and Electronic Engineering in University College Cork, for writing and coordinating the PCEdu-1 Photon Counting Fundamentals Pack.