Photon Detection Probability

Experiment 3

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1 Objectives

The objectives of this experiment are as follows:

- To measure the photon detection probability (PDP) of a photon counting detector.
- To illustrate the variation in photon detection probability with wavelength.
- To investigate the variation in photon detection probability with excess bias.

2 Equipment

- 2 Power supplies (not supplied)
- 1 Ammeter (not supplied)
- 1 PC (not supplied)
- 1 Integrating sphere (supplied)
- 1 Filter holder (supplied)
- 1 White light source (supplied)
- 1 Set of neutral density filters (supplied)
- 1 Set of narrow bandpass filters (supplied)
- 1 PIN photodiode and PIN calibrated responsivity chart (supplied)
- 1 SensL photon counter (supplied)
- SensL Integrated Environment software (supplied)

3 Measurement of Photon Detection Probability

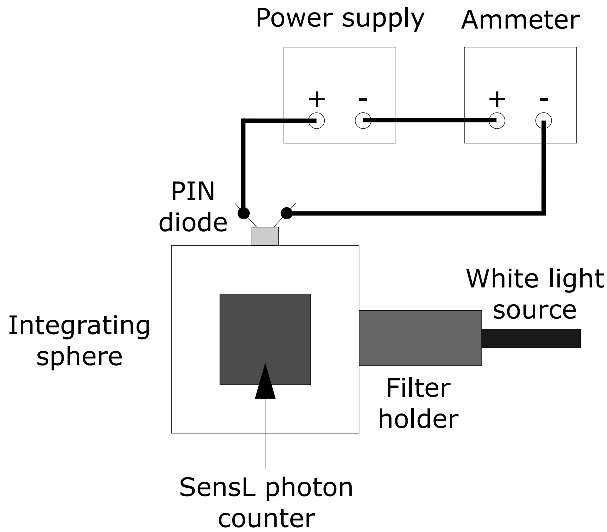

Figure 1: Experimental setup for PDP measurement.

- Connect the SensL photon counter, PIN photodiode and white light source to the integrating sphere as shown in Fig. 1.
- Install the SensL Integrated Environment software onto the PC. Using the first power supply, bias the photon counter paying particular attention to the biasing sequence, i.e. initially switch on V_{cc}, then the APD bias and finally the quench voltage, (see the supplied photon counter installation and user guide for further information).
- Connect the supplied USB lead to the photon counter and to the computer. Open the SensL Integrated Environment software. For information on the photon counter GUI (graphical user interface) refer to the user manual supplied or select 'Help' on the software.
- When the start screen appears, navigate to the toolbar and select the option labelled 'Window' followed by 'Results'. Click 'PCDMini' followed by 'Channel' on the 'Results' window to view the diode temperature, the diode voltages and the count frequency.

- Navigate to 'Window' on the toolbar and open the 'Graphs' window by selecting 'Graphs'. Select 'This Computer', 'PCDMini', 'Channel', 'Counts' and 'Count Frequency'. Then press the 'Play' icon to observe the count rate (see the software installation manual and Experiment 2 Section 5).

- Using the second power supply, place a reverse bias of 5 V on the PIN photodiode.

- Set the APD bias to 5 V above the breakdown voltage.

- Turn off the room lights.

- Record the current on the ammeter. This is the dark current, I_{dark}, flowing through the PIN diode.

- Record the count rate given on the user interface. This is the dark count rate, N_{dark}.

- Turn on the room lights.

- Place the 600 nm bandpass filter into the filter holder.

- Place the OD 0.5 neutral density filter into its filter holder and in turn into the main filter holder. Place the second (empty) filter into the filter holder to aid with alignment. Place the lid on the filter holder.

- Turn off the room lights and switch on the white light source.

- Read the current on the ammeter, I_{light}, and the count rate from the computer, N_{light}.

- Calculate the current generated in the PIN, I_{PIN}, due to the white light source using:

$$I_{PIN} = I_{light} - I_{dark} \tag{1}$$

- Calculate the power incident on the PIN using the current I_{PIN} and the PIN responsivity at 600 nm (see the supplied PIN responsivity chart).

- Since using an integrating sphere ensures that the PIN's optical power density is equal to that of the photon counter, the power on the photon counter can be found from:

$$Photon\ counter_{power} = \frac{Photon\ counter_{active\ area}}{PIN_{active\ area}} \cdot PIN_{power} \tag{2}$$

The power can therefore be approximated using:

$$Photon\ counter_{power} = 4.94 \times 10^{-6} \cdot PIN_{power} \tag{3}$$

The actual photon flux incident on the photon counter can be calculated using:

$$N_{in} = \frac{Photon\ counter_{power}}{Photon\ energy} = \frac{Photon\ counter_{power}}{h\nu} \tag{4}$$

where N_{in} is the incident photon flux, h is Planck's constant (6.625×10^{-34} Js) and ν is the frequency of the light, given by:

$$\nu = \frac{c}{\lambda} \tag{5}$$

with c being the speed of light (3×10^{8} ms^{-1}) and λ the wavelength of the light (600 nm in this case).

- The photon detection probability can be calculated using:

$$PDP = \frac{N_{light} - N_{dark}}{N_{in}} \cdot 100\% \tag{6}$$

4 Measurement of Photon Detection Probability Versus Wavelength

- Repeat the procedure outlined in Section 3 for each of the remaining 3 bandpass filters (405 nm, 500 nm and 694 nm).

- Plot a graph of PDP (y-axis) versus wavelength (x-axis).

5 Measurement of Photon Detection Probability Versus Excess Bias

- Repeat the procedure in Section 3 with the detector excess bias set to 0 V.
- Increase the excess bias in steps of 1 V, repeating the procedure at each bias, until an excess bias of 10 V has been reached.
- Plot a graph of PDP (y-axis) versus excess bias (x-axis)

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6 Summary

After completing Experiment 3, the reader should be able to answer the following questions:

1. How is PDP measured?
2. How would you account for the dead time of the photon counter when measuring PDP?
3. What effect does wavelength have on PDP?
4. What effect does excess bias have on PDP?

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