Active and Passive Photon Counting

Experiment 5

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1 Objectives

The objectives of this experiment are as follows:

- To observe the detector count rate achievable using an active quench/reset circuit.
- To observe the detector count rate achievable using a passive quench/reset circuit.
- To compare active and passive photon counting.

2 Equipment

- 1 PC (not supplied)
- 1 Power supply (not supplied)
- 1 Oscilloscope (not supplied)
- 1 PIN photodiode (supplied)
- 1 SensL Passive Quench Circuit (PQC) (supplied)
- 1 Integrating sphere with filter holder (supplied)
- 1 SMA to BNC lead (supplied)
- 1 White light source (supplied)
- 1 Set of neutral density filters (supplied)
- 1 Set of narrow bandpass filters (supplied)
- 1 SensL photon counter (PCM) (supplied)
- SensL Integrated Environment software (supplied)

3 Active Photon Counting

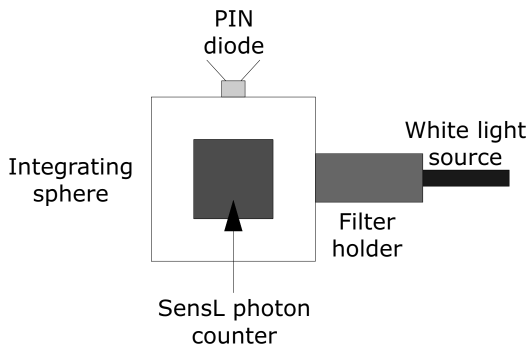

Figure 1: Experimental setup for active quench/reset photon counting.

- Connect the SensL photon counter, PIN photodiode and white light source to the integrating sphere as shown in Fig. 1. This places the photon counter in the dark. The room lights may be turned off for the measurements, to increase the darkness.
- Install the SensL Integrated Environment software onto the PC. 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).
- Set the APD bias to 5 V above the breakdown voltage (the breakdown voltage is supplied by the manufacturer).
- Turn off the room lights.
- Record the count rate given on the user interface. This is the dark count rate.
- Turn on the room lights.
- Insert the 600 nm narrow bandpass filter into its filter holder, the OD 2.0 neutral density filter into its filter holder and both filters into the main filter holder. Also insert the second (empty) neutral density filter holder into the assembly to aid with alignment.
- Connect the photon counter output to the oscilloscope. To do this, connect the SMA to BNC lead to the SMA connector on the photon counter and in turn to the scope.
- Set the volts per division on the scope to 2 V and adjust the timescale to 100 ns per division. Set the trigger level to ≈ 500 mV (with the baseline of the waveform set at 0 V). setup the oscilloscope so that it displays the frequency of the pulses that cross the trigger. This is the count rate.
- Turn off the room lights and turn on the white light source.
- On the 'Graph' window, click on the 'Page Clear' icon (it resembles a sheet of paper). Next click on the green 'Play' icon to begin collecting the count rate over time. Notice that the count rate on the scope is the same is the same as that shown on the results window of the GUI.

- Use the cursors on the oscilloscope to measure quench time (see Fig. 2) and reset time (see Fig. 3). Decrease the time per division to increase the accuracy of the measurement.

- Add the quench and reset times to obtain the total dead time and calculate the maximum count rate achievable using Eq. 1 below:

$$Max\ count\ rate = \frac{1}{dead\ time} \tag{1}$$

- In the example shown here, the quench time is 2.62 ns and the reset time is 58.00 ns giving a dead time of 60.62 ns. This dead time means that count rates as high as $1/60.62$ ns ≈ 16.5 MHz can be recorded.

- A count rate of ≈ 13 kHz was recorded here (see Fig. 4). Clearly, the photon counter can measure this count rate and much higher count rates with ease due to its active quench/reset circuitry.

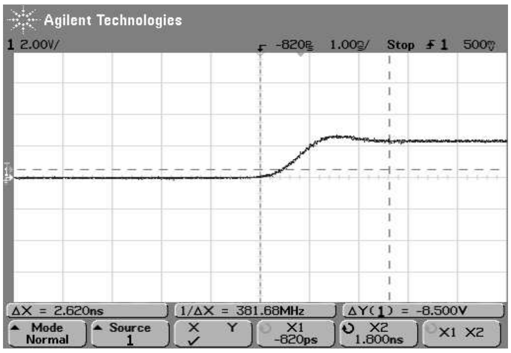

Figure 2: Measuring quench time of the PCM using an oscilloscope.

4 Passive Photon Counting

- Set up the equipment as shown in Fig. 5. Note that the PIN diode is used as a port plug to keep the equipment in the dark.

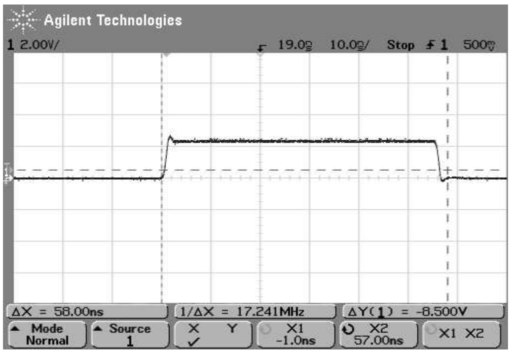

Figure 3: Measuring reset time of the photon counter using an oscilloscope.

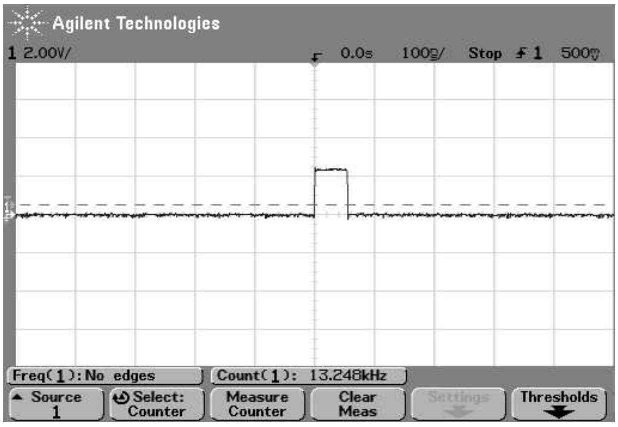

Figure 4: Measuring count rate using an oscilloscope and the photon counter.

- Set the load resistor of the SensL PQC to 100 kΩ. To do this switch the second switch (red switch) on and the others off (refer to Module 6 Section 2.1 for the circuit diagram of a PQC).
- Set the current limit on the power supply to 10 μA and reverse bias the diode 3 V above the breakdown voltage the breakdown voltage of the photon counting detector, contained within the PQC, is supplied by the manufacturer).
- 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.

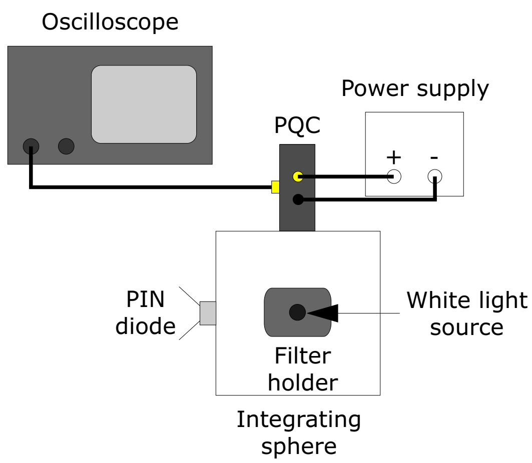

Figure 5: Experimental setup for passive quench/reset photon counting.

- 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 set at 0 V). 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 PQC detector. Fig. 6 shows what should typically be observed. Notice that the amplitude of the pulse is ≈ 3 V corresponding to the excess bias and the dark count is ≈ 120 cps (or 120 Hz).

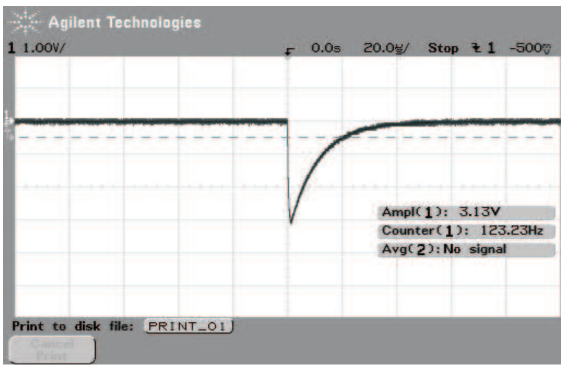

Figure 6: Waveform from PQC biased 3V above the breakdown voltage and placed in the dark.

- Turn on the room lights.
- Insert the 600 nm narrow bandpass filter and the OD 2.0 neutral density filter into their filter holders and in turn into the main filter holder. Also insert the other neutral density filter holder into the assembly to aid with alignment.
- Turn off the room lights and turn on the white light source.
- Read the count rate from the oscilloscope. The count rate should have increased.
- Measure the quench time and reset time of the pulse using the cursors on the oscilloscope (see Module 6 Section 2.1 if necessary) and then calculate the total dead time and the maximum count rate achievable (see Section 3).
- In the example shown here the dead time is $\approx 40\mu$s (see Fig. 6). This implies that the PQC with the resistance set to 100 kΩ can measure count rates up to $1/40\ \mu$s $\approx 25,000$ cps.
- Repeat the procedure above for load resistances of 500 kΩ and 2 MΩ. A load resistance of 500 kΩ is obtained by switching the orange switch on and all the other switches off and a resistance of 2 MΩ is achieved by switching the yellow switch on and switching the other switches off.

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5 Summary

After completing Experiment 5, the reader should be able to answer the following questions:

1. For the case of active quench/reset photon counting, how does the measured count rate compare with the calculated maximum count rate achievable?

2. For the case of passive quench/reset photon counting, how does the measured count rate compare with the calculated maximum count rate achievable?

3. How does changing the resistance on the PQC affect the total dead time measured?

6 Acknowledgements

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