

FIG 2. Circuit diagram for reverse-biasing an LED and using an op-amp comparator (LM311) to produce a 5 V output pulse. V_{bias} is typically around 24 V for the AND114R LEDs.

discriminator to the output. Here, an inexpensive LM311 op-amp comparator is used for this purpose. The output will remain at ground until a voltage pulse at the non-inverting input (+) of the op-amp rises above the voltage at the inverting input (-). The ‘pull-up’ resistor on the output sets the amplitude of the output pulses to 5 V. The voltage at the inverting input is controlled by the potentiometer between the inverting input and the 5 V supply.

This basic discriminator circuit is highly useful in getting students to understand the triggering on an oscilloscope. By monitoring the voltage at the two inputs and the output of the op-amp, students can visually see that 5 V output pulses only occur when the original pulses cross the voltage threshold set by the potentiometer. This forces students to confront the idea that they are discarding some events based on the discriminator level.

Finally, the TTL-level pulses produced can be detected by any number of devices. We have used oscilloscopes, LabView DAQs, Vernier LabQuests, and TeachSpin’s Pulse Counter/Interval Timer. With these devices, tests of the statistical properties of the arrival of photons at the detector are possible.

III. RESULTS

Figure 3 illustrates typical distributions of the number of counts per interval compared to Poisson and Gaussian distributions with the same mean and standard deviation as the data. The data (using ambient room light as the source) is reasonably well described by a Poisson distribution for all three intervals. The noticeable discrepancy is due mostly to afterpulsing, which causes the distribution’s variance to not be equal to its mean as expected for Poisson distributions. As expected, the Gaussian matches poorly for small average numbers of counts, but agrees very well

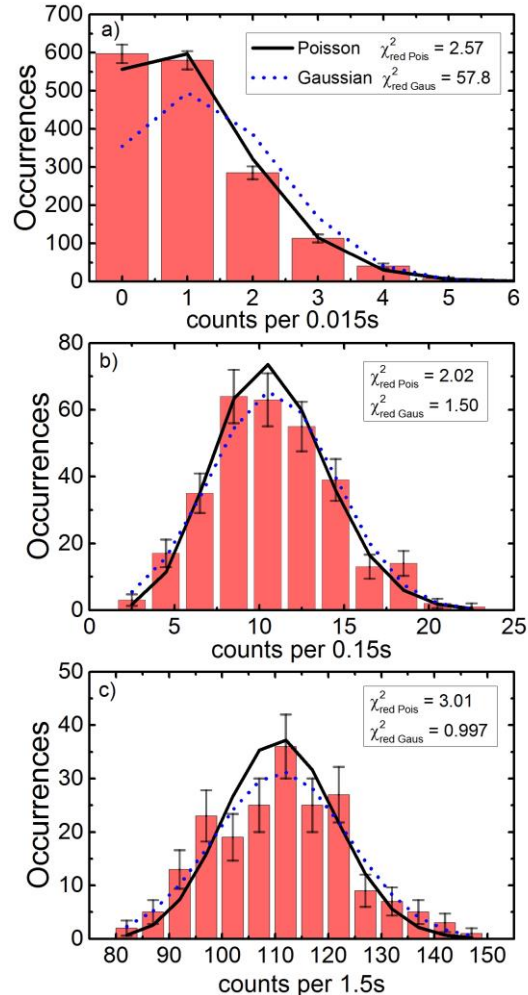


FIG 3. Histograms of the number of counts per interval for intervals of a) 0.015 s, b) 0.15 s, and c) 1.5 s. Poisson (solid) and Gaussian (dashed) distributions with the same mean and standard deviations as the data are shown as well. The error bars represent the square root of the values.

when the average increases and the distribution becomes symmetric.

Figure 4 shows typical data of the time between pulses. The expected exponential distribution is broken at very short time intervals by a large spike as a result of the afterpulsing. Those correlated pulses are produced at very short intervals after a ‘real’ pulse and are easily distinguished in this plot. The dead time of this detection system can be controlled by the choice of the quenching resistor in series with the LED as seen in Fig 5.

IV. CONCLUSIONS

This experimental system provides another inexpensive means by which students can investigate the statistics of

