C.2.2 Hands-on Photon Counting Statistics

SG6222

Related Experiment
A.1.1
B.1.2
C.2.1
D.1

Ordering Options

Equipment	
Code	**Description**
WK5600XEAAAA	SP5600E - Educational Photon Kit
or the all inclusive Premium Version	
WK5600XANAAA	SP5600AN - Educational Kit - Premium Version

Purpose of the experiment

Statistical properties of the light pulses emitted by a LED driver.

Fundamentals

Spontaneous emission of light results from random decays of excited atoms and it is expected to be Poissonian. SiPM can count the number of impacting photons, shot by shot, opening up the possibility to apply basic skills in probability and statistics while playing with light quanta displaying the spectrum of the SiPM response to a high statistics of pulses. The spectrum is composed by a series of peaks, each ones correspond to different number of cells fired at the same time. Each peak is well separated and occurs with a probability linked at first order to the light intensity fluctuations. In SiPM the homogeneity of the response is quite high , however, since fired cells are randomly distributed in the detector sensitive area residual differences in the gain become evident broadening the peak.

A key point in the analysis technique was the estimation of the area underneath every peak, essential to reconstruct the probability density function of the emitted number of photons per pulse. An easy procedure is to consider each peak as a gaussian, so spectra recorded in response to photons impacting on the sensor can be seen as a superposition of Gaussians, each corresponding to a well defined number of fired cells. A binned Gaussian distribution of N_{pk} events may be written as:

$$y_i = y_{max} e^{\frac{-(x_i - x_0)^2}{2\sigma^2}}$$

where yi is the number of events in the bin centred on x_i and y_{max} is the peak value, measured in x_0. Since $y_{max} = N_{pk}/(\sigma\sqrt{2\pi})$, knowing the content of the bin centred in x_0 and estimating σ leads to N_{pk}. The standard deviation can also be calculated in a simple way by the Full Width at Half Maximum (FWHM), obtained searching for the position of the bins with a content equals to $y_{max}/2$ and presuming that FWHM = 2.355σ

Schrödinger's Cat Paradox

Schrödinger's cat is a famous illustration of the principle in quantum theory of superposition, proposed by Erwin Schrödinger (Nobel Prize in Physics in 1933). Schrödinger's cat serves to demonstrate the apparent conflict between what quantum theory tells us is true about the nature and behaviour of matter on the microscopic level and what we observe to be true about the nature and behaviour of matter on the macroscopic level -- everything visible to the unaided human eye.
Here's Schrödinger's thought experiment: We place a living cat into a steel chamber, along with a device containing a vial of hydrocyanic acid. There is, in the chamber, a very small amount of hydrocyanic acid, a radioactive substance. If even a single atom of the substance decays during the test period, a relay mechanism will trip a hammer, which will, in turn, break the vial and kill the cat.

http://whatis.techtarget.com/definition/Schrodingers-cat

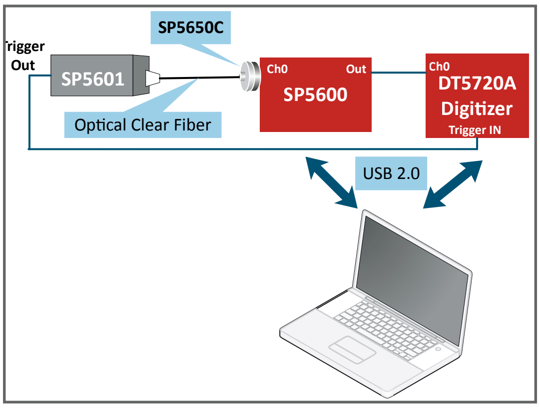
Equipment

SP5600E - Educational Photon Kit

Model	SP5600	DT5720A	SP5601	SP5650C
Description	Power Supply and Amplification Unit	Desktop Digitizer 250 MS/s	LED Driver	Sensor Holder for SP5600 with SiPM
				
	p. 145	p. 145	p. 146	p. 146

Requirements

No other tools are needed.



Experimental setup block diagram.

Carrying out the experiment

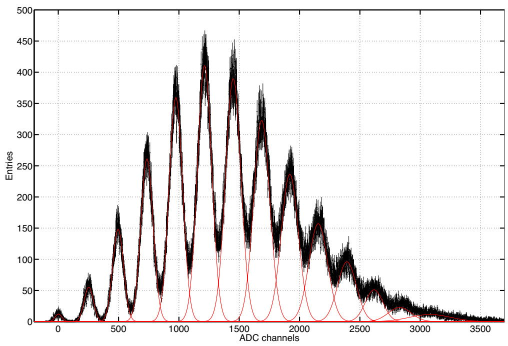
Plug in the SP5650A into one channel of SP5600 and connect the analog output to DT5720A channel 0. Remove the protection cover of the SP5601 and SP5650A, spread the optical grease on both ends of the optical fiber and connect them. Use internal trigger mode on SP5601 and connect its trigger output on the DT5720A trigger IN. Connect via USB the modules to PC and power ON the devices. Use the default software values or optimize the parameters to perform the experiment.

Results

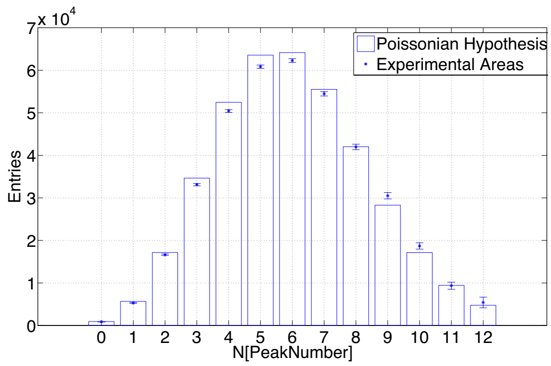
The probability density function of the emitted number of photons per pulse can be estimated by the evaluation of the area underneath every peak.

Two different hypothesis can be investigated to evaluate the statistical model and mean number of photoelectrons: Model Independent (the mean photon number is nothing but the mean) and Poissonian hypothesis (mean value obtained by presuming a pure Poissonian behaviour and by referring to the probability P(0) of having no fired cell when the expected average value).

A complete and more complex analysis that include also considerations about detector structure is reported in the following section in the D.1 note.



Photoelectron spectrum probing a LED source measured with a Hamamatsu SiPM. The Individual Gaussians are shown in red.



Data from the light spectrum compared to a simple Poissonian.