
Photon Counting

Photon Counting with a PMT

Lodovico Lappetito

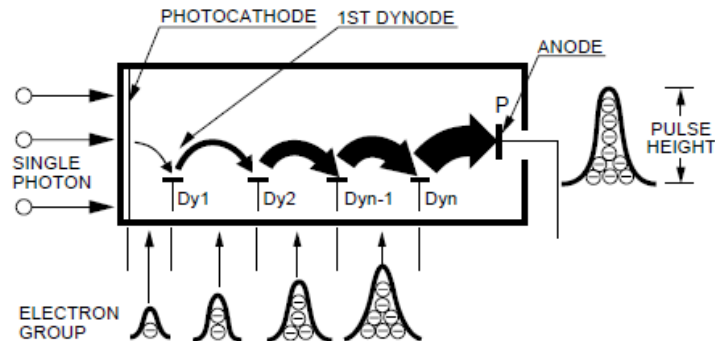
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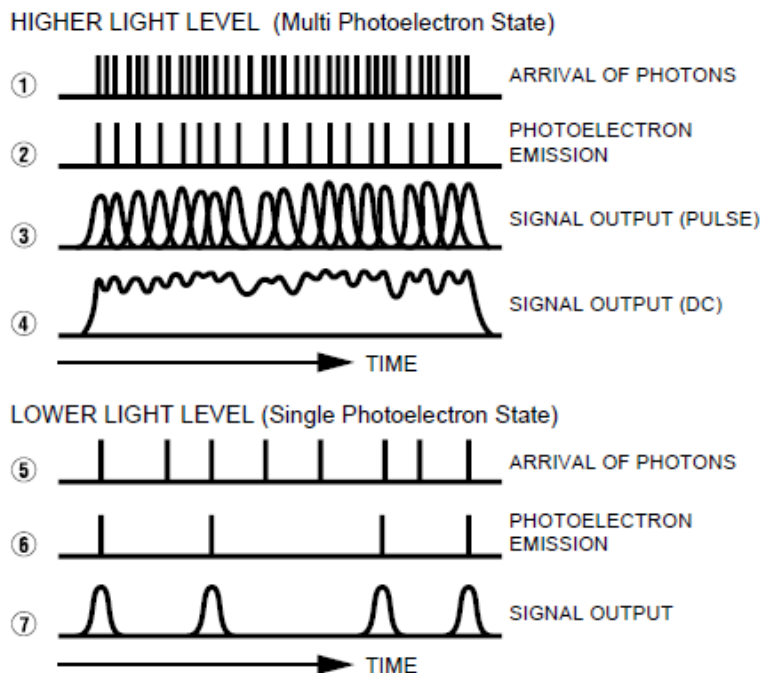
Photon Counting with a PMT

In the measurement of weak light signals, the ultimate limit of sensitivity is to reveal the arrival of single quanta of optical radiation in the visible and near infrared, that is, individual photons. Given the low energy level associated with a photon it is evident the inherent difficulty in this measure. The detection of individual photons can be made with solid-state sensors, such as avalanche photodiodes (APD) or photomultipliers (photomultiplier tube, PMT), in which between anode and cathode is interposed a sequence of electrodes, called dynodes.

An electron emitted from the photocathode is accelerated by a voltage of a few hundred volts and hit the first dynode, causing the emission of several secondary electrons (usually three to five), which in turn are accelerated towards the second dynode, where they cause a new emission of electrons, and so on. The number of electrons grows exponentially with the number of used dynodes and the amplification reaches values even higher than a million. The amplification factor is affected by statistical fluctuations which, however, given the nature of the amplification, are rather moderate.



The photomultipliers are very useful both as analog photodetectors, endowed with a high internal amplification, both as digital detectors of single photons, by connecting the output to a circuit that, starting from the pulses supplied by the detector in response to single photons, generate pulses suitable to be treated by counting circuits or for measuring the time of photon arrival.



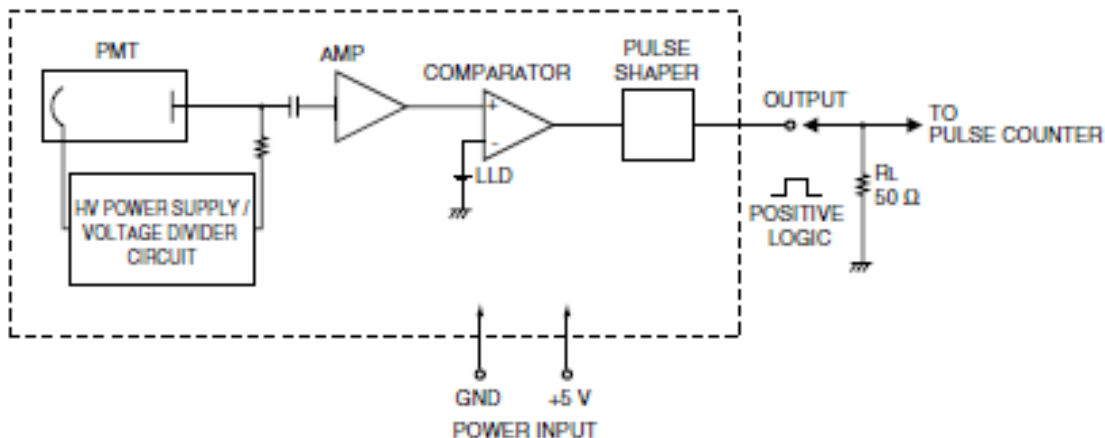
Photomultiplier



As photomultiplier was used the type H7828 Hamamatsu, which contains a 19mm photomultiplier tube, the high-speed circuit for counting photons and a power supply section that supplies the high voltage to the tube. The high voltage for the tube and the threshold level of the discriminator are pre-setup to the optimal level in order to allow operation of the module by simply connecting the power supply to + 5V.

The spectral response of the phototube is from 300nm to 650nm, the sensor is therefore suitable to be used in the visible range.

Block Diagram



Photomultiplier Data Sheets

Input Voltage : 4.5 – 5.5V

Peak Sensitivity Wavelength : 420nm

Dark Count : 200 events/s

Pulse-pair Resolution : 70ns

Output Pulse Width : 30ns

Output Pulse Height : 3.0V

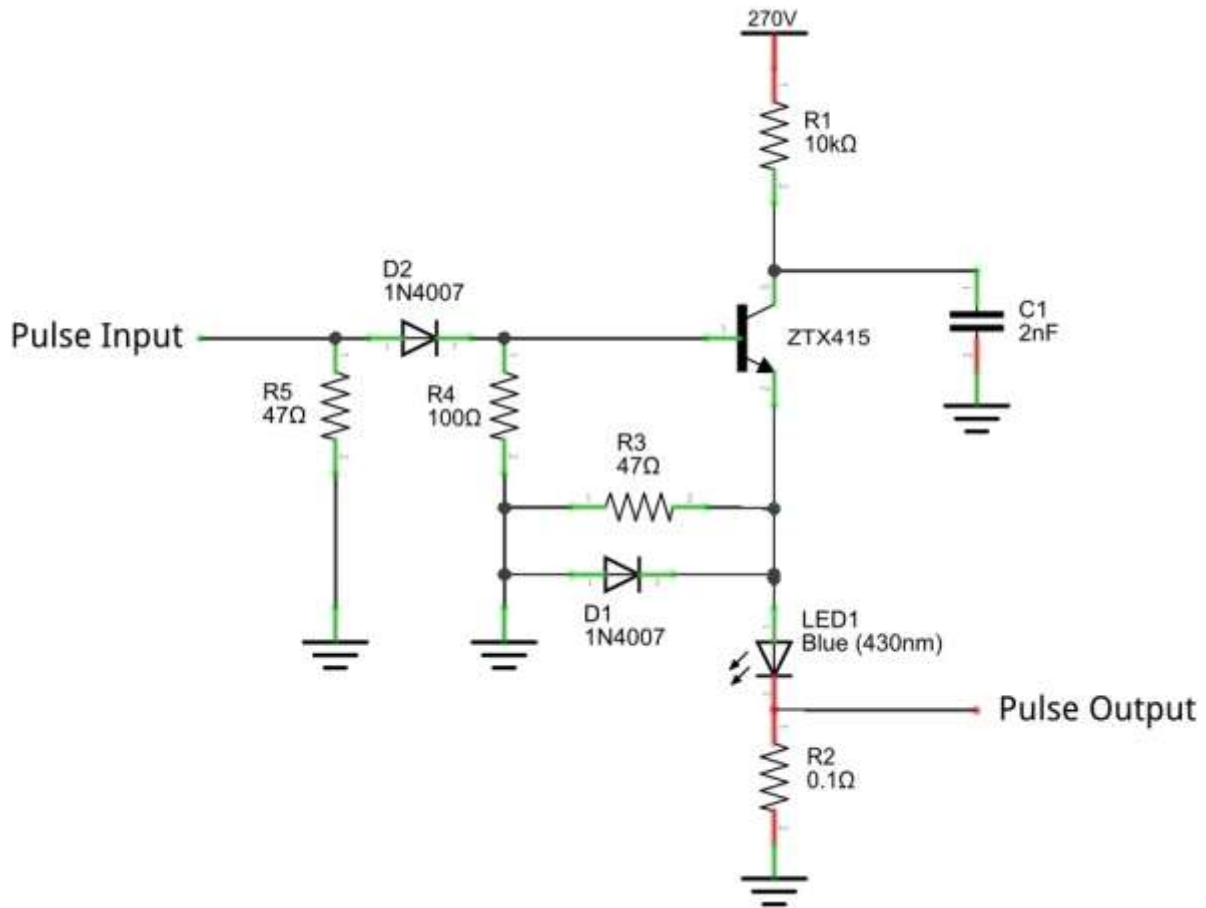
Load Resistance : 50ohm

Signal Output Logic : positive

Fast Pulser

As a light source a normal diode LED (blue - UV) has been used, driven by a circuit for the generation of ultra-short pulses. From the scheme below it can be seen that the LED is driven by an avalanche transistor ZTX415 biased at 270V. The charge is accumulated in the capacitor C1 and then released in a very short time when a pulse arrives at the base of the transistor. On the resistor R2, to 0.1ohm, it may be taken the signal that corresponds to the impulse of current flowing in the diode LED.

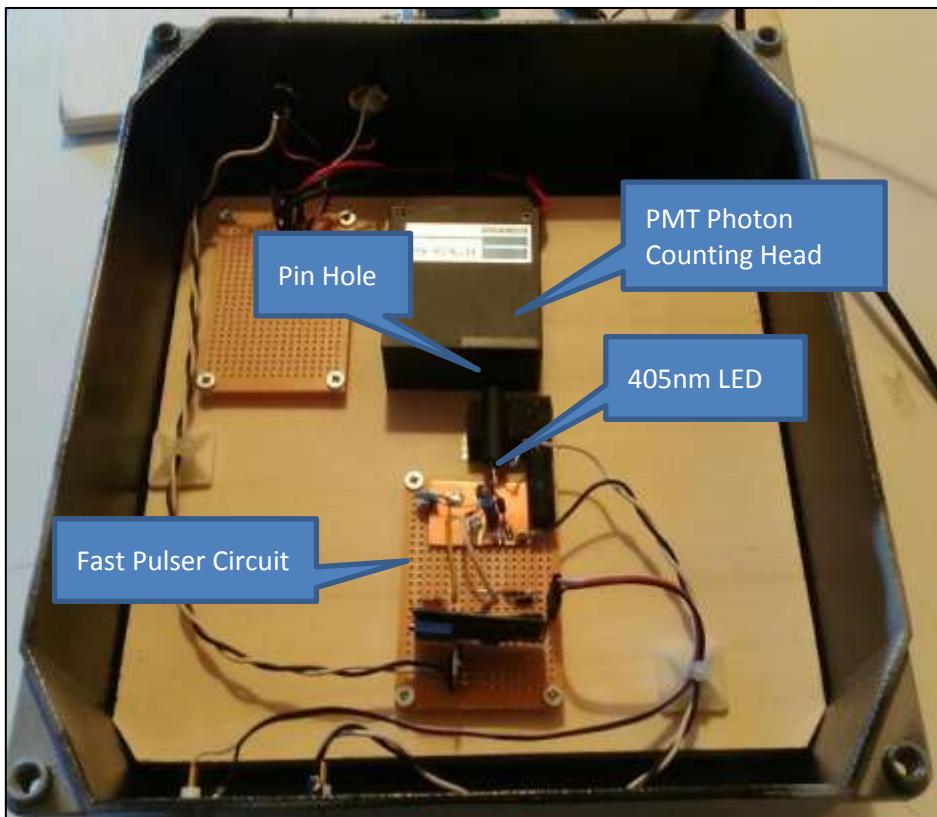
In the following pages you see the oscilloscope trace of the current pulse: is a spike of about 10V and a duration of 10ns, so extremely short. In order to reduce the pulse duration it is necessary to reduce the parasitic inductances of the path followed by the current, in particular the resistance R2 and the connections between C1, the transistor, the LED, R3 and D1. This can be achieved by very short wiring and using a large ground area. The resistors are also to be chosen with low parasitic inductance.



Experimental Setup

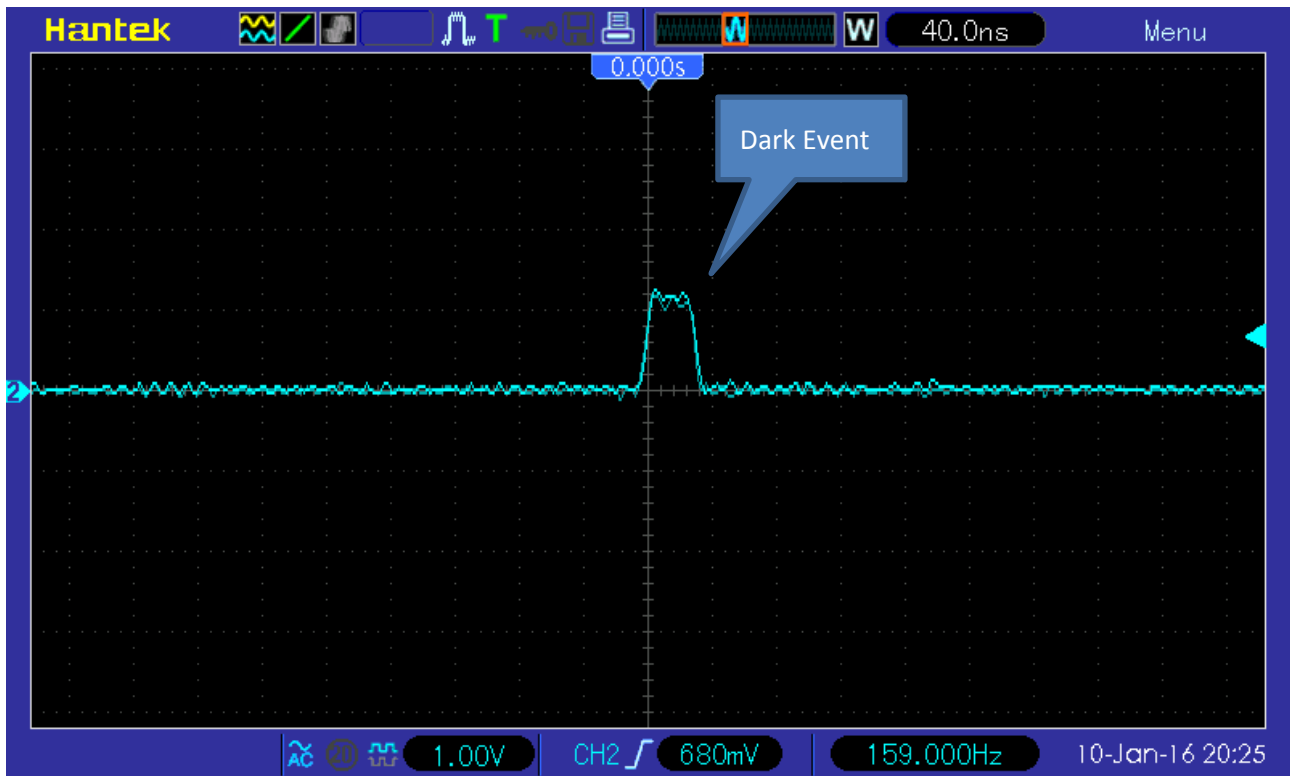


External view of "Counting Dark Box"

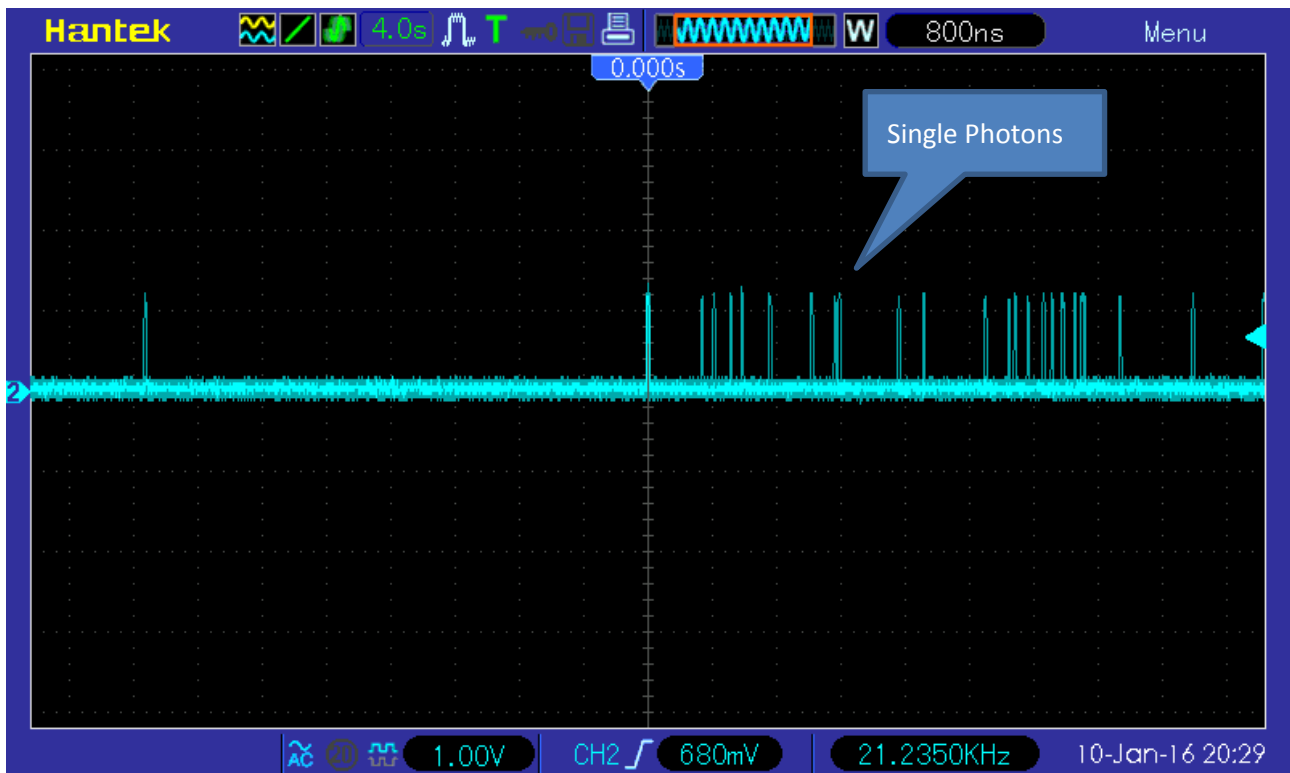


Internal view of "Counting Dark Box"

Photon Counting Measures



Dark pulse – dark rate = 159 Hz (T = 20°C)
dark rate = 50 Hz (T = 0°C)

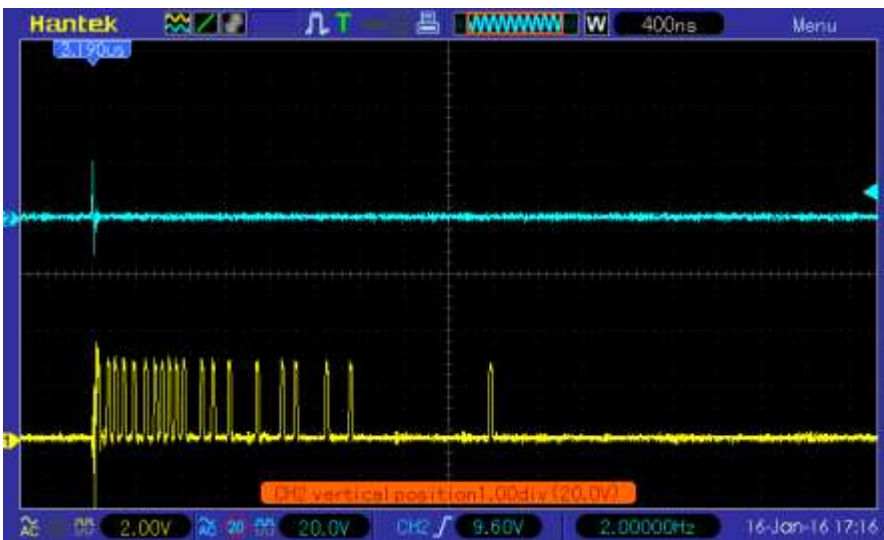


Pulses at low level light



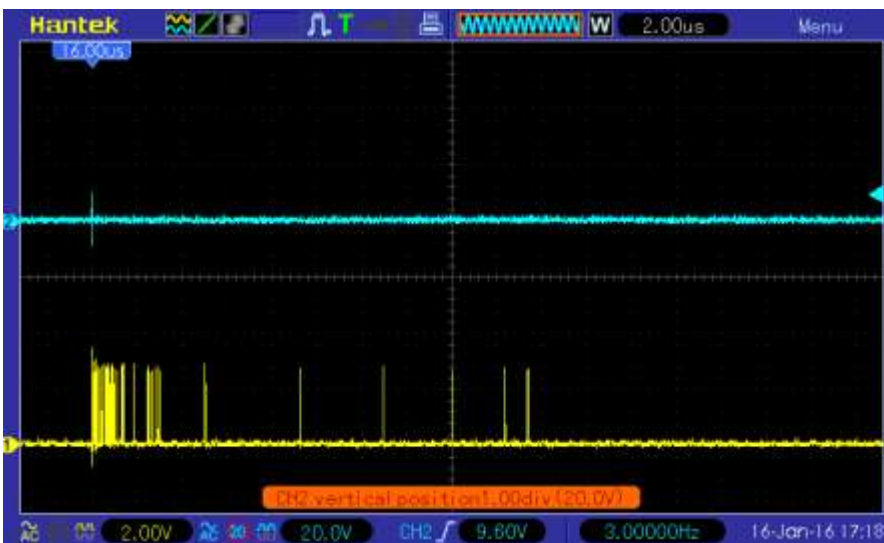
The upper blue trace shows the trend of the current pulse through the LED . The impulse, very short, has a duration of about **10ns**.

The yellow trace below is the output of photon counter module. **Each pulse corresponds to a photon captured by the photocathode of the PMT.**



Oscilloscope Trace extended on a time duration of a few **microseconds** .

It is clear that the photonic pulses are extended approximately from 2 to 3 microseconds after the current pulse.



Oscilloscope Trace extended on a time duration of a few tens of microseconds. It is evident that the photonic pulses are thickened just after the current pulse and then go decreasing because the LED is fading.