Characterization of multi pixelated photon counters with fast and slow detectors for multiple applications

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Introduction

In the modern era of experimental physics, a variety of methodologies are applied to serve a wide range of applications. These applications are spread over, but not restricted to, nuclear physics, high energy physics, atomic physics, medical imaging and biosciences. Different domains have varying requirements in terms of detectors and associated instrumentation, primarily depending on the range of incident energies that are being dealt with. Nevertheless, it has often been found that most of the experimental facilities, at some point or the other, require devices that are sensitive to incident radiation as well have high counting abilities. Devices that can count as less as a single incident photon and have a response in the range of a few thousandth-of-millionth of a second will find wide acceptance in the most modern settings of lowest to highest energy experiments. Since the year 2005, a category of such advanced optoelectronic devices are available- called avalanche photodiodes (APD).

Multi-Pixelated Photon Counter

An APD can be used individually- single photo avalanche diode (SPAD), or as advancement, in arrays of a few thousand single units (called pixels). The operation range for these APD are in their Geiger mode, which ensures a cascade of charges produced in response to a single photon strike- thus a high gain. However, once the self-sustaining charge avalanche is created, a passive quenching circuit is employed in order to limit the current flowing to the diode during its breakdown when a photon strikes. This is done using a series of resistors that lower the reverse bias seen by a diode until below its breakdown voltage. This stops the avalanche in a diode induced by a photon strike and readies the diode for subsequent photon detections. An array that uses multiple such SPAD is called an MPPC (multi-pixelated photon counter). An MPPC in comparison to conventional photo multiplier tubes can be operated at a very low bias of a few tens of volts and is not susceptible to external magnetic fields. However when multiple single units of SPAD are used in an array, there is a distinct possibility of a single photon firing off multiple pixels (crosstalk). There is also an issue of afterpulse wherein there are delayed pulses from one (or multiple) pixel(s) in response to photons detected. The MPPC that is being discussed here has been procured from Hamamatsu [1]. It is the S13360-6050PE version and features low crosstalk, low afterpulses, low dark current count and high photon detection efficiency. This MPPC has a 6x6 mm active area with a pixel pitch of 50 μm, a spectral range of 320-900 nm and a gain of 1.7×10^6. The MPPC device has been tested with fast (plastic scintillators and cerium bromide ($CeBr_3$) crystal) as well as slow detectors (sodium iodide (NaI) crystal) and the test results have been reported in this manuscript.

Test Details

The MPPC has been coupled to a plastic scintillator (NE 102) and the setup well covered with Teflon tape, aluminum foil and black tape to make it light tight. Tests were conducted by coupling the MPPC to a $CeBr_3$ crystal using a light guide and an index matching optical grease and also a NaI crystal using a light guide. As shown in Figure 1, the assemblies were well covered up to ensure low light leakage. This MPPC device runs with an available online software application provided by the manufacturer. The MPPC is connected to the test board that houses a bias circuit which requires ±5 volt and 0 volt supplies. There is a temperature sensor that governs the performance of the MPPC with respect to ambient temperature. The device output can be directly read out using a SubMiniature version B (SMB)-Lemo cable. The test device has onboard protection against supplying overvoltage to the MPPC.

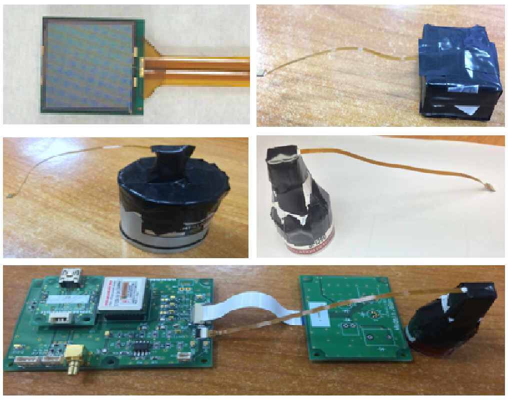

Fig 1: *(clockwise from top left) MPPC unit's sensitive area, MPCC coupled to plastic scintillator, MPPC coupled to $CeBr_3$ crystal using light guide, MPPC-$CeBr_3$ connected to control board and MPPC coupled using light guide to NaI crystal.*

Results

The response of the MPPC coupled to the plastic scintillator and $CeBr_3$ scintillator were recorded using a digital phosphor oscilloscope (DPO) with 2.5GHz bandwidth and 40GS/s real time sampling rate (for single channel). Figure 2 displays screen grabs of signals obtained for the sets of tests conducted. The MPPC-plastic scintillator combination gave a fast response and the rise time of the signals was in a few nanoseconds (ns) range. The signal amplitude was a few hundred millivolts (mV). For MPPC-$CeBr_3$ combination, the signal rise time was of the order of 1 (ns) and its amplitude was ~50-60 mV. However, for the slower MPPC-NaI combination, the rise time was ~200 ns and the amplitude of the combination was around 20-30 mV.

The Hamamatsu MPPC has provision for two separate outputs: Sout and Fout. The former can be used for extracting energy information while the latter gives timing information. Currently, work is being undertaken to compare signals from both the outputs for several scintillator combinations in order to completely characterize the MPPC device.

Also, further work is being done to characterize the most advanced MPPC procured from Hamamatsu (S14160-6050HS). This sample has an active photosensitive surface of 6x6 mm with a pixel pitch of 50 microns. Modifications made in the sample include a larger spectral range (290-900 nm), higher gain ($2.5x10^6$), higher photo detection efficiency (>50% at 450 nm) and uses HWB (hole wire bonding) allowing a very small dead space in the active area.

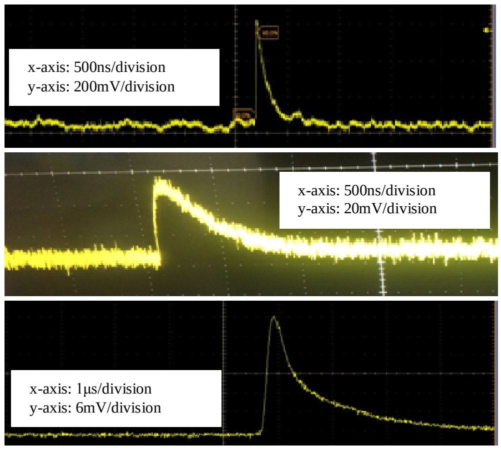

Fig 2: *Oscilloscope screen grab for MPPC coupled to (top) plastic scintillator, (middle) $CeBr_3$ scintillator and (bottom) NaI scintillator.*

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References

[1] Hamamatsu http://www.hamamatsu.com/eu/en/product/category/3100/4004/4113/index.html