Construction of a Test Stand for Evaluation of Silicon Photomultiplier Devices

I. Senderovich and R.T. Jones

October 1, 2006

Abstract

The nuclear physics group at the University of Connecticut has undertaken the project of developing the photon tagger microscope using silicon photomultipliers (SiPM) as the basic scintillation detectors. We report on the initial stage of SiPM testing.

Photons with energies up to 12 GeV will be produced in Hall D in Jefferson Lab via coherent bremsstrahlung (CB) of electrons in a diamond crystal. This technique produces a broad radiation spectrum: the energy of the photon is not known *a priori*. Its energy, however, can be measured (i.e. it can be "tagged") by measuring the energy of the post-bremsstrahlung electron that produced it, which has a known initial energy equal to the beam energy: 12 GeV.

This tagger will be implemented by dispersing the post-bremsstrahlung electrons in a magnetic spectrometer and detecting them on the focal plane. This spectrometer is equipped with a broad band detector array and a higher resolution detector "microscope" covering the narrow energy band of the primary CB peak. The latter detector is instrumented as a packed array of about 600 square 2mm scintillating fibers with SiPMs used for photon detection. The following are the principal advantages of SiPMs compared to the more commonly used photo-multiplier tubes (PMTs):

1. no high voltage required (bias voltages of order 50V are sufficient)
2. response times are about a factor two faster
3. geometric cross section comparable to that of the fiber

Our group is presently concerned with developing a test setup in the lab and then testing and characterization of commercially available SiPM devices.

1 Test Stand

This work requires a testing environment in which fast light pulses of controlled amplitude can be generated and background eliminated. A test stand has been constructed for this purpose. It is essentially a hermetically sealed chamber with a pulsed blue diode illuminating the detector. These are separated by a distance of order 1 m to minimize the solid angle subtended by the detector surface in order to test the detector at low light intensities. The pulser electronics are designed such that the pulse duration is controlled by the amplitude of a square wave from a function generator. A close-up of the LED pulser circuit is shown in Fig. 1. The LED itself, excited by a high-repetition rate pulse train (in order to make its output visible), is shown on the same figure.

Power supplies of appropriate ratings and test equipment have been procured. We have configured a data acquisition system for gathering large statistics on the detector response. These will enable us to understand the noise levels in our test stand and then measure the sensitivity of respective photodetectors.

The stand is currently being tested with a hybrid photo-diode (HPD), which has well known characteristics. This device requires high voltage so appropriate circuitry for bias and readout have been included in the test stand. A photograph of the test stand with associated electronics is shown in Fig. 1. The typical response signal to a minimal pulse height is shown on the same figure as well as on the screenshot of our data acquisition system shown in Fig. 2.

2 SiPM Search

A search is underway for a SiPM with desirable characteristics at acceptable cost and which can be mass-produced. Specifically, we are searching for units with high gain (of order 10^6), high dynamic range and low dark rates without resorting to cooling the units. In general, rates of 10 MHz per device are acceptable for the tagger microscope readout. Spurious counts are negligible at this rate considering an expected signal pulse height is about 100 photoelectrons and a pulse width of 50 ns.

Sample SiPMs have been procured from Photonique, a distributor for CPTA, one of the original developers of SiPMs. These include their tested $1 \times 1mm^2$ units (shown in Fig. 3) and newer $2.1 \times 2.1mm^2$ units (shown in Fig. 4).

3 Outlook

After we have calibrated the photon statistics of the light pulser using the HPD, we will proceed to test the response of the two types of SiPM devices discussed above. SiPM operating parameters of interest include the following.

1. gain vs. bias voltage
2. efficiency
3. dark rate
4. temperature dependence of the above parameters

As soon as these have been measured, as sample scintillating fiber illuminated by a radioactive beta source will be used to study the response of the SiPM to scintillation light.

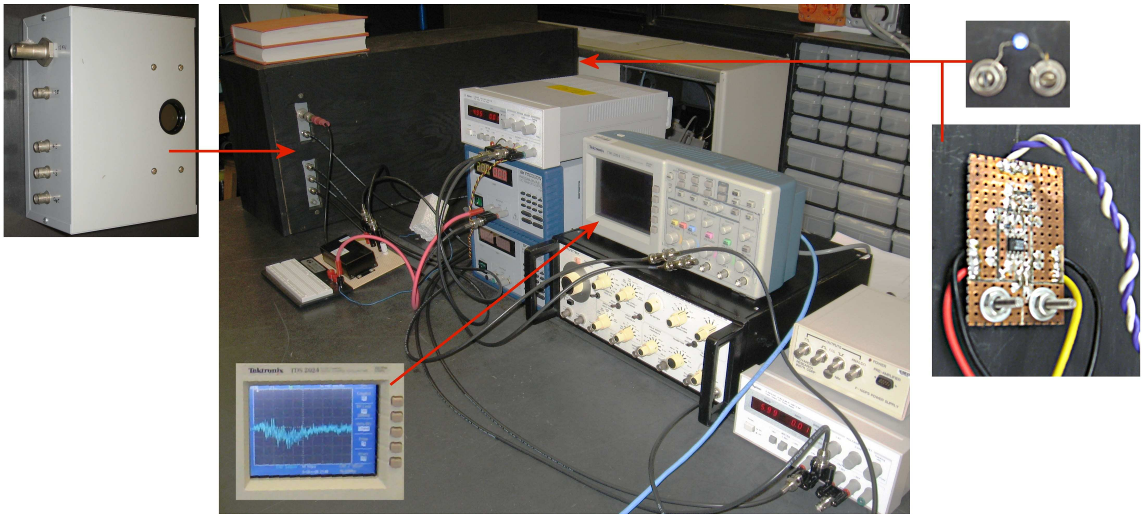

Figure 1: Test setup in the process of measuring the HPD response. The black box in the back is the dark chamber used to test the photodetectors, with detector electronics on the left side and pulser on the right. The HPD unit is shown separately on the left and the pulsing LED with its pulse shaping amplifier circuit on the right. (The pictures on the right show pulser electronics on both sides of the chamber wall.)

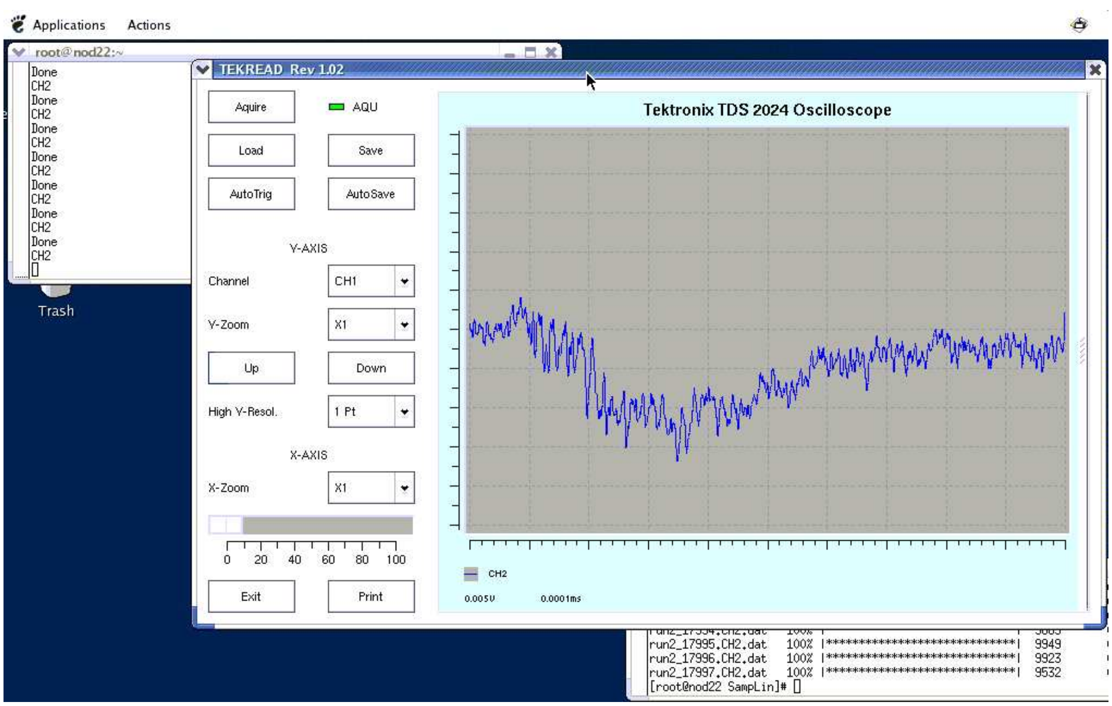

Figure 2: A screenshot of data acquisition software. HPD responses to light pulses are being collected to analyze the statistics of photon detection.

Figure 3: Photonique device SSPM-050701GR-TO18: $1 \times 1mm^2$ sensitive area with 556 pixels. Note the millimeter markings for scale.

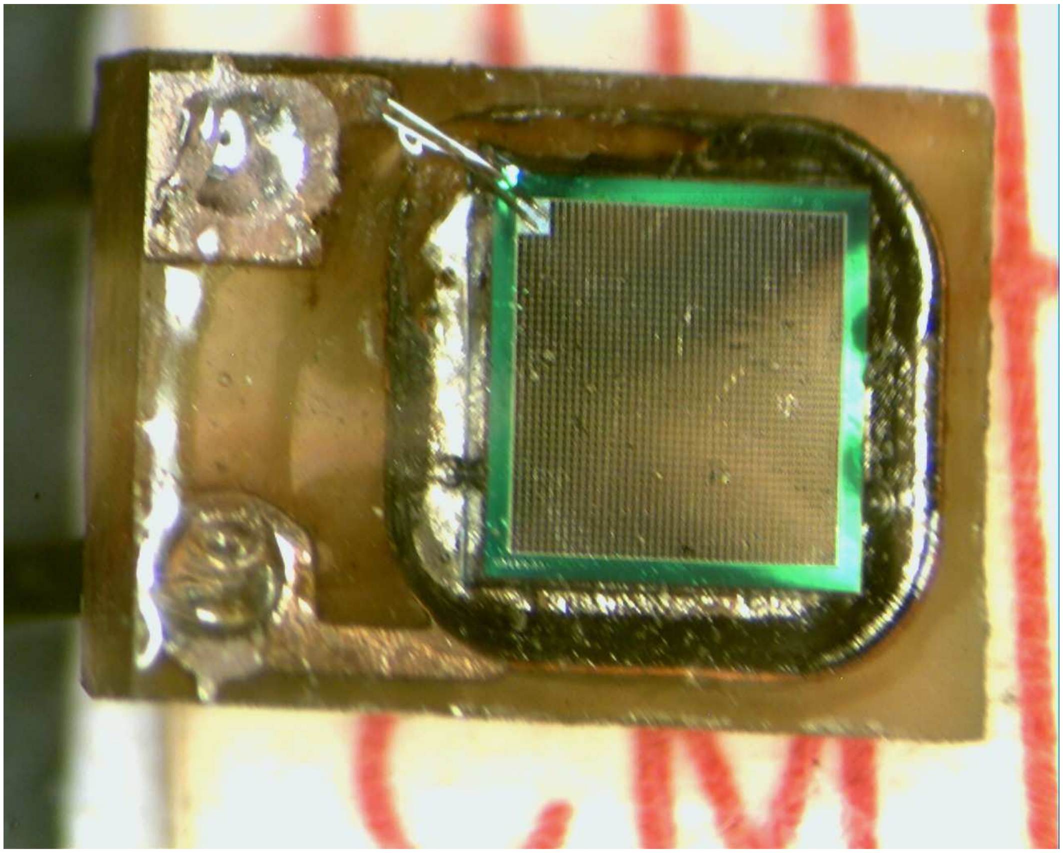

Figure 4: A new Photonique SiPM-0606GR: $2.1 \times 2.1mm^2$ sensitive area with 1700 pixels

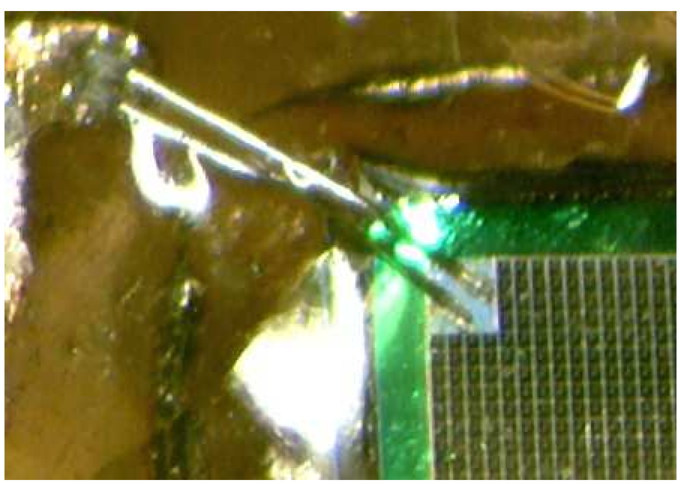

Figure 5: A detail of the pixels and the electrode connecting the grid on the $2.1 \times 2.1mm^2$ device.