Characterization of Visible Light Photon Counters

Suyong Choi
for the DØ Collaboration
Department of Physics, Seoul National University
151-742 Seoul, South Korea

1 Introduction

DØ will upgrade the main tracker with an entirely new system of 80000 channel scintillating fiber tracker [1]. The fiber tracker will consist of 2.8 meter long, 835 μm diameter scintillating fibers arranged in four super-layers. The optical signal from the fibers will be detected by visible light photon counters (VLPCs). Motivation for using VLPCs as a photodetector is it's high quantum efficiency and fast response, as we will have a shorter beam crossing of $132ns$ after the upgrade.

2 VLPC

VLPC is one of a family of devices developed by Rockwell International based on impurity band conduction (IBC) mechanism [3]. High gain and low gain dispersion is achieved by the 50meV band gap in the gain region of the device, where only electrons participate in the avalnche process. The sixth generation of these devices has a high quantum efficiency of about 70% and a gain of more than 60000 at nominal operating points. It is also a very fast device with rise time less than $13ns$.

3 VLPC Characterisation

The VLPC chips produced by Rockwell have 4x2 pixel arrays with individual pixels of $1mm$ in diameter. The first step of the assembly process is to mount and wire-bond the arrays on an aluminium-nitride substrate.

A test cassette holds 8 hybrids or 64 channels at a time. The moderately vacuum tight cassette is to be placed in a cryostat with warm end outside of the cryostat. The cassette has connectors for the QPA02 preamplifier cards. Two red LED sits inside the cassette and a clear acrylic bar, which acts as a light guide, extends down to the cold end where it is connected to a diffuser. 8 chips are placed in a holder and then assembled. Once it is assembled, each pixel faces the diffuser.

A red LED was used for the characterization of the VLPCs. It was chosen for its fast reponse to drive pulses. The VLPCs show relatively flat response in the visible range, so the use of a red light rather than a green one should not compromise the measurements.

Bias and readout is done by spring loaded pins that touch the pads connected to the pixels through the wire bonds. The signal output of the VLPC goes through QPA02 preamplifier board which has a gain of approximately 2700. The signal is then digitized by LeCroy 2249A charge integrating ADCs. The gate for the ADC is provided by the pulse generator trigger output after generating sufficient delay. Gate width is 100 ns.

The test cassette, after the chips are mounted, is inserted into a cryostat. Liquid helium is used to cool down the cryostat to around 10K and actively maintained by a temperature controller.

An IBM compatible personal computer is used to control the whole system. It controls the temperature, bias voltage and pulse parameters. The PC is also used to read out the data from ADCs and store them on disk for analysis.

For each run, we take pedestal data and pulser data. During the pedestal run, pulse going into the LED is inhibited but the preamplifier and VLPC are at operating voltages, therefore no light reaches the VLPC. Dark count rate, noise from the VLPC itself, can be measured from it. The pulser run is taken right after the pedestal run with pulses going into the LED. Each run consists of 20000 triggers.

We acquired data at various temperature settings from 9.0K to 12.0K in 1.0K steps and VLPC biases from 6.0V to 6.8V in steps of 0.2V. We also tried pulsing the LED at different rates of 1kHz, 250kHz and 1MHz. The data taken are from 8 chips, 63 pixels. One pixel did not have bias connection.

4 Results

Pedestal and pulsed spectra are shown in Figure 1. From the pulser data, we measure the gain of VLPC, which is the amount of charge produced in an avalanche per photoelectron. The first peak in the pulser spectrum is the 0 photoelectron peak, which means that there is no avalanche induced by photoelectrons. The second peak corresponds to 1 photo electron peak. The difference between the means of the first peak and the second peak then gives the gain. One photo electron avalanche contains about 58000 electrons when taking into account the gain of the preamplifier of about 2700. The gain increases as we raise the bias and temperature.

Average number of photo electrons is determined from the histogram by

$$< p.e. >= \frac{< Histogram > - Pedestal}{Gain}.$$

Temperature and bias depedence of average number of p.e. is shown in Figure 2. Average number of p.e.'s is a relative measure of quantum efficiency since the average number of photons arriving at the VLPC is constant. The effect of raising the temperature and bias voltage is to raise the quantum efficiency. At around 12K and 6.8V, the device reaches a plateau.

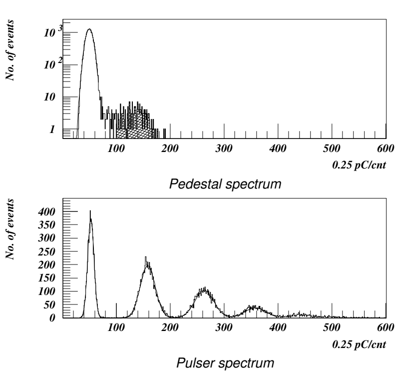

Figure 1: Top:VLPC pulse spectrum with LED illuminating the VLPC. Botton:Pedestal spectrum with dark counts hatched. 1 ADC channel corresponds to $0.25pC$.

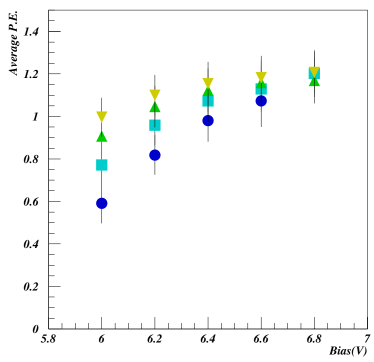

Figure 2: Effect of temperature and bias on the average number of photoelectrons. It clearly shows that QE saturates. Circle:9K Square:10K Triangle:11K Inverted triangle:12 K

In order to determine the noise level from the preamplifier and dark current from the VLPC, a gaussian fit is done to the pedestal spectra. Number of events above a threshold of a half photo electron, is due to intrinsic thermal noise from VLPC or due to infrared photons impinging on the chip and creating an avalanche(Figure 1).

The dark count from the pedestal histogram is converted to dark count rate,

$$Dark\ Count\ Rate = (Dark\ Count/20000) / (100ns).$$

Since the dark count rate tells us how often the noise affects the device, the higher the dark count rate, the less sensitive the device is to a single photon. Figure 3 shows the dependence of dark count rate on temperature and bias voltage. Note that the noise rises rapidly with respect to the bias applied.

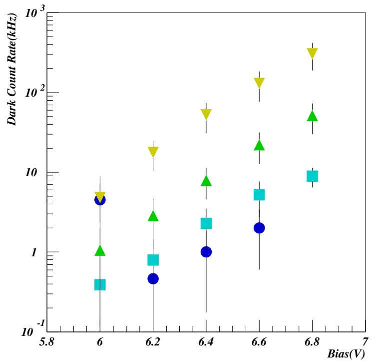

Figure 3: Dark count rate– Circle:9K Square:10K Triangle:11K Inverted triangle:12 K

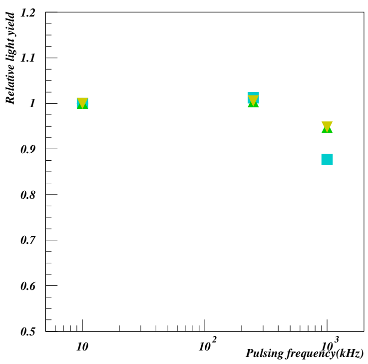

Figure 4: Effect of rate on average number of p.e.'s at 6.8V– Square:10K Triangle:11K Inverted triangle:12 K

	HISTE IV	HISTE V	HISTE VI
Gain	12000	17000	>60000
QE (%)	60	70	70
Gain variation (%)	20	10	5

Table 1: Summary of characteristics of HISTE VI

The effect of LED pulsing rate is shown in Figure 4. At high rates, the quantum efficiency drops but higher temperature mitigates such effects. The study of rate effect is ongoing.

5 Conclusion

We have demonstrated that HISTE VI has a low noise and high gain. Table 1 summarizes the characteristics of HISTE VI and compares with other generations.

1. The DØ Collaboration DØ Internal note 2542.
2. A. D. Bross, R. C. Ruchti and M. R. Wayne, SCIFI 93 (World Scientific, Singapore, 1995) pp. 641-650.
3. A. D. Bross, R. C. Ruchti and M. R. Wayne, SCIFI 93 (World Scientific, Singapore, 1995) pp. 613-629.