Silicon Photon Multipliers Light Response Properties:first results

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***Abstract*—The presented results are obtained during the first steps taken in order to develop a setup and measurement procedures which allow to compare properties of diverse kinds of silicon photomultiplier. The response to low-intensity light was studied for silicon photomultipliers produced by MEPhI/PULSAR (Russia), CPTA (Russia), Hamamatsu (Japan), ITC-irst (Italy) and SensL (Ireland).**

I. Introduction

FAST development of the silicon photomultiplier technology results in a number of different sensor types available on market and produced by various manufacturers. Despite different commercial names of the devices, here all of them are referred as SiPM.

The measurements discussed here include current-voltage characteristics and studies of the SiPM response to low-intensity light. The results of the former measurements are mostly used to check the sample operability and to define the range of bias voltages for the latter studies. The measurements of the SiPM response to the light provide a number of parameters suitable for the comparison of different samples.

Five samples of silicon photomultipliers produced by the following manufacturers have been studied: CPTA[1] produced samples distributed by Obninsk University and Forimtech[2], HAMAMATSU produced Multi-Pixel Photon Counter S10362-11-025C [1], ITC-irst[3], SensL[4] and MEPhI/PULSAR [2] produced samples were compared on the base of the measurement results.

II. Measurement Setup

In order to obtain the SiPM response to low-intensity light, the sensors were illuminated with a light emitting diode operated in a pulse mode. The LED drive developed by Institute of Physics ASCR (Prague) was used. The drive provides current pulses with tunable amplitude and duration with a sharp rise time down to 2 ns [3]. The signal from SiPM was read out with a charge-sensitive preamplifier and digitised with an integrating ADC. The LED pulse of about 6 ns duration and ADC gate of 65 ns width were synchronised by means of a common trigger.

The measurements were done at room temperature. Temperature variation during the measurements done for one sample did not exceed 2°C, for all measurements discussed here the total variation was less than 4°C.

[1]CPTA, Russia, http://www.zao-cpta.ru

[2]Forimtech SA, http://www.forimtech.ch

[3]ITC-irst, Italy, http://www.itc.it/irst

[4]SensL, Ireland, http://www.sensl.com

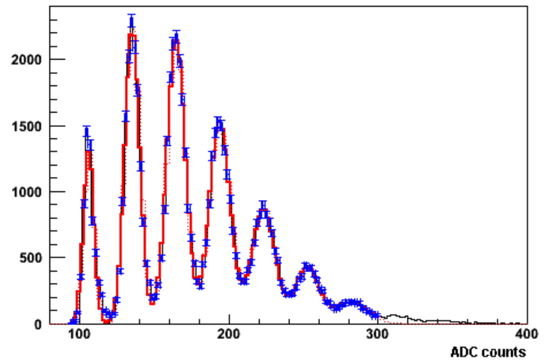

Fig. 1. ADC spectrum of the SiPM response to the low-intensity pulsed light fitted to a superposition of seven gaussian peaks.

III. Measurement Results

Fig. 1 shows an example of the SiPM response to low-intensity light measured with the described setup. The peaked structure indicates the number of cells fired during one light pulse, starting with the pedestal for no cells fired. The distance between peaks corresponds to the SiPM gain. The spectrum is fitted as a sum of gaussian distributions:

$$\sum_i G(N_i, \mu_i, \sigma_i) = \sum_i G(N_i, \mu_0 + i \cdot g, \sigma_i), \qquad (1)$$

where μ_0 corresponds to the pedestal position and g is gain in units of ADC counts. From statistical considerations the width of i^{th} peak σ_i can be expressed as

$$\sigma_i = \sqrt{\sigma_0^2 + i \cdot \langle \sigma_{px} \rangle^2}, \qquad (2)$$

where σ_0 is the pedestal width and $\langle \sigma_{px} \rangle$ represents fluctuations of the one-cell response averaged over the active area of the sample.

The gain as a function of the overvoltage $U_{bias} - U_{brd}$ was studied for several values of the bias voltage. The breakdown voltage U_{brd} is defined here as the bias voltage corresponding to the gain equal to one. The results are shown in fig. 2 (top). Fig. 2 (bottom) shows the dark current as function of the overvoltage.

Fig. 3 shows gain normalised to the corresponding values of pedestal width σ_0 (top) and $\langle \sigma_{px} \rangle$ (bottom) as functions of

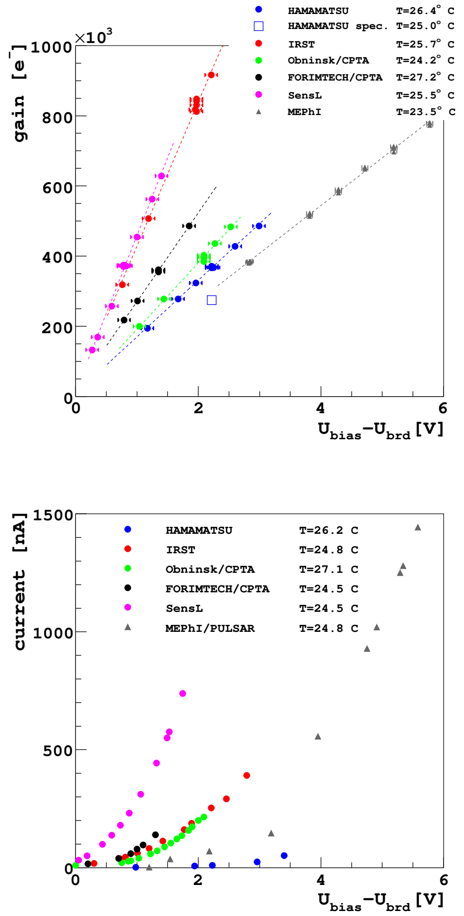

Fig. 2. Gain (top) and dark current (bottom) as a functions of the overvoltage.

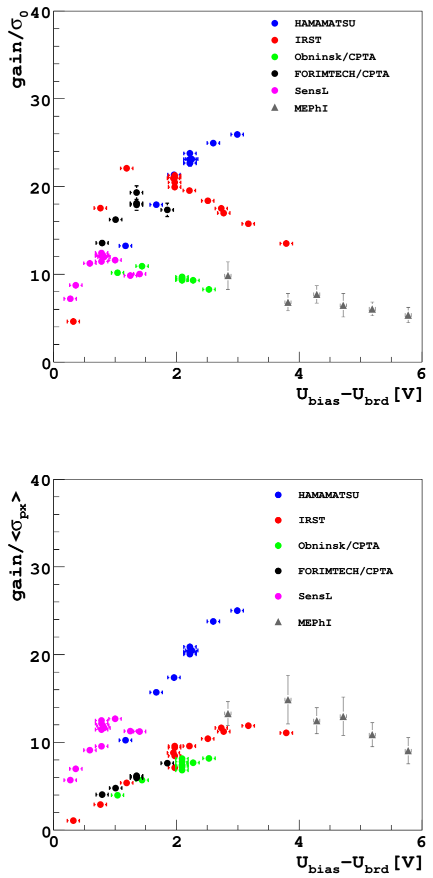

Fig. 3. The gain normalised to the corresponding values of pedestal width (top) and $\langle\sigma_{px}\rangle$ (bottom) as functions of the overvoltage.

the overvoltage. Being averaged over the active area of SiPM, $\langle\sigma_{px}\rangle$ contains statistical and systematic parts:

$$\langle\sigma_{px}\rangle \sim \sqrt{N + \sigma_{nu}^2}, \tag{3}$$

where N is the average number of charge carriers in the avalanche and σ_{nu} represents non-uniformity of the amplification over the SiPM active area. Since gain is proportional to the carriers number, $g \sim N$, the ratio $g/\langle\sigma_{px}\rangle$ shown in fig. 3 (bottom) tends to a linear behaviour for the low gain values $N << \sigma_{nu}^2$. For the high gain values $N >> \sigma_{nu}^2$ the dependence would correspond to square root low $g/\langle\sigma_{px}\rangle \sim \sqrt{N}$ in the case of a constant σ_{nu}. As seen from fig. 3 (bottom), the ratio $g/\langle\sigma_{px}\rangle$ obtained for some of the samples indicates growth of the non-uniformity factor σ_{nu} with the bias voltage.

IV. Conclusion

The obtained results demonstrated operability and potential of the developed setup. Further development and tune of the setup, measurement procedure and data treatment will allow to obtain comparative characteristics of diverse types of silicon photomultipliers.

V. Acknowledgements

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