Scintillation Light Readout Using Silicon Photomultiplier - Review and Experimental Results

Alon Osovizky *Member, IEEE*, Udi Wengrowicz, Max Ghelman, Ilan Cohenzada, Vitaly Pushkarsky, Dimitry Ginzburg, Yehuda Gabay, Asaf Algom, Rami Seif, Avi Manor, Arie Beck, Eli Vulaski, Michael Ellenbogen, Danny Tirosh

***Abstract*–This work summarizes a continuous study of the Silicon Photomultiplier (SiPM) device photo-coupled to various scintillation crystals for profound investigation in the radiation detection and isotope identification research field.**

Radiological and electrical measurements which have been carried out led to an obvious illation regarding the optimal scintillation crystal to use with SiPM. CsI(Tl) was selected as the most appropriate and further, more intense, tests were performed, among them temperature stability and the obtained energy resolution.

I. INTRODUCTION

THE emitted light from the scintillation crystals, which are widely used for hard x-rays and soft γ -rays detection, is invariably detected by various light sensors. The Silicon Photomultiplier (SiPM) is a novel and rapidly developing technology. While being a light sensor it is readily investigated in the radiation detection field. This work explores and compares the characteristics of several SiPM configurations coupled to CsI(Tl) scintillation crystal, and describes the results achieved. Such radiation detectors are found to provide good response to the international regulations requirements for HLS equipment and health physics instrumentation.

II. MATERIALS & METHODS

The CsI(Tl) crystal was photo-coupled to various SiPM devices (described in Table 1), after showing the best signal to noise ratio (SNR) among other examined crystals, mainly due to its matching of the emitted light wavelength to the SiPM's spectral response range and the high light yield.

Radiological and environmental tests have been performed with a layout which combined a self-designed, universal, read-out electronic circuit, a preamplifier and a selected SiPM (SensL, 3 mm x 3 mm) coupled to CsI(Tl) crystal. These tests included: linearity tests (with ^{137}Cs source), energy resolution (FWHM) over 60-1900 keV range, radiation hardness test (for γ -rays), ambient temperature stability over the range of -20°C - +50°C and its effect on the energy equivalent noise level.

TABLE I
SPECIFICATIONS OF VARIOUS TESTED SIPMS AS STATED BY THE MANUFACTURERS

Diode active area	1 x 1 mm		3 x 3 mm			6 x 6 mm	12 x 12 mm
Manufacturer	**Hamamatsu**	**SensL**	**Photonique**	**Zecotek**	**SensL**	**SensL**	**SensL**
Parameters							
Number of pixels	1600	400	8100	100000	3640	14560	58240
Pixel size	25x25 μm	35x35 μm	33x33 μm	9x9 μm	35x35 μm	35x35 μm	35x35 μm
Operating Voltage	70 V	29.8 V	16.5 V	100 V	29.5 V	29.5 V	29.5 V
Gain	2.75×10^5	1×10^6	1.8×10^5	2×10^5	1×10^6	1×10^6	1×10^6
PDE	25%	37%	30%	15%	37%	13-30%	13-30%

III. RESULTS

The tested detector setup showed good radiological response, which was expressed in the linearity of the readings in the range of 0-100 mR/h (Fig. 1); best achieved resolution of 7.5% for 662keV and 23% for 59 keV energy lines; and about 25 keV noise level at the room temperature and 40 keV at 50°C, which enables the detection of ^{241}Am.

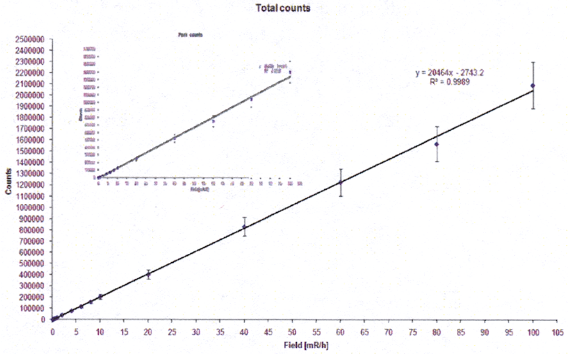

Fig. 1. Total counts linearity of responsivity to radiation fields from 0-100 mR/h. Inset – peak counts linearity.

The results presented in table 2 demonstrate the effect of the diode dimension and an appropriate coupling surface of the crystal on the scintillation light collection efficiency. Although larger diode surface improve the energy resolution due to increase in light collection, the noise is increased due to cross-talk effect which is intensified in larger diodes.

Manuscript received November 14, 2008.

A. Osovizky, V. Pushkarsky, D. Ginzburg, E. Vulaski, M. Ellenbogen, are ROTEM Industries Ltd, Beer-Sheva, 84190, Israel (telephone: +972-8-6579730, e-mail: alon@rotemi.co.il, dimgiz@rotemi.co.il)

U. Wengrowicz, M. Ghelman, Y. Gabay, A. Algom, R. Seif, A. Manor, A. Beck, D. Tirosh are with the Electronics & Control Laboratories, Nuclear Research Center - Negev, Beer-Sheva, Israel (e-mail: manora@bgu.ac.il).

This duality retains the noise threshold in a stable level.

TABLE II
NOISE THRESHOLD AND ENERGY RESOLUTION OBTAINED FOR DIFFERENT TYPES OF SIPM

diode		CsI Crystal [mm³]	Noise Threshold [keV]	Res [%]	
				^{241}Am	^{137}Cs
SiPM Single diode 9mm²		3x3x15	27	23	14
		8x8x30	40	26	15
		12.5x12.5x12.5	36	32.4	11.2
SiPM Quad		12.5x12.5x12.5	29	39	10.7
Array	Quad	8x8x30	30	34	9
	center	8x8x30	100	-	13
	side	8x8x30	160	-	16
SPM Plus		8x8x30	35	32	10
		12.5x12.5x12.5	36	34	7

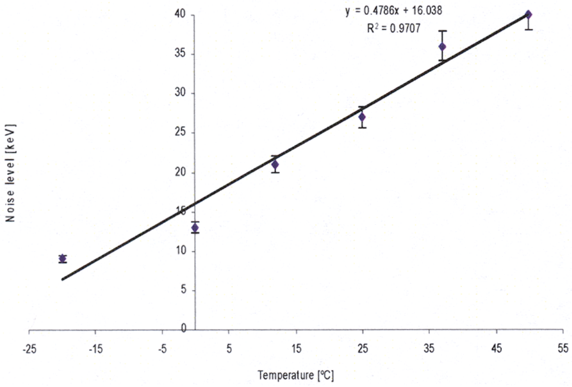

Fig. 2. Ambient temperature stability – test results.

The results presented in Figure 1 and Figure 2 were obtained using 3 mm x 3 mm x 15 mm CsI(Tl) crystal, photo-coupled to 3 mm x 3mm SiPM device (SensL) and attached to appropriate read-out electronics.

The radiation hardness results, presented in Figure 3, were obtained using 8 mm x 8 mm x 30 mm crystal coupled to the same layout, and irradiated by a strong ^{137}Cs source in exposure rate of 0.1 R/h up to cumulative dose of 7 R.

The spectrum, showed in *Figure 4*, displays the spectral responsivity and the energy linearity of the SiPM device, obtained with 12.5 mm x 12.5 mm (coupling surface) crystal, which was photo-coupled to 12 mm x 12 mm SiPM (SensL).

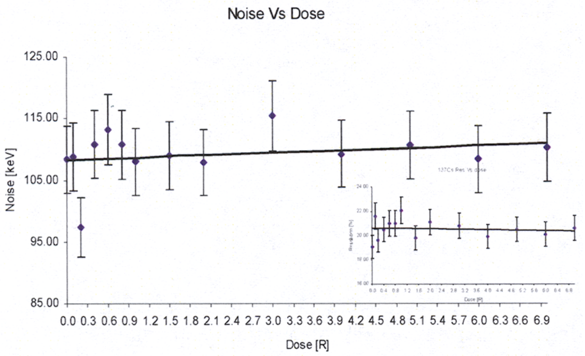

Fig. 3. Radiation Hardness – tested parameters for degradation due to cumulative exposure: energy equivalent noise level. Inset - resolution for ^{137}Cs (662 keV).

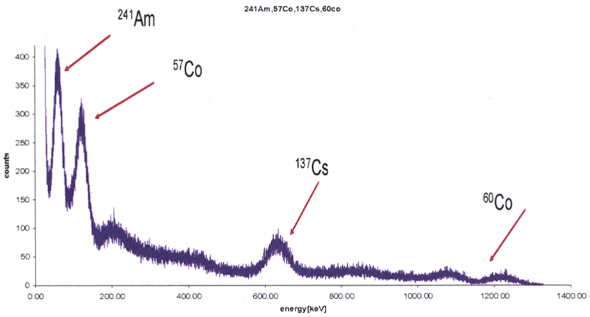

Fig. 4. Energy spectrum for various isotopes.

IV. CONCLUSIONS

The neoteric SiPM device was successfully photo-coupled to a scintillation crystal to produce a novel radiation detector. The obtained results were compared to the traditional detector modules combined of the same crystal attached to ordinary PMT. Although the comparison shows quite similar results for both technologies, there are a few advantages with the SiPM: an ultra small size, high gain with little power consumption (low bias voltage), very fast recovery time and insensitivity to magnetic fields.

For the future objectives it is essential to cover more varieties of scintillation crystals for better suitability to different kinds of applications. In addition, more work should be done to study the SiPM resistance to heavy particles radiation

REFERENCES

[1] P.Buzhan, B. Dolgoshin and A. Ilyin, "An advanced study of silicon photomultiplier," ICFA Instrumentation Bulletin, 2001

[2] www.sensl.com