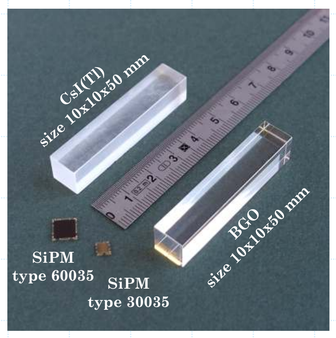
USING OF A NEW GENERATION OF SILICON PHOTOMULTIPLIERS IN PORTABLE GAMMA RADIATION SCINTILLATOR BASED DETECTORS

Sergey Gushchin, Viktors Fjodorovs, Victor Ivanov, Anatoli Loutchanski, Vadims Ogorodniks
ZRF RITEC SIA, Riga, Latvia

Modern Silicon Photomultipliers (SiPM) with various scintillators are successfully used as gamma radiation detectors. SiPM has low current consumption, very small size and high gain. It provides advantage in comparison with the most commonly used vacuum tube Photomultiplier Tube and Silicon P-I-N diodes. However, strong dependence of the SiPM gain on operating temperature limits the scope of these detectors potential applications. Scintillators light output temperature dependence also poses a serious problem. We have proposed method and developed scheme for stabilization of scintillator detectors parameters in a temperature range from -20 °C to + 50 °C, based on microprocessor's control of the SiPM bias voltage.

Detectors with two types of scintillator crystals CsI(Tl) and BGO from Shanghai SICCAS High Technology Corporation were fabricated. Two sizes of scintillator crystals 10x10x50 mm and Ø5x10 mm were used. Two types of C-Series low noise SiPM from SensL Technologies Ltd. were applied. Small size detectors are designed for medical application is surgical gamma probes and bigger size detectors are designated for use in handheld personal radiation detectors.

Scintillator crystals and SiPMs



Properties of the used scintillator crystals

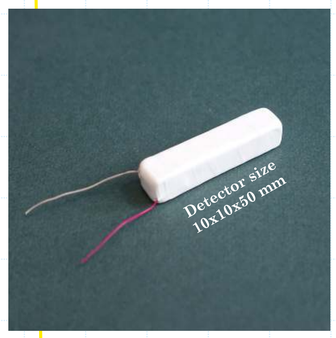
Scintillator	Used Sizes, mm	Light yield*, photon/keV	Density*, g/cm^3	Temperature response of light output*, %/C 25 °C to 50 °C	Decay time*, ns	Emission peak*, nm	Thickness to stop 50% of 662 keV photons, cm
CsI(Tl)	10x10x50 Ø5x10	54	4.51	0.01	1000	550	2
BGO	10x10x50 Ø5,5x10	8-10	7.13	-1.2	300	480	1

* Information from Saint-Gobain Crystals Data Sheet

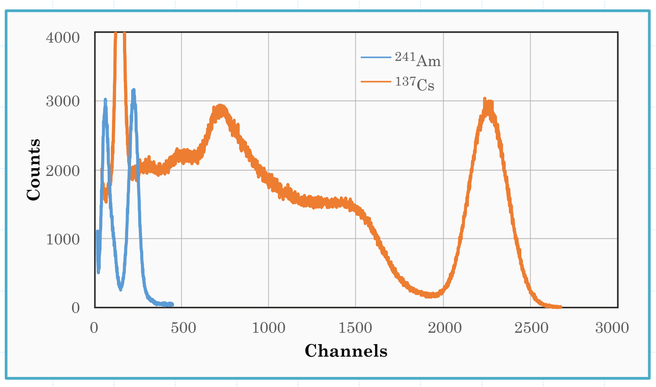
Performance parameters of the used SiPMs

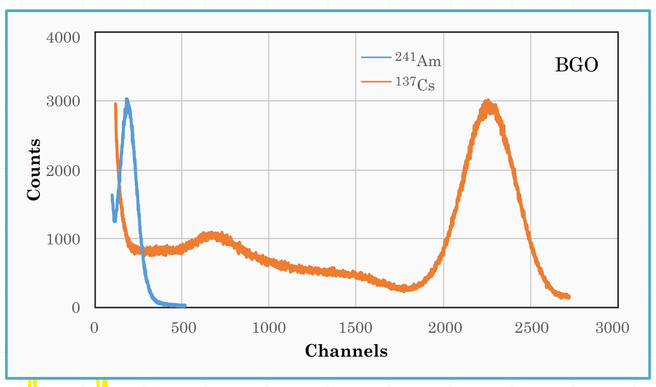
SiPM type	Ative area size, mm	Peak Wavelength, nm	Breakdown voltage Min/Max, V	Overvoltage Min/Max, V	Gain (anode to cathode readout) at overvoltage 2.5 V	Gain temperature dependence, % / °C	Dark count rate at overvoltage 2.5 V typical, kHz
30035	3x3	420	24.2/24.7	1/5	$3x10^6$	-0,8	300
60035	6x6	420	24.2/24.7	1/5	$3x10^6$	-0,8	1200

View of assembled detector



^{241}Am and ^{137}Cs spectra measured with CsI(Tl) and BGO detectors of 10x10x50 mm at room temperature

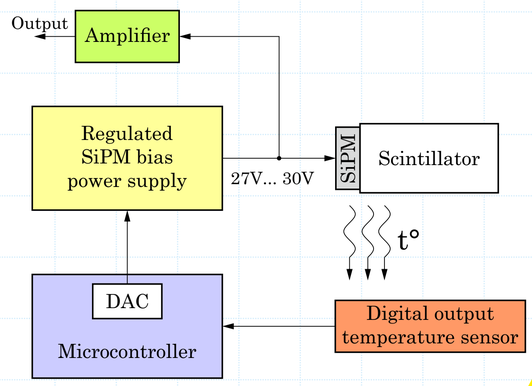




Properties of fabricated scintillator detectors measured at room temperature 20 °C under the same conditions

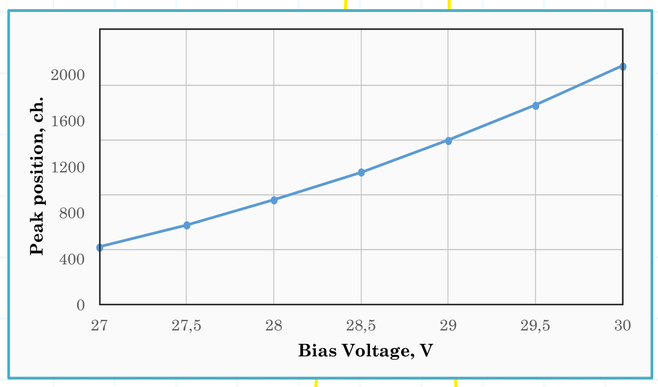
Detector	Crystal size, mm	SiPM Type	Reflective coating material	Total thickness of reflective coating, mm	Energy resolution (FWHM) at 662 keV, keV	Low energy threshold, keV	Count rate in the 662 keV peak area, cps
CsI(Tl)	Ø5x10	30035	Teflon tape	1	35	5	2,1
CsI(Tl)	10x10x50	60035	Teflon tape	2	65	6	88,3
BGO	Ø5,5x10	30035	Teflon tape	1	66	17	12,8
BGO	10x10x50	60035	Teflon tape	2	102	37	351,2

The block diagram of correction module of detector output signals temperature dependence

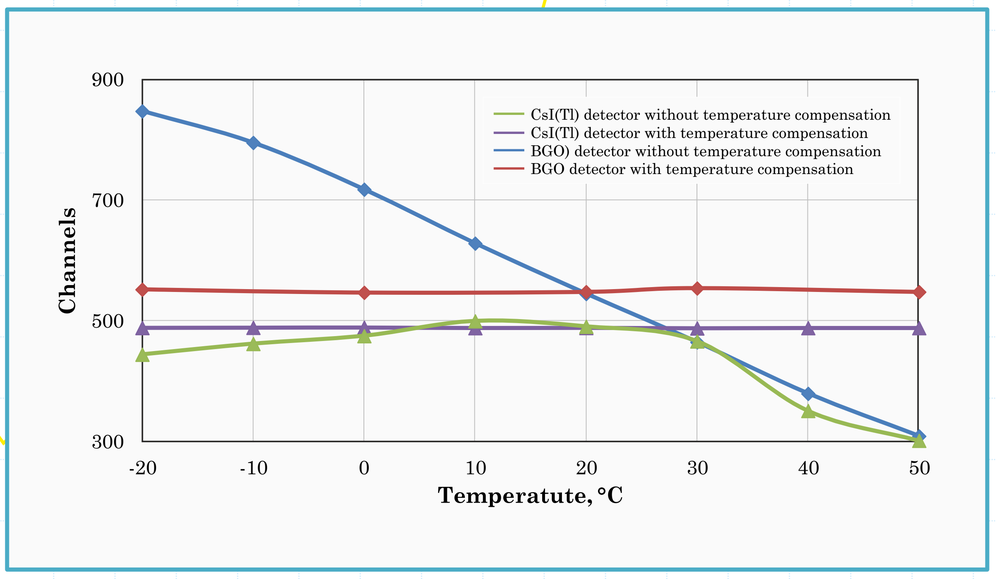


Before using the temperature stabilization circuit, its calibration must be performed. The calibration consists in determining SiPM bias voltages at which the recorded peaks 662 keV are located at the same channel at different operation temperatures. These values are stored in the microprocessor memory as a Look Up Table (LUT) and are used later to set the SiPM bias voltage when the operation temperature changes. Regulation functions implementation were tested both LUT based with step equal to 10 °C for -20 °C to +50 °C range and analytically. Numerical modeling show that third degree polynomial interpolation is sufficient for operation up to 35 °C for both BGO and CsI(Tl) detectors. Operation at temperature higher than 35 °C requires higher degree of polynomial. Practical experiments show that use of temperature sensor of 1% accuracy is sufficient to provide precision stabilization.

A typical dependence of the 662 keV peak position on SiPM bias voltage measured at room temperature



Peak 662 keV position versus temperature



Main results

- Fabricated CsI(Tl) and BGO scintillator detectors with SiPM C-serie from SensL have a low noise level, which provides a wide range of registered energies of gamma radiation starting from 6 keV for CsI(Tl) detector of 10x10x50 mm and SiPM of 6x6 mm and from 37 keV for BGO detectors with the same sizes of crystal and SiPM;
- Were proposed and tested method and scheme for compensation of temperature instability of the SiPM gain as well as temperature dependence of scintillators light output;
- Shift of the peak 662 keV position in the tested temperature range from -20 °C to +50 °C without compensation scheme application was 0,55 %/°C for CsI(Tl) detector and 0,79 %/°C for BGO detector. With stabilization scheme application it was reduced up to 0,012 %/°C for CsI(Tl) detector and up to 0,022 %/°C for BGO detector.

Further development aims at achievement of better long-term amplification stabilization, lower power consumption and size reduction.

NUCLEAR RADIATION
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ZRF RITEC SIA
23 Aizkraukles St. office 407, Riga, LV-1006, Latvia
Tel./Fax: +371-67543304, E-mail: ritec@ritec.lv