Infrared Illuminated CdZnTe detectors with improved performance

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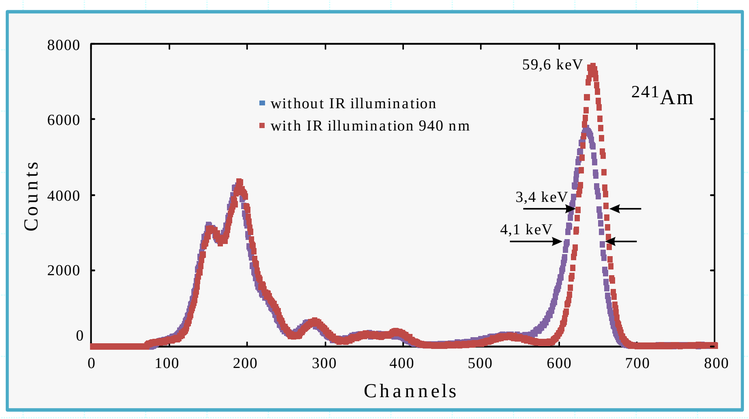
It was found that illumination by IR light with a properly chosen wavelength close to the CdZnTe absorption edge can significantly improve spectrometric characteristics of CdZnTe quasi-hemispherical detectors [1]. IR radiation was noted to influence the detector's sensitivity, changing the equilibrium between free and trapped carriers and improving charge collection. The positive effect can be achieved at low levels of illumination depending on the wavelength used and detector's operation temperature. Infrared illumination can be performed using conventional low-power IR SMD LEDs. Different detection probes with CdZnTe quasi-hemispherical detectors from the smallest volumes of a few cubic millimetres to the larger with volumes of 1.5 cm^3 and 4.0 cm^3 were fabricated and tested.

Quasi-hemispherical CdZnTe detectors [2] have a rather simple design and good spectrometric and operating performances. The quasi-hemispherical detectors are rectangular with a length-width-height ratio of A × A × (A/2), have large negative electrode on five sides and a positive dot electrode in the centre of one of the large sides. CdZnTe crystals from REDLEN Technologies were used to fabricate the detectors. Commercially available CdZnTe miniature detection probes [3] were modified and new detection probes for the large volume detectors were designed and fabricated. The detection probe consists of the CdZnTe quasi-hemispherical detector, the IR LEDs placed near the detector and the charge sensitive preamplifier mounted inside of a sealed housing with permanent attached cable. The LEDs and probe's preamplifier were powered from the same power source of ± 12 V. Required illumination intensity was set by adjusting the LED direct current. Commercially available IR LEDs with wavelength of 940 nm or 1050 nm were used as IR light sources. During the measurements LEDs direct currents did not exceed 0.3–0.7 mA for the LED of 940 nm and 5–12 mA for the LED of 1050 nm depending on the CdZnTe detector used.

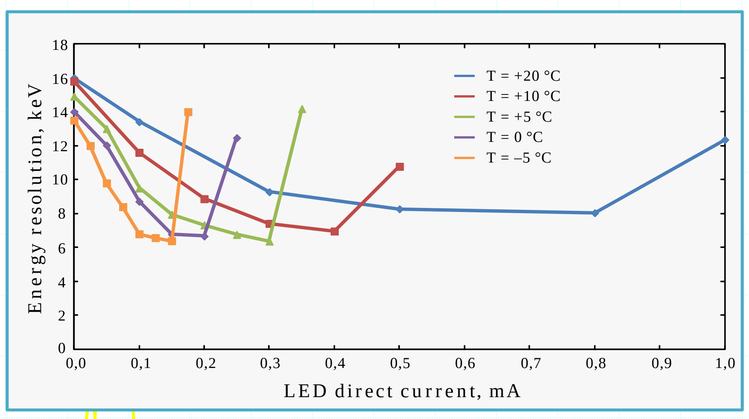
Spectrometric detection probes with the CdZnTe quasi-hemispherical detectors:
1 – type SDP310 with detectors from 1mm^3 to 60 mm^3,
2 – type SDP500 with detector of 500 mm^3,
3 – type SDP1500 with detector of 1500 mm^3,
4 – type SDP4000 with detector of 4000 mm^3.

The results of measurement obtained with the modified probe SDP500S. Quasi-hemispherical detector volume 500 mm^3. Operating voltage 1000 V.

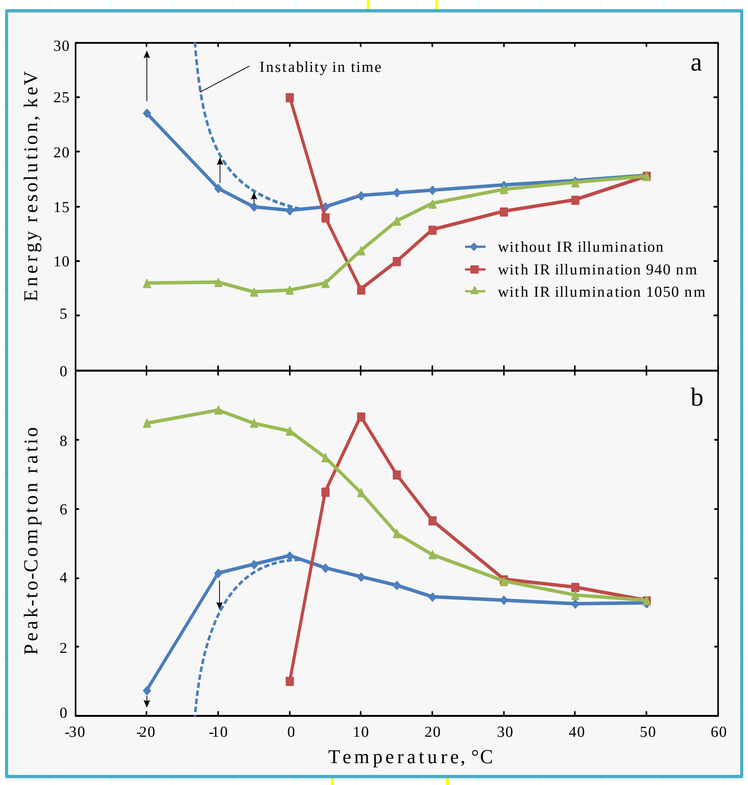
Spectra of ^{241}Am measured without and with IR illumination (940 nm).



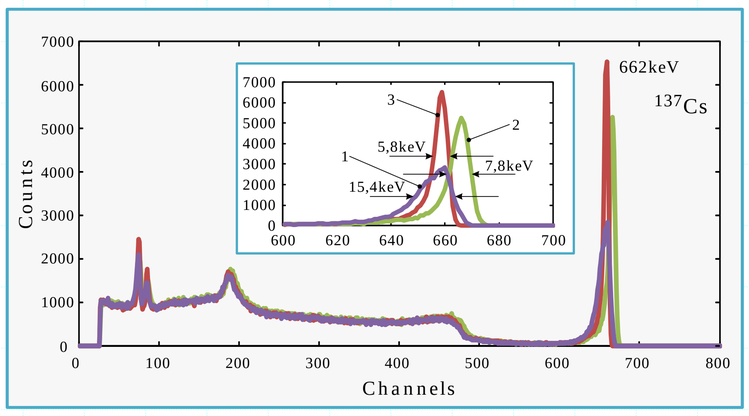
Energy resolution (FWHM) at 662 keV dependencies on the LED (940 nm) direct current for various operation temperatures.



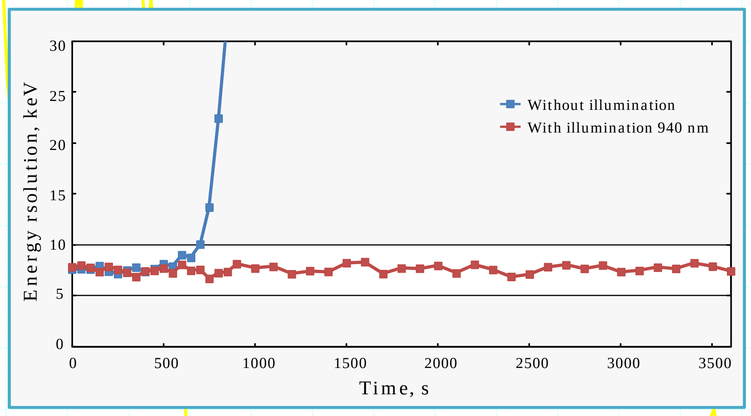
Dependencies of the energy resolution (FWHM) (a) and peak-to-Compton ratio (b) at 662 keV measured without and with IR illumination (940 nm) at LED's direct current of 0.2 mA and with IR illumination (1050 nm) at LED's direct current of 8 mA on the operation temperature.



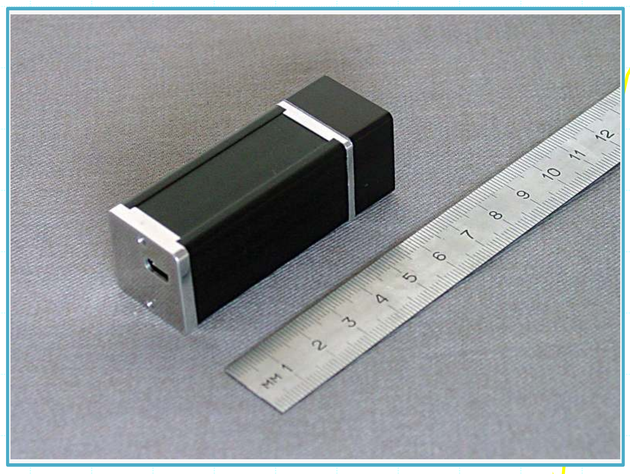
Spectra of ^{137}Cs measured without (1) and with (2) IR illumination (940 nm) at room temperature and at - 5 ºC (3).



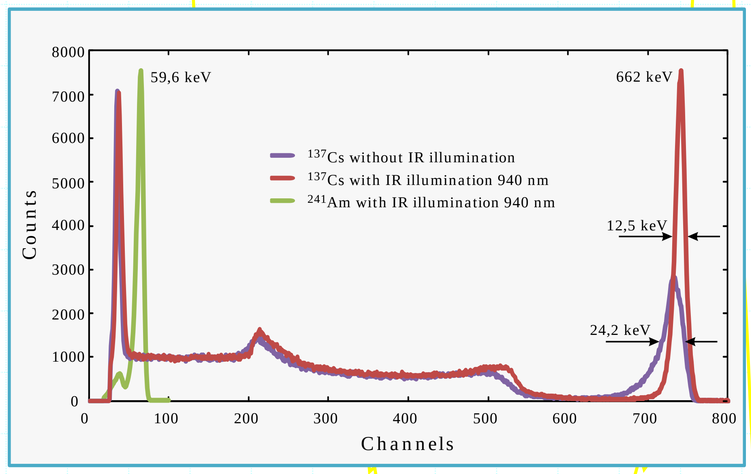
Time dependence of the energy resolution (FWHM) at 662 keV without and with IR illumination (1050 nm) at operation temperature - 20 ºC.



Prototype of the USB Micro Gamma-Radiation Spectrometer based on the GBS Elektronik Micro MCA527 [4] with interchangeable detector's module with CdZnTe quasi-hemispherical detectors of 60 mm^3, 500 mm^3 or 1500 mm^3.



Spectra of ^{137}Cs and ^{241}Am measured by the probe SDP4000 with quasi-hemispherical detector of 4000 mm^3 without and with IR illumination (940 nm) at room temperature. Operating voltage 2200 V.



Characteristics of the CdZnTe detection probes with quasi-qemispherical detectors without and with illumination by the IR light of 940 nm measured at room temperature.

?	Probe type	Detector size, mm	Optimal operation voltage, V	Energy resolution (FWHM) at 662 keV, keV		Peak-to-Compton ratio	
				Without illum.	With illum.	Without illum.	With illum.
1	SDP310	1.5x1.5x0.75	100	14.4	6.0	1.8	3.7
2	SDP310	3x3x1.5	200	9.8	5.6	3.2	5.1
3	SDP310	5x5x2.5	500	7.9	5.7	6.2	8.5
4	SDP500	10x10x5	1000	15.4	7.8	4.8	9.4
5	SDP1500	15x15x7.5	1500	10.0	7.2	7.5	13.3
6	SDP4000	20x20x10	2200	24.2	12.5	4.8	13.1

MAIN RESULTS

- Modified commercially available CdZnTe probes types SDP310 with detectors up to 60 mm^3 and SDP500 with detectors of 500 mm^3 and new probes SDP1500 with detectors of 1500 mm^3 and SDP4000 with detectors of 4000 mm^3 were fabricated and tested.
- Significant improvements of spectrometric characteristic in a wide gamma-energy range under influence of the correct chose illuminating wavelength and correct adjusted illumination intensity were obtained.
- The degree of improvement was different for different detectors due to the different source materials used in the detectors and their dimensions.
- The low intensity IR illumination by wavelength of 940 nm was used at room and at the near room temperatures.
- IR illumination by a wavelength of 1050 nm improves energy resolution and stability of the detector at low temperatures.

REFERENCES

[1] V. Ivanov, P. Dorogov, A. Loutchansky, L. Grigorjeva, D. Millers, "Improving the Performance of Quasi-Hemispherical CdZnTe Detectors Using Infrared Stimulation", IEEE Trans. Nucl. Sci., vol. 59, no. 5. pp. 2375-2382, 2012.

[2] K. Zanio, "Use of Various Device Geometries to Improve the Performance of CdTe Detectors," Rev. de Phys. Appl., vol. 12, pp. 343-347, 1977.

[3] Spectrometric detection probes Types SDP310 and SDP500 data sheets, ZRF RITEC SIA, http://www.ritec.lv

[4] MicroMCA527 data sheet, GBS Elektronik GmbH, http://www.gbs-elektronik.de

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