Influence of Infrared Stimulation on Spectroscopy Characteristics of Coplanar Grid CdZnTe detectors

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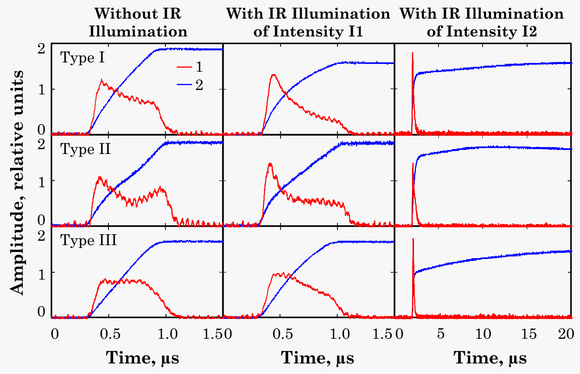
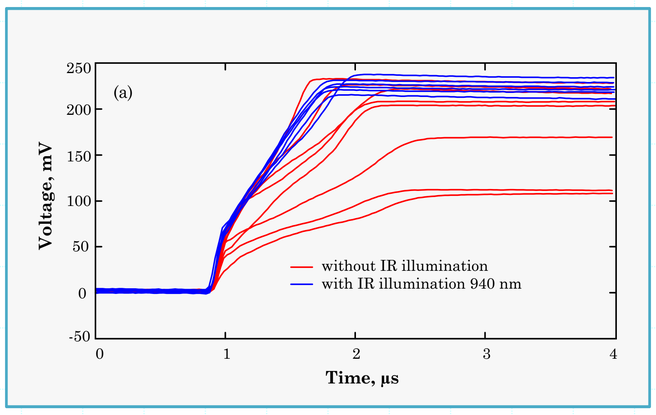
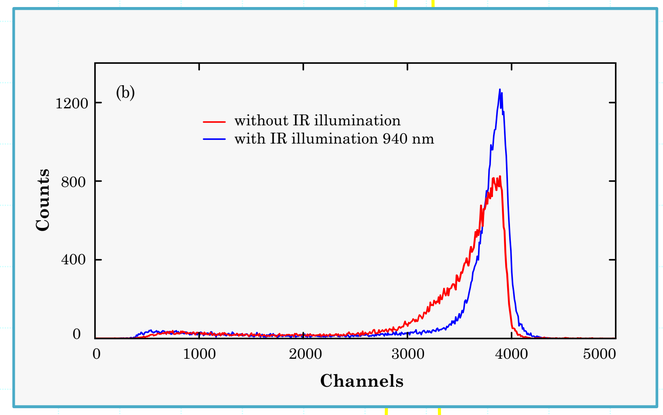
Illumination by infrared (IR) radiation with wavelengths close to the CdZnTe absorption edge greatly influences the internal electric field distribution, charge transport and spectrometric characteristics of the CdZnTe detectors. It was found that the spectrometric characteristics of quasi–hemispherical detectors can be noticeable improved via low intensity IR stimulation using wavelengths of approximately 900-950 nm at room temperature [1]. In this work, preliminary results of IR stimulation on the spectrometric characteristics of coplanar-grid CdZnTe detectors as well as results of further studies of planar and quasi-hemispherical detectors under IR stimulation are presented. Methods based on the transient current and the transient charge pulses waveforms analysis from alpha particle as well as alpha and gamma–radiation spectra analysis were used to investigate the effect of IR illumination on the detectors characteristics.

Alpha particle (5.5 MeV) response of planar CdZnTe detectors (Au/CdZnTe/Au) of 10 mm x 10 mm x 5 mm size



Typical transient current (1) and transient charge (2) pulses waveforms from alpha particles measured at operating voltage of 500 V without and with IR illumination 940 nm of differed intensity I ($I_2 > I_1$).

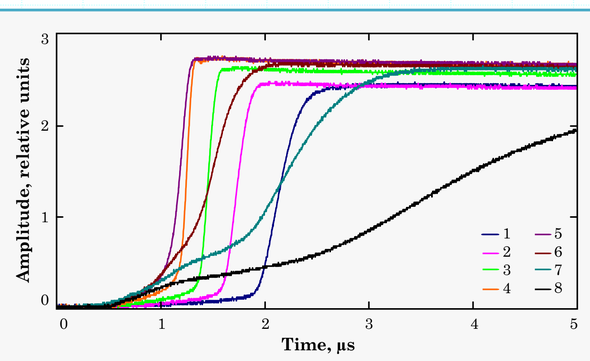




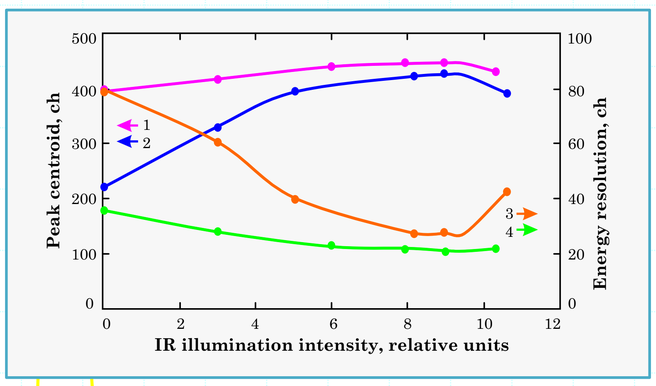
Output signals waveforms (a) and pulse-height alpha spectra (b) obtained with nonuniform planar CdZnTe detector without and with IR illumination.

Obtained differences in output pulses waveforms measured with planar detectors are defined by variation in electric field distribution from detector to detector. IR illumination leads to change in an electric field distribution increasing it near the cathode. IR illumination can improve charge collection uniformity in nonuniform detectors.

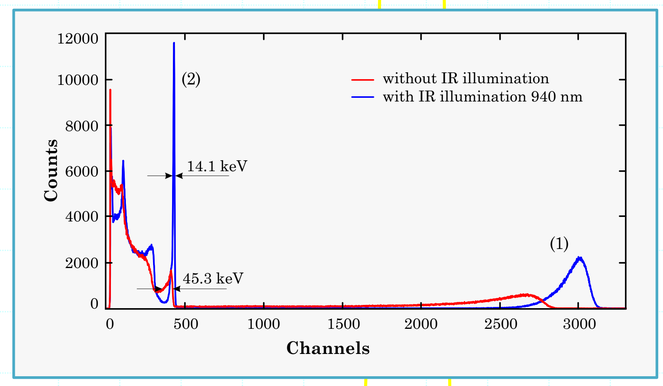
Alpha particle response and gamma-radiation spectra measured with quasi-hemispherical detectors of 10 mm x 10 mm x 5 mm size fabricated by RITEC



Output signals waveforms from alpha particles measured without (1) and with IR illumination 940 nm of different levels: 2 – I_1, 3 – I_2, 4 – I_3, 5 – I_4, 6 – I_5, 7 – I_6, 8 – I_7 ($I_1 < I_2 < I_3 < I_4 < I_5 < I_6 < I_7$).



Dependencies of the alpha peak centroid (1, 2) and energy resolution (3,4) on IR illumination intensity 940 nm for central (1, 4) and corner (2, 3) regions of the detector.

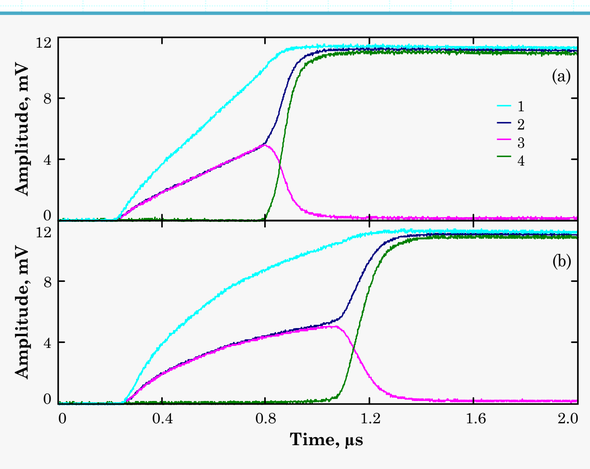


Alpha (1) and gamma–radiation spectra of ^{137}Cs (2) measured without and with IR illumination.
Time of measurement 1000 s.
Operating voltage 1000 V.

IR illumination improves charge collection in quasi-hemispherical detectors by reducing the charge collection time and improving uniformity of the charge collection in the detector volume.

This positive effect is mainly due to the redistribution of the electric field in quasi-hemispherical detector by the action of IR illumination. Electric field near the large cathode increases.

Measurements with coplanar grid detectors of 10 mm x 10 mm x 10 mm size supplied by Redlen Technologies



Spectra of ^{137}Cs measured without and with IR illumination.

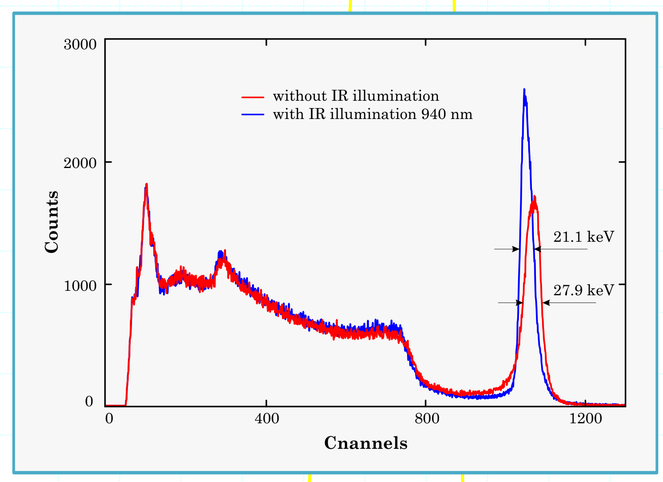
$U_{cathode}$ = –800 V, $U_{collecting\ gride}$ = +30 V.

Time of measurement 1000 s.

Output signals waveforms from alpha particles measured without (a) and with (b) IR illumination 940 nm.

1 – summarized signal, 2 – collecting electrode signal, 3 – no-collecting electrode signal, 4 – difference signal.

$U_{cathode}$ = –2000 V, $U_{collecting\ gride}$ = +100 V.



The obtained waveforms from alpha particle indicate the formation of region with increased electric field near the cathode. At the same time the electrons drift time between the cathode and region near to the anode grid becomes longer. Improvements of charge collection efficiency and energy resolution under IR illumination at alpha particle registration were not obtained. Some improvement of energy resolution at gamma-radiation 662 keV under IR illumination was achieved.

More visible improvement of energy resolution was obtained at rather low operating voltages. At high operation voltages when the initial energy resolution became much better the effect of IR illumination was negligible. For example the energy resolution at 662 keV measured without IR illumination at $U_{cathode}$ = –1500 V, $U_{collecting\ grid}$ = +120 V was 11.3 keV and with IR illumination it was improved only up to 11.1 keV.

MAIN RESULTS

- Spectrometric characteristics of planar CdZnTe detectors under IR illumination were not improved noticeable. In some cases a small improvement of charge collection uniformity was obtained.
- Spectrometric characteristics of quasi-hemispherical detectors were noticeably improved by a low intensity IR illumination using wavelengths of approximately 900–1000 nm at room temperature.
- Some improvement of spectrometric characteristics of coplanar grid gamma-radiation detectors was obtained under IR illumination. More visible improvement of energy resolution was obtained at rather low operating voltages.

The mechanism of impact of IR illumination on the CdZnTe detectors of all tested types is similar. IR light with a wavelength below the fundamental absorption edge penetrates deeply into the detector and influences charge carriers trapping and detrapping processes, thus changing the balance between trapped and free charge carriers. We assume the presence of three processes caused by IR radiation:

The first it is the holes detrapping form the deep levels, which causes increasing of the positive space charge in the detector sensitive volume. Presence of this positive space charge leads to the increasing electric field near the cathode. In the case of quasi-hemispherical detectors the increased electric field at the cathode is a very positive factor.

The second it is the reduction of electrons residence time on the shallow traps. This leads to reduction in a time of a full electrons collection.

The third, IR radiation has an impact on charge carriers trapped at defect levels around inclusions, structural defects, sub-grain boundaries and so on. This defect levels in greater or lesser extent always present in the detector's material. Releasing the charge carriers trapped at these defect levels, the IR illumination improves uniformity of the charges collection.

REFERENCE

[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.

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