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# Composite detector for mixed radiations based on CsI(Tl) and dispersions of small ZnSe(Te) crystals

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**Abstract**

A new large area detector of high-energy X-ray and β-radiation has been designed and studied. A composite material based on small-crystalline ZnSe(Te) was applied onto the wide surface of a light guide. An experimental specimen has been prepared, which showed β-sensitivity $C_\beta = 5.5\,cm^2$. The spectrograms of a $^{90}Sr + ^{90}Y$ β-source obtained with the specimen under study make it possible to evaluate the age of the source by the ratio of low- and high-energy regions of the spectrum.

The combined detector (CD) comprises a single crystalline plate of ZnSe(Te) placed onto the output window of a scintillating transparent light guide made of CsI(Tl) in the shape of a truncated pyramid. The CsI(Tl) light guide is used to create an additional channel for detection of γ-radiation, as well as for protecting the photodiode from the penetrating radiation. It is shown that introduction of the light guide does not worsen the energy resolution characteristics of ZnSe(Te). Separate detection of α- and γ-radiation has been achieved under simultaneous excitation by $^{239}Pu$ (ZnSe(Te), $R_\alpha = 6\%$) and $^{241}Am$ (CsI(Tl), $R_\gamma = 20\%$). The use of selective optical filters allows separation of the peaks of total absorption (p.t.a.) in the case of their superposition.


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## 1. Introduction

Solid-state scintillation detectors (SD) comprising scintillation crystals (S) and silicon p–i–n photodiodes (PD) are widely used in dosimeters,

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radiometers, spectrometers, in technological equipment for medical diagnostics, environment monitoring, customs and security control, etc.

One of the factors limiting the broad use of "scintillator-photodiode" detectors is the small area of the photosensitive surface of the photodiode ($S \sim 1\,cm^2$). This disadvantage can be partially removed by the use of crystals with large sensitive volume. However, this leads to "hanging over" of the scintillator above the PD input window, which leads to noticeable deterioration of the signal at the detector output.

To date, for detection of β-radiation, the most widely used scintillators were *p*-terphenyl, CsI(Tl) or NaI(Tl). However, alkali halide crystals are hygroscopic, which requires their additional protection against moisture. Operation under conditions of high humidity leads to deterioration of the crystal surface, a "dead layer" is formed, and detector characteristics are subsequently changed. Crystals of *p*-terphenyl have bad spectral matching with Si-photodiode, and they can be used only in combination with photomultiplier tubes (PMT).

A promising scintillator for γ-quanta and charged particles is ZnSe(Te) [1–3]. This scintillation crystal is characterized by its combination of characteristics making it the optimum choice for "scintillator-photodiode" detectors used in low-energy arrays of X-ray inspection systems. The most important parameters of ZnSe(Te) crystals produced by Scientific Technological Center for Radiation Instruments are presented in Table 1 in comparison with CsI(Tl). It is clearly seen that ZnSe(Te) is obviously superior in such qualities of primary importance as conversion efficiency and absolute light output, afterglow, spectral matching, and hygroscopicity. In addition, absorption depth in CsI(Tl) at energies of less than 40 keV is less than 0.25 mm. This means that the negative influence of the surface layer upon scintillation parameters is negligible with ZnSe(Te), but it is significant with thinner CsI(Tl) samples. Thus, advantages of ZnSe(Te) in comparison with CsI(Tl) as scintillator for low-energy detector arrays are clear and undeniable.

Among the advantages of ZnSe(Te), one should also note its high radiation stability (not less than $10^7$ rad) and high upper limit of working temperature (up to 100 °C). All this shows that ZnSe(Te) is the most promising material for "scintillator-photodiode" detectors of radiation in the range 40–60 keV.

However, the existing technological processes do not allow obtaining ZnSe(Te) single crystals larger than 3 cm in diameter. Detector sensitivity can be increased with larger area of the output window and creation of optimum light collection conditions in the scintillator. One of the ways to

Table 1
Principal parameters of scintillators ZnSe(Te)

| Parameter | Scintillator material | | |
|---|---|---|---|
| | CsI(Tl) | ZnSe(Te) "fast" | "slow" |
| Melting temperature (K) | 894 | 1773–1793 | 1773–1793 |
| Density $\rho$ (g/cm$^3$) | 4.51 | 5.42 | 5.42 |
| Effective atomic number (Z) | 54 | 33 | 33 |
| Hygroscopicity | low | no | no |
| Emission maximum, $\lambda_{max}$ (nm) | 550 | 610 | 640 |
| Afterglow, $\delta$ (after 6 ms) (%) | $<0.05$ | $<0.05$ | $<0.05$ |
| Attenuation coefficient of intrinsic radiation ($\lambda_{max} = 610-640$ nm), α (cm$^{-1}$) | $<0.05$ | 0.05–0.2 | 0.05–0.2 |
| Light yield from PD with respect to CsI(TI) at 1 mm thickness, $E_x = 60$ keV (%) | 100 | up to~110 | up to~140 |
| Decay time, τ (μs) | 1 | 1–3 | 30–70 |
| Maximum value of the spectral matching factor $K_u$ | 0.77 | 0.9 | 0.92 |
| Refraction coefficient (n) | 1.79 | 2.61 | 2.59 |
| Light yield, photons/MeV-γ | $5.5 \times 10^4$ | up to $6 \times 10^4$ | up to $7.5 \times 10^4$ |
| Depth of 90% absorption X-ray (40 keV) (mm) | $<0.25$ | 0.65 | 0.65 |