

1D- and 2D-matrices scintillation elements on the crystals base ZnSe(Te), $CdWO_4$, CsI(Tl), $Bi_3Ge_4O_{12}$

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Results are presented of light output and uniformity of scintillation parameters of 1D and 2D-matrices for different conditions of their preparation. It has been shown that with grinded scintillators based on ZnSe(Te) and $CdWO_4$ light output is higher as compared with the polished ones. Energy resolution and light output has been measured for 2D-scintillators on the ZnSe(Te) base for α-particles from ^{235}Pu. Advantages of 2D-scintillators over monolithic scintillators are shown.

Представлены результаты исследований светового выхода и однородности сцинтилляционных параметров 1D и 2D-матриц в зависимости от условий их изготовления. Показано увеличение световыхода шлифованных сцинтилляторов на основе ZnSe(Te) и $CdWO_4$ относительно полированных элементов. Исследовано энергетическое разрешение и световыход 2D сцинтилляторов на основе ZnSe(Te) для α-частиц ^{235}Pu. Показаны преимущества 2D матриц по сравнению с монолитными сцинтилляторами.

In many fields of medicine, visualization methods of internal structures of humans based on tomographic studies are used more and more extensively used. These methods of computer graphics are known as volume visualization.

Recently, substantial interest has been noted in methods of image construction using γ- and X-rays. These methods can be used in medical and technical introscopy, in customs and security inspection systems, as well as in systems for γ-image construction.

At present, several types are known of multi-element scintillation matrices and detectors on their base. Fig. 1 shows several types of scintillation matrices in the form of mosaics made of scintillation crystals. To decrease the probability for light from one luminescent flash coming from one scintillation cell to another, as well as to increase emission efficiency of each element, an adhesive-reflecting material is introduced into the inter-element space. However, in the

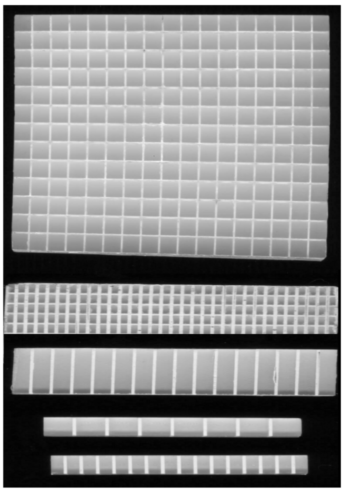

Fig. 1. General view of 1D and 2D scintillation matrices.

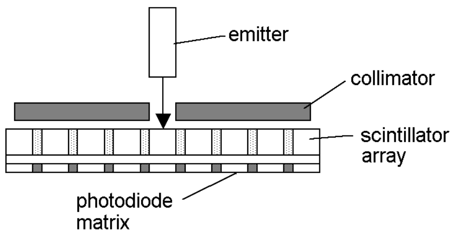

Fig. 2. Block diagram of the installation used for channel interference measurements.

case of Compton scattering, in order to prevent the electron transition from one cell to another, the interelement space is commonly filled with metal components, e.g., Wood's alloy [1].

Linear or 1D matrices (arrays) of scintillation crystals are used in scanning X-ray introscopic systems for security & customs inspection, technical defectoscopy, medical computer tomographs. Design and size of the arrays are determined by parameters of the scintillation crystal, effective energy of the radiation source, required spatial resolution values of the introscopic system.

Main characteristics of scintillators that are commonly used for these purposes are given in Table 1. From the data presented, it follows that the most suitable for fast introscopic systems are BGO, $CdWO_4$, ZnSe(Tl) and plastics. Accounting for light output, the best among them are ZnSe(Tl) и $CdWO_4$.

As the use of Cd-containing materials is forbidden in EC countries, the most widely used material is CsI(Tl), because its light output is rather high, and its production and applications are technologically well developed.

At present, there is a tendency towards creation of equipment that could function on the real time scale, ensure obtaining of quasi-tri-dimensional images and detection of substances with specified atomic mass of the components. In this aspect, we assume that the most promising for future applications in multi-element detector systems are ZnSe(Te) — for low energies, CsI(Tl) — medium energies, $CdWO_4$ — high energies.

In this work, we have studied 1D and 2D scintillation matrices made of crystals CsI(Tl), $CdWO_4$ и ZnSe(Te). With the aim of studying the effects of scintillator surface treatment quality, uniformity parameters, channel interference under X-ray irradiation, γ-detecting properties, we have prepared samples of multi-element 1D- and 2D-arrays. The fabrication procedure involved cutting of monolithic crystal pieces of ZnSe(Te), CsI(Tl) и $CdWO_4$.

It has been shown that for ZnSe(Te) and $CdWO_4$, it is preferable to have all surfaces grinded. The signal value increase could reach 15–20 %. This can be explained by substantial difference of refraction coefficients between the scintillator and the optical adhesive connection to the photoreceiver.

Channel interference under X-ray excitation was studied using an installation with block diagram as shown in Fig. 2.

Histograms of the channel interference values are presented in Fig. 3.

For 2D-arrays, scintillation properties were studied in the spectrometry mode (Fig. 4,5).

It has been shown that, to ensure channel interference not higher than 10 %, the gap between the channels, filled with a reflective-adhesive composition (TiO_2 + MgO + epoxy adhesive), should be not less than 0.25 mm.

In conclusions, as a result of experimental studies of multi-element scintillators, it has been established that:

— to exclude channel interference above 10 %, the gap between channels filled with reflecting-adhesive composition (TiO_2 +

Table 1. Properties of scintillators used in introscopic systems

Scintillator	Density, g/см^3	Maximum emission wavelength, nm	Light yield, photons/MeV	Refractive index	Decay constant, ns	Afterglov, %/3ms
$CdWO_4$	8.00	480	15000	2.25	1.1	0.05
BGO	7.13	480	9000	2.15	0.3	0.05
CsI(Tl)	4.51	560	59000	1.84	1.0	5
NaI(Tl)	3.67	415	38000	1.85	0.23	5
ZnSe(Te)	5.42	640	45000	2.58	10	0.05
Plastics	1.03	420	≈10000	1.58	0.02	0.05

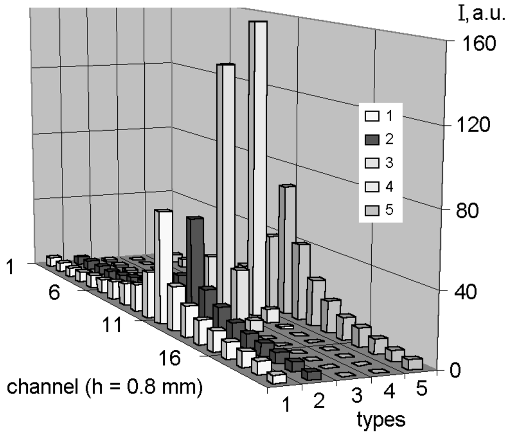

Fig. 3. Mutual interference of neighboring channels for different scintillators and types of scintillation elements: 1 — single crystal plate ZnSe(Te) with $h = 0.8$ mm; 2 — single crystal plate ZnSe(Te) with $h = 0.6$ mm; 3 — composite small-crystalline plate ZnSe(Te) (grain size 0.4 mm); 4 — individual single elements for each channel; 5 — single crystal plate CsI(Tl) with $h = 0.8$ mm.

MgO + epoxy adhesive) should be at least 0.25 mm thick;

— for ZnSe(Te) and $CdWO_4$, it is preferable to have all surfaces grinded. The signal value increase is 15–20 %;

— 2-D arrays fabricated from a monolithic piece ensure high signal uniformity over each channel and can be used in position-sensitive detectors, as well as in spectrometric detectors.

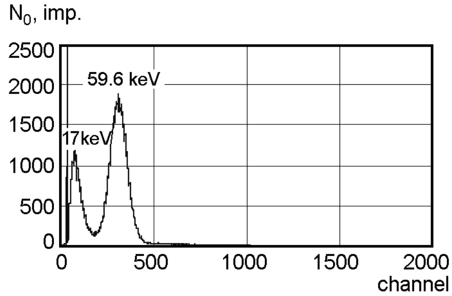

Fig. 4. Pulse amplitude distribution spectrum for a mosaic detector of dimensions 26.5×18.5×2.5 mm^3, composed of 105 tomographic elements based on CWO of dimensions 2.5×1.5×1.5 mm^3, produced by STC RI, under gamma-excitation from ^{241}Am, E = 69.6 keV, R = 33.6 %, t = 4 μs, k = 1, with immersion C = 30.6 with respect to CsI(Tl).

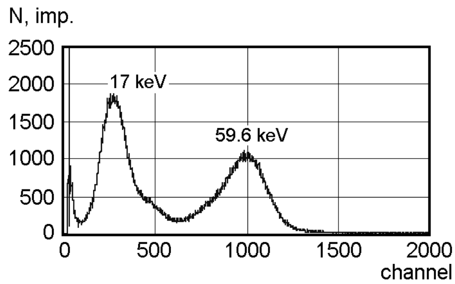

Fig. 5. Pulse amplitude distribution spectrum for a mosaic detector of dimensions 56×42×6.5 mm^3, composed of 221 tomographic elements based on CsI(Tl) of dimensions 3×3×5 mm^3, produced by STC RI, under gamma-excitation from ^{241}Am. E = 69.6 keV, E = 17.6 keV, R = 63.1 %, t = 4 μs, k = 1, with immersion.

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Сцинтиляційні елементи 1D- та 2D-матриць на основі кристалів ZnSe(Te), $CdWO_4$, CsI(Tl).

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Представлено результати досліджень світлового виходу й однорідності сцинтилляційних параметрів 1D і 2D-матриць у залежності від умов їх виготовлення. Показано збільшення світлового виходу шліфованих сцинтиляторів на основі ZnSe(Te) і $CdWO_4$ щодо полірованих елементів. Досліджено енергетичне розділення та світловий вихід 2D сцинтиляторів на основі ZnSe(Te) для α-часток ^{235}Pu. Величина $R_{\alpha} \approx 5$ %. Показано перевагу 2D матриць в порівнянні з монолітними сцинтиляторами.