PROPERTIES UNIFORMITY STUDIES FOR SCINTILLATION ELEMENTS OF 1D- AND 2D-MATRICES ON THE BASIS OF CRYSTALS ZnSe(Te), $CdWO_4$, CsI(Tl), $Bi_3Ge_4O_{12}$

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Results are presented on parameters of light output and uniformity of scintillation properties 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 have been measured for 2D-scintillators on the basis of $CdWO_4$, CsI(Tl), ZnSe(Te) for γ-radiation and α-particles from ^{235}Pu. Advantages of 2D-scintillators over monolithic scintillators are shown. This work has been carried out with support under CRDF Project UE2-2484-KK-02.

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1. INTRODUCTION

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

Recently, a 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 of multi-element scintillation matrices and detectors on their base are known. 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 the emission efficiency of each element, an adhesive-reflecting material is introduced into the inter-element space. However, in the case of Compton scattering, in order to prevent the electron transition from one cell to another, the inter-element space is commonly filled with metal components, e.g., Wood's alloy.

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

2. EXPERIMENT

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 Tabl.

From the data presented, it follows that the most suitable for fast introscopic systems are BGO, $CdWO_4$, ZnSe(Tl) and plastics. Taking account of light output, the best among them are ZnSe(Tl) and $CdWO_4$.

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.

Properties of scintillators used in introscopic systems

Scintillator	Density, g/cм^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

In this work, we have studied 1D and 2D scintillation matrices made of crystals CsI(Tl), $CdWO_4$ and 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) and $CdWO_4$.

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 the 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 the block diagram as shown in Fig.2.

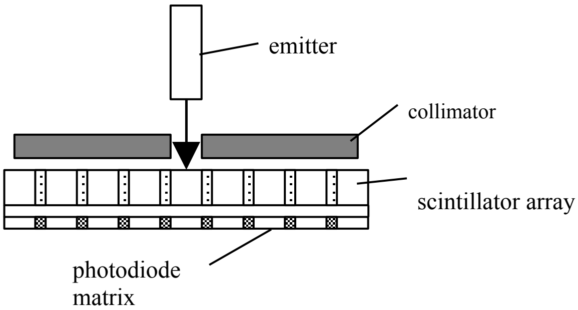

Fig.2. Block diagram of the installation used for channel interference measurements

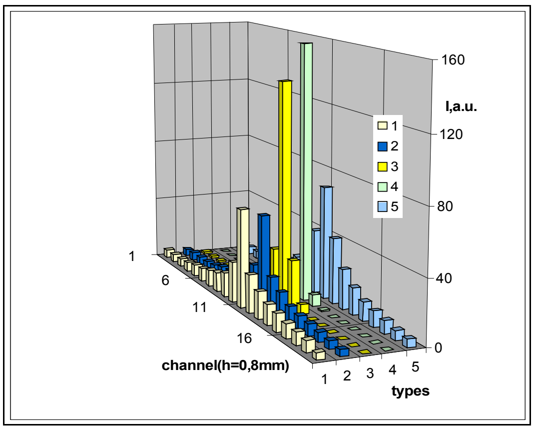

Fig.3. Mutual interference of neighboring channels for different scintillators and types of scintillation elements: 1 - single crystal plate ZnSe(Te) with h=0.8 mm; 2 - single crystal plate ZnSe(Te) with h=0.6mm; 3-composite small-crystalline plate ZnSe(Te) (grain size 0,4 mm); 4 - individual single elements for each channel; 5 - single crystal plate CsI(Tl) with h=0.8 mm

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.

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

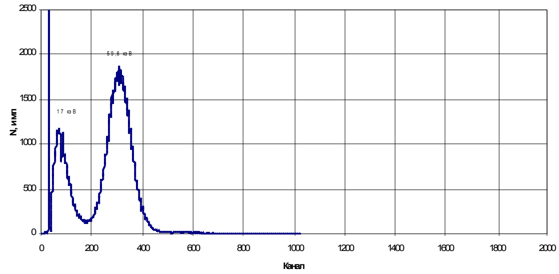

Fig.4. Pulse amplitude distribution spectrum for a mosaic detector of dimensions 26.5x18.5x2.5 mm, composed of 105 tomographic elements based on CWO of dimensions 2.5x1.5x1.5 mm, produced by STC RI, under gamma-excitation from 241Am., E=69.6 keV, R =33.6%, t=4 μs, k=1, with immersion C=30.6 with respect to CsI(Tl)

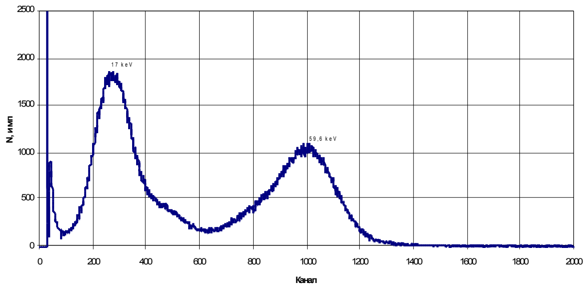

Fig.5. Pulse amplitude distribution spectrum for a mosaic detector of dimensions 56x42x6.5 mm, composed of 221 tomographic elements based on CsI(Tl) of dimensions 3x3x5 mm, produced by STC RI, under gamma-excitation from 241Am. E=69.6 keV, R=28,4%, E=17.6 keV, R=63.1%, t=4 μs, k=1, with immersion

CONCLUSIONS

As a result of theoretical calculations and experimental studies of multi-element scintillators, it has been established that:

1. to exclude channel interference above 10%, the gap between channels filled with reflecting-adhesive composition (TiO_2 +MgO+ epoxy adhesive) should be at least 0.25 mm thick.
2. for ZnSe(Te) and $CdWO_4$, it is preferable to have all surfaces grinded. The signal value increase is 15...20%.
3. 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.

ИССЛЕДОВАНИЕ ОДНОРОДНОСТИ СВОЙСТВ ЭЛЕМЕНТОВ СЦИНТИЛЛЯЦИОННЫХ 1D - И 2D - МАТРИЦ, ИЗГОТОВЛЕННЫХ НА ОСНОВЕ КРИСТАЛЛОВ ZnSe(Te), $CdWO_4$, CsI(Tl), $Bi_3Ge_4O_{12}$

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Представлены результаты исследований параметров светового выхода и однородности сцинтилляционных свойств 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. Показано преимущество 2D-сцинтилляторов по сравнению с монолитными сцинтилляторами.

ДОСЛІДЖЕННЯ ОДНОРІДНОСТІ ВЛАСТИВОСТЕЙ ЕЛЕМЕНТІВ СЦИНТИЛЯЦІЙНИХ 1D - И 2D - МАТРИЦЬ, ВИГОТОВЛЕНИХ НА ОСНОВІ КРИСТАЛІВ ZnSe(Te), $CdWO_4$, CsI(Tl), $Bi_3Ge_4O_{12}$

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Представлено результати досліджень параметрів світлового виходу й однорідності сцинтиляційних властивостей 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. Показано перевагу 2D-сцинтиляторів у порівнянні з монолітними сцинтиляторами.