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A small-sized spectrometric detection block of the scintillator-photodiode system for determination of radionuclide localization sites

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A new small-sized spectrometric gamma-radiation detection block of scintillator-photodiode system has been developed. The block is of $\varnothing 10\times 60$ mm^2 size and consists of a CsI(Tl)–Si PD detector, charge-sensitive amplifier, shaper and an output matching channel. The sensitivity at E = 60 keV is 0.2 pulse·s^{-1}/μR·h^{-1}.

Разработан новый малогабаритный спектрометрический блок детектирования γ-излучения системы сцинтиллятор-фотодиод. Блок имеет размеры $\varnothing 10\times 60$ мм^2 и состоит из детектора CsI(Tl)–Si ФД, зарядочувствительного усилителя, формирователя и выходного согласующего каскада. Чувствительность блока при E = 60 кэВ составляет 0,2 имп.·сек$^{-1}$/мкР·час$^{-1}$.

The problem of detection and identification of ionizing radiation by small-sized detectors is of importance for many fields of applied technical physics and radiation medicine. Detectors of such type should meet a set of specific requirements: small size, high sensitivity, good energy resolution, absence of high voltage. An experimental sample of γ-radiation detection block of $\varnothing 10\times 60$ mm^2 size has been developed and produced. The detection block consists of a detector of scintillator-photodiode system, charge-sensitive amplifier, pulse shaper and output matching stage. Hamamatsu S 6775 photodiodes were used, with photosensitive area of 26 mm^2. The photodiodes selected had minimum dark current at the working voltage of 10 V.

CsI(Tl) crystals were additionally prepared by thermal annealing. Thermal treatment of the crystal favors leveling of its luminescent characteristics over the crystal volume and leads to a certain increase in light output due to removal of small internal nonuniformities and improvement of stoichiometric composition. To verify this, we took a CsI(Tl) crystal of $50\times 50\times 30$ mm^3 size and cut it into two equal parts. One part was subject to thermal annealing, and the other was left untreated. Then samples of $5\times 5\times 10$ mm^3 size were prepared, 10 pieces from each part, and their light output was measured in relative units. The results obtained are presented in Table 1.

As it can be seen from the Table, the light output values of untreated crystals had scatter within 10 %, while for the annealed crystals it was much lower (2–3 %, i.e., within experimental errors), and the maximum light output increased. Thus, additional annealing of CsI(Tl) crystals leads, firstly, to a certain increase in light output, and secondly, to lowering of its scatter. This result is very important for devel-

Table 1. Light output was measured in relative units

No. Light output	1	2	3	4	5	6	7	8	9	10	Ave.
Before annealing (r.u.)	254	260	260	238	255	252	244	256	257	243	252
After annealing (r.u.)	258	261	260	255	260	254	255	258	257	255	257

Table 2. Number of counts in 60 s under irradiation of the crystal by gamma-quante of ^{241}Am

Crystal shape	Cube	Parallele-piped	Cylinder			Prism		Ellipse
Size, mm	4×4×4	4×4×8	5×4	5×8	5×10	4×4×8	5×5×8	10
Number of counts in 60 s	58	63	64	69	70	55	60	85

opment of scintillator-photodiode detectors of small volume.

The crystal shape in scintillator-photodiode systems plays an important role in light collection, ultimately affecting the photocurrent value in the current mode or the electric charge in the counting (spectrometric) mode. However, a limited space within the detection unit housing (~∅8.5 mm) does not allow one to fully use the advantages in light collection that can be obtained with a crystal of appropriate shape. Nevertheless, such experiments had been carried out. CsI(Tl) scintillation crystals of several shapes were prepared:

— Cube of 4×4×4 mm^3;

— Parallelepiped of 4×4×8 mm^3, where 4×4 mm^2 is the dimensions of the output window;

— Cylinder of ∅5 mm, ∅7 mm passing into a plate of 4×4 mm^2 with height of 4, 8 and 10 mm;

— Hexagonal prism with an output window of 4×4 mm^2 or 5×5 mm^2, and height of 8 mm;

— Rotation ellipsoid (an ellipse in an axial cross-section) with its output plane

— normal to the ellipse axis and passing through its minor focus (length 10 mm).

As a controlled parameter, we will take the number of pulses/s under irradiation of the crystal by gamma-quanta of ^{241}Am (59.2 keV). The radiation direction was along the crystal axis, and an S 3590-01 photodiode of 10×10 mm^2 area was used as photoreceiver. Then measurements were carried out in the counting mode using ^{241}Am. Results obtained for crystals of different shape are shown in Table 2. It can be seen that the best results (as for sensitivity) were obtained with cylindrical samples. The shape of ellipsoid remains the best. An increase in crystal height above 5 mm practically does not increase the number of counts for ~60 keV energy. Differences in sensitivity are related only to the scintillator shape.

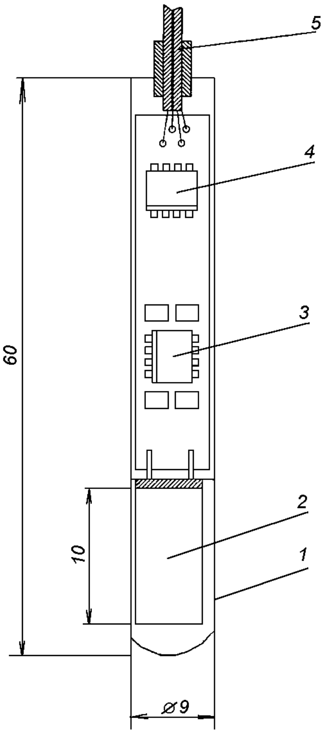

Fig. 1. Assembling diagram of the detection block: *1* — thick-walled titanium tube, *2* — CsI(Tl) crystal, *3* — charge-sensitive amplifier, *4* — shaper of semi-Gaussian pulse, *5* — shaper output.

Thus, we have chosen CsI(Tl) crystals of sizes 4×4×8 mm^3, 4×4×10 mm^3 and ∅5 mm and height 10 mm. For the cylinder, the output window was prepared square-shaped with 4×4 mm^2 sides. Crystals were attached to photodiodes using an optical adhesive. Firstly, they were wrapped into light reflecting MgO powder. The detector and board with electronic components were placed into a thick-walled titanium tube of 10 mm external diameter. An assembling diagram of the detection block is shown in Fig. 1. The electronic part of the detection block consists of a charge-sensitive amplifier and a shaper of semi-Gaussian pulse on

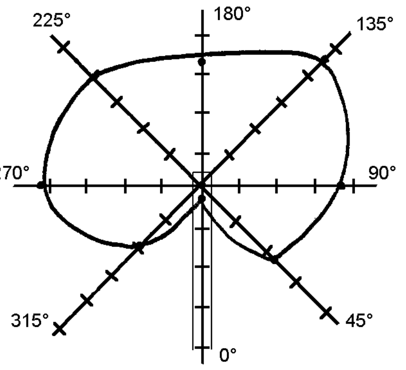

Fig. 2. Diagram of sensitivity direction for the detection block (^{241}Am source).

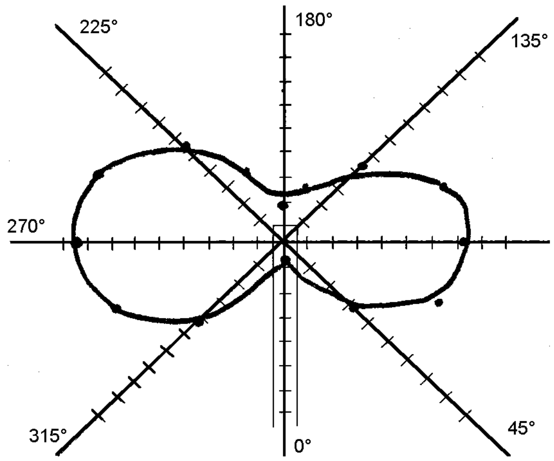

Fig. 3. Diagram of sensitivity direction for the detection block with a cylindrical filter (^{241}Am source).

a quadrupled operation amplifier. Tuning of the electronic part of the detection block consisted in the choice of operation points by minimum noise level at the shaper output. Technical characteristics of the amplifier (when a signal comes from the receiver) — noise level (recalculated to ~30 keV

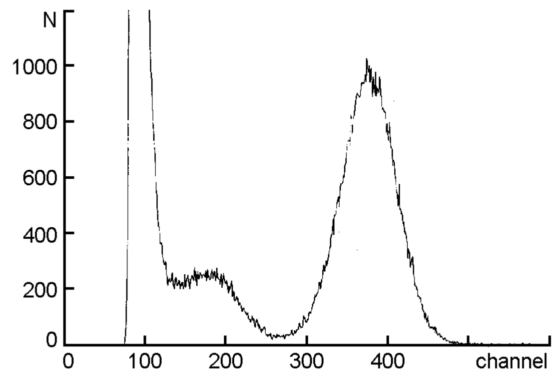

Fig. 4. Energy spectrum of ^{241}Am.

value), amplitude of signals from the shaper for the case of a signal from detectors — the noise level recalculated into energy ~30 keV, the amplitude of signals coming from the shaper ~0.2–0.3 V.

The sensitivity of the detection block with a CsI(Tl) crystal of ∅5×10 mm^2 size is 0.2 pulse·s^{-1}/μR·h^{-1}. The measurements were carried out using ^{241}Am source. Signals from the detection block can go either to a recalculating device or to a multi-channel spectrum analyzer. In the first case, the detection block functions in the dosimeter mode. Fig. 2 shows a diagram of the detection block sensitivity direction (a directed action is sometimes required). Fig. 3 shows the direction diagram with a cylindrical filter. In this case, the detection block has improved sensitivity from the tube end side. With signals coming from the detection block to the input of a multi-channel analyzer, the energy spectrum of ^{241}Am radiation is measured, which is shown in Fig. 4.

Thus, a new small-sized detection block of scintillator-photodiode system has been developed, which can find broad application in different fields of applied radiation physics.

Малогабаритний спектрометричний блок детектування системи сцинтилятор-фотодіод для визначення місць локального зосередження радіонуклідів

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Розроблено новий малогабаритний спектрометричний блок детектування γ-випромінювання системи сцинтилятор-фотодіод. Блок має розміри ∅10×60 мм^2 і складається з детектора CsI(Tl)–Si ФД, зарядочутливого підсилювача, формувача та вихідного узгоджуючого каскаду. Чутливість блока при E = 60 кеВ складає 0,2 імп.·сек$^{-1}$/мкР·год$^{-1}$.