# New Scintillation Materials and Systems for Registration of Radiation

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## Abstract

Some new original results and original invention on advanced scintillation materials and detection systems for registration of gamma-rays, neutrons, neutrinos, beta-particles, electron and ion radiation developed with collaborators from Kyrgyzstan, Russia and France are presented.

## 1. Introduction

Scintillation method is still one of the main used for the detection of ionizing radiations. Universality of this method is considered to be its main advantage. It can be used for registration of almost all types of radiation in a wide range of energy (varying from several eV to tens GeV).

In previous papers [1-4], we have reported results on the development of new scintillation materials and scintillation devices which have been made before the end 2006 (more than 160 inventions). In this short paper some new original results on advanced scintillation materials and scintillation detection systems developed and patented recently are presented.

## 2. Scintillation Materials

### 2.1 (Li,Na)F Based Materials

The new proposed scintillation material with high efficiency of thermal neutron detection [RU-patent 2270463, 2006] has the composition, at %: $^{6}LiF:UO_2(NO_3)_2$ 99,94-99,98; $^{3}He$ 0,02-0,06. The registration of thermal neutrons occurs through the (n, α) reaction on the $^{6}Li$-nuclei with an interaction cross section of $940\times10^{-24}$ cm$^2$ and through the (n, p) reaction on the $^{3}He$-nuclei with the interaction cross section of $4000\times10^{-24}$ cm$^2$. Maximum of scintillation wavelength is $\lambda\sim$ 530 nm. The effective atomic number $Z_{eff}$ = 8.2.

The new material for the registration of neutrinos was proposed [Application for RU-patent 2005140702, 2005] on the base of NaF composition, mol.%: NaF 99,97–99,60; $YbF_3$ 0,01–0,3; $UO_2(NO_3)_2$ 0,01–0,05 and bound oxygen 0,01–0,05. The proposed NaF:Yb,U,O compound exhibits higher scintillation efficiency for neutrino detection due to the large neutrino capture cross-section by $^{176}Yb$ and $^{19}F$ isotopes [5] and due to effective energy transfer to $UO_5F$ luminescent centers.

### 2.2 $Caf_2$ Based Materials

Two new scintillation materials based on $CaF_2$ have been developed. The first scintillator [RU-patent 2244320, 2005] has the composition (atomic %): $CaF_2$ 99,25-

99,59; $EuF_3$ 0,4-0,7; $^3He$ 0,01-0,05. The registration of thermal neutrons occurs in two ways. The first way is (n,p) reaction on the Eu-nuclei with an interaction cross section of $4600\times10^{-24}$ $cm^2$ (for a natural composition of Eu isotopes). The second way is (n, p) reaction on the $^3He$ nuclei with a cross section of interaction $4000\times10^{-24}$ $cm^2$. Parameters of scintillations: $\tau = 800$ ns, $\lambda = 435$ nm, $Z_{eff} = 16.5$, output is 52% of that of NaI:Tl (for $^{137}Cs$), energy resolution is 12% (for $^{137}Cs$).

The second new $CaF_2$ based scintillator was proposed for the registration of thermal and fast neutrons [RU-patent 2276387, 2006]. It has the following composition (atomic %): $CaF_2$ 99,25-99,59; $EuF_3$ 0,39-0,66; $^3He$ 0,01-0,05; H 0,01-0,04. Due to the presence of H-nuclei, the proposed scintillator can detect fast neutrons. The scintillation parameters (decay time, maximum of scintillation wavelength, output, energy resolution) for $CaF_2$:(Eu,$^3$He,H) are similar to scintillation parameters of $CaF_2$:(Eu,$^3$He) described before.

### 2.3 $Srf_2$:(Er, Nd,Tm) Based Materials

$SrF_2:Er^{3+}$ was proposed as a new VUV-scintillation material [6]. In $SrF_2:Er^{3+}$ crystals two emission bands in VUV-region were observed: the known band at 165.4 nm and a new fast emission band at 146.4 nm with a decay time around 600 ps. $SrF_2$:Tm (luminescence band at 167 nm) and $SrF_2$:Nd (luminescence band at 187 nm) are also promising VUV-scintillators [6].

### 2.4 AgCl-AgBr-AgI compound doped with Tl

AgCl-AgBr-AgI compound doped with Tl was proposed as a new scintillation material for the registration of gamma-rays and electron beams [Application of RU-patent 2005114646, 2005]. Parameters of the scintillator: $\lambda = 675$ nm, $\tau \sim 40$ ns, $Z_{eff} = 45.7$, transparent in the 0.4-40 μm range.

### 2.5 6Li-glass based materials

The scintillation material $^6Li_2O$-MgO-$SiO_2$-$Ce^{3+}$ for registration of thermal neutrons was proposed [7,8]. Parameters of scintillation: $\lambda = 400$ nm, decay time of fast component $\tau = 16.7$-45.8 ns, of slow components $\tau = 60$-108 ns. This glass has higher light output (1.25-1.8 times) than the well-known NE-905 glass [7].

## 3. Detection Devices

During two last years some new scintillation detectors and systems for registration of gamma-rays, beta-particles, electrons and neutrons have been developed by scientists from Kyrgyzstan, Russia and France. Several inventions were proposed: “Fiber optic X-ray scintillation detector” on the base of AgCl-AgBr-AgI fibers [RU-patent 2248011, 2005], “Fast and thermal neutron scintillation detector” [RU-patent 2259573, 2005], “Scintillation detector of neutrons” with $^6$Li-glass cone type sensor [RU-patent 2272301, 2006], “Scintillation detector” with photodiode registration and spectrum shifter [RU-patent 2248588, 2005], “Scintillation sensor for electron and beta-particles registration” [RU-patent 2251124, 2005], “X-ray imaging scintillator” with 6 μm space resolution [RU-patent 2261459, 2005], “Light fiber scintillation detector” on the base of BGO fiber [RU-patent 2262722, 2005] and “Scintillation detector” [Application of RU-patent 2005131345, 2005]; “Neutron scintillation detector” in collaboration with SRTIOM of State Optical Institute [Application of RU-patent 2005125151, 2005], and spherical type detector [Application of RU-patent 2006103686, 2006]. Some of these inventions are described below.

### 3.1 Scintillation cone type detector for neutron registration

Scintillation cone type detector for neutron registration was proposed using plastic and $^6$Li-glass scintillators [RU-patent

2272301]. The scheme of the proposed device is presented in Fig. 1. The fast neutrons are moderated by both external and internal H-containing moderators. Most of them are registered mainly by a $^{6}$Li-glass scintillator disk ($\tau$ = 60-80 ns, $\lambda$ = 390-400 nm). The intermediate and slow neutrons are moderated mainly by the external moderator and registered by additional $^{6}$Li-glass scintillator in the hollow cone form. The detector works in account mode.

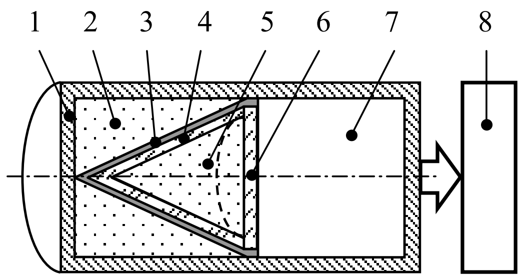


Fig. 1: Scintillation detector of neutrons

1. case;
2. external moderator of neutrons;
3. light reflection film;
4. additional cone type $^{6}$Li-glass scintillator;
5. internal moderator of neutrons;
6. main $^{6}$Li-glass scintillator;
7. photomultiplier;
8. operation block.

**3.2 Scintillation bulk-fiber type detector for registration of neutrons and gamma-rays**

Scintillation bulk-fiber type detector for registration of neutrons and gamma-rays was proposed using plastic and BGO fiber scintillators [RU-patent application 2005131345, 2005], Fig. 2. Plastic H-containing scintillating cylinder is used for the registration of fast neutrons ($\tau$ = 4-8 ns, $\lambda$ = 420-480 nm). BGO fibers are inserted inside a plastic scintillator situated between the mirror and the photodetector. BGO fibers are used for light collection of photons emitted by the plastic scintillator and as scintillation sensors for gamma-rays. Similar bulk-fiber construction for fast and thermal neutrons registration was proposed with $^{6}$Li glass fibers [RU-patent 2005125151, 2005].

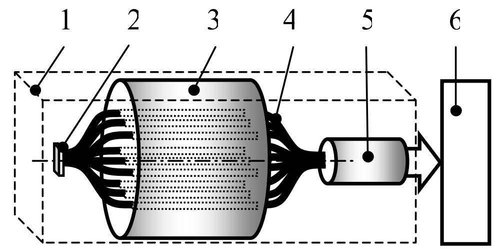


Fig. 2: Scintillation detector of neutrons

1. case;
2. mirror;
3. plastic scintillator;
4. BGO fibers;
5. photodetector;
6. operation electronic block.

**3.3 Scintillation sensor for beta and electron radiation**

Scintillation sensor for beta and electron radiation was proposed [RU-Patent 2251124, 2005]. The scheme of the proposed device is presented in Fig. 3. The sensor works as follows. Electron radiation passes through the wedge performer along the Z axis on the length of maximum extrapolated run of electrons. It means that only a part of the beta-radiation approaches the scintillation screen. So, along the X axis only a part of photodetector cells will be loaded. The last loaded cell will determine the thickness of the performer and it is possible to determine the energy maximum of incident radiation. Operation electronic block determines a coordinate of the last loaded cell and energy maximum of incident radiation.

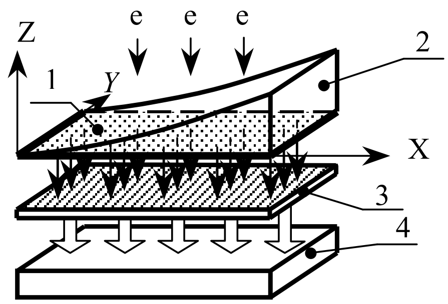


Fig. 3: Scintillation sensor for electron and β-radiation

1. one dimensional scintillation screen;
2. performer of radiation;
3. one dimensional photodetector;
4. operation electronic block.

### 3.4 Scintillation spherical type detector for registration of gamma-rays and neutrons

Scintillation spherical type detector for registration of gamma-rays and neutrons was proposed [Application of RU-patent 2006103686, 2006], Fig. 4. This device contains a spherical scintillator (consisted of two hemispheres 1 and 2), reflecting layer 3 (disposed on the surface of the hemispheres), two PIN-photodiodes 4 and 5 (installed "back" to "back" into hole 6 situated in the centers of the hemispheres), canal 7 for cable 8, which connects PIN-photodiodes with operation block 9. The device is situated in the case 10.

Scintillating materials are CsI:Tl or $Bi_4Ge_3O_{12}$ or $Lu_2SiO_5$:Ce for gamma-rays detection and stilbene for neutrons detection. All photons appearing in hemispheres are focused to the center of the sphere (where PIN-photodiodes are situated) due to reflecting layer 3. So, the volume of the scintillation crystal is not limited by the dimensions of input windows of photodiodes. Furthermore, the proposed device provides 4π-geometry of light collection, improving its radiation sensitivity.

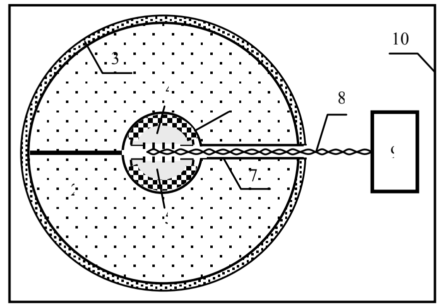


Fig. 4: Spherical radiation detector for registration of gamma-rays and neutrons.

The examples of devices created on the base of new results obtained in USTU–UPI are shown in Fig. 5. The gamma-spectrometer "PEGAS" was created within the project of International Science-Technical Center.

## 4. Conclusion

All proposed scintillation materials and devices can be used as radiation detectors in nuclear and high energy physics, geophysics, biophysics, biochemistry, radiochemistry. They are perspective for medical imaging, for industrial applications involving non-destructive radiation control, for radio ecological monitoring of state, sport and shopping areas, water and territories, for customs control.

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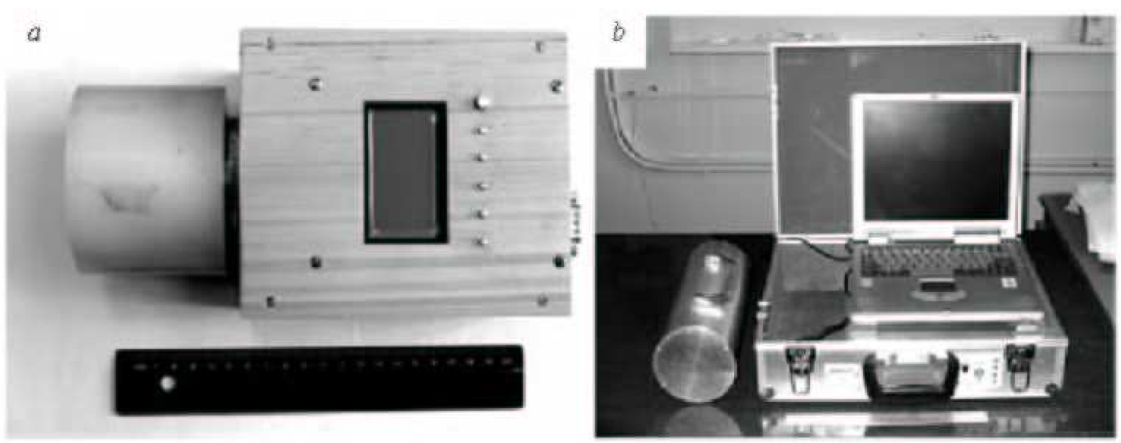


Fig. 5: (a) Neutron detector on the base of $^{6}$Li-glass scintillator and (b) Gamma-spectrometer “PEGAS”