DETECTORS FOR IONIZING RADIATION BASED ON CRYSTAL SCINTILLATORS

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Main purpose

The purpose of the research is to design and develop high precision and reliability radiation detectors intended to physical processes diagnostics in nuclear power facilities and for radiation control on nuclear power plants.

Requirements

- Detectors should be able to provide measurements of gaseous products of ^{85}Kr, ^{85m}Kr, 88Kr, ^{133}Xe and ^{135}Xe fission in more wide range of 10^4 — 3.7 10^{14} Bq/m3 ± 15% in compare with existing monitors and to identify radionuclide in controlled gas-air sample;

- Detectors should have the ability to detect gamma-rays in liquid media monitoring volumetric activity of ^{137}Cs with maximum measured value of 5 10^7 Bq/kg ± 15% and to identify ^{134}Cs, ^{136}Cs, ^{138}Cs, ^{131}I, ^{133}I, ^{24}Na radionuclides;

- Detectors should provide detection of 60Co activity in gaseous medium with maximum measured value of 10^{12} Bq/m^3.

Requirements

- Energy resolution on isotope 137Cs should be no less than 4—5%;
- Upper limit of working temperature range no less than +80°C;
- Should be stable under the stress temperature influence;
- Lack of hydroscopicity is desirable;
- Dependence of the detection efficiency on temperature should be negligible;
- Detection time for the single quantum no more than ~ 100 ns.

Considering the requirements listed previously and proceeding from table data it is advisable to analyze following detectors: $Bi_4Ge_3O_{12}$ [BGO]; $LaBr_3$(Ce); Lu_2SiO_5Ce [LSO]; $Lu_{1.8}Y_{0.2}SiO_5$(Ce) [LYSO] и $YAlO_3$(Ce) [YAP(Ce)].

Experimental verification of the applicability of detectors based on CsI(Tl), BGO and LSO

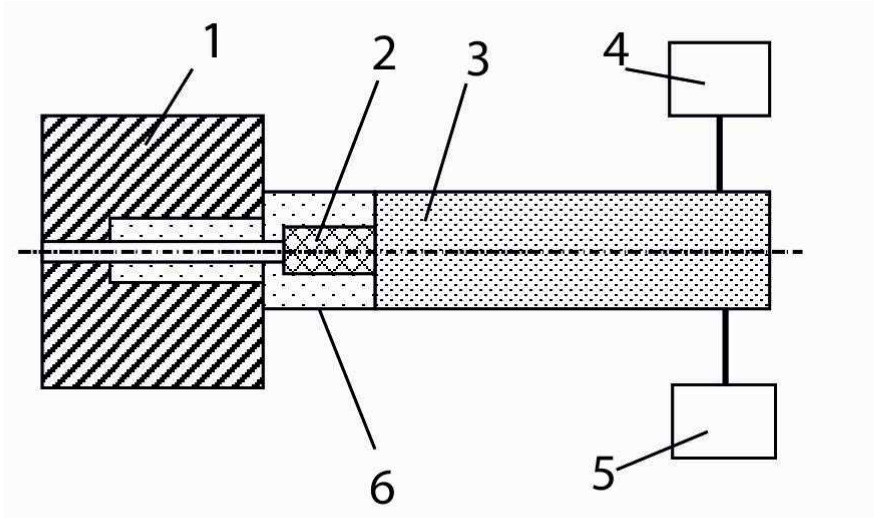

Figure1. Appearance and design of the detection unit: 1 — lead collimator, 2 — scintillator detector, 3 — PMT containing aluminum case, 4 —power supply unit, 5 — amplifier, 6 — detachable body part.

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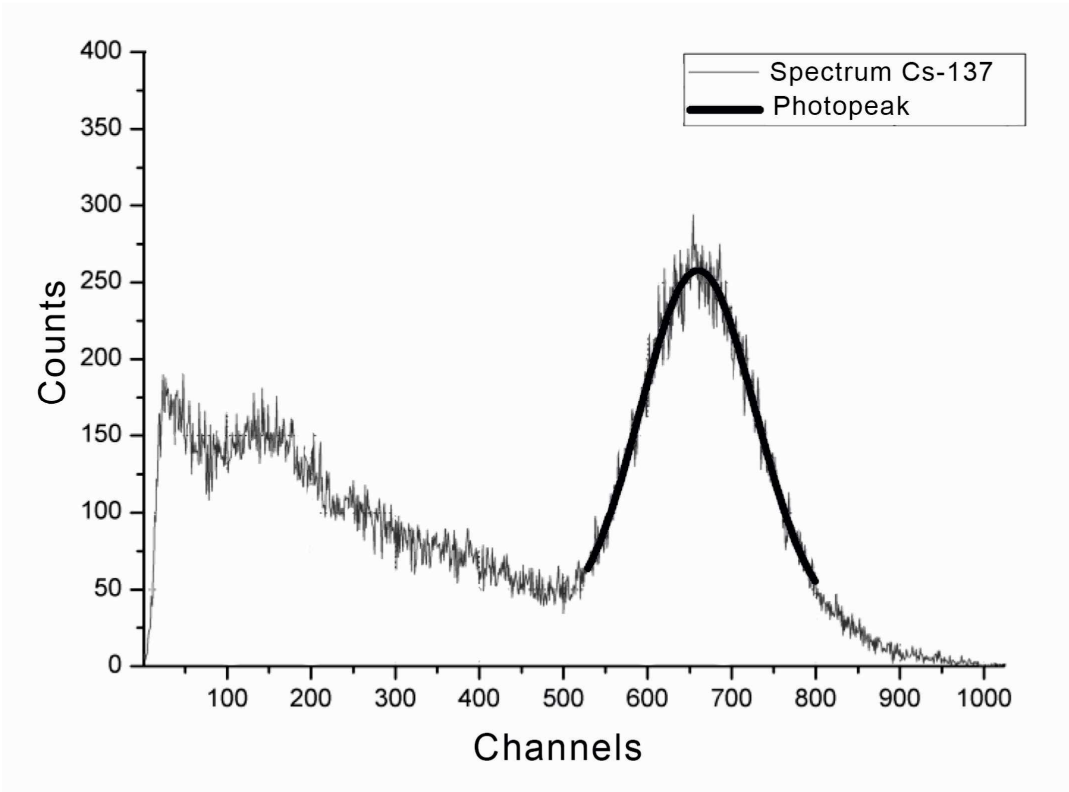


Figure2. ^{137}Cs spectrum with BGO scintillator.

Experimental verification of the applicability of detectors based on YAlO3(Ce) and LaBr3(Ce)

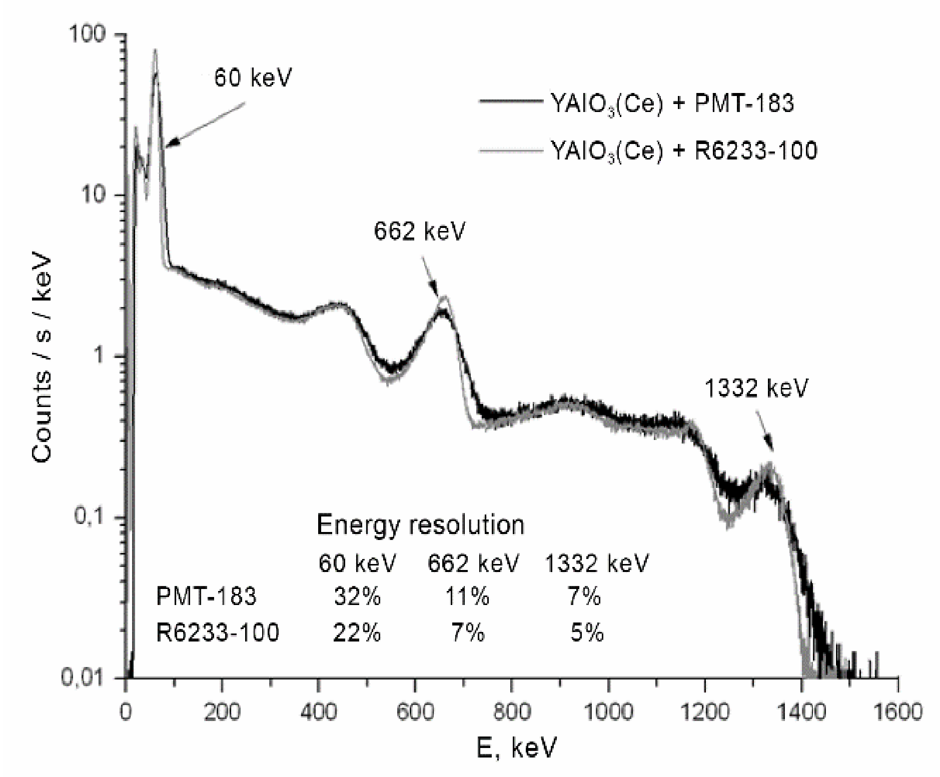


Figure 3. Energy spectrum with YAlO3(Ce) scintillator ø70×10 mm and FEU-183 and R6233-100 PMTs.

Experimental verification of the applicability of detectors based on $YAlO_3$(Ce) and $LaBr_3$(Ce)

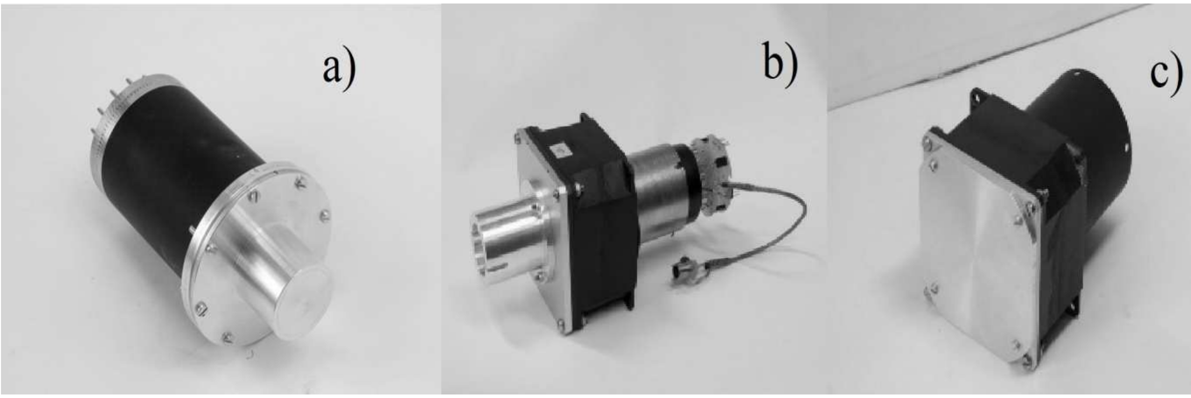


Figure4. Appearance of prototypes:

a) LABR-1 – the prototype based on ø25x25 mm $LaBr_3$(Ce) crystal is placed in optical contact with 46 mm photocathode of Hamamatsu R6231-100 PMT;

b) LABR-2 – the prototype based on ø25x25 mm $LaBr_3$(Ce) is placed in optical contact with 72 mm photocathode of FEU-183 PMT;

c) IAP-1 - the prototype based on $YAlO_3$(Ce) 10mm height and 70 mm diameter is placed in optical contact with 70 mm photocathode of Hamamatsu R6233-100 PMT.

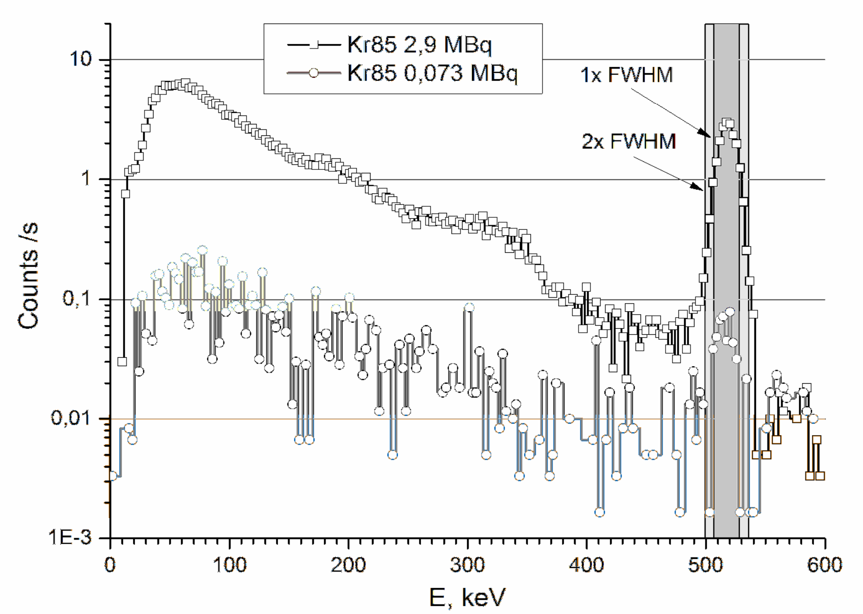


Figure 4. ^{85}Kr spectrum obtained with LABR-1.

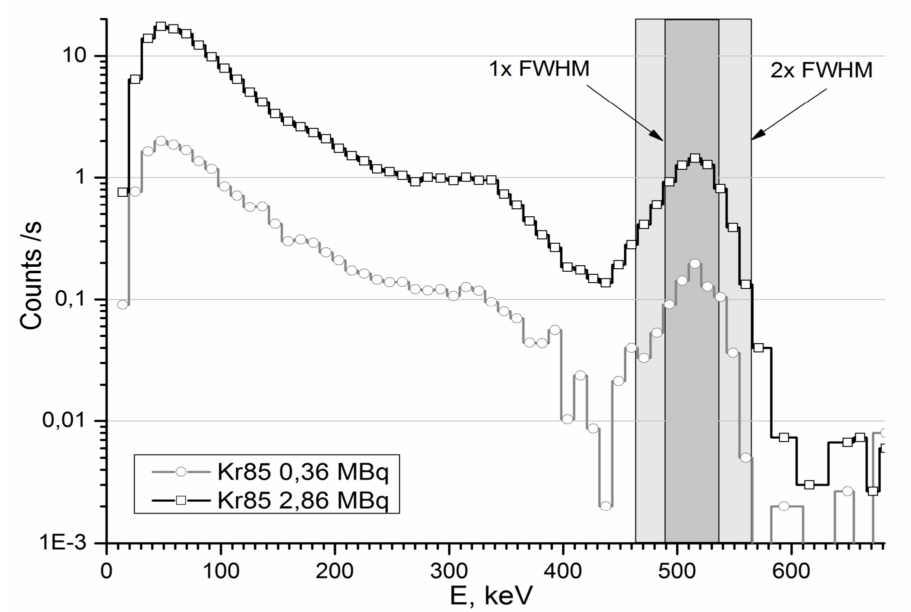


Figure 5. ^{85}Kr spectrum obtained with IAP-1

Crystal scintillator detectors study by measuring the gaseous medium activity

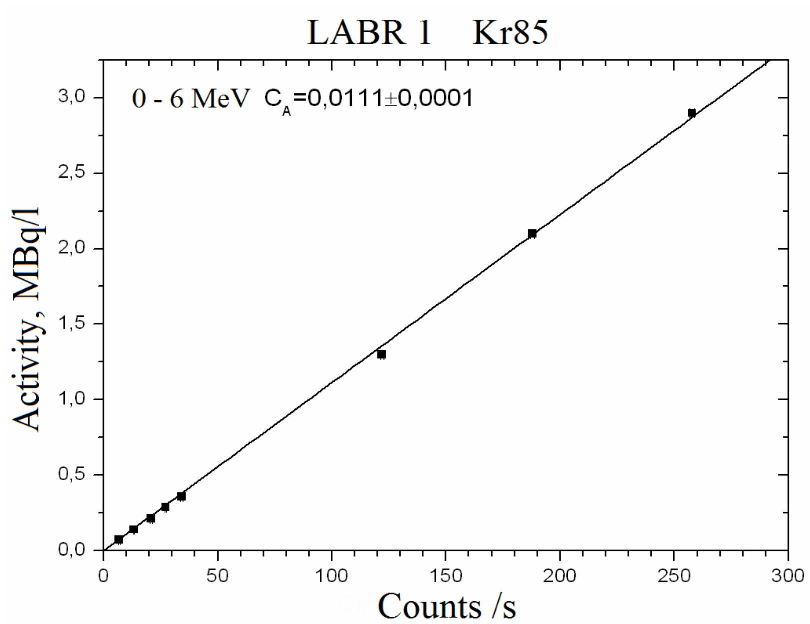


Figure 4. ^{85}Kr spectrum obtained with LABR-1

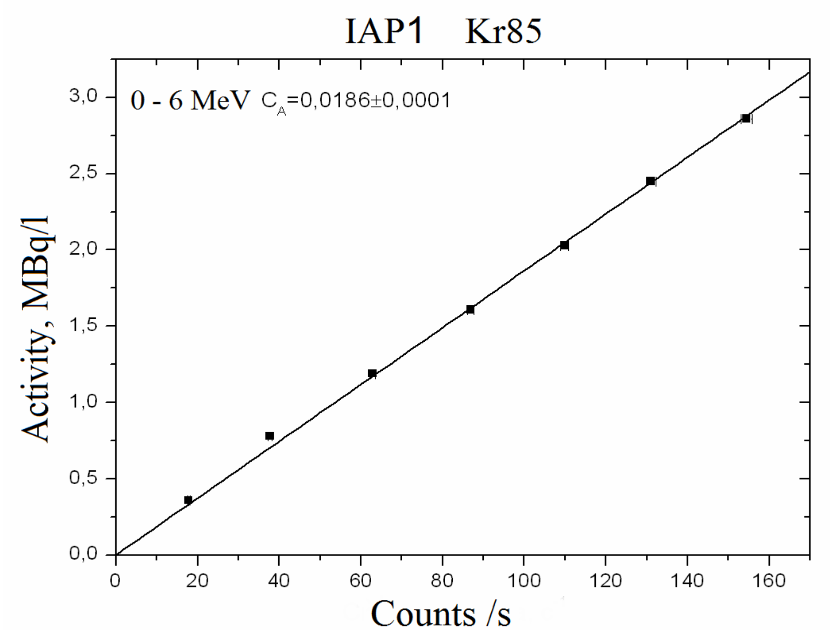


Figure 5. ^{85}Kr spectrum obtained with IAP-1

Concentration limits

The upper level of activity (activity which may be registered by proposed devices) depends on a processing time of a single interaction which equals to 10-6 s for modern processors. Thus overall counting rate must not exceed 10^6 samples/s. For LABR-1 and IAP-1 :

A_{LABR-1} = (2.9*10^9Bq/m^3 10^6)/ 250s^{-1} = 1.16 10^{13}Bq/m^3, where 2,9 10^9 Bq/m^3)/250s^{-1}- rate for activity per one detector count (see fig. 6), 10^6 - limit for detecting count rate.

A_{IAP-1} = (2.86*109Bq/m^3 10^6/160 s^{-1} = 1,8 10^{13}Bq/m^3

The lower level of activity which possible to be registered by proposed devices is determined by a detector efficiency, background and a measuring time.

A $_{LABR-1}$=0,21/(t measurement)0,5

And following the same approach for IAP-1

A_{IAP-1}=0,45/(t measurement)0,5.

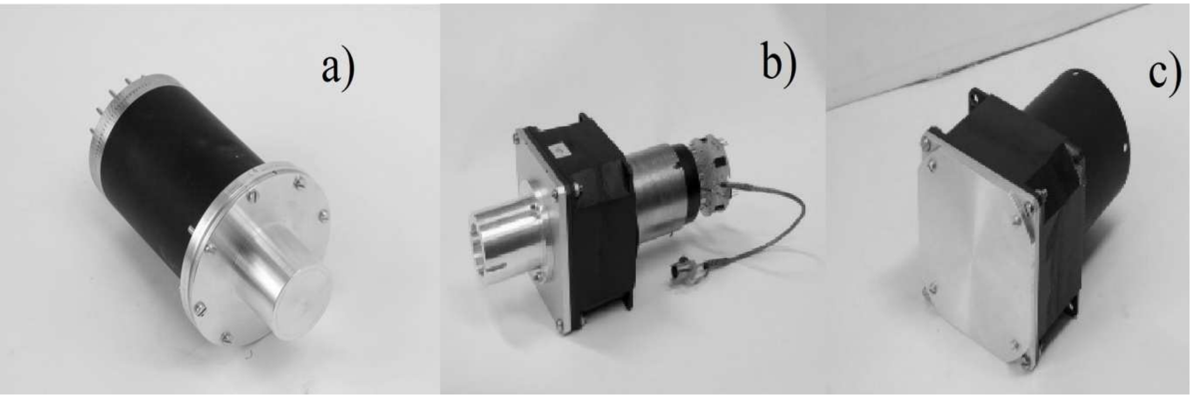
With 100s measuring time the lowest activity will be 2.1 10^7Bq/m^3 for LABR-1 prototype and 4.5 10^7Bq/m^3 for IAP-1.

To obtain the required accuracy it is necessary to increase measuring time up to 400-500 s.

Conclusion

In this study prototyping and experimental research of opportunities of crystal scintillator detectors were conducted.

It was demonstrated, that the minimum measuring level of gas medium activity with 100s measuring time will be $10^7 Bq/m^3$ and the maximum of activity will be 10^{13} Bq/m^3 for LABR-1 and IAP-1 based detectors.



Thank you for your attention!