Characterization of GAGG:Ce and $CeBr_3$ scintillators for high energy gamma ray monitoring in plasma devices

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NCBJ is involved in the modernization of gamma in for the Joint European Tokamak (JET). One of the diagnostic tools is tokamak plasma tomography, currently based on 19 detectors with Ø20×15mm CsI:Tl scintillators coupled to PiN diodes. However, the response of CsI:Tl is crystal to radiation slow, therefore the detectors will be replaced with faster scintillators within the Gamma Camera Upgrade project. The $CeBr_3$ [1] and GAGG:Ce (Gadolinium Aluminum Gallium Garnet) [2] scintillators are the potential candidates for this application.

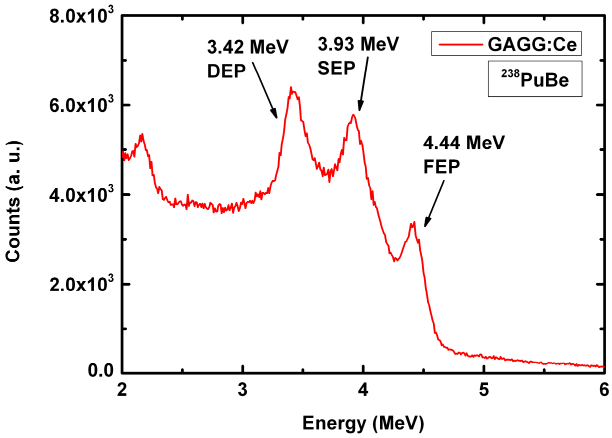

Fig. 1. ^{238}PuBe spectrum measured with the 1”×1” GAGG:Ce scintillator coupled to a PiN-diode.

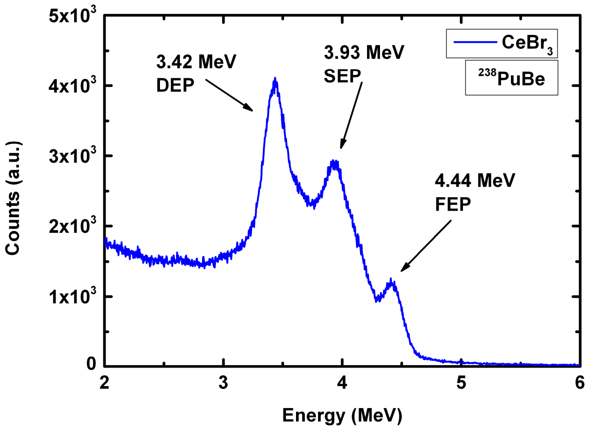

Fig. 2. ^{238}PuBe spectrum measured with the 1”×1” $CeBr_3$ scintillator coupled to a PiN-diode.

The $^{9}Be(\alpha,n\gamma)^{12}C$ reactionis used for plasma monitoring in tokamaks. 4.4 MeV photons produced in this reaction are registered in detectors placed outside the fusion device.

To find the best scintillation material we tested two 1”×1” cylindrical scintillators, $CeBr_3$ and GAGG:Ce coupled to 10×10 mm^2 Hamamatsu S3590 series PiN diodes. In this report we focused on energy resolution measurements with both scintillators. The signal from the PiN diode was amplified by a Cremat CR-110 preamplifier, and shaped with an Ortec 672 spectroscopy amplifier with a shaping time of 2 μs. Finally, the signals were recorded with a Tukan8K Multichannel Analyzer.

Fig. 1 and Fig. 2 present the response of the GAGG:Ce and $CeBr_3$ scintillators to a ^{238}PuBe source, emitting 4.4 MeV γ rays. The single and double escape peaks (SEP and DEP, respectively) are also indicated in the spectra. 4.4 MeV γ rays are detected in a scintillator by an electron-positron pair creation. After annihilation of a positron inside the crystal, two 511 keV photons are emitted. It is possible that one or two of those photons can escape the scintillator, which gives rise to the 3.42 MeV and 3.93 MeV peaks in the spectrum.

In Table 1 the results of the energy resolution measurements are presented.

Table 1. The energy resolution of the GAGG:Ce and $CeBr_3$ scintillators.

Energy (MeV)	FWHM (%)	
	GAGG:Ce	$CeBr_3$
3.416	5.6	5.8
3.927	4.5	5.0
4.438	3.8	3.6

Summarizing, the GAGG:Ce and $CeBr_3$ scintillators coupled to a PiN diode have sufficient energy resolution of a few % at 4.4 MeV, see Table 1. GAGG:Ce has the advantage over $CeBr_3$, as it has a higher density and a higher atomic number, therefore it is more efficient for high energy γ ray detection. However, GAGG:Ce contains Gd and Oxygen, contributing to a higher radiation background when exposed to neutron radiation.

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References

[1] P. Guss et al., NIM A 608 (2009) 297–304
[2] P. Sibczyński et al., NIM A 772 (2014) 112–117