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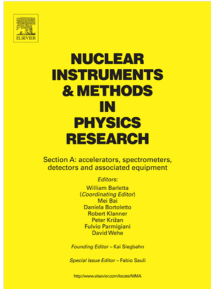

Multi-layer fast neutron detectors based on composite heavy-oxide scintillators for detection of illegal nuclear materials

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Multi-layer fast neutron detectors based on composite heavy-oxide scintillators for detection of illegal nuclear materials

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Abstract
We developed and characterized a new type (designated ZEBRA) of multi-layer composite heavy-oxide scintillator detectors for fast neutron detection for homeland security and nuclear safeguards applications. In this heterogeneous detector medium, composite layers comprised of micro-granules of heavy-oxide scintillators (ZWO, CWO, PWO, BGO, GSO(Ce), GOS(Ce) and others) dispersed in transparent plastic are alternated with layers of clear plastic that serve as scintillation light guides and as a neutron moderator material. The physical peculiarities of the neutron interactions and the principal mechanisms of fast neutron registration in these detectors are discussed in detail. The fast neutron intrinsic detection efficiencies and sensitivities of ZEBRA-detectors based on BGO, ZWO and GSO(Ce) composite scintillators in response to neutrons from ^{239}Pu-Be and ^{252}Cf sources were measured. These detectors had cross-sectional areas ranging from 16 to 100 cm^2. The sensitivities of such detectors of size 100×100×41 mm^3 were found to be 40-51 cps/(nps×cm^{-2}), a level that is comparable to the sensitivity of a typical ^{3}He counter of 1600 cm^2 area. The intrinsic efficiencies and sensitivities of the ZEBRA-detectors also compare favorably with those of fast neutron detectors based on large-size heavy-oxide single crystals, but the multi-layer composite ZEBRA structures are much less expensive and can be easily manufactured in much larger dimensions. This work represents a significant advance from earlier single-crystal detector types as part of our effort to explore alternatives and improvements to conventional ^{3}He counters.

Keywords: Fast neutron detection; Inelastic and Resonance neutron scattering; Radiation detectors; Multi-layer scintillator detectors; Nuclear safeguards; He-3 alternatives.

1. Introduction

One of the main challenges in nuclear security is the creation of detection systems for fast neutrons and mixed neutron/gamma radiation that would be highly efficient, compact, inexpensive, robust with respect to unfavorable conditions, and reliable in operation (see [1] and additional references therein). Reliable recognition of special nuclear materials (e.g., highly enriched Uranium and weapons grade Plutonium), and other neutron-emitting radioactive materials requires the creation of detectors with high detection efficiency for fast neutrons (intrinsic efficiency not less than 50-60%). At the same time, practically all of the state-of-the-art detectors proposed for the replacement of ^{3}He counters due to the shortage of ^{3}He [2] can directly detect only slow and/or thermal neutrons, relying on the radiative capture reactions of light nuclei such as ^{6}Li or ^{10}B with high thermal neutron absorption cross-sections, but with relative insensitivity to fast neutrons. Many types of such neutron detectors have been proposed

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