Title of the cycle of papers: Composite scintillators based on lithium glass for thermal neutron detection

Authors list: E. S. Kuzmin, I. Yu. Zimin, V. L. Malyshev. (Dzhelepov Laboratory of Nuclear Problems), G. D. Bokuchava, A. A. Kruglov (Frank Laboratory of Neutron Physics).

Prize category: methodology, research and technology papers.

Abstract: Some of the most popular thermal neutron detectors are those based on ^{3}He. Over the last decade, the cost of ^{3}He gas has risen sharply. This situation is driving the search for new neutron detection technologies.

Existing detectors lack the performance characteristics required to fully replace helium-based counters. One such detector is lithium glass. Its advantages include transparency, high neutron detection efficiency, and a short "dead time." A significant drawback of this scintillator, however, is its high sensitivity to γ-rays.

There are two main approaches to reducing γ-sensitivity. The first involves creating scintillators with a heterogeneous structure (composites) based on lithium glass. The second entails n/γ-discrimination through analog or digital signal analysis. This cycle of papers presents the results of developing a detector based on a heterogeneous scintillator.

A Monte Carlo model of a thermal-neutron scintillation detector based on NE 912 lithium glass has been developed and verified. The model was verified by comparing its results with experimental data obtained from exposing a prototype to beams of thermal neutrons and γ-rays. The characteristics of the scintillator — specifically, the light output upon neutron capture and its temporal parameters — have been determined.

The interaction of thermal neutrons and γ-quanta with composites — consisting of fragments of a ^{6}Li-containing glass scintillator embedded in an organic matrix — was modeled. The objective of the research was to determine a composite structure that offers high sensitivity to thermal neutrons while effectively suppressing signals from γ-quanta. Through this modeling, optimal structural parameters for the composite, such as fragment size and glass concentration, were identified. The simulation results indicate that, under thermal neutron irradiation, these optimized composites can achieve a neutron detection efficiency of at least 50%, with a sensitivity to γ-quanta at a level of $\eta < 10^{-6}$.

Composite scintillator samples, consisting of NE 912 lithium glass fragments embedded in an organic matrix, have been developed and fabricated. The samples were produced with dimensions of Ø40 × 2 mm and lithium glass concentrations of 25%, 30%, and 35%. Epoxy resin, acrylic resin, and a silicone compound were used as the neutral matrix materials. The samples were tested as part of a scintillation detector

using a thermal neutron beam and a ^{60}Co γ-ray source. The thermal neutron detection efficiency and γ-sensitivity were measured and compared to those of a homogeneous glass scintillator. The results confirm that it is possible to reduce the detector γ-sensitivity by two orders of magnitude, at the cost of only a minor (50%) decrease in neutron detection efficiency.

A comparison was made between the results of using digital methods for γ-ray suppression and those obtained using heterogeneous scintillators. To process signals from a detector with a monolithic scintillator, three different algorithms for γ-discrimination were applied: fixed-threshold detection, and pulse-shape discrimination (PSD) using two digital signal-processing techniques — charge integration and pulse-duration measurement. The study demonstrated that, for a homogeneous scintillator, the various PSD methods exhibit roughly similar performance in distinguishing thermal neutrons from γ-rays, yet they are significantly less effective than the fixed-threshold detection method. Furthermore, the quality of n/γ discrimination in this case is inferior to the results achieved with a heterogeneous scintillator using fixed-threshold detection.

In the last paper samples of thickness 2–20 mm are considered to find a configuration with improved characteristics. Monte Carlo simulations have shown that the sample with a thickness of 15 mm has a neutron conversion efficiency of 0.7, while γ-sensitivity remains at the same level as that of samples with a thickness of 2 mm.

The results of the work were presented at 5 seminars and 3 conferences, and published in 5 articles. Work in this area is ongoing, utilizing Russian-made scintillators.

Papers:

1. E. S. Kuzmin, G. D. Bokuchava, I. Yu. Zimin, A. A. Kruglov, N. A. Kuchinskiy, V. L. Malyshev, A Monte Carlo Model of the Neutron Detector Based on Lithium-Glass Scintillator – Nuclear Experimental Technique – 2021 – No. 2 – P. 195–201.
2. E. S. Kuzmin, I. Yu. Zimin, Optimization of the Structure of a Heterogeneous Scintillator for Registration of Thermal Neutrons – Nuclear Experimental Technique – 2021 – No. 5 – P.657–662.
3. E. S. Kuzmin, G. D. Bokuchava, I. Yu. Zimin, A. A. Kruglov, N. A. Kuchinskiy, Manufacturing and Characteristics of Composite Scintillators Based on Lithium Glass – Nuclear Experimental Technique – 2022 – No. 4 – P. 583–588.
4. E. S. Kuzmin, G. D. Bokuchava, I. Yu. Zimin, A. A. Kruglov, N. A. Kuchinskiy, V. L. Malyshev, Comparative Analysis of the Neutron–Gamma Discrimination Methods for Scintillators Based on Lithium Glass – Nuclear Experimental Technique – 2024 – No.2 – C. 234–239.

5. E. S. Kuzmin, I. Yu. Zimin, V. L. Malyshev, Monte Carlo Study of Thermal Neutron and Gamma-Ray Conversion in a Composite Scintillator – Physics of Particles and Nuclei Letters – 2026 – No. 6 – P. 876–882.

Список докладов на конференциях:

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2. 29th International Scientific Conference of Young Scientists and Specialists (AYSS-2025), Heterogeneous scintillator for detecting thermal neutrons based on lithium glass, E. S. Kuzmin, G. D. Bokuchava, I. Yu. Zimin, A. A. Kruglov, V. L. Malyshev, Dubna, 2025 г.
3. Сессия-конференция секции ядерной физики ОФН РАН «Физика фундаментальных взаимодействий» Монте-Карло исследование конверсии тепловых нейтронов и гамма-излучения в композитном сцинтилляторе., И. Ю. Зимин, Е. С. Кузьмин, В. Л. Малышев, Новосибирск, 2026 г. (постер).