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Preliminary test of the scintillator with optical fiber (SOF) detector in a pulsed thermal neutron experiment

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Abstract

A scintillator with an optical fiber detector (SOF) consists of a small amount of the ZnS(Ag) scintillator mixed with a transparent adhesive material and a thermal neutron converter (^{6}LiF). It is tightly connected to the tip of an optical fiber. The other tip is optically coupled with a small photomultiplier. The SOF detector was assembled and checked in Institute of Nuclear Physics (IFJ PAN). A preliminary test has been done to compare the SOF detector and the ^{3}He proportional counter which has been used for a long time in the pulsed neutron experiments carried out in the Neutron Transport Physics Laboratory (IFJ). It was find that the SOF detector may be used successfully instead of the ^{3}He proportional detector. Small dimmensions of the detector (diameter is about 2 mm) allow to obtain accurate information on the spatial distribution of the thermal neutron flux inside a small investigated system.

1. Scintillator with optical fiber detector

A scintillator with an optical fiber detector (SOF) consists of a small amount of scintillator tightly connected to the tip of an optical fiber and the other tip is optically coupled with a small photomultiplier. It was originally developed by Mori et al. [1, 2]. The scintillator on the tip of the fiber was ZnS(Ag) mixed with LiF enriched with ^{6}Li up to 99.9% and transparent adhesive material. The other type of the scintillator like the plastic one may be used as well as the other type of the thermal neutron converter, e.g. boron. The scintillator and the fiber are covered with a lightproof screen. The idea of the SOF detector is presented in Fig. 1. We use the thermal neutron SOF detector based on a plastic fiber with diameter 2 mm and the lenght 2.1 m. The scintillator is ZnS(Ag) mixed with LiF enriched with ^{6}Li up to 99.9% and adhesive material with the volume ratio of 1:1:1. The thickness of the scintillator is about 1.5 mm. The reactions between ^{6}Li nuclei and thermal neutrons emit alpha particles and tritons which produce scintillations as a result of interacting with ZnS(Ag). The emission spectrum of ZnS(Ag) has a maximum at 450 nm [3] and well matches Hamamatsu type R1635 photomultiplier with the bialkali photocatode which diameter is 8 mm. We use a bunch of three SOF detectors connected to one photomultiplier (Fig. 2).

2. Tests of the SOF detector in the pulsed neutron experiment

In the pulsed neutron experiment the investigated sample is irradiated with a pulsed beam of fast neutrons. The neutrons are slowed down in the sample and the die-away rate of escaping thermal neutrons is measured with a thermal neutron detector [4, 5]. The thermal neutron flux is very intense during the neutron burst and decays to the background value before the next burst. Therefore the thermal neutron detector should have a good dynamic range of linearity. A preliminary test has been done to compare the SOF detector and the ^{3}He proportional counter used till now in the pulsed neutron experiments. A simplified diagram of the measuring system is shown in Fig. 3. A 9 cm paraffin cuboid – covered by a cadmium layer with a hole for the SOF detector on the top and with an opening on the bottom for a ^{3}He detector – has been irradiated by 14 MeV fast neutron bursts. The duration of neutron burst has been equal to 100 μs and the repetition time has been 1.3 ms. After each neutron burst the neutrons thermalized in the sample have diffused up to the final absorption or have been scattered outside. The SOF and ^{3}He detectors counted thermal neutrons. Both die-away curves of thermal neutrons have been registered in two multiscalers which have had the dwell time equal 2 μs. An example of the die-away curves is presented in Fig. 4. The decay constant of the fundamental exponential mode of the thermal neutron flux derived from the recorded curves has been 14 724 ± 334 s^{-1} for the SOF detector and 14 876 ± 56 s^{-1} for the ^{3}He one. The difference does not exceed the statistical deviations. The standard deviation of the decay constant from the SOF detector is higher because its active volume is much smaller than of the ^{3}He detector and the counting statistics is poorer. The sensitivity to the fast neutrons of the optical fiber has been checked. The scintillator has been shielded by borated paraffin 2 mm thick cadmium and 2 mm thick lead. Optical fibers have been irradiated with a pulsed fast neutron beam as in the previous test. It was found that the sensitivity to the fast neutrons of the optical fiber is negligible in this measurement conditions.

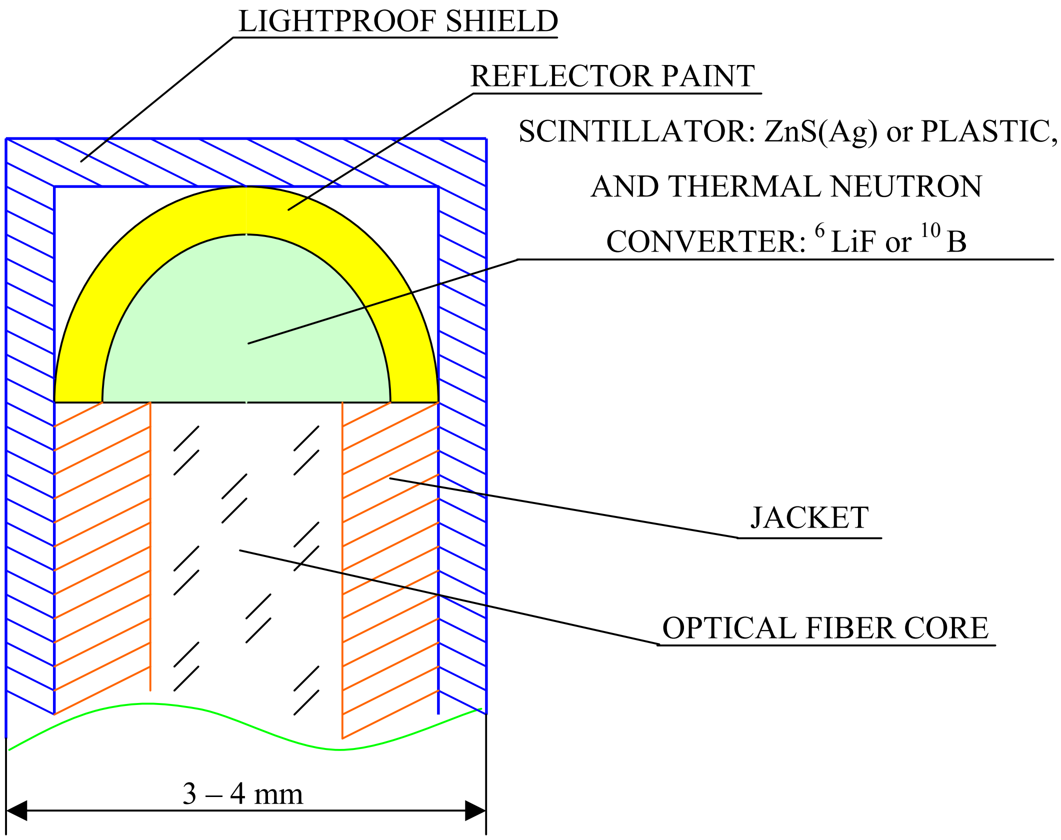

Figure 1. Schematic diagram of a SOF detector.

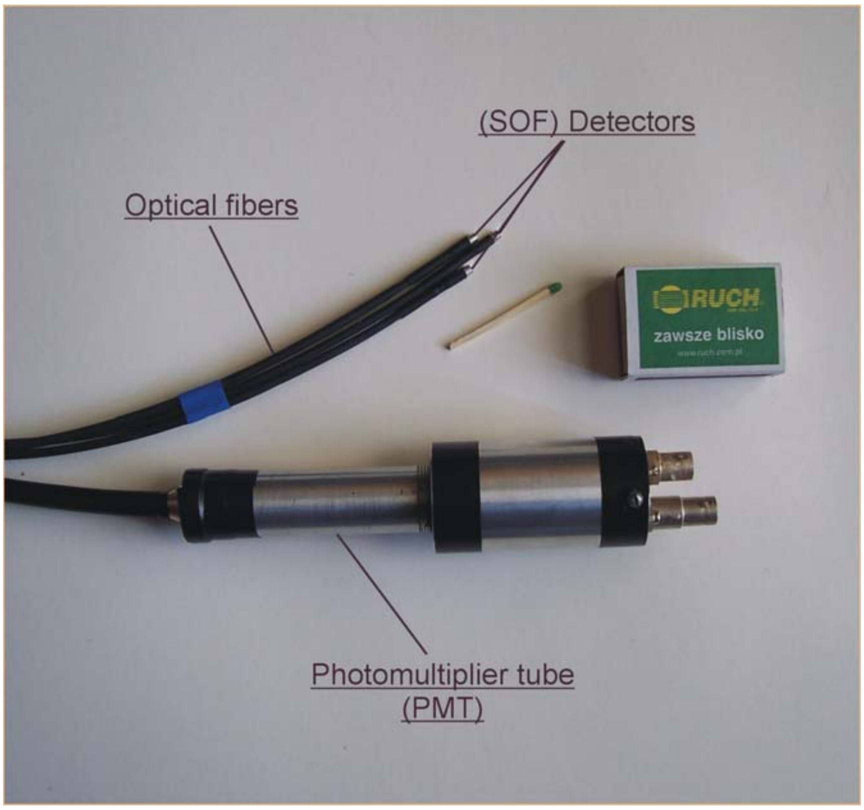

Figure 2. The SOF detector.

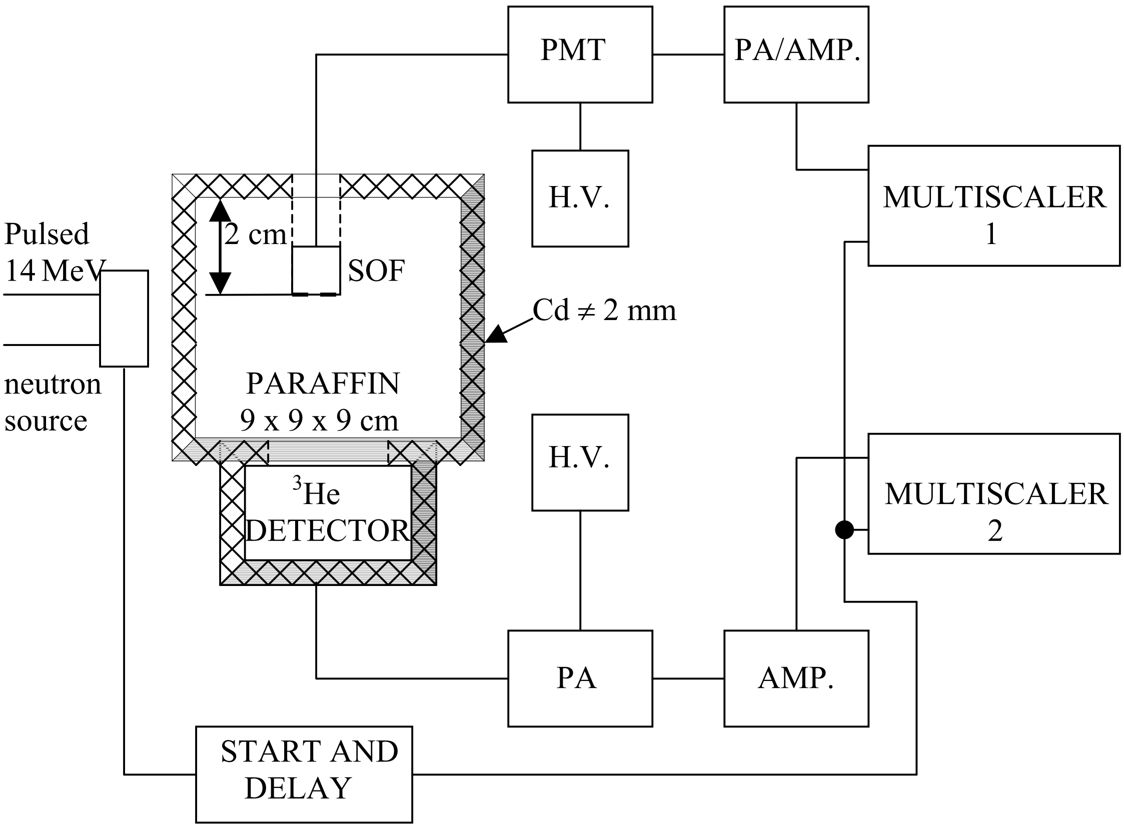

Figure 3. Measuring system.

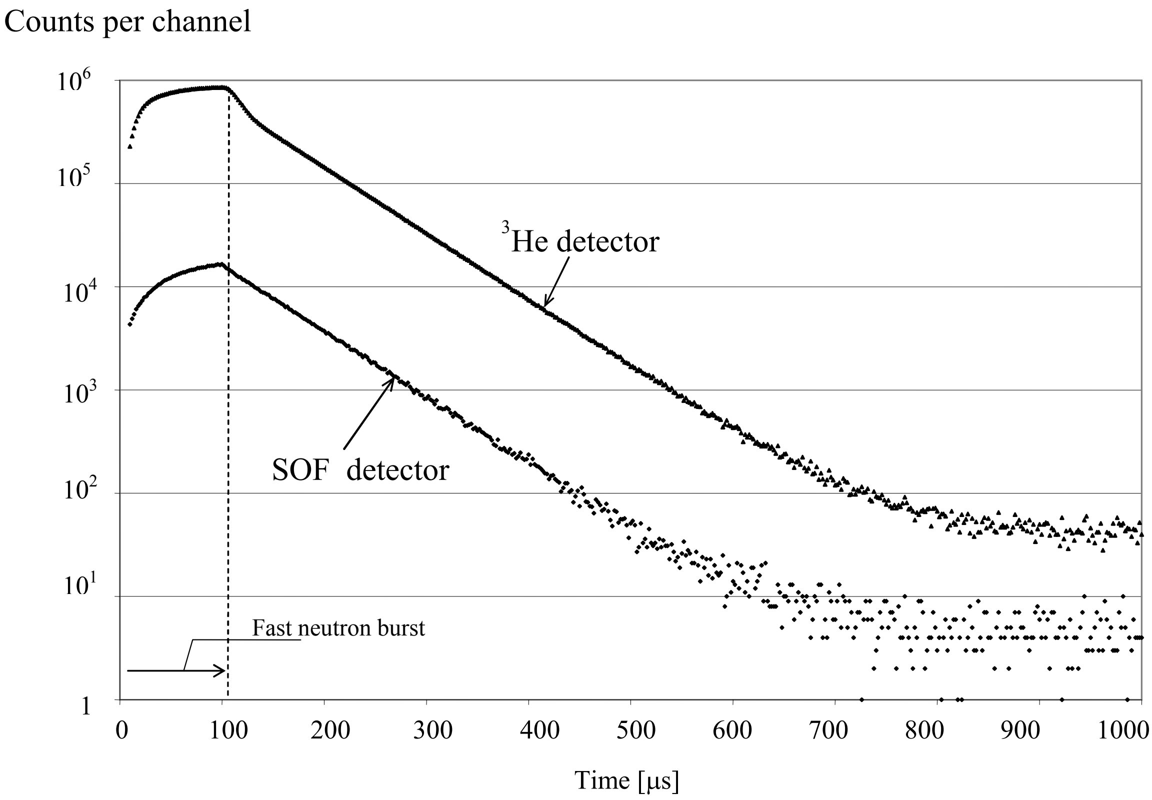

Figure 4. Thermal neutron die-away curves measured by the SOF and ^{3}He detectors.

Conclusions

Small dimensions of the SOF detector allow to use it as a quasi-point detector. Thus, a measurement of the spatial distribution of the thermal neutron flux in a small medium is possible without disturbing the neutron field. The fiber optic connection between the scintillator and photomultiplier makes the SOF detector resistant for a harsh electromagnetic enviroment which occurs e.g. in the proximity of working plasma focus devices. The sensitivity to gamma rays of the scintillator makes difficult to measure only a pure signal from thermal neutrons. The problem is solved by a pulse height discrimination or by using a pair of the SOF detectors, one with a thermal neutron converter and the other without [6]. The scintillation decay time equal 200 ns for the ZnS(Ag) scintillator ensures a wide dynamic range of measurements. It may be improved be using the plastic scintillator with the decay time on the order of a few nanoseconds. The SOF detector is a very convenient replacement of the ^{3}He or BF_3 proportional detectors used in the pulsed thermal neutron experiments.

References

[1] C. Mori, T. Osada, K. Yanagida, T. Aoyama, A. Uritani, H. Miyahara, Y. Yamane, K. Kobayashi, C. Ichihara, S. Shiroya (1994)
Simple and quick measurement of neutron flux distribution by using an optical fiber with scintillator.
J. Nucl. Sci. Technol. **31**, 248.

[2] C. Mori, A. Uritani, H. Miyahara, T. Iguchi, S. Shiroya, K. Kobayashi, E. Takada, R.F. Fleming, Y. K. Dewaraja, D. Stuenkel, G.F. Knoll (1999)
Measurement of neutron and γ-ray intensity distributions with an optical fiber-scintillator detector.
Nucl. Instrum. Meth. **A 442,** 129.

[3] G. F. Knoll. (2000)
Radiation Detection and Measurement.
Wiley, New York.

[4] E. Krynicka, K. Drozdowicz, U. Woźnicka, U. Wiącek, B. Gabańska (2005)
Thermal neutron diffusion cooling in two-region small systems.
J. Phys. D:Appl. Phys. **38,** 2967.

[5] E. Krynicka, U. Wiącek, K. Drozdowicz, B. Gabańska, G. Tracz (2006)
Monte Carlo simulations of the pulsed thermal neutron flux in two-zone systems with Plexiglas – Using the MCNP code with a modified hydrogen-data library.
Nucl. Instrum. Meth. **B 251,** 19.

[6] M. Ishikawa, H. Kumada, K. Yamamoto, J. Kaneko, G. Bengua, H. Unesaki, Y. Sakurai, K. Tanaka, T. Kosako (2005)
Development of a wide-range paired scintillator with optical fiber neutron monitor for BNCT irradiation field study.
Nucl. Instrum. Meth. **A 551,** 448.