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A study on developing of fiber-optic neutron detection system using Gd_2O_2S:Tb and evaluating the system through the KUCA experiment

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1. Introduction

Since the nuclear reactor is run based on the nuclear chain reaction, sustaining and changing the number of neutrons is very important for power generation. For this, continuous observation of neutron flux is significant. For example, the gold wire activation method is used to obtain information on neutron flux distribution in the research reactor.

The main problem of current neutron detectors such as BF_3 detector and ^{3}He gas tubes is that they require specific conditions to measure neutron contribution separately and yet they have difficulty in measuring neutron contribution separately. Particularly, in the case of the gold wire activation method used in research reactor, it takes several hours for preparation and measurement, and has poor position resolution. To resolve these problems, various attempts are proceeding in industrial and academic fields [1].

In this study, a fiber-optic neutron sensor for real-time neutron detection was developed. The fiber-optic neutron sensor consists of encapsulated Gd_2O_2S:Tb scintillation powder and plastic optical fiber. The optical fiber has several advantages such as long signal transmissive distance and fewer disturbances from external environment. By selecting Gd_2O_2S:Tb as scintillator, the fiber-optic sensor can have very high cross section for neutron. The fiber-optic neutron sensor was connected to a photon counter-type MPPC module to acquire the neutron information in real time.

2. Materials and experimental setup

Gadolinium has the highest cross section for thermal neutron among the natural elements. The two major isotopes for Gd, ^{155}Gd and ^{157}Gd, have cross section of 49,122 barn and 255,000 barn, and abundance of 14.8 % and 15.7 % each in natural Gd [2]. One of the major reaction products is conversion electron which is produced by neutron absorption of Gd. For the neutron detection and imaging, 72 keV conversion electron which is promptly emitted after the neutron capture and accounts for 39% of reaction products is mainly detected [3]. In this study, Gd_2O_2S:Tb scintillation powder was used for neutron detector. Fig. 1 shows the fiber-optic neutron sensor structure using Gd_2O_2S:Tb.

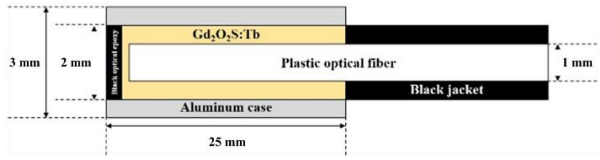


Fig. 1. The structure of fiber-optic neutron sensor using Gd_2O_2S:Tb

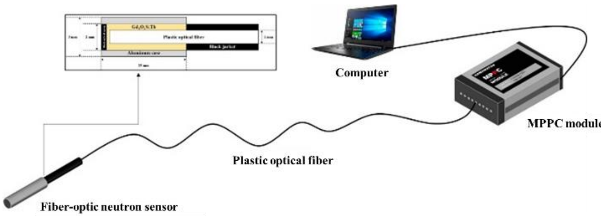


Fig. 2. Schematics for the neutron detection system

Fig. 2 shows the whole fiber-optic neutron detecting system which contains fiber-optic neutron sensor, plastic optical fiber, photon counter-type MPPC array module.

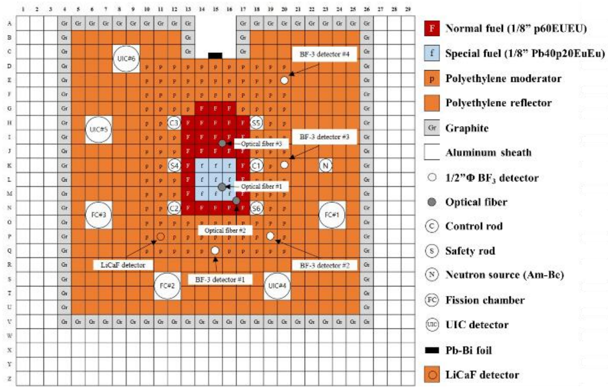


Fig. 3. Top view of the configuration of A-core

The experiment was conducted in the A-core of the accelerator-driven system(ADS) at the Kyoto University Critical Assembly(KUCA). Fig. 3 shows the top view of A-core. The spallation neutrons and the thermalized neutrons which is emitted from the Pb-Bi target located in (15, C) were detected at the position (16, C) through the fiber-optic neutron sensor. The proton beam was irradiated to the Pb-Bi target with intensity of 100 MeV to induce the emission of neutrons [4].

3. Results

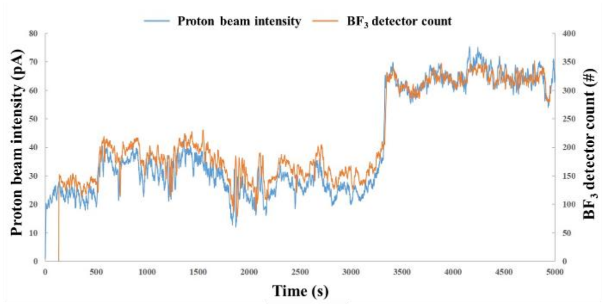
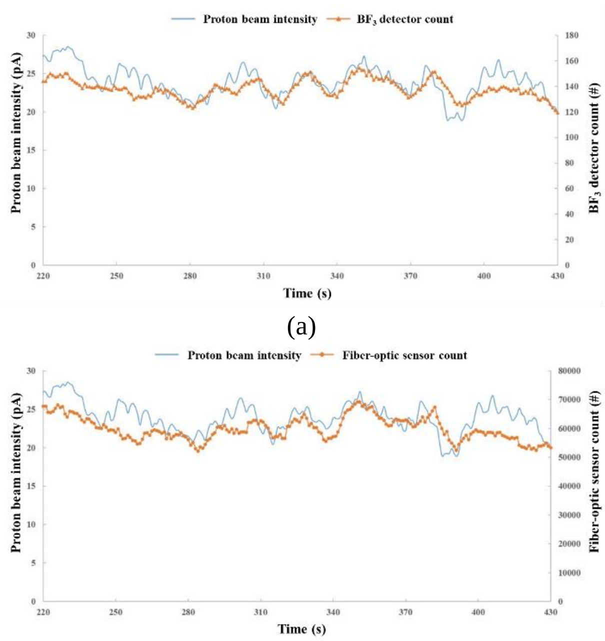


Fig. 4. BF_3 detector neutron count curve compared with proton beam intensity

To verify the correlation between the neutron generation and the proton-target reaction, the BF_3 neutron detector count data and the proton beam intensity data were compared. BF_3 detector is located at (20, E) as shown in Fig. 3. The proton beam intensity data and the BF_3 detector data were provided by Kyoto University. Fig. 4 shows that the neutron generation is proportional to the proton beam intensity.



(b)

Fig. 5. (a) BF_3 detector / (b) fiber-optic sensor neutron count during proton irradiation

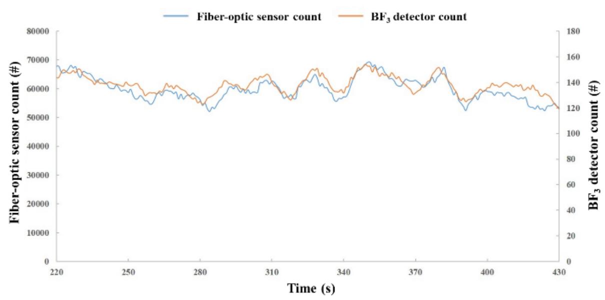


Fig. 6. Fiber-optic/BF_3 detector neutron count comparison

Fig. 5 shows neutron count curves of BF_3 detector and fiber-optic sensor while the proton beam is irradiated to the target. Fig. 6 shows the neutron count curve of the fiber-optic neutron sensor compared with BF_3 detector count curve. The graphs show that the fiber-optic sensor successfully detected the neutrons.

4. Conclusion

In this study, the fiber-optic neutron sensor using Gd_2O_2S:Tb was fabricated and the simple real time neutron counting system with a MPPC module has been developed. The neutron signals from the proton-target collision reaction was measured at KUCA. By comparing with proton beam intensity and BF_3 sensor neutron count, performance evaluation of the fiber-optic sensor has been carried out. Since one of the main advantages of fiber-optic sensor is smaller size compared with conventional neutron detector which is resulted in the better spatial resolution, it is expected that the fiber-optic neutron sensor has advantages comparing with currently used neutron detectors.

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