CO8-1 Demonstration experiment of detecting the HEU sample using a low-cost inspection system

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INTRODUCTION: A compact and low-cost non-destructive inspection system to detect hidden nuclear material is required in the fields of nuclear security. We developed a new nuclear material detection method, called the active rotation method, using a neutron source of Californium-252. In the method, a neutron source is rotated at a speed of thousands of rpm by the rotation machine nearby a measurement object. Meanwhile, it is possible to detect nuclear materials by confirming the deformation of the time-distribution spectrum obtained by a neutron detector near the object. The rotation machine is compact and low-cost. In addition to the rotation machine, we developed a water Cherenkov detector as a low-cost neutron detector. In previous studies, we accomplished detections of natural uranium of approximately 8,000 g by using a low-cost non-destructive nuclear material detection system composed of a rotation machine and a water Cherenkov neutron detector (WCND) in KUCA[1]. The purpose of this year is to detect smaller nuclear material, which is approximately 4 g of highly enriched uranium (HEU) using the developed system.

EXPERIMENTS: The experimental setup is shown in Fig.1. The dimensions of the neutron rotation machine are approximately 60cm in width, depth, and height. The rotation machine can rotate the disk (diameter 32cm), where a neutron source is installed at its outer periphery, at a rotation speed between 0 and 4000 rpm. A neutron source of Californium-252 is set in the disk, the radioactivity was 2.2 MBq. It is noted that the 2.2 MBq is smaller than the 3.7 MBq of the Japanese-approved devices with a certification label of Californium-252. In this experiment, we used approximately 4 g of HEU. The uranium sample was surrounded by polyethylene blocks. The WCND basically consists of an aquarium (30x25x30cm) and four PMTs (Photomultiplier tube). The PMT (2 inches diameter) is the Hamamatsu H11284-100. A transparent acrylic panel is attached to the top of the aquarium, installing the PMTs there. Since water filled up to the top surface, there was no air gap between the PMT and water. Measurements of the neutron time distribution were performed by a multi-channel scaler (MCS) that was synchronized with the disc rotation signal from the servomotor.

RESULTS: Figure 2 shows an example of experimental results of the HEU sample when the rotation speed is 4000 rpm. The measurement time for the experiment was 10 minutes. A comparison between the time-distribution spectra at 4000 rpm and 300 rpm reveals that the integrated value after the center (around 6000 micro-seconds at 4000 rpm) increased only for the HEU sample, but not for a blank sample (sample without nuclear material).
Thus, we have successfully detected approximately 4 g of HEU using low-cost non-destructive nuclear material detection system.

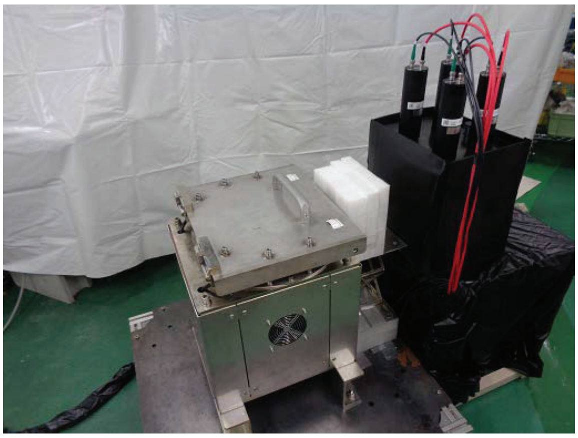

Fig. 1. The rotation machine (left), the water Cherenkov detector (right), and measurement object containing HEU (middle).

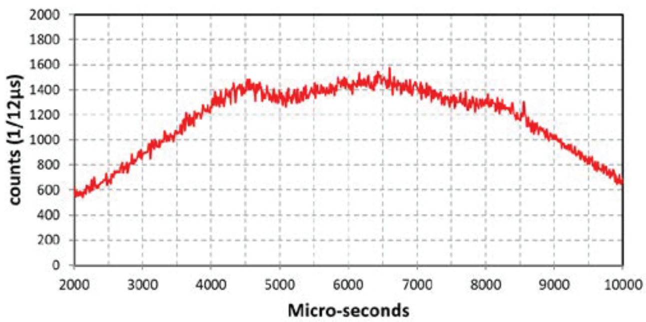

Fig. 2. Neutron events distribution of the HEU sample. The measurement time was 10 minutes with the rotation speed of 4000 rpm.

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CO8-2 Establishment of a novel mutation breeding using Boron Neutron Capture Reaction (BNCR)

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INTRODUCTION: Boron Neutron Capture Reaction (BNCR) is based on the nuclear reaction of ^{10}B atom with thermal/epithermal neutron already applied to cancer treatment (BNCT) [1, 2]. As a new utilization method of BNCR, this study aims to establish a novel mutation breeding using BNCR.

The method attempts mutagenesis by immersing plant seeds in a ^{10}B-enriched boron compound, re-drying, and then irradiating the seeds with thermal neutrons to induce BNCR. A similar method has been tried with barley and observed an effect in the M1 generation and a mutagenic effect in the M_2 generation [4, 5]. Its mutagenic effect depends on chemical and physical factors such as ^{10}B concentration, thermal neutron intensity, and irradiation time. In our previous experiments, they have tried immersing seeds in ^{10}B-enriched *p*-boronophenylalanine (BPA) [3] and ^{10}B-enriched boric acid ($H_3{}^{10}BO_3$) as ^{10}B-enriched boron compounds in rice. The germination rate of each treated seed was investigated after BNCR, and the results showed that there was no decrease in germination rate for BPA-treated seeds in the 1-100 mM concentration range, whereas $H_3{}^{10}BO_3$ treated seeds showed a concentration-dependent decrease in germination rate. It is assumed that these results are due to differences in the uptake of ^{10}B into plant seeds by different boric acid compounds. Currently, the effects of mutagenesis are being confirmed. This report selected disodium mercaptoundecahydrododecaborate (BSH), a boron cluster, as a new boron compound to be examined.

EXPERIMENTS: The experimental material used *Oryza sativa* L. cv. Nipponbare. The dry seeds were immersed into different boron concentrations (0, 10, 50, 100, 1000, 2000 ppm) of ^{10}B-enriched BSH for 24 h and 1000 and 2000 ppm BSH for 36 h. The solvent used was PBS buffer. The samples were washed with water and re-dried. The seeds in 6-mL tubes were irradiated with thermal neutron for 90 minutes in the Kyoto University Research Reactor (KUR). After the irradiation treatment, the seeds were cultured in petri-dishes with continual moistening of filter paper at 25℃ under a photoperiod of 16 h light and 8 h dark, and the germination rate was examined 14 and 21 days after sowing. As a control experiment, seeds that were only treated with BSH soaking and not irradiated with thermal neutrons were sown in the same method, and germination rates were investigated.

RESULTS: BSH treatment did not decrease the germination rate with or without BNCR. This result is similar to BPA treatment. In $H_3{}^{10}BO_3$ treatment, seeds immersed for 24 or 36 h in solutions of 50 mM or higher concentration have been found to significantly decrease the germination rate of seeds with BNCR, in our results. These results indicate the selection of boron compounds to be used in this mutation breeding in BNCR. To determine these differential effects on germination rate, the uptake and localization of ^{10}B in seeds are currently being investigated using molecular biological techniques. In addition, the treated M1 and M2 generations are being grown sequentially in the field to investigate mutants.

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