Application of bubble detector in FIREX program

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Abstract. In a Fast Ignition Realization Experiment (FIREX), measurement of the primary and the secondary neutron yield is one of the key diagnostics. However, gamma-ray background generated by an ultra-short pulse laser irradiation makes it difficult to measure the neutron yield in the fast ignition experiment. We adopted a bubble neutron detector as a promising gamma-insensitive detector to be developed and started to examine the feasibility of the detector using commercially available dosimeters provided from BTI inc. [1].

1. Bubble detector
The bubble detector is a reusable, passive integrating detector that allows instant, visible detection of radiation. In this detector, radiation deposition becomes visible through the formation of gas bubbles in an elastic polymer (Fig.1). Number of bubbles is proportional to the quantity of the radiation. Formation of a bubble is a threshold process depending on the deposition energy in a superheated droplet (Fig.2). Thus one can make it gamma-ray sensitive or insensitive by changing the composition of droplets. Farther more, a set of neutron detectors with different threshold energy for detected neutrons can be composed. However the sensitivity of the detectors to neutrons is naturally lower than that of a conventional plastic scintillator. We used the Bubble detectors from BTI Inc. to confirm the sensitivity of the detectors in the implosion experiment [2] (Fig.3).

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2. Measurement of gamma-ray dose equivalent

It is required to evaluate gamma-ray insensitive performance of neutron bubble detectors. Gamma-ray dose generated with an ultra-short pulse laser (PW beam of the GEKKO XII) was measured by a gamma-ray bubble detector (It is called "BDGAMMA" at BTI). The target used in this experiment was a deuterated polystyrene shell with a gold cone (Fig.6). Laser energy of 230.76 J in 1 ps was injected to the cone. A BDGAMMA was located at 168 cm from the target. Nominal sensitivity of the detector was 11.2 bubbles/µSv. 883 bubbles were counted in the BDGAMMA after the shot. It corresponds to 78.8 µSv. Additionally the detector was shipped with nominal sensitivity data calibrated by using $^{137}$Cs. We tried to calibrate the detector to MeV gamma-rays. We irradiated a BDGAMMA with gamma-rays from $^{60}$Co (1.17 MeV, 1.33 MeV gamma-rays). The measured sensitivity was found to be one order of magnitude lower than the nominal value calibrated by $^{137}$Cs. This discrepancy is not understood yet. Spectral response on the gamma-ray energy is to be examined.

![Fig.4 Deuterated polystyrene shell with a gold cone.](image)

3. Gamma-ray spectrum analysis

Whether the BDGAMMA can be applied to the gamma-ray spectrum measurement was examined. Figure 7 shows the measurement condition. Three BDGAMMA’s were used with Pb filters (none, 3 cm, 6 cm). PW laser energy was 307.58 J. Target was a Au plate. The gamma-ray dose measured with each BDGAMMA’s were 66.3, 32.2, and 19.2 µSv, respectively (Fig.6, 7). The results correspond to gamma-ray energy of about 1 MeV.

![Fig.5 Arrangement of Pb filters.](image)

![Fig.6 Generated bubbles in BDGAMMA exposed to x-rays generated with PW laser irradiation.](image)

![Fig. 7 The change in the number of bubbles depending on the thickness of the lead filter.](image)
4. Gamma-ray insensitivity of a bubble neutron detector
An experiment in order to confirm the gamma-insensitive performance of a bubble neutron detector was done. The target was cryo deuterium foam shell with Au corn. Neutron yield in this target shot was zero. PW laser energy injected to the core was 230.76 J. Distance from the target to the bubble detector was 25 cm, and thickness of the stainless steel casing was 3 mm. (Fig.8)
The amount of the gamma-ray irradiation of the bubble neutron detector was estimated from bubbles observed simultaneously with BDGAMMA to be 23.7 mSv (Fig.9). As a result, bubble neutron detector generated no bubble. Thus, it was confirmed that bubble neutron detector is gamma-ray insensitive to its amount of 23.7 mSv or less.

5. Summary
Neutron bubble detector was shown to be insensitive to gamma-ray to its amount of 23.7 mSv or less. These bubble detectors are expected to be useful in the FIREX project. In the FIREX program with stronger gamma-ray environment, it might be necessary to examine the design of the shielding material and the Pb filter in the gamma rays spectrum analysis.

References
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