Investigation of a prompt gamma-ray imaging detector with an 8 x 8 array $LaBr_3(Ce)$ scintillator and MPPC for Boron Neutron Capture Therapy

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Introduction: In order to improve the quality of treatment of boron neutron capture therapy (BNCT), it is necessary to perform the detection of boron concentration during BNCT irradiation. In general, boron concentration has been evaluated by prompt gamma-ray analysis with a high purity germanium detector or the induced coupled plasma. However, these procedures are not able to obtain the information of the boron concentration during irradiation. The determination of boron concentration in real-time can be achieved by measuring the prompt gamma rays emitted from the reaction between ^{10}B and thermal neutrons. However, there are 511 keV annihilation gamma rays in BNCT irradiation fields; as a result, it is required to discriminate between prompt gamma rays of 478 keV and annihilation gamma rays. Our previous study achieved that the energy resolution at 511 keV was below 6.5 % that can discriminate between 478 and 511 keV when a slab of $LaBr_3(Ce)$ scintillator and an 8 x 8 array Multi-Pixel Photon Counter (MPPC) were employed. However, the position resolution was not good; thus we used an 8 x 8 array $LaBr_3(Ce)$ scintillator to obtain better position resolution. This paper reports the concept of this system and the results of the characteristics of this system.

Materials and methods: A pixel size of an 8 x 8 array $LaBr_3(Ce)$ scintillator was 5 x 5 x 10 mm^3, and reflectors' thickness made from $BaSO_4$ between scintillators was 1 mm. The scintillator was placed in front of an MPPC. The MPPC is a type of silicon photomultiplier (SiPM). The outputs of 64 channels were fed to an amplifier unit. The 64 analog outputs were digitalized by ADCs. These digital signals were stored on a personal computer. Moreover, every channel of an amplifier and ADCs can work independently. The scintillation light in a pixel of the scintillator was so high that the signal was saturated; therefore, we had to eliminate events that light saturation occurred. An Na-22 source provided the 511 keV gamma rays, and the source was used to confirm the energy resolution at 511 keV below 6.5 %. To confirm the position resolution, a collimator made by a lead which has a small hole was used.

Results: Gamma rays spectra had a double peak in spite of a single peak because scintillation light in a pixel of the divided scintillator was saturated. However, after the events that caused double peaks eliminated, gamma rays spectra had a better energy resolution than original spectra. The energy resolution at 511 keV was below 6.0 % on average. Moreover, by dividing the scintillator into 8 x 8, the position resolution was better than a slab of this scintillator.

Conclusion: This study shows that the energy resolution at 511 keV with an 8 x 8 array scintillator was below 6.0 % after eliminating events of light saturation. Moreover, by using a divided scintillator, we obtained a better position resolution with this scintillator than with a slab of the scintillator.

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