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Characterization Experiments of $LaBr_3(Ce)$ and $CeBr_3$ Scintillator

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1. Introduction

Sodium iodide (NaI(Tl)) scintillator is commercially widely used as gamma-ray scintillator because they have good scintillation properties, such as good energy resolution, high light output and the availability in large volume. The lanthanum bromide ($LaBr_3(Ce)$) scintillator can be a powerful alternative to NaI(Tl) scintillator with the advantage that it can provide better energy resolution, light output, and fast decay time compared to the NaI(Tl) scintillator. However, since $LaBr_3(Ce)$ has its own radioactivity, there is a fatal weakness that the degradation of energy resolution occurs in low energy. Cerium bromide ($CeBr_3$) can be solution of this $LaBr_3(Ce)$ own radioactivity problem.

We want to experiment with the difference between the two scintillations. Before the comparison, in order to make a reasonable comparison between the two scintillators, it must be made in the case where both detectors are in optimal operating conditions. Because the optimal conditions of the detector may be different depending on the experimental settings, we need to find the optimal condition by using our experimental setting. After finding the optimal experimental conditions, we will compare $LaBr_3(Ce)$ and $CeBr_3$ scintillator.

2. Methods and Results

2.1 Experiment setup

In the experiment, we used two scintillator, Saint-Gobain Brilliance 380 1.5"x1.5" $LaBr_3(Ce)$ scintillator integrated with R9420 Hamamatsu photomultiplier tube (PMT) and Scionix 3"x3" $CeBr_3$ scintillator integrated with R6231 Hamamatsu PMT. The preamplifier we used was Ortec 113 scintillation preamplifier. And we used Ortec 572A shaping amplifier. Multichannel analyzer (MCA) we used was Ortec 921E. Figure. 1 and Figure. 2 show overall connection of equipment and experiment setup.

In $LaBr_3(Ce)$ experiment, we used preamplifier and shaping amplifier for signal processing. We set amplifier shaping time at 0.5 us and amplifier gain at 1. Experiment was carried out with the gain of shaping amplifier as low as possible in order to see the change of the count rate while raising voltage until 1500 V, the maximum voltage of R9420 PMT. But when voltage of more than 1100 V was applied, it was already over 10 V, which is maximum range of MCA. So, in case of $LaBr_3(Ce)$, we measured for 600 seconds as live time up to 1100 V. Radiation source used in this process was rod type Cs-137.

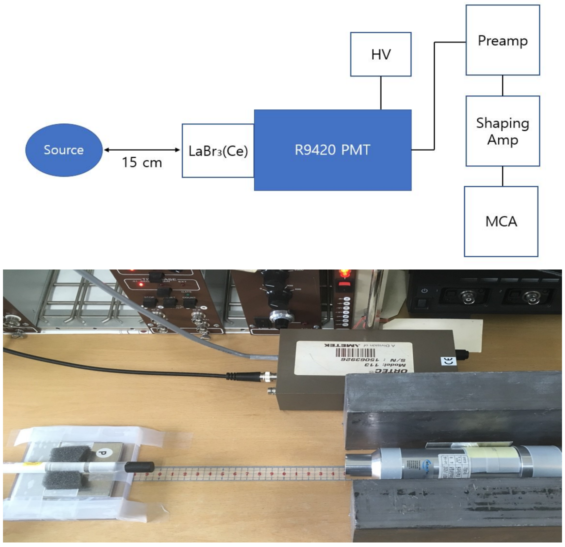

Fig. 1. $LaBr_3(Ce)$ experiment block diagram(up) and experiment setup(down)

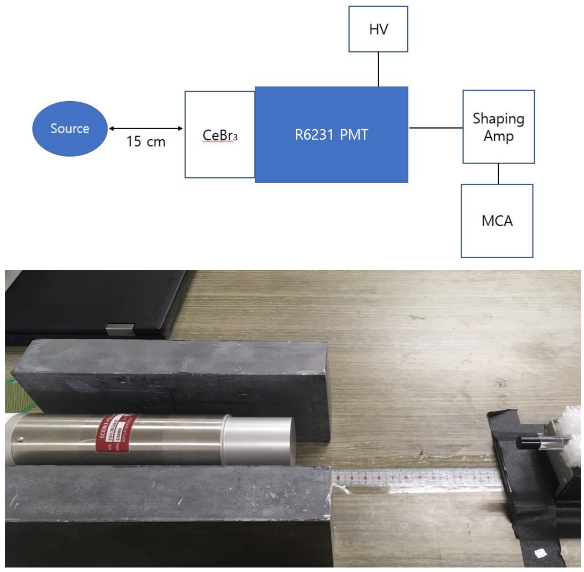

Fig. 2. $CeBr_3$ experiment block diagram(up) and experiment setup(down)

In $CeBr_3$ scintillator, as you know from figure. 2 block diagram, detector connected only shaping amplifier and MCA. Shaping time was set at 1 us. And amplifier gain was at 1. With increasing the voltage up to 1200 V, we measured for 300 seconds as live time. Also, we used rod type Cs-137 in this process.

2.2 Optimization of operating voltage

By changing the applied voltage, measurement was proceeded. According to below figure. 3, it can be seen that there is almost no change in the count rate from 800 to 1100 V even in the change of voltage. Therefore, if the measurement is made within this voltage range, it can be stably counted. In addition, Figure. 4 is shown that the energy resolution of 900, 1000, 1050, and 1100 V is lower than 0.035. Therefore, the operating voltage was set at 900 V, which is one-third of range from 800 V to 1100 V and has good energy resolution.

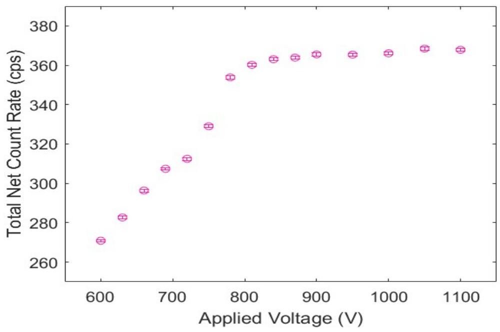

Fig. 3. Total net count rate curve of $LaBr_3$(Ce)

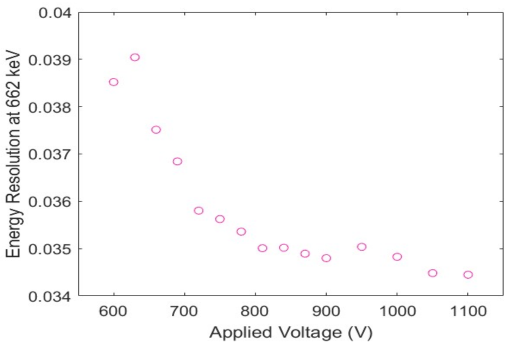

Fig. 4. Energy resolution curve of $LaBr_3$(Ce)

In the case of $CeBr_3$, according to Fig. 5, it is possible to count stably from about 750 V to 1200 V. And we know that energy resolution of $CeBr_3$ was good at 800 V and 1200 V in Figure. 6. Considering two factors mentioned before, stable count rate and good energy resolution, we considered 800 V as the optimal operating voltage of $CeBr_3$.

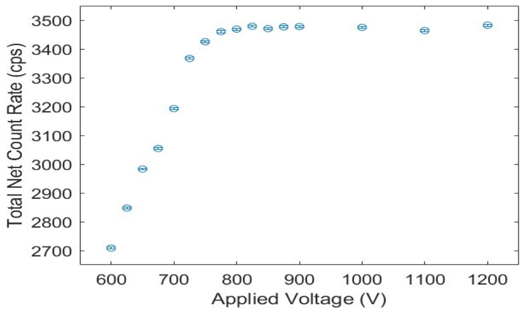

Fig. 5. Total net count rate curve of $CeBr_3$

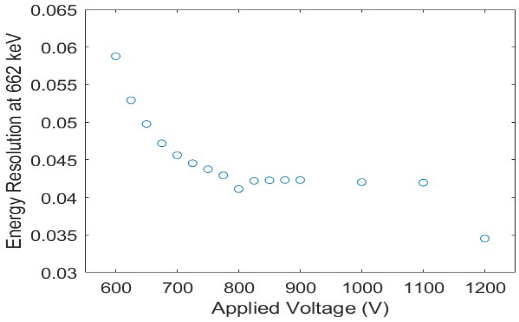

Fig. 6. Energy resolution curve of $CeBr_3$

2.2 Detector calibration

Before using radiation detector, energy and efficiency calibration should be preceded. For the calibration, rod type Ba-133, Cs-137, Mn-54, Na-22, and Co-60 are used as radiation source. Changing the radiation source, we measured for 1800 seconds as live time. Same process was carried out on the two scintillators.

Even with the limited number of radiation sources, energy calibration is experimentally accurate. However, it is practically difficult to obtain the efficiency of the detector all energy range. So, we used MCNP 6 simulation to get detector efficiency curve.

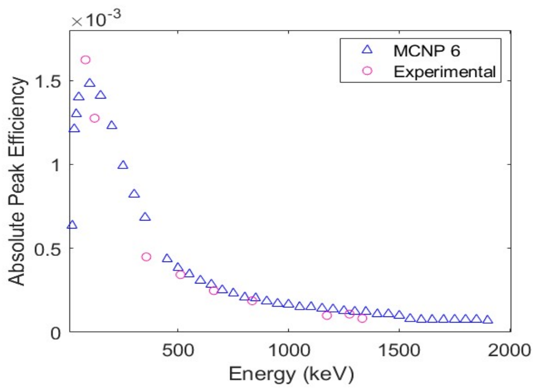

Fig.7. Absolute peak efficiency simulated by MCNP 6 and experimental absolute peak efficiency of $LaBr_3$(Ce)

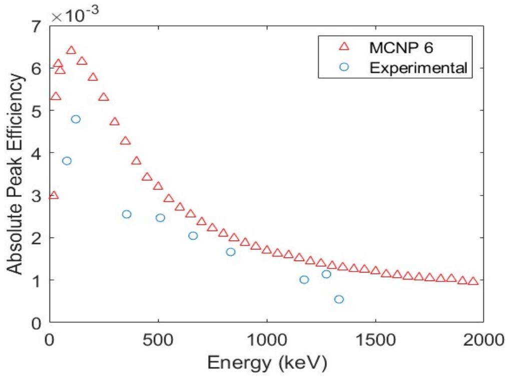

Fig. 8. Absolute peak efficiency simulated by MCNP 6 and experimental absolute peak efficiency of $CeBr_3$.

Figure.7 and Figure. 8 show simulated absolute peak efficiency and experimental absolute peak efficiency of two scintillator. In common, the results of simulation are higher than those obtained through experiments. The principle of actual scintillation detector is as follows. Gamma ray entering the scintillator produces a visible photon corresponding to the energy deposited to the scintillator. And the generated visible photon must enter the PMT. There is a loss in each of these processes. However, in the case of the MCNP 6 F8 tally used in the simulation, the energy deposited in one area designated by the user unconditionally produces visible photons and all visible photons are measured. This difference of the process results in high MCNP simulation results.

3. Conclusions

Through the experiments, we have found the optimized operating voltage of $LaBr_3$(Ce) and $CeBr_3$ in our experimental equipment. And using the measurement data and the simulation data, we derived the absolute peak efficiency curve of two scintillators. We have also discussed the difference between the simulation results and the experimental results, which can be deduced from the difference between the detection process of the simulation and the detection process of the actual scintillator. Later, additional discussion will be made to rationally compensate the difference between simulation and actual scintillator experimental results. Once all the characterization processes have been completed, we will compare the properties of the two scintillators.

ACKNOWLEDGEMENTS

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