SiPM-based Gamma Detector Evaluation Study for In-Situ Ocean Radiation Monitoring System

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In-situ environmental radiation monitoring is essential in preventing nuclear accidents in advance and in assessing the radiation dose that is likely to be received by the individuals. Since most of the nuclear power plants are located along the coastal area, radiation monitoring in the ocena environment is also very important. However, due to the high radiation attenuation in the water, it is challenging to monitor radiation in the ocean environment. In this study, we suggest a new approach to effectively monitor radiation in the ocean by scattering small and light-weighted radiation detector modules in a fishing net mesh. This approach will enable radiation mapping in a wide area around nuclear power plants and provide 2D or 3D radiation dose information. Each detector module requires 1) high sensitivity in order to minimize attenuation effect inside the water environment, 2) compact and light weight and 3) on-board wireless data communication.

Here, we chose to use a silicon photomultipler (SiPM) optically coupled with high-sensitivity scintillation crystal to achieve high sensitivity while maintaining a compact size. A prototype ocean radiation detector was developed using SensL MicroFJ-60035-ArrayJ 8×8 SiPM array and front-end electronics, on-board SiPM biasing, temperature compensation, and resistor-based charge division network were designed and developed (Fig.1). Five different scintillation crystals (GAGG:Ce, LYSO:Ce, $LaBr_3$, $CeBr_3$, and NaI(Tl)) with the size of 24×24×20 and 48×48×20 mm^3 were tested to find the proper candidate for high performance ocean monitoring. A digitizer module (DT5702, CAEN, Italy) was used for data acquisition and waveforms were post-processed to extract detector performances of energy resolution, energy linearity, and photopeak gain. As a results of detector evaluation study, $LaBr_3$ and $CeBr_3$ crystal showed the best energy resolution of 4.60±0.11% and 5.32±0.04% at 28 V bias voltage along with high photopeak gain, but energy linearity degraded rapidly with increaing bias voltage. GAGG and NaI(Tl) crystal showed still good energy resolution of 8.75±0.21% and 9.27±0.34% at 30V bias voltage with very good energy linearity along SiPM bias voltage. LYSO crystal showed the worst results in terms of energy resolution. (Fig. 2)

In conclusion, we designed and developed a prototype SiPM-based ocean radiation monitoring device and evaluated detector performances with five different scintillation crystals. As a further study, a wireless communication module will be developed and tested in a water environment.

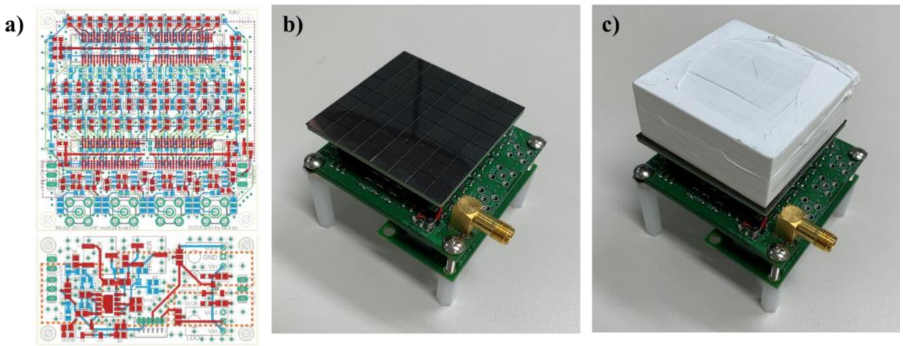

Fig. 1. a) Front-end electronics for SiPM-based detector developed in this study. b) A prototype detector module with SensL MicroFJ-60035-ArrayJ c) coupled with GAGG scintillation crystal.

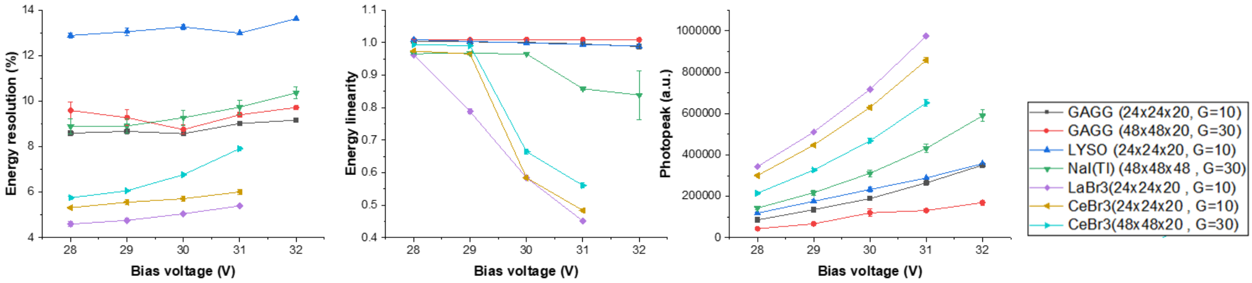

Fig. 2. Energy resolution, energy linearity and photopeak gain measurement results of five different scintillation crystals coupled with in-house developed SiPM-based detector module.

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