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Prompt gamma imaging with gamma electron vertex imaging system for proton beam range monitoring

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Thanks to the dose characteristic so-called Bragg peak, proton therapy can deliver a very conformal dose to the target volume while minimizing the dose to adjacent normal tissues and critical organs. However, the proton dose distribution in the patient, especially the beam range might deviate from the planned one due to dose calculation errors, organ motions or patient setup errors. To overcome this limitation and fully utilize advantages of proton therapy, the real-time monitoring technique based on the prompt gamma (PG) imaging was suggested [1].

To measure the two-dimensional PG distribution with the high detection efficiency, we proposed a new imaging method, gamma electron vertex imaging (GEVI), and demonstrated the possibility of the imaging method [2]. To determine the emission position, an incident PG is converted to an electron by Compton scattering, and then the trajectory and energy of the converted electron are measured by two hodoscopes and a calorimeter, respectively. To reconstruct image, the effective events are determined from triple coincidence events by applying the optimal energy window and then, the line back-projection algorithm is employed on interaction positions in the first and second hodoscope detectors.

Based on the previous results, in the present study, we improved the GEVI imaging system for clinical applications, and tested its performance for therapeutic proton beams. To increase the field of view in the beam direction, the active area of hodoscope detector (= DSSD array) was increased to 10 cm × 5 cm. The EJ200 plastic scintillation detector of 16 cm × 8 cm × 5 cm was used to cover the extended active area. With this expansion, it was expected that the FOV and the imaging sensitivity will be increased by two times. To improve the data acquisition speed of the imaging system, we had developed a FPGA-based DAQ system.

To estimate the performance of the imaging system, a proton pencil beam extracted from the 230-MeV cyclotron at Samsung Medical Center in Korea was used. In this study, 82, 120 and 150 MeV proton beams were used and 6.24×10^9 protons (corresponding to 1 s measurement for 1 nA proton beam) were used for each measurement case. By changing the proton beam energy and irradiation locations, the PG images were measured and then, the beam ranges were determined within 3 mm error. We expect that the imaging system can be used to proton therapy monitoring by measuring the PG distribution.

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References

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