Introduction of Beam Profile Monitoring System Using Phosphor Screen and TE-cooled CMOS Camera

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1. Introduction

KOMAC (Korea Multi-purpose Accelerator Complex) has operated 100-MeV proton linear accelerator since 2013. A quality assurance (QA) of proton beam profile is required for uniform proton irradiation in the sample. Uniformity criteria, defined as difference between the maximum and minimum of the intensity divided by mean intensity, should be meet under 10% within target diameter. TR103, a general purpose irradiation facility, has generally conducted quality assurance of beam profile with Gafchromic film™ dosimetry [1]. Recently, for in-situ proton beam profile monitoring, P43 phosphor screen and TE-cooled CMOS camera were introduced and tested to confirm performance. Post processing of acquired image data and calculating uniformity within target area were conducted using Python.

2. Methods and Results

2.1 P43 Phosphor Screen & TE-cooled CMOS Camera

Phosphor screen composed of P43 (Gd_2O_2S:Tb) layer on Al substrate has a detection area of 310 mm × 310 mm and peak wavelength of 545 nm. It has a decay time of 1.5 ms to 10% and shows high light efficiency. TE-cooled CMOS camera (ASI183MC Pro, ZWO) has a sensor size of 13.2 × 8.8 mm and thermoelectric cooler which can cool sensors up to -10 ℃ [2]. In general, the amount of hotspots in the image is proportional to the amount of radiation accumulated in the sensor. As leakage current of defective sensor is proportional to the temperature, cooled camera is radiation resistant in high radiation environment [3]. Fig. 1 shows setup of the P43 phosphor screen and TE-cooled CMOS camera.

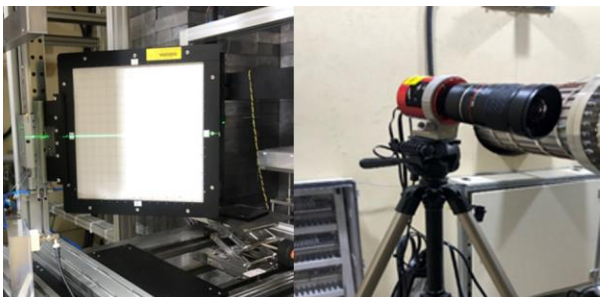

Fig. 1. Setup of the P43 phosphor screen and TE-cooled CMOS camera at TR103

2.2 Beam Profile Measurement Test

Proton beam profile measurement test was conducted at the TR103 of which flux is about 10^{10}~10^{11} #/(cm^2·pulse) and proton energy at the target is 100 MeV. Phosphor screen was irradiated by beam under an angle of 45°. Cooled camera was placed perpendicular to the screen. Fig. 2 shows TR103 irradiation facility and device layout. Captured beam image is shown in Fig. 3. To analyze beam profile, following procedures were performed using Python also shown in Fig. 4

1) Background subtraction and image smoothing
2) Geometrical correction for tilted screen
3) Selecting Region Of Interest (ROI)
4) X-Y coordination by converting pixel to mm

Horizontal beam profiles analyzed by phosphor screen and HD-V2 film were compared. As shown in Fig. 5, the uniformity, 6.8% and 6.2% respectively, showed 10% difference within 30 mm diameter.

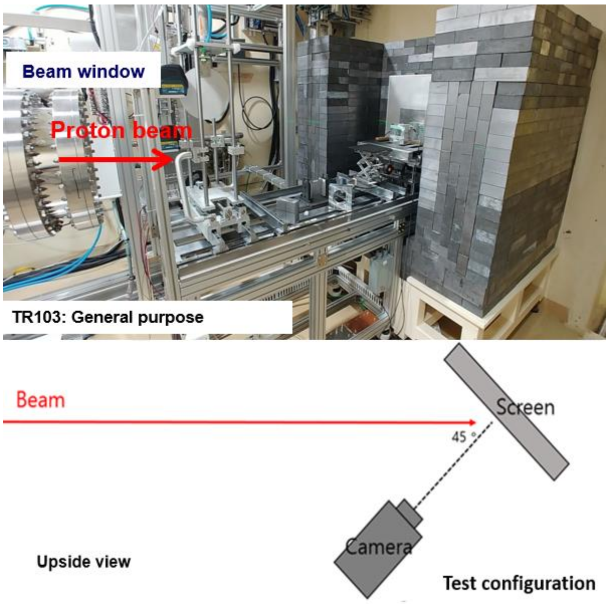

Fig. 2. View of general purpose irradiation facility, TR103 (top) and configuration of device layout (bottom)

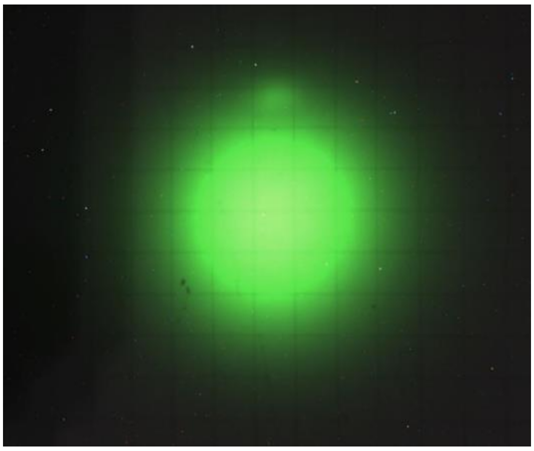

Fig. 3. Captured beam profile image using phosphor screen and cooled camera

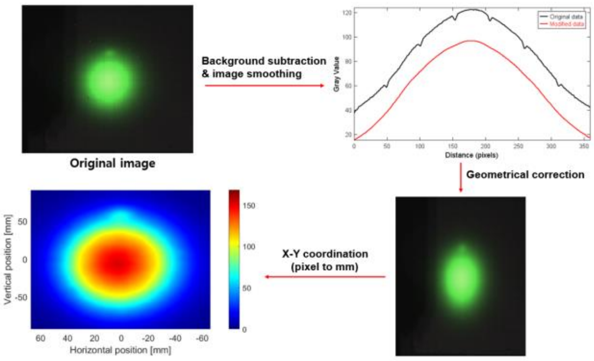

Fig. 4. Post processing of image data using Python

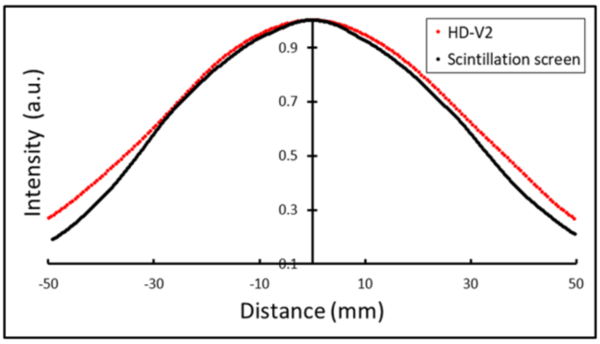

Fig. 5. Horizontal beam profile measured using phosphor screen and cooled camera showing 10% difference within 30 mm diameter.

2.3 Light Output Linearity Test

The test to confirm linearity between light output and beam flux was conducted. As increasing the pulse width, beam flux was measured by faraday cup located where the screen is installed. As shown in Fig. 6, the light output of P43 phosphor screen shows good linear response throughout the overall range without saturation.

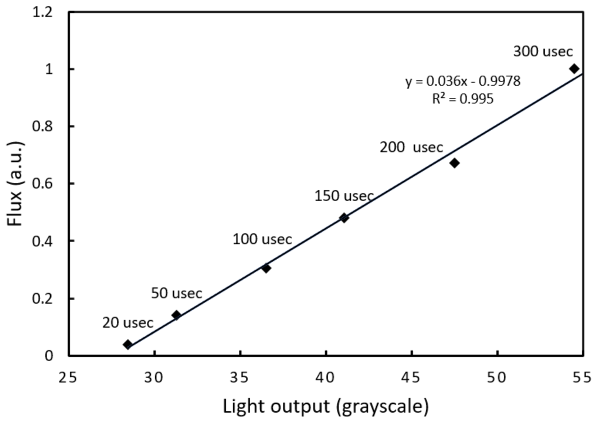

Fig. 6. Linearity between light output and beam flux

3. Conclusions

Beam profile monitoring system using P43 phosphor screen and TE-cooled CMOS camera was introduced. Phosphor screen was irradiated by 100 MeV proton beam and cooled camera captured beam profile. Post processing of image data such as background subtraction, image smoothing, geometrical correction, selecting ROI and X-Y coordination was performed using Python. Comparing beam uniformity measured using phosphor screen and cooled camera, it showed 10% difference within 30 mm diameter. The light output and beam flux showed good linearity throughout the overall range without saturation. This system is expected to allow in-situ beam profile monitoring and QA.

REFERENCES

[1] http://www.gafchromic.com
[2] ZWO, ASI183 Manual, 2021.
[3] Alexander Huber, el al. Response of the imaging cameras to hard radiation during JET operation, Fusion Engineering and Design 123, pp.669-673, 2017.