DEVELOPMENT OF A SCINTILLATION SCREEN MONITOR FOR TRANSVERSE ION BEAM PROFILE MEASURMENT AT THE KHIMA PROJECT*

Seon Yeong Noh#, Se Duk Chang, Tae-Keun Yang Ji-Gwang Hwang, and Ga Ram Hahn
Korea Institute of Radiological and Medical Sciences
75 Nowon-gil, Nowon-gu, Seoul, 01812, Korea

Abstract

The scintillation screen monitor measures transverse profile of ion beam in beam transport line. The Korea Heavy Ion Medical Accelerator Project (KHIMA) has developed a scintillation screen monitor in the high energy beam transport (HEBT) line. The images of each beam pulse were recorded by CCD camera and evaluated the beam properties by the LabVIEW®-based in-house program in real time. We designed a scintillation screen monitor using phosphor screen, P43. In order to investigate the limits of scintillating screen during beam profile monitoring at low intensity, we designed a remote control device of iris for the incoming light adjustment to the CCD camera. In this paper, we present details of the image processing system using the LabVIEW® and the beam profile measurement results from the in-beam test.

INTRODUCTION

In the Korea Heavy Ion Medical Accelerator (KHIMA) project at the Korea Institute of Radiological And Medical Sciences (KIRAMS), to measure the beam properties i.e. position, size and intensity, we have studied using scintillating screen monitor and the imaging analysis method. The beam properties can be inferred by measuring the visible light from the scintillation screen when the charged particle passing through. The resulting photon emission represents the two-dimensional beam distribution and can be recorded by a standard optical device, a charge-coupled-device (CCD) camera. The scintillating screen provides many advantages, such as a high resolution of beam profile,a direct intercepting method to observe beam profiles, and a simple structure etc. For the high energy beam transport (HEBT) line of KHIMA, a prototype beam profile monitoring system was manufactured and tested in MC50 cyclotron facility at KIRAMS. Through the preliminary experimental results, we checked and evaluated the beam position, size and intensity by using a developed image analysis program.

FABRICATION OF SCINTILLATION SCREEN MONITOR

Hardware

As shown in Fig. 1, the scintillation screen monitoring system consists of a very thin phosphor screen and CCD camera. The prototype system used a gadolinium sulphate oxide doped with Terbium (Gd_2O_2S:Tb) phosphor screen for convert the proton beam path to visible light [1]. And, a high spatial resolution CCD camera (type: 659 × 494 pixels, H:0.169mm/pixel, V:0.14mm/pixel, model: acA640-90gm, Basler, Germany) was adopted to record the emitted light the scintillation screen.

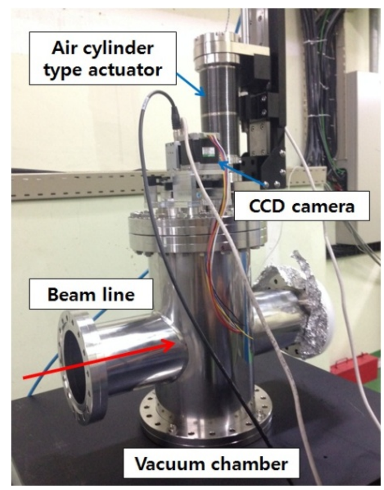

Figure 1: Photograph of the 2D beam imaging system.

The CCD camera was located perpendicularly to the beam axis, and the 100 mm diameter scintillation screen was mounted on the holder 45 degree tilted with respect to the beam axis. The 2 dimensional beam profiles display on the computer screen, and can be stored by the LabVIEW®-based data acquisition program [2,3]. The schematic drawing of the 2D beam imaging system is shown in Fig. 2.

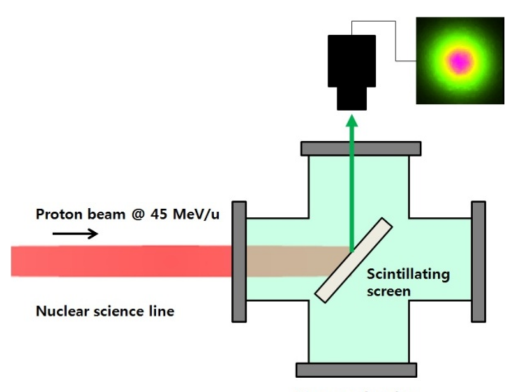

Figure 2: Experimental setup of 2D beam imaging.

*Work supported by KIRAMS
#synoh@kirams.re.kr

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2D Beam Image Processing Software

The beam profile and position were determined by a series of image processing. The work flow was shown in Fig. 3. The detailed image processing steps follow as:

1) An image was taken based on an appropriate exposure time and the CCD gain condition.

2) A median filter removes the noise from the CCD.

3) The image distortion by 45 degree tilting scintillation screen was corrected for the horizontal and vertical direction.

The first region of interests (ROI) is selected to remove unnecessary reflected image by the structure of scintillation monitor. The size of the 1st ROI is limited by the size of the scintillation screen. After the noise removal from the 1st ROI, the FWHM of the beam is calculated. And the 2nd ROI which is doubled area of FWHM is selected to remove the noise from the periphery. The 2nd ROI selection process applies dynamically in response to the measured beam profile [4].

After noise removal, the center of mass algorithm calculates the beam center. It calculates the partial sum of intensities for each 1D line projection profile and 2D intensity profile in order to obtain the correct beam size even if the entering beam is non Gaussian distribution. Depending on the purpose of beam, it is required the beam current confirmation for the appropriate irradiation.

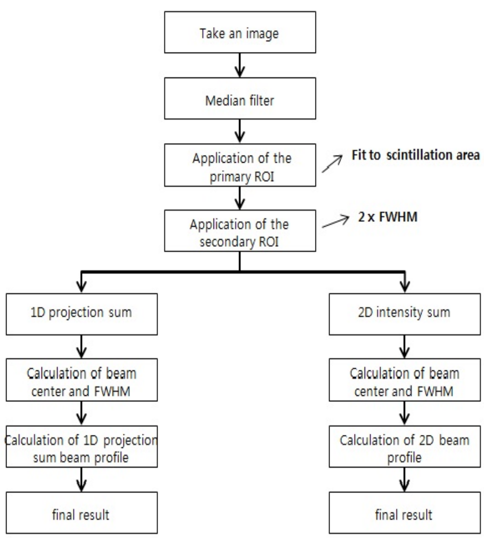

Figure 3: The flow chart of image processing.

The HD-V2 GaF film, which has no electrical noise effect and distortion free, was used to verify the profile image from CCD camera. A piece of GaF film was attached at the entrance of the vacuum chamber and installed in MC50 nuclear science beam line. The 45MeV proton beam was irradiated for 1 minute 30 seconds using100nA beam current. In case of HD-V2 GaF film, the green image components among the RGB show linearity for the incoming proton beam. So, we have selected the green intensity through the image analysis and applied for the beam property calculations as shown in Fig. 3. Figure 4 shows the obtained image from the GaF film.

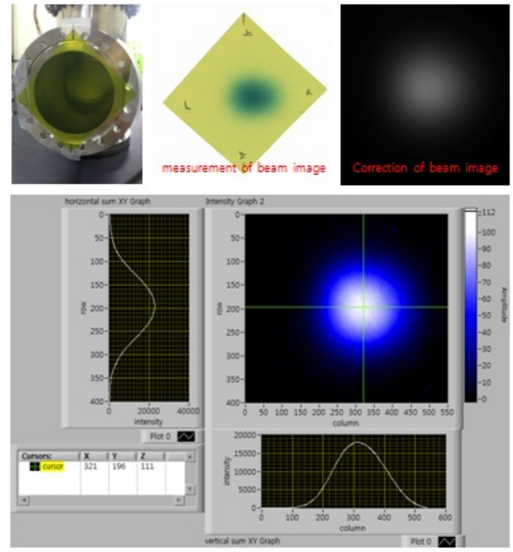

Figure 4: Measured beam profile using by GaF film at vacuum chamber entrance.

RESULT

Comparing GaF Film and P43 Screen

To compare the beam sizes from the GaF film and the scintillation screen results, the beam sizes were normalized for both cases. Also, in order to evaluate the CCD background noise, the original image and the image after removing background noise were compared. Referentially, CCD dark noise can be removed by subtracting beam-off image. Background noise removal method is subtracting the average value by selecting a number of points of the border of 2nd ROI from the original beam intensity.

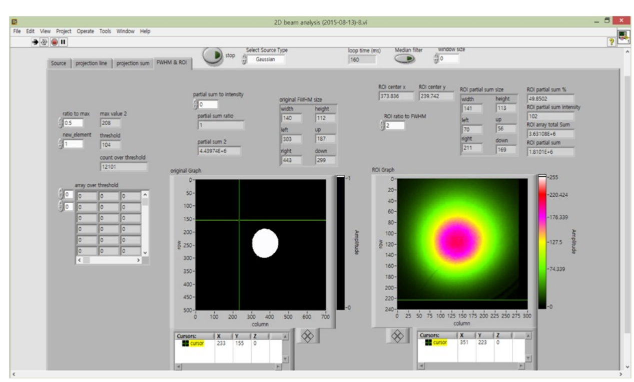

Figure 5: Capture of the beam profile analysis program.

Figure 5 shows a snapshot of the analysis program. First, the horizontal and the vertical beam sizes are calculated from the CCD image, which averaged 10 frames within 2 seconds. For the 1D projection sum profile, the 68 % beam size of total intensity is as follows. The beam size is 20.3 and 25.18 mm for vertical and horizontal directions.

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Corresponding to 98% of the total beam intensity (for Gaussian distribution 2sigma is 95%), the vertical and horizontal beam size were 40.88 mm and 50.02 mm. For the 2D intensity profile, the beam size of 68% of total intensity is 28.98 mm and 36.17 mm for vertical and horizontal

The beam center at the 1st ROI is (8.45 mm, 2.1mm) and the 2nd ROI is (9.13 mm, 1.82 mm). As a result, there was little difference on the beam center calculation between 1st and 2nd ROI.

In case of CCD images, the beam size difference between the background noise subtraction image and the normal image shows less than 1.35mm difference. In case of the beam center position, the difference shows less than 0.5 mm.

During the analysis of the GaF film result, the median filter applied for the beam profile calculation. And, the Table 1 shows the comparison between the CCD and the GaF film analysis results.

Table 1: Comparing GaF Film and P43 Screen

Material	Name			Horizontal (mm)	Vertical (mm)
P43 screen	1st ROI	Beam center position		8.45	2.1
		1D profile	Beam size (68%)	25.18	20.30
			Beam size (95%)	50.02	40.88
		FWHM		28.73	22.82
	2nd ROI	2D profile	Beam size (68%)	36.17	28.98
GaF film	1st ROI	Beam center position		8.62	0.68
		1D profile	Beam size (68%)	26.03	20.62
			Beam size (95%)	48.17	38.70
		FWHM		26.87	34.65
	2nd ROI	2D profile	Beam size (68%)	39.55	31.27

As a result, the 68% beam size of total intensity at the 1D profile, the difference between the CCD and GaF film results shows below 1mm for vertical and horizontal direction. And for the 95% beam size case, the difference shows below 2mm for both directions. And for the 2D intensity profile, the beam size from the GaF film is bigger by 3.4mm for horizontal and 2.3 mm for vertical. It would be required more analysis on CCD intensity profile calculation.

To measure the beam position accuracy, the monitor was placed at several different positions and obtained the each beam profile. As shown in Fig. 6, the beam is passing through the collimator of 3.5 mm diameter and the beam position was measured while moving 20 mm for horizontal direction and 10mm for vertical direction. The beam position measurement results were summarized in Table 2.

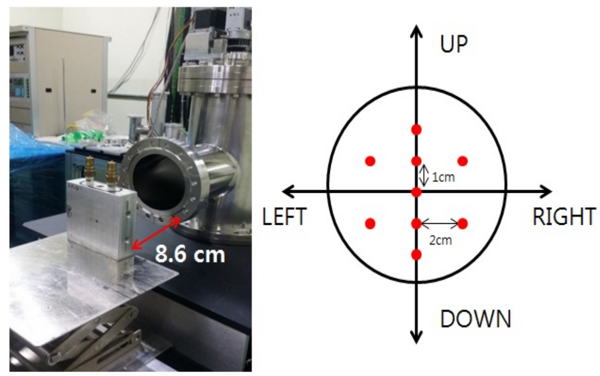

Figure 6: Scanning of beam position using the collimator.

Table 2: The Result of the Beam Position

Move (mm)		Measurement (mm)	
X	Y	X	Y
0	10	0.075	10.01
0	0	0.00	0.00
0	-10	0.078	-9.35
-20	10	-20.30	10.01
-20	-10	-20.04	-10.26
20	10	20.01	9.77
20	-10	20.36	-9.93

CONCLUSION

We have manufactured and tested a prototype beam profile monitoring system at KIRAMS. In order to determine the beam profile measured by the CCD, we compared with the one measured at the vacuum chamber entrance GaFfilm. In case of beam size measurement, the CCD image without background noise reduction was closer to the GaF film result. The beam size difference between the CCD and GaF film results could be generated by their physical position difference. The P43 scintillation screen is located in 173 mm beyond the GaF flim. In case of beam position measurement, the real beam center position did not correctly match the center of the beam that is measured by the method of the center of mass.

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Because the measurement of the beam position at a periphery was affected by the beam cut due to the scintillation screen size of 100mm diameter. The designed scintillation screen monitor and the analysis program have featured on selecting the 2nd ROI in real time for moving beam center. When the beam size is big enough, the center of beam can be calculated correctly using only the 1st ROI because there is little noise from CCD. But when the beam size is small, the 2nd ROI would be required to calculate the center of beam correctly. We could calculate the real beam size (Position) of a certain percent of the total intensity using actual the 2D profile data without graph fitting. In the future analyzing the beam image of CCD and GaF film will be done to more accurately correct the cause of the differences in beam size and the beam position.

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