

THE DEVELOPMENT OF SCINTILLATING SCREEN DETECTOR FOR BEAM MONITORING AT THE KHIMA PROJECT

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Abstract

It is important to measure the beam properties such as position, size and intensity, when we control the medical beam qualities. Therefore, we have developed a scintillation screen monitor for beam profile. The scintillation monitor would be installed at High Energy Beam Transport (HEBT) section to measure the beam parameters. The designed system uses a terbium-doped gadolinium oxysulfide (Gd₂O₂S:Tb) phosphor screen and a high speed charge coupled device (CCD) camera. The CCD camera provides the maximum frame rate as 90 FPS and the image resolution as 659 X 494. The camera is mounted at the distance of 260mm from the center of the scintillation screen, which is mounted at 45 degree tilted to the beam axis. The image analysis program was made by National Instruments LabVIEW using IMAQ driver. To reduce the image processing time, we optimized the image processing flow and used LabVIEW built-in function. To evaluate the scintillation screen monitor system, we measured the beam size and the center position of the proton beam on MC-50 at KIRAMS. In this paper, we present the manufactured beam profile monitoring system based on using a scintillating screen monitor and the in-beam test results.

INTRODUCTION

The Korea Heavy Ion Medical Accelerator (KHIMA) project at the Korea Institute of Radiological And Medical Sciences (KIRAMS) has developed a beam diagnostic device using a scintillation screen to evaluate the beam properties, such as the center position, the size and the intensity distribution at a beam line. The diagnostic device uses CCD camera to acquire a beam image and evaluate the beam property through the image processing according to the proposed flow chart [1]. For the calculation efficiency, the region of interest (ROI) was selected, and the background noise elimination was performed [2,3]. To verify the performance of the scintillation screen monitor, some in-beam experiments were followed using 45 MeV protons, which has 100nA of beam current from the MC-50 cyclotron at KIRAMS. And, the measured beam was fitted to the Gaussian distribution for calculating beam profile. Also, we have tracked the beam center changes when we move the beam using scanning magnet. Evaluating the result of the experiment, we could confirm the performance of the monitor, which can be used in real-time monitoring.

BASIC HARDWARE COMPONENT

The basic configuration of the scintillation screen monitor is that a 45 degree tilted P43 plate (decay time: 1 μ s, diameter: 100mm) as shown in Fig. 1 and the CCD camera (model: acA640-90-gm, Basler, Germany) mounted perpendicular to the beam line [4]. And a pneumatic actuator was used for inserting and pulling out the phosphor screen for the beam path. The incoming proton beam is converted into the visible light by the phosphor screen, and these lights are acquired by the CCD camera. The obtained images are used for the analysis of the beam size, the center position and the intensity distribution determination.

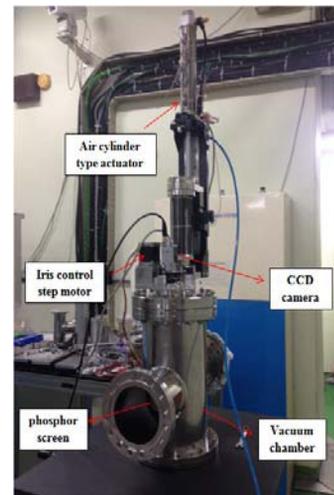


Figure 1: Photograph of the scintillation screen monitor.

BEAM IMAGE PROCESSING FLOW

The analysis program was made by NI LabVIEW using the IMAQ driver to determine the beam size and center position based on the image from the CCD camera. The phosphor screen was tilted as a 45 degree to the beam path, therefore, the image from the perpendicularly installed CCD camera obtains prospectively distorted images. In addition, an optimized image processing sequence is necessary because the beam property analysis speed and accuracy were changed by the image processing sequence after obtaining the image from the CCD camera. The schematic diagram of the image processing flow was shown in Fig. 2.

First, we set offset X, offset Y and x, y width values of CCD camera to get 1st rectangular ROI. Second, we set 2nd circular ROI using circular graphic UI tools to get the scintillation screen area image. And after cropping circular image, we apply a median filter to the image to eliminate noise. Fourth, we correct the perspective distortion due to the 45 degree tiling of the screen. Fifth, we subtract noise threshold value that is calculated from the boundary intensity distribution of scintillation screen. Lastly, we apply Gaussian fitting to the image and get σ_{rms} , FWHM and the center of beam profile and save the results [5].

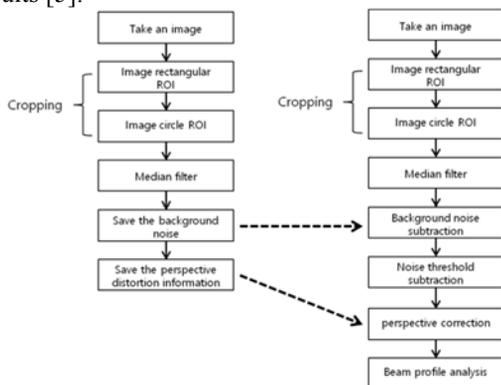


Figure 2: pre-beam test flow (left) and real beam analysis flow (right) result.

IMAGE ANALYSIS PROGRAM

The programmed User Interface has five tabs; pre-camera setting, image distortion correction, 2D-image display, image projection sum and Gaussian fitting and 2D-line intensity analysis tab. Fig. 3 shows the UI tab to display the size and center of beam and to save the result.

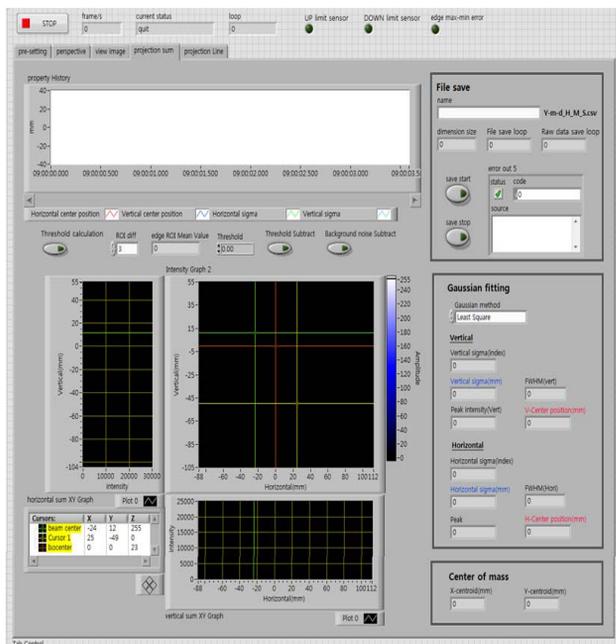


Figure 3: screen shot of User Interface program for scintillation screen monitor.

Calculating Noise Threshold Using Boundary Intensity Distribution

To eliminate the noise, we need to decide the noise intensity threshold of beam distribution and subtract the value from the image. To decide the noise threshold level, we choose another circular ROI that has smaller diameter than the circular ROI for scintillation screen. The intensities on the gap area between two ROIs was considered as noise. The size of the gap can be entered by user. The figure on the right side shows an example of 5 pixel difference between two ROIs (Fig. 4).

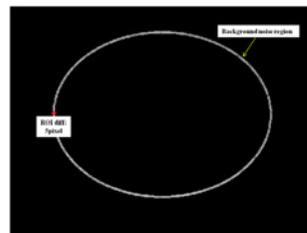


Figure 4: noise level calculating region.

Image Distortion Correction

We have to correct the image distortion caused by the setup between the 45 degree tilted phosphor screen and CCD. To correct the perspective image distortion, we use NI IMAQ correct calibrated image function. As shown in fig. 5, to get a degree of perspective distortion, we placed 5mm square pattern on the screen position and select at least 4 points. Right of Fig. 5 shows the distortion corrected image. We can use the same calibration information until the structural configuration change of the scintillation monitor. In perspective UI tab, we can calculate new calibration information also.

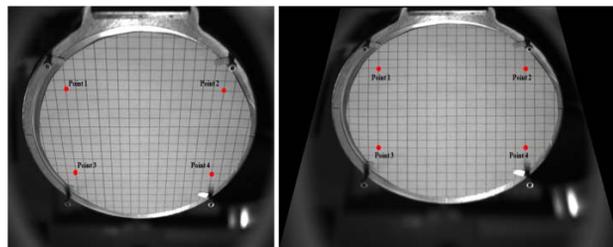


Figure 5: before image correction (left) and after image correction (right).

TEST

We verified the beam analysis program by calculating the beam size and the center position of the Gaussian distribution data of various sigma values and intensities. We changed sigma value of Gaussian distribution data from 1 to 5 and checked the calculated beam profile.

Measurement of Beam Size Using the Various Gaussian Distribution Data

Figure 6 shows the Gaussian fitting error of various beam intensities according to sigma values. As you can see, we show the fitting error percentage in Fig. 6 as we change the maximum intensity from 25 to 250. The result shows that all the fitting errors are about 4% at maximum intensity 25 except for sigma value 1. And when the maximum intensities are above 125, all the fitting errors are below 1%. Because the Gaussian distribution is symmetric, the fitting center positions are same as the input Gaussian distribution. If we use the Least-absolute residual fitting method, the error reduced until 0.2~0.3%.

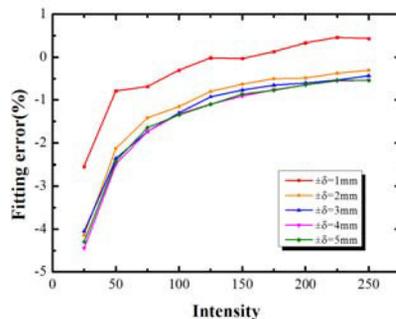


Figure 6: Fitting error graph of various beam intensities and sigma values.

MC 50 Proton Beam Test

To verify the beam size and the center position, we tested the scintillation monitor system at MC50 proton beam line. As shown in Fig. 7, we measured and calculated the size of the 30 MeV proton beam 8nA current using our scintillation monitor system.



Figure 7: the picture of MC50 beam line and scintillation screen monitor.

The analysis result shows that the beam size is 2.275 mm and 8.3348mm as sigma for the vertical and horizontal direction. Fig. 8 shows the measured image.



Figure 8: Measured beam image.



Figure 9: Picture of scanning magnet.

As shown in experiment setup on Fig. 9, the beam position was changed by scanning magnet, and the beam position and beam size were measured. We moved the beam to the 20 positions along the horizontal and vertical direction. The graph shows that the beam position moved 1.87mm and 1.83mm on average for each step of horizontal and vertical. And the standard deviations of the beam positions are 0.122mm and 0.0173mm for each position step (Fig.10).

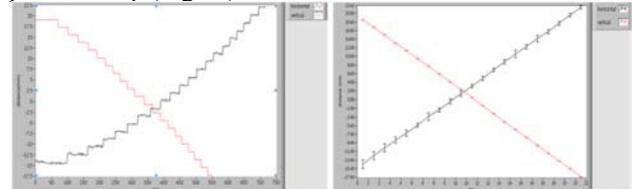


Figure 10: beam position movements by changing scanning magnet current.

CONCLUSION

We tested the performance of the scintillation screen monitor of calculating the beam profile and we obtained reasonable results. Gaussian fitting using CCD image data of 8bit integer decrease the fitting accuracy due to the data conversion. Therefore, it is necessary to use CCD image data of 12bit integer in order to get more precise fitting result. Because the MC50 cyclotron beam energy spectrum is not wide enough, we need to test if the scintillation screen monitor gives linear response and to verify how much errors are in case of wide heavy ion beam spectrum of 60~230MeV. In the future experiments, we will test the scintillation monitor with ion chamber monitor to get more precise analysis regardless of the beam condition.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (no. NRF-2014M2C3A1029534). And this experiment conducted at the MC50 cyclotron facility operated by KIRAMS, supported by the National R&D Program through the Korea Institute of Radiological and Medical Sciences funded by the Ministry of Science, ICT & Future Planning. (No.1711021909).

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