BEAM PROFILE MEASUREMENT WITH CCD CAMERA AT PEFP

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Abstract

We are developing a non-interactive beam profile monitor based on the background gas fluorescence technique using a standard CCD camera for RFQ beam matching at PEFP Low Energy Beam Transport (LEBT). This paper will review the measurement performance and discuss some of the resulting data under background gas pressure. Various beam focus by two solenoids and steering conditions will be also studied with the CCD camera.

INTRODUCTION

In the PEFP (Proton Engineering Frontier Project), the ion source capable of 20 mA, 50 keV proton beam is matched to the 3.0 MeV RFQ by using the LEBT. Non-destructive diagnostic method that gives the profile of a proton beam is of considerable interest for the RFQ beam matching at the LEBT [1]. A beam profile monitor (BPM) using a charge coupled device, or CCD, was constructed and evaluated. The residual gas at the LEBT has a pressure around 4 x 10^{-5} Torr containing mainly H_2 and N_2 [2]. Gas molecules in the beam pipe interact with the passing proton beam and then the neutral or ionized residual gas is promoted to excited state. The CCD camera can collect the photons emitted by the electron transitions of the excited molecules, leading to measurement of the beam profile.

Figure 1: The installation of the CCD beam profile monitor at the PEFP LEBT.

EXPERIMENTAL PROCEDURE

Two steering magnets were placed in the LEBT between two solenoid lenses to provide the desired beam position and angle at the RFQ match point. The steering magnets have a capability of independent control of X and Y motion.

The MegaPlus1.4i digital camera used for beam profile measurements has a CCD sensor providing a 1317 x 1035 pixel array with 6.8 x 6.8 μm^2 square pixels and 256 gray levels for each pixel. The camera also features accumulation mode, which significantly reduces dark current. The CCD camera was installed perpendicular to the axis of the proton beam path, in order to measure vertical and horizontal profiles (Fig. 1). The image grabber and XCAP V2.2 software were used to collect the beam profile information from the CCD camera and calculate the vertical and horizontal beam intensity projection. A crucial point for the operation of the CCD BPM monitor is a precise focal distance setting. An LED was installed on the center of the beam path to determine the focal distance and to achieve a pixel-to-mm calibration.

The Faraday cup is installed at the center of the RFQ entrance to measure the beam position and the CCD BPM is located at 6.5 cm from the Faraday cup. A photo of the Faraday cup is shown in Fig. 2, consisting of cylindrical graphite with a diameter of 8 mm and a conical entrance

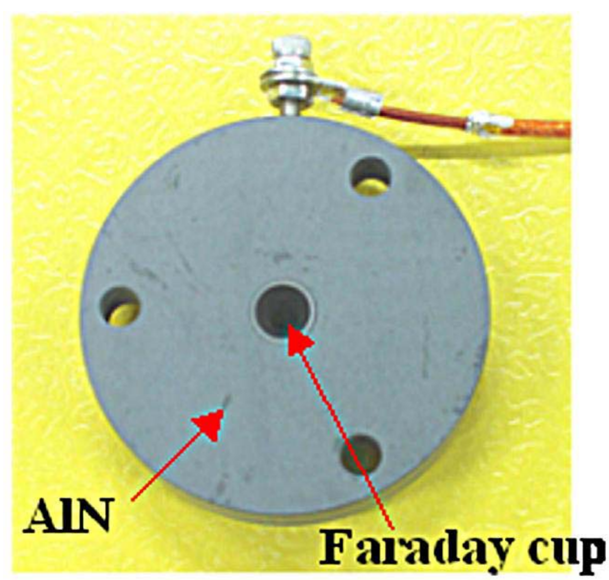

Figure 2: The assembled Faraday cup.

for flux dispersion. The signal current is fed out through aluminium nitride for heat transmission into the adjacent copper plate and electrical insulation.

PERFORMANCE

TRACE calculation for 20 keV, 2 mA proton beam with $\alpha = -0.5$, $\beta = 0.2$ mm/mrad, and $\varepsilon_N = 0.2\pi$ mm mrad, gives the predicted magnetic field value of two solenoids for the matching beam using the input parameters of $\alpha = 0.69$ and $\beta = 0.035$ for the PARMTEQM RFQ simulations. According to the TRACE, the matched beam is obtained for $B_{sol\#1} = 1300$ G and $B_{sol\#2} = 2100$ G.

Various beam focusing and steering features were easily studied using the CCD BPM in single shot mode over 3 sec, at a background gas pressure of 4 x 10^{-5} Torr. Low energy and current proton beam (20 keV, 2 mA) was used for the preliminary tests. Figure 3 shows images of the proton beam before operating the steering magnet and after steering correction. A very low background image is obtained due to the installation of black anodizing hoods inside the beam pipe and between CCD camera lens and the view port. The initial offset without steering operation is 1.6 mm and the signal current from the Faraday cup is 20 μA. With $B_{st\#1} = 8$ G and $B_{st\#2} = 5$ G, the maximum signal current, 106 μA, was attained, and the offset of the proton beam for injection into the RFQ was corrected. The steering magnet can correct the offset above 3 cm in the alignment of the ion source to the RFQ match point.

Figure 4 shows the intensity profile measured along the vertical line around proton beam. The measured smallest beam size, meaning the most efficient beam focusing, was obtained with $B_{sol\#1} = 1300$ G and $B_{sol\#2} = 1800$ G, being in good agreement with the TRACE results. In addition to the incident protons, the other light sources such as delayed decay, back scattered protons, and electrons by inelastic collisions, could broaden the recorded beam profile [3]. Therefore we estimate the beam size to be less than 2.2 mm FWHM from the beam profile measurements.

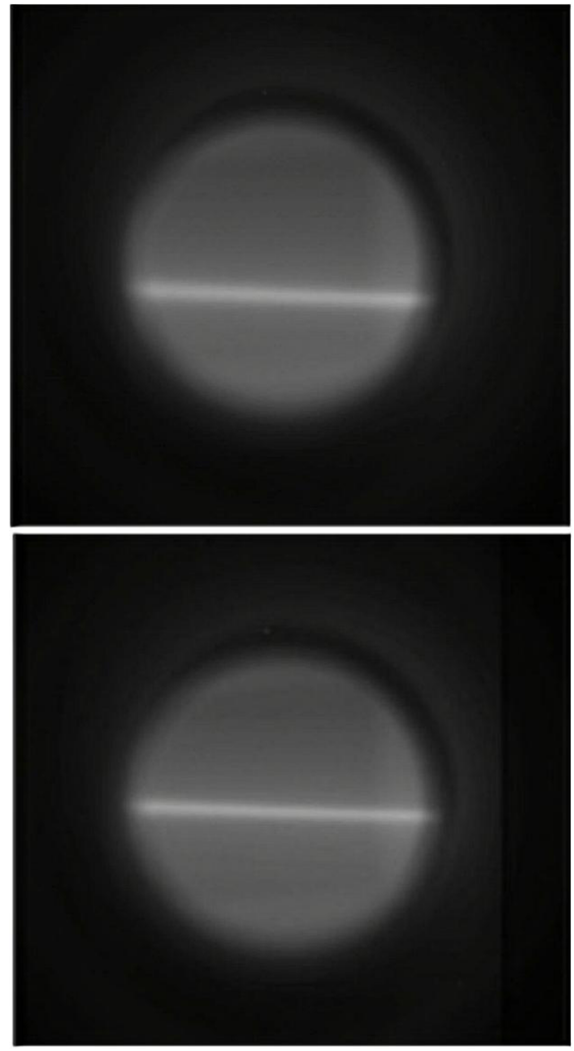

Figure 3: Two beam images, measured with the CCD beam profile monitor: (a) before operating the steering magnet and (b) after steering correction.

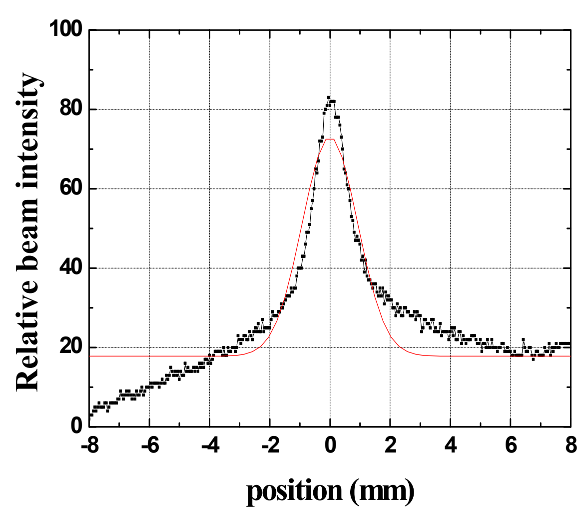

Figure 4: Intensity profile obtained along the vertical line around the proton beam.

CONCLUSIONS

The CCD beam profile monitor has been constructed and a preliminary test on the proton beam of the PEFP linear accelerator has been arranged under residual gas pressure of 4 x 10^{-5} Torr. The proton beam was substantially focused with beam size of 2.2 mm FWHM for $B_{sol\#1}$ =1300 G and $B_{sol\#2}$ = 1800 G, and the result is consistent with the TRACE simulation. Two steering magnets installed in the LEBT provide a wide range of beam centroid motion at the RFQ match point, permitting rapid, on-line correction of beam misalignment between the ion source and RFQ by using the CCD BPM. We also measured the current from the Faraday cup to find out the accurate and absolute beam position by comparing with the CCD beam profile. Emittance measurement using CCD camera and mathematic methods is planed for the future.

REFERENCES

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