Emittance monitor with view screen and slits

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Abstract

We have constructed a beam emittance monitor with a view screen and movable slits. The view screen is used to detect the proton beam collimated by the slits. By this method, the beam emittance can be measured more precisely or more quickly than that by the conventional way. The material of the screen is an alumina ceramic doped with the chromium oxide. The fluorescence is observed by a CCD camera and digitized by an image freezer. We have already used the emittance monitor to measure the 50 keV and 2 MeV proton beam.

Introduction

The ICR proton linac at Kyoto University is composed of a 50 keV H^+ ion source, 2 MeV RF-Quadrupole (RFQ) linac and 7 MeV Alvarez linac [1]. The linac is designed to accelerate a 50 mA proton beam. The beam transport elements and the beam monitors are important to avoid the beam loss in the high current linac. Some profile monitors and Faraday cups are installed in the beam line. The profile monitors consist of view screens and CCD cameras. We have developed an emittance monitor using the profile monitor and movable slits. The profile monitor is used to measure the spread of the transverse momentum of the beam.

At the election linac, the pepper pod method for the emittance measurements is often used. This method is similar to the pepper pod method but the movable slit is used instead of the pepper pod plate. It is more suitable in the low energy ion linac because an unnormalized emittance is relatively large. Compared with the double slits method, the measurement time is significant short. The high resolution of the transverse momentum can be gotten compared with the multi-wire method because of the high position sensitivity of the view screen.

Configuration of the monitor

A schematic diagram of the beam emittance monitor is shown in Fig 1. The slits define the transverse position and spread of the beam. The transverse momentum can be measured by the screen that is located at the downstream of the slits. The screen can be flipped by electro-magnetic actuator on the beam axis [2]. The fluorescence from the screen is observed by a CCD camera and digitized by an image freezer. The image data is analyzed by a personal computer.

View screen

The view screen is AF995R by Desmarquest. The area of the screen is 50 mm x 50 mm and the thickness is 1 mm. The fluorescent material is an alumina ceramic (99.5 % - Al_2O_3) in which a little chromium oxide is homogeneously doped. The material has a high resistance against a radiation damage and a high temperature caused by the beam, which are suitable characteristics as the view screen [3]. The maximum working temperature of the screen is 1800 °C.

The spectrums of the fluorescence were measured at the screen by 50 keV, 2 MeV and 7 MeV proton beam. A monochrometer and a photo multiplier tube were used in

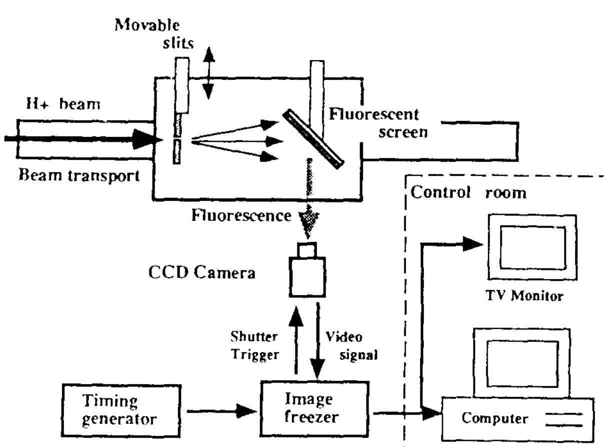

Fig. 1 Schematic diagram of the beam emittance monitor system.

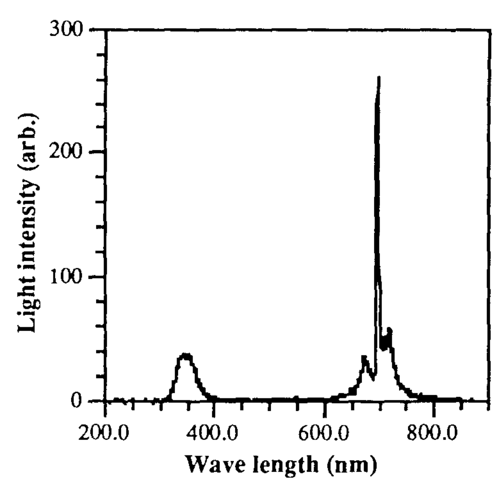

Fig. 2 Spectrum of the fluorescence of the screen. The beam energy is 50 keV and the current is 0.2 mA.

the measurements. The result at the 50 keV beam is shown in Fig. 2. The major peak is at 696 nm and the wavelength of this peak is independent on the beam energy. There is a broad peak around the 350 nm. The 696 nm peak is very bright and used as the light source of the profile and the emittance monitor in usual measurements.

The residual of the 696 nm fluorescence is shown in Fig. 3. The beam energy is 2 MeV at the current of 0.2 mA. The decay time depends on the beam energy. It is 1 msec at the 50 keV beam and 2.5 msec at the 2 MeV beam. The long residual is not problem in the usual measurements but it becomes a defect when the emittance and profile of the beam from the ion source are measured. The beam quality may change within the macro beam pulse of 600 μsec. It depends on the status of the plasma in the ion source chamber. The short residual is needed in this usage. We have tested the 350 nm fluorescence as the light source. The fluorescence of 350 nm has short residual in the case of electron beam [4]. Fig. 4 shows the pulse shape of the 350 nm fluorescence and the beam current. The beam energy is 50 keV and the beam current is 5 mA. The response of the fluorescence is enough fast for the beam pulse measurements. Fig. 5 shows a beam profile using the 350 nm fluorescence. The beam condition is the same as that of the Fig. 4. The 696 nm fluorescence is removed by the color filter to collect only the 350 nm fluorescence. The shutter speed of the CCD camera is 64 μsec and synchronized with the timing of the linac. The shutter speed corresponds to the pulse width of the RF in the linac cavity.

Fluorescence monitor

The image on the screen is viewed by the CCD camera. The imager is a 1/2" size and the interline transfer type CCD. The effective number of the CCD elements is 768 x 494. The resolution of the camera is 0.2 mm/element on the view screen. The g value of the CCD camera is 1.0 and the CCD output voltage is proportional to the input light intensity. The shutter speed is adjustable from 8.3 msec to 32 μsec and the shutter timing is synchronized with the linac operation.

The CCD output signals are digitized with 256 steps by the image freezer and the digitized image is held in the memory until the next external shutter trigger enters. The froze image is displayed on the TV monitor and the video signals are also transferred to the personal computer through an interface board. The CCD output signal is calibrated and the calculation result of the emittance is displayed on the monitor of the computer.

Performance of the emittance monitor

The main specification of the emittance monitor is shown in table 1. The resolution of the beam size depends on the slit width. The slit plate is made of copper and the width of the slits is 0.2 mm. The resolution of the transverse momentum depends on the distance between the slits and the view screen. As the position resolution on the screen is 0.2 mm and the distance is 500 mm, the

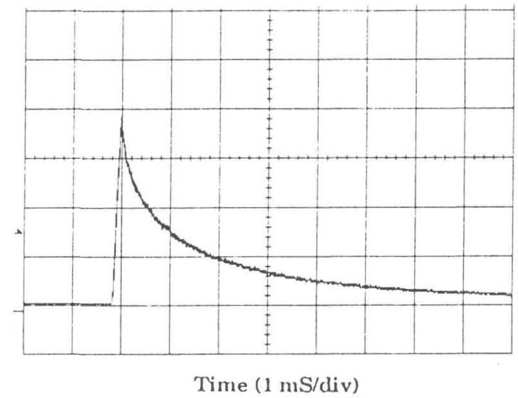

Fig. 3 Residual of the 698 nm fluorescence of the screen. The beam energy is 2 MeV and the current is 0.2 mA

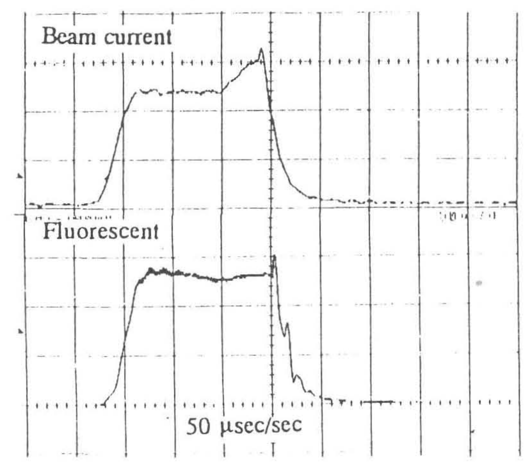

Fig. 4 Pulse shape of the 350 nm fluorescence and the beam pulse. The beam pulse is measured by a Faraday cup and the current is 5 mA.

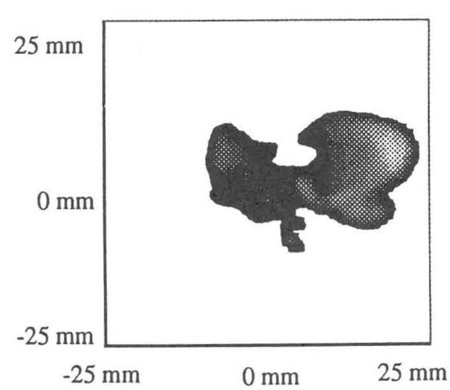

Fig. 5 Beam profile using the 350 nm fluorescence. The beam energy is 50 keV and the current is 5 mA

resolution of the angle is 0.4 mrad. The measurement time is 180 seconds per one axis when the slits are moved with 0.5 mm steps within ±20mm range.

Fig. 6 (a) shows the measured 100 % emittance of the 50 keV beam at the entrance of the RFQ linac. The beam current is 5 mA. The aberration by the electro-static lenses in the low energy beam transport is displayed in the figure. The 100 % unnormalized emittance is 170 π·mm·mrad. Fig. 6 (b) shows the 2 MeV beam emittance. It is measured at the down stream of the RFQ linac. The beam current is 0.2 mA. The unnormalized emittance is 29.5 π·mm·mrad.

Conclusion

We have developed the beam emittance monitor that consists of the beam slits and the profile monitor. The beam emittance was measured successfully at the 50 keV and 2 MeV beam.

The short measurement time is desirable for the daily operation. It takes much time to process the image data in the present system. It is possible to cut the measurement time up to the half if the faster image processor is used.

References

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[3] T.Shirai, et al., "Study of Beam Profile Monitor for the Proton Linac", Bull. Inst. Chem. Res. Kyoto Univ., 71, 15, 1993

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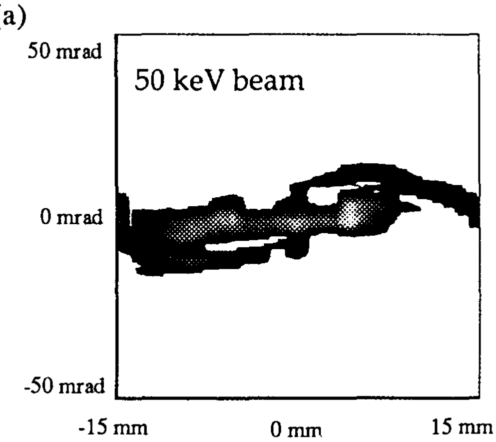
Table 1 Main specification of the emittance monitor

Resolution of position	0.2 mm
Resolution of inclination angle	0.4 mrad
Measurement range	±20 mm, ±50 mrad
Measurement time	180 sec



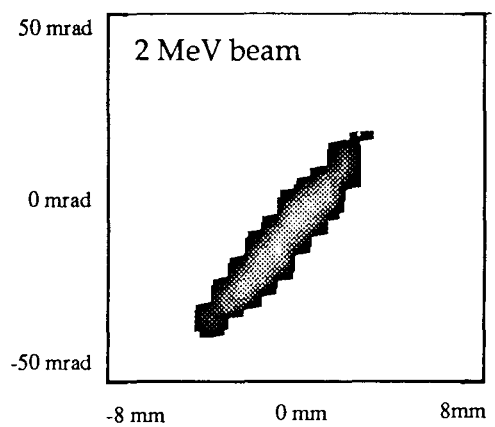


Fig. 6 (a) : Measured unnormalized emittance of the 50 keV beam at the entrance of the RFQ linac. The beam current is 5 mA.
(b) : Measured unnormalized emittance of the 2 MeV beam at the downstream of the RFQ linac. The beam current is 0.2 mA.