Parallel Plate Ionization Chamber for the Medical-use Heavy-ion Beams

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Abstract

We have developed a Parallel Plate Ionization Chamber (PPIC) in order to measure the time structure of the slow-extracted beam intensities. The series of tests shows that the PPIC can be a useful beam monitor for the time-structure measurements of beam intensity. We also try to use PPIC as a profile monitor. The preliminary results of this type of PPIC are described.

1 Introduction

The radiation therapy using the ion beams has merits of higher dose concentration. The spot scanning method is considered to be outstanding to effectively use this merit. We are planning to test this method at HIMAC (Heavy Ion Medical accelerator in Chiba)[1].

Intensity of beams slowly extracted from a synchrotron, in general, varies in time mainly due to the current ripple in the synchrotron magnets. The speed of spot scanning can be controlled to realize the accurate dose distribution. In this system, the intensity of the slow-extracted beams should be measured at the upstream of the irradiation point in non-destructive way.

As a beam monitor for this purpose, a Parallel Plate Ionization Chamber (PPIC) is chosen from less disturbance to the beam and its wide dynamic range. The performance of the PPIC [2] for the intensity measurement is investigated with C^{6+} beams extracted from HIMAC. We have also developed such a PPIC as can be used for profile monitor using the strip electrodes. The preliminary test results of the profile monitor are described in this paper.

2 Experimental Setup

The PPIC is composed of three plane electrodes as shown in Fig. 1. These electrodes are made of 3 μm-thick aluminized polypropylene film (270 μg/cm^2 for the polypropylene and 20 μg/cm^2 for the aluminium). The gap distance between these electrodes is adjusted with the spacers.

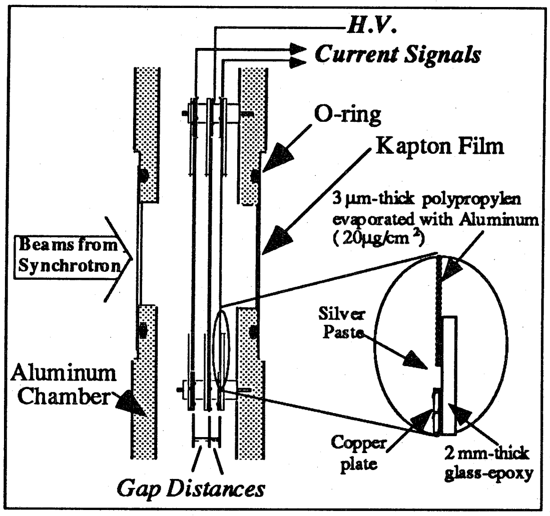

Fig. 1 The cross sectional view of the PPIC.

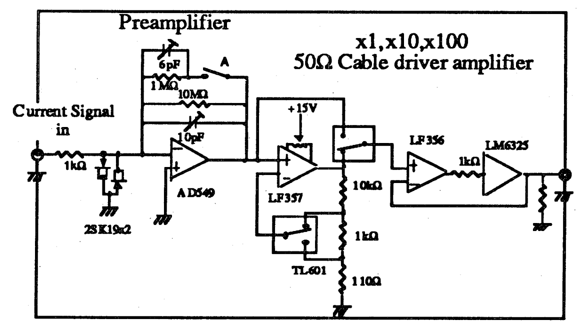

Fig. 2 The trans-impedance amplifier system. It consists of 10/100 MΩ pre-amplifier and x 1, x 10, x 100 Cable driver amplifier.

In the set of experiments the C^{6+} (290 MeV/u) beams slow-extracted from synchrotron with RF-KO method [3][4] at around 11/3 resonance are measured. Corresponding to the repetition rate of the frequency modulation of RF-KO field, we can see the beam ripple. The frequency usually used for therapies is 777 Hz, and changed up to 3 kHz to study the time response of PPIC system.

Before the time structure measurement, we measured the plateau characteristics under the various beam intensities. The picked up signals from the PPIC were integrated during 10 spills in order to reduce the statistical errors. Because of the fluctuation of C^{6+} beam intensities, we normalized the output signals of the PPIC by that from the reference monitor. We select the HIMAC ion chamber which is calibrated with Faraday cup as the reference monitor.

The charges from the PPIC were converted into voltage signals with current amplifiers and observed by a digital oscilloscope (HEWLETT PACKERD 54540A) triggered by the timing signal of beam extraction. The trans-impedance amplifier system is shown in Fig. 2. The pre-amplifier with high gain was designed for the fast component measurement of the PPIC signals. The absolute gain of the amplifier can be selected from 1 M, 10 M, 100 M, and 1 GΩ in order to realize a wide dynamic range of detector system. We compared PPIC signals with those of the 0.2 mm-thick plastic scintillation counter which has been used as a "Ripple Monitor" at just after the extraction point to investigate the time response of the PPIC.

3 PPIC Results

3.1 Detector Performance

The plateau curves of the PPIC for the C^{6+} beams (1.3×10^9, 1.9×10^8, 1.7×10^7 and 1.7×10^6 pps) are shown in Fig. 3. The charge signal from the PPIC normalized by that of the reference monitor should be independent of the variation of the beam intensity. The PPIC (3 mm gap distance) needs applied voltage of 300 V to reach the plateau region for the beam with intensity 1.3×10^9 pps. On the other hand, only 50 V is sufficient

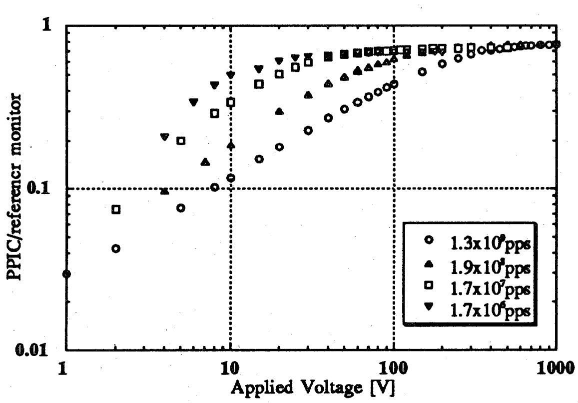

Fig. 3 The plateau curve of PPIC (3 mm gap distances) with 759.6 Torr-air for the beams of C^{6+} (290 MeV/u). The frequency modulation of RF-KO is 777 Hz. The ordinate is the ratio between the output charge from the PPIC and the reference monitor.

for that with the intensity 1.7×10^6 pps.

We conclude that the dynamic range covered with the PPIC is from the almost maximum intensity of C^{6+} beam at HIMAC (2×10^9 pps) to about 10^6 pps or somewhat wider.

3.2 Time Structure Measurement

We have measured the time structure of the RF-KO extracted beam intensity with PPIC. The time structure of the C^{6+} beams measured with PPIC (4.2 mm gap distance) and Ripple Monitor is shown in Fig. 4. The frequency modulation of RF-KO is 3 kHz, and we can see the beam ripple of corresponding frequency. Figure 5 shows the frequency spectra. Both detectors have the peak at 3 kHz and its harmonics in the frequency spectra. These components come from the repetition

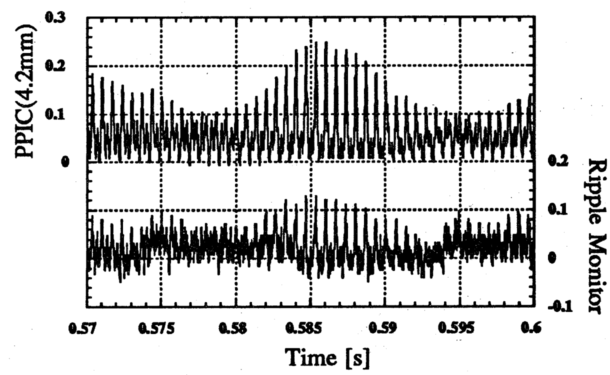

Fig. 4 Time structure measured by the PPIC (4.2 mm) with the 758.8 Torr-air (upper) and the Ripple Monitor (lower). The beam intensity is 5.7×10^8 pps C^{6+} (290 MeV/u) and the frequency modulation rate of RF-KO field is 3 kHz.

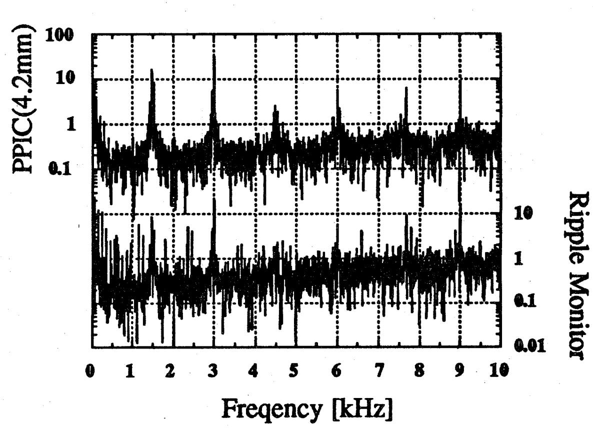

Fig. 5 Frequency spectra of the signals from the PPIC (4.2 mm) with the 758.8 Torr-air (upper) and the Ripple Monitor (lower). The repetition rate of the frequency modulation of RF-KO field is 3 kHz.

rate of the frequency modulation of the RF-KO field. Because the plastic scintillation counter is fast enough to respond the beam change in kHz order, it is concluded that our PPIC with air and its electric circuit achieve the kHz order time response.

4 Construction of Multi-Strip PPIC

We have developed the other type of PPIC that has the multi-strip electrodes in order to measure the profile of heavy ion beams. Figure 6 show the new multi-strip PPIC (MuSIC). The MuSIC has strip electrodes for the beam profile projected horizontal and vertical direction. The Music also has plane type 60 x 120 mm electrodes in order to measure the time structure of total beam intensity. The multi-strip electrodes are aluminized polypropylene, the surface aluminium of which is cut into many stripes with laser. Each strip width is 2 mm (minus 15 μm for cutting line width). These electrodes are fixed on the glass-epoxy frame and precisely set on the aluminum frame with guide pole and spacer.

Atmospheric-pressure air is chosen as the counter gas in the MuSIC because the response of air is fast enough to catch up with the beam ripple. And 4 mm gap distances is selected considering the S/N ratio and the voltage to reach the plateau region.

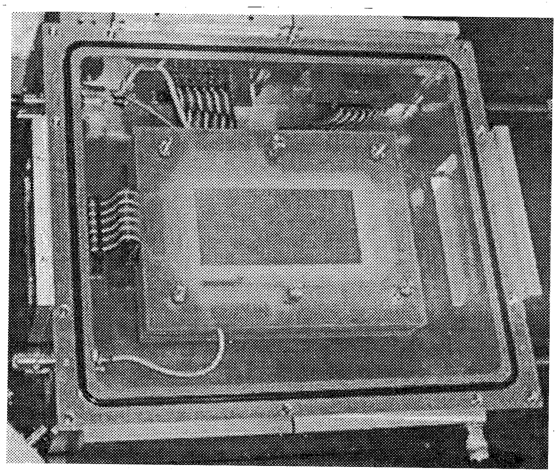

Fig. 6 The newly developed multi-strip PPIC (MuSIC).

5 Result of MuSIC

The horizontally projected profile of C^{6+} (290 MeV/u) beam is obtained from 30 strip electrodes. The pre-amplifiers with a gain of 10 MΩ convert current signals the voltage signals. These signals are multiplexed, and amplified by programmable gain amplifier, then measured with a digital oscilloscope

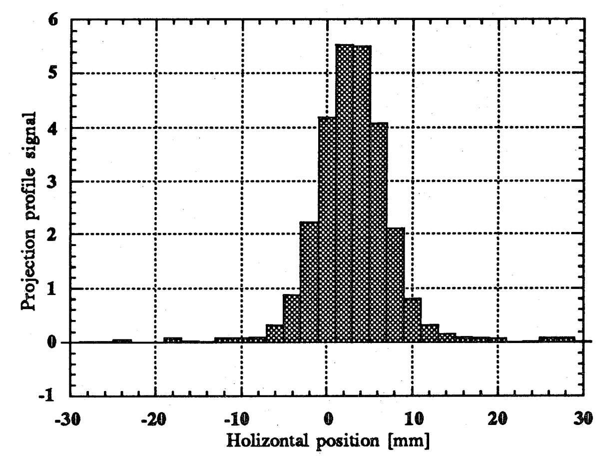

Fig. 7. The preliminary results of C^{6+} (290 MeV/u) beam profile. The beam intensity is 4 x 10^8 pps. The applied voltage of MuSIC is 500 V.

(Yokogawa DL1500L). The preliminary result of the profile measurement is shown in Fig. 7. The ordinate is the voltage of each strip signals, and the abscissa is the position for projection direction.

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