Secondary-Electron-Emission Type of Beam Profile Monitor for the HIMAC-Injector (6 MeV/u)

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Abstract

A beam profile monitor with the secondary-electron-emission phenomenon has been developed for radiation-biology experiments at the HIMAC (Heavy Ion Medical Accelerator in Chiba)–injector (RFQ + 100MHz Alvarez). It is basically composed of three thin electrodes whose effective area and gap distances are 32 × 32 mm^2 and 2 mm, respectively. 1 mm-thick Al foil is used as a central electrode. Electrodes on both sides are 2 mm thick alminized polypropylene films having a pattern of 16 strip-lines (1.5 mm wide and 0.05 mm spaced). These are, respectively, used for sensing vertical and horizontal profiles of secondary electrons emitted from the stripped electrode. It may be noted that the thickness of our beam profile monitor is very thin, i.e., the total amount of matter is less than 750 mg/cm^2. The charges induced in each strip-line is integrated with a respective pre-amplifier and the online beam profile is processed with a micro-computer. The sensitivity of the amplifier is determined by the beam intensity of the injector, i.e., 0.1 nA order. The overall characteristics of the beam profile monitor under the bombardment with 6 MeV/u α and C^{6+} ions from the HIMAC-injector are discussed.

1 Introduction

In the previous works, we reported a very thin secondary electron emission monitor (SEEM). It was designed as an intensity monitor for radiation-biology experiments, instead of the Faraday-Cup, and for studying the time structure of bunched heavy-ion beams from the HIMAC-injector in NIRS [1]. The relation between the secondary electron (SE) emission yields and vacuum-surface conditions was studied [2]. The relation between the SE emission yields and Atomic number (z) of various injected ions was also discussed [3].

The importance for beam profile monitors is now increasing in the radiation-biology experiments and accelerator physics. In the former case it is used to obtain the information on a precise irradiation intensity and its distribution. On the other hand, in the latter case the knowledge about the spatial distribution of accelerating particles is extremely necessary to study the beam tuning. In this case it is particularly desired the amount of matter for the monitor is as possible as little.

In the present work, we describe the outline of the developed two-dimensional SE emission type of beam profile monitor for the HIMAC-injector. Experimental results and characteristics are also presented.

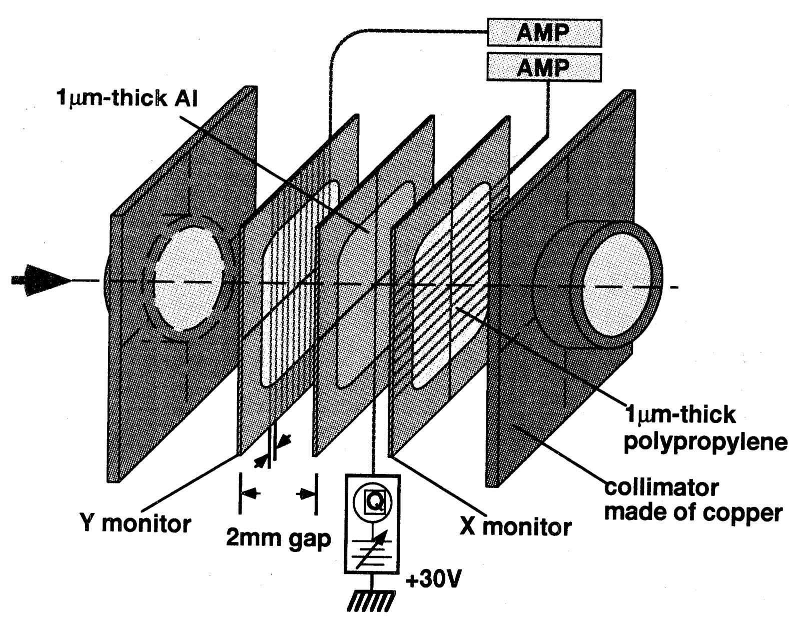

Fig. 1. Schematic view of the SE emission profile monitor. Two collimators made of copper and three foils whose thickness is 1 μm are shown.

2 Experimental Setup

Fig. 1 shows a schematic view of the present beam profile monitor. It consists of three electrodes which has 32 × 32 mm^2 active area, and two collimators. The arrangement of electrodes is the same as that in the previous SEEM [1]. The central electrode is 1 mm thick Al foil, attached 1 mm thick copper frame whose interior area is 32 × 32 mm^2. Other two electrodes having the pattern of 16 strip lines mounted in 2 mm thick ceramic frame placed at the both sides of the central electrode. The forming of pattern (1.5 mm wide and 0.05 mm spaced) is made with the laser cutting. These are used for the measurement of horizontal- (X) and vertical-profile (Y), respectively. Gap distance between the central and other electrodes is kept 2 mm with teflon spacers. Two collimators, made of copper and 2 mm thick, are placed outside inlet- and outlet-electrode. These are not only for limiting the beam size but also for adjusting the outside electric field of inlet- and outlet-electrode, i.e., they provide an adequate ground level to the outside electrodes of SEEMs with three electrodes.

The profile monitor was located in the vacuum chamber on the beam line, and operated under the vacuum of 10^{-6} - 10^{-8} Torr. It is connected to the integrated circuit through a "doubly-shielded coaxial cable" with a length of 5 m which would be effective to reduce the noise. Digitized signals from the data acquisition system are fed into the measurement room 40 m far from the accelerator room. The plus voltage was applied to the central electrode via Keithley electrometer. The inlet- and outlet-electrode were set in a ground level. Signals from total 32 strip-lines are individually fed into the pre-amplifier of the data acquisition system. Beam profiles in the X and Y directions per pulse are displayed as an online data. Fig. 2 shows a timing chart of the data acquisition system. A control signal of switching magnet located downstream the linac was used as a trigger signal of the acquisition system. In this system, minimum trigger repetition is 0.5 sec and sufficiently fast to the linac beams (1.67 Hz). While the gate signal of the acquisition system starts 250 nsec later than the trigger signal, this delay does not influence to the measurement error, e.g., less than 0.1 %. Any gate width of 100, 500 μsec and 1 msec can be selected by a rotary switch. Usually the beam is started about 700 μsec later than the trigger signal.

In the arrangement of applied voltage of our profile monitor, only SE electrons are emitted from surfaces of the inlet and outlet electrode facing the central electrode contributes to the signals, that is, SE from outside surfaces of them and both surfaces of the central electrode do not contribute to the signals.

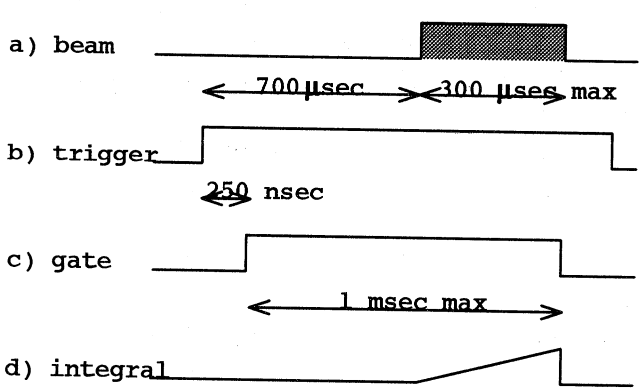

Fig. 2. Timing chart of data acquisition system. a) an input beam whose width are changeable in 5 – 300 μsec. b) a control signal of switching magnet downstream of the linac used as a trigger pulse. c) a gate signal generated in the data acquisition system. d) an output of integral charge connected to a computer. 250 nsec delay of the gate from the trigger is negligible.

3 Experimental Results

Fig. 3 shows the measured two beam profiles for C^{6+} heavy

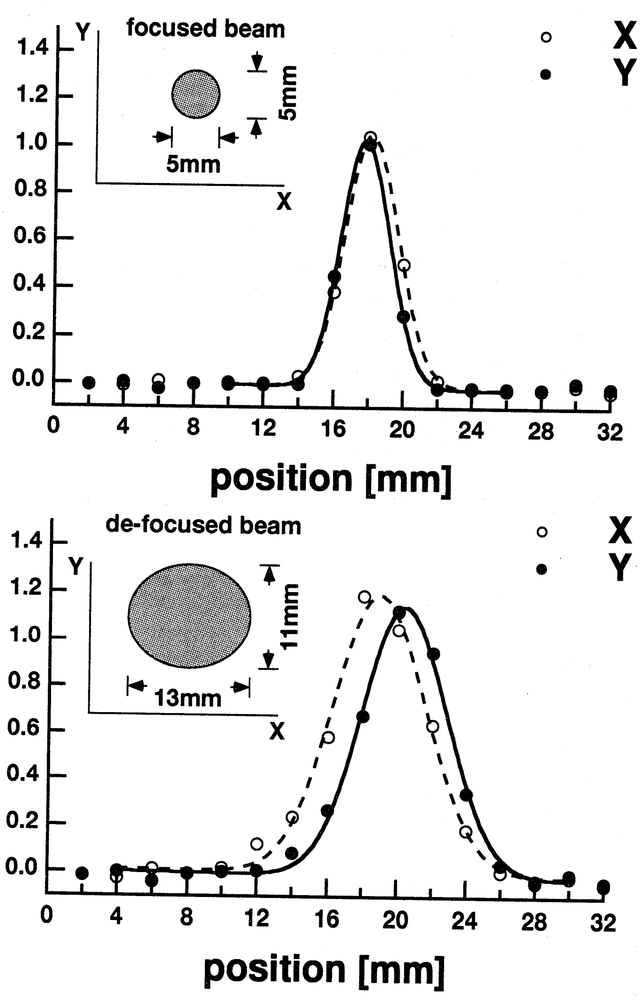

Fig. 3. Comparison of line shape with beam size. C^{6+} beam from linac was used. Beam was tuned for upper: focused circle shape and lower: defocused ellipse one.

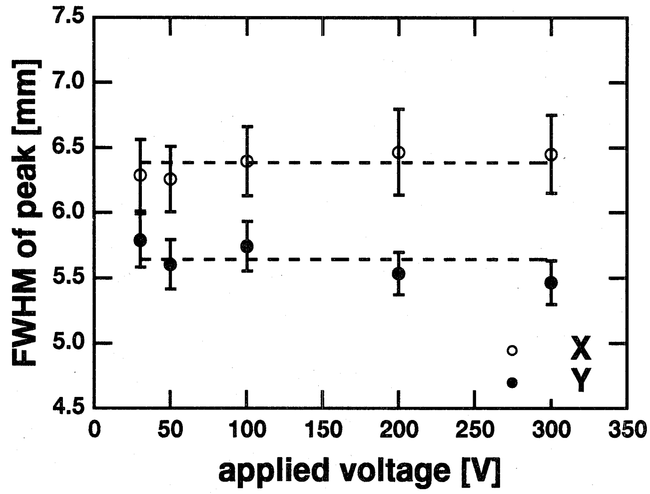

Fig. 4. Voltage dependence on line shape. Full width at half maximum (FWHM) of profile are shown at 30 – 300 V on electrode. Shapes of profile measured at X and Y foils can be regarded as gaussian for example in Fig. 3.

ions from the HIMAC-injector. While beams are tuned like a focused circle shape or like a defocused ellipse one, the precise information about the beam profile can be obtained as indicated in the figure. These beam profiles are also confirmed by the dose sensitive paper. The full width at ninth maximum are given in the upper left corner in each figure. As shown in the figure, the both profiles agree with each other very well.

While, in the previous experiment, it is found that the kinetic energy of SE is almost less than 20 eV [1], the characteristics of emission yield versus operation voltage should be in detail investigated. The operation voltage was applied up to 300 V. Fig. 4 shows the relation between the full width at half maximum (FWHM) and operation voltage. There is no change due to the

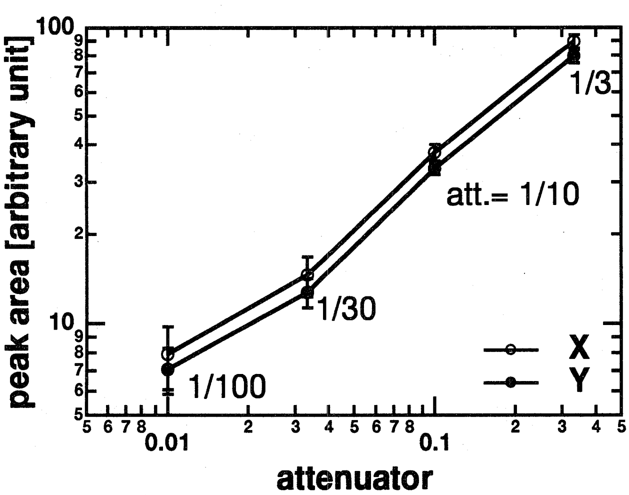

Fig. 5. Attenuator dependence on peak area. Attenuation factors indicated at its control panel are shown. Beam intensity was about 8 μA at peak and 50 μsec width of beam pulse in this measurement.

operation voltage in the range of 30 - 300, 30 V on electrode voltage is enough to collect the emitted SE.

The yield characteristics of SE emission from metalized films have a good linearity for the beam intensity [1]. To study the beam intensity dependence on the yield an attenuator was inserted into the beam line. Before inserting the attenuator the beam intensity at the peak was 8 μA (the pulse width of 50 μsec). By inserting various attenuators the beam with the intensity of 1/3, 1/10, 1/30 and 1/100 of the original beam can be obtained. As shown in Fig. 5, the present beam profile monitor can be used in the range of beam intensity of 100 times. In addition the attenuation factors measured were consistent with the above designed ones.

4 Summery

We have developed a very thin SE-emission type of beam profile monitor with an effective area of 32 × 32 mm^2 for heavy ion at the HIMAC injector. Two-dimensional profile information is obtained with electrodes having 16 strip-lines, which are 1.5 mm wide and 0.05 mm spaced. Basic characteristics of the profile monitor are tested in the vacuum of 10^{-6} to 10^{-8} Torr under the bombardment with α and C^{6+} ions with an energy of 6 MeV/u. It was found that the dependence of operation voltages is found to be negligible small, i.e., in the operation voltage of 30 V to 300 V the yield is constant. By changing the beam intensity, we confirmed the monitor is usable for the beam intensity of a 0.1 nA level. Since the amount of matter of the monitor is very little, it may be applied to the therapy with the HIMAC beam.

Acknowledgement

The authors are very gratefull to Dr. T. Honma, HIMAC operators, Mr. T. Owada of Antex Ltd., Mr. M. Mitani of Minotos Ltd, Mr. T. Kadowaki and Mr. J. Yoshizawa of Kaizu Works Ltd. This experiment was performed under 11p-009 of Research Project with Heavy Ions at NIRS-HIMAC, which has been supported by the Science and Technology Agency of Japan.

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