Basic Design of Beam Diagnostic Device for Injection Line of the JAERI Tandem Accelerator

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Abstract

Basic design of beam diagnostic device has been made for the injection line of JAERI tandem accelerator. The device can measure distribution of beam flux in the four-dimensional phase space. The measurement is made with scanning phase space by two deflectors and counting incident particles shifted to the center of beam line by the deflectors.

1 Introduction

Distribution of a particle beam on the phase space is one of concerns in an accelerator system. (The phase space means a space of showing position and direction of particles here.) In the JAERI tandem accelerator, many kind of ion species from light ions to heavy ions like gold are injected to the tandem from one of 3 negative ion sources. We must tune these injection beams to transport them through the tandem. This task is done by manual tuning with observation of beam profile monitors and Faraday cup current readings in the present. But the following method is more straightforward. In the method, we first measure a phase space distribution of the incident beam. After that, we tune optical elements of the upstream to give the distribution of the beam that the accelerator can accept. This method needs an instrument to measure the distribution. For the daily operation of the accelerator, the measuring time must be short. Previously, Tajima and others have made measurements of emittance of the incident beam for the tandem [1]. The purpose of the work was mainly knowing emittance value and not intended to use on daily accelerator operations. Its measurement time was very long. So we have started development of a new instrument for the method in the injection line of the tandem.

2 Design objectives

We set following design objectives, considering the instrument will be set in the injection line of the tandem and used in daily accelerator operation.

a. Size: the instruments can be set in the space of the injection line of the tandem.
b. Energy and charge state of Particle: 220KeV and minus 1 nominal.
c. Dimensions: Enables 4 dimension measurements. The instruments can measure distribution of beam in 4 dimensional phase space, that is X-X'-Y-Y' space.
d. Resolution of position: About 0.3 mm.
e. Resolution of direction: Less than 0.3mrad.
f. Scan range of position: Wider than ±10mm.
g. Scan range of direction: Wider than ±8mrad at the center of the beam line.
h. Measuring time: Less than 30seconds for coarse measurement.
i. Typical beam current : 10nA to 1 μA.

One of the typical characteristics were about 16mm·mrad for the emittance and 15mm for width of the beam of the injection line[1]. The result is used to estimate the density of the beam.

3 Design Policy and Construction

We considered using collimetor which define position and gradient of beam current in X and Y axis. The measurement is made by scanning position in the phase space which pass through the collimetor. Measuring speed is very important in our case. So, mechanical scanning is avoided and scanning by electric method is suitable. Electrostatic scanning is selected because the energies of particles for deferent ion species are constant and low. Electrostatic field is independent from mass of particles. Because expected electrical current through the collimetor is very small and integration of electrical current is time consuming, we decide to measure the counting rate of particles through the collimetor.

The above policy leads a construction showing Fig.1. From the up stream, the first electrostatic deflector, the second electrostatic deflector, the first aperture, the second aperture and a particle counter are aligned. The two apertures are set in the center of beam line and they form a collimeter. Combination of the two deflectors works as beam shifter and deflector. It selects a part of the beam to shift to the center of the phase space, which pass through the collimetor. In this configuration, other devices for the accelerator namely slits and or Faraday cups can be set among the elements after the second deflector.

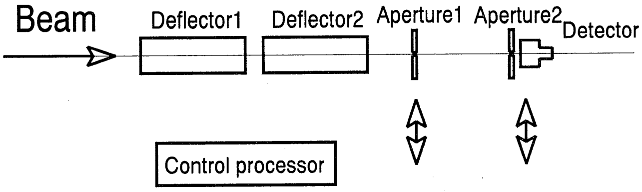

Fig.1 Construction of Beam Diagnostic Device:
The apertures and the particle detector are retracted from the beam course when a measurement is not made.

4 The Deflectors

We started the design of the deflectors from parallel plate deflector. Characteristic of the deflector is as follows.

$$\Delta X' = (q \cdot V \cdot l)/(2d \cdot E) \quad (1)$$

$$\Delta X = (q \cdot V \cdot l^2)/(4d \cdot E) \quad (2)$$

Where $\Delta X'$ and ΔX show change of gradient and change of position which caused by the deflector at its end point respectively. E and q are the energy and the charge of the particle respectively. V, l and d are the voltage, the length and the gap width of the deflector respectively. For faster scanning, deflection voltage V needs to be lower. So, the length, l is desired to be longer. We think about combining two deflectors for different direction, X and Y into one deflector. Figure 2 shows concept of a shroud type deflector, which can deflect beam in either X and Y directions. The shroud deflector consists of thin wire electrodes stretched between two insulator frames, forming a box shape. The wires are connected to the next wires with resisters. The amounts of deflection for X and Y directions are added or subtracted and fed into the corner wires. In the box shaped area, parallel electrostatic field is obtained with exception of disorders near the wires and the field is a superposition of fields obtained with application for X or Y deflections separately. In our design, parameters of l = 600mm and d = 50mm are selected for the deflectors. Maximum deflection voltage of 1KV is selected. It is in the range where a high-speed amplifier is available in a moderate cost. The deflector has another merit that a loading effect of the beam current is very small.

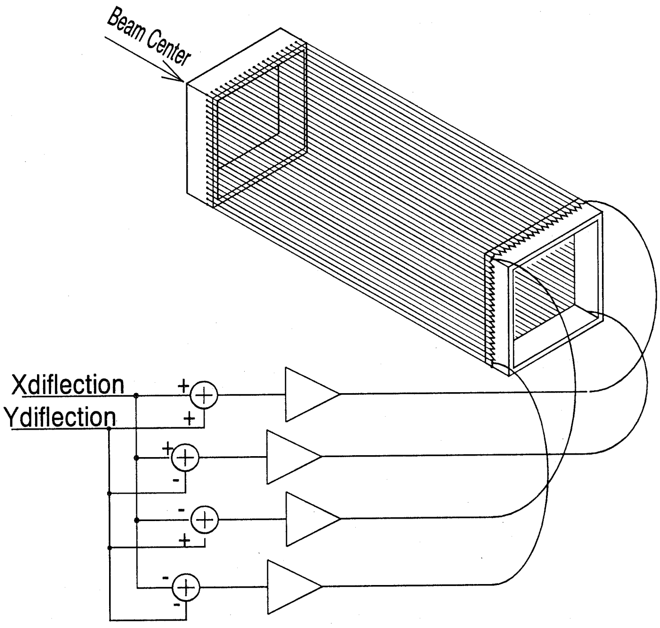

Fig.2 Shroud Type Deflector

5 Collimeter

The design of the collimeter is restricted by resolution for position and direction of measurements and counting rate of the particle detector. From the resolution, two apertures of 0.2mm×0.2mm with an interval of 1000mm are enough. On the other hand, typical flux of the particle through the collimeter for the incident beam of 1 μA is expected to be about 4×10^7counts/seconds from the work by Tajima etc.[1]. This counting rate is too large for a particle detector described later. Sizes of apertures should be selected for appropriate counting rate.

6 Detection of Particles

Particle through the collimeter hits an appropriate target material and generates secondary electrons, which are amplified by a micro channel plate (MCP). To get higher permissible counting rate, the secondary electrons must be scattered to the active area of the MCP. We expect maximum counting rate of about 10^6counts/second with an appropriate optical design and usage of a low resistance and small-pore MCP. This counting rate means that we can obtain 10^3counts in 1milli-seconds. The collimeter will be optimized to limit the counting rate.

7 Scan Algorithm and Control Processor

This device scans a beam profile in the 4 dimensional phase space. The space is too large for the device to scan corner to corner. So, scanning algorithm is very important.

We are considering two steps scan, where a coarse scan is made in the first step and secondly a fine scan is made in the region where beam current is detected in the coarse scan. It is another problem to display a result of the scan with 4 parameters. But in many cases, representations of two density maps in position and direction of axis, integrated for the other axis are enough.

A control processor is needed to establish complicated scanning algorithm. The deflection voltages of deflectors are controlled by the processor through digital to analog converters(DAC's). The processor also has a counter and a timer to measure flux in the channel. And the processor must be fast to enable a fast measurement. We hope the processor can output new setting values for the deflectors every several microseconds.

8 Conclusion

The basic design work of beam diagnostic device for the injection line of the JAERI tandem accelerator has been discussed. The device has been designed for daily accelerator operation. But, the distribution measured by the device in the four-dimensional phase space may give us new information about ion sources.

References

[1] S. Tajima et al., "タンデム加速器入射ビームのエミッタンス測定(Emittance Measurement of Incident Beam of JAERI Tandem Accelerator)", JAERI-memo 02-104