COMPACT AND COMPLETE BEAM DIAGNOSTIC SYSTEM FOR HCI AT IUAC

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Abstract

Design efforts result into the fabrication of a compact and complete beam diagnostic system for High Current Injector (HCI) accelerator system [1] at Inter-University Accelerator Centre (IUAC), New Delhi, India. HCI is an upcoming accelerator facility and will be used as an injector to the existing SC-LINAC. It consists of high temperature superconducting Electron Cyclotron Resonance (HTS-ECR) ion source [2], normal temperature Radio Frequency Quadrupole (RFQ), IH-type Drift Tube Linear (DTL) resonators [3] and low beta superconducting quarter wave resonator cavities to accelerate heavy ions having $A/q \leq 6$. The diagnostic system is especially designed and fabricated to get the complete beam information like current, profile, position, transverse and longitudinal emittances, bunch length and energy of incident ion beam at the entrance of DTL resonators. The compactness is preferred to minimize the transverse and longitudinal emittance growth at the entrance of DTL resonators. Various beam parameters of heavy ion beams at different energy have been carried out to validate the design and fabrication of the system. Here, the design, fabrication and various test results are presented.

DIAGNOSTIC SYSTEM FABRICATION

Compact Diagnostic System

A compact diagnostic box in Fig.1 is made of 10 mm thick stainless steel material. As the drift space between two DTL cavities is crucial, to accommodate the diagnostic chamber and quadrupole triplet, we need to minimize the drift. A highly compact diagnostic chamber has been designed and fabricated indigenously at IUAC. The diagnostic chamber is of 70 mm longitudinal length. The radial dimension of the box is approximately 160 mm and the beam aperture is 20 mm. The diagnostic box is circular in shape. There are four ports available in the box. Three will be used for Faraday cup, slit scanner and capacitive pick-up. One is left for pumping purpose. The chamber was leak tested at the leak rate of $1x10^{-11}$ mbar.l/s. Without any separate pumping station, the vacuum of $1x10^{-7}$ mbar was achieved, but this can be further improved by adding a separate pumping station.

Faraday Cup

A water cooled Faraday cup (FC) has been fabricated to measure the current. The cup has a beam aperture of 25 mm and its length is 20 mm along the beam direction (Fig. 2). It is made of Oxygen Free High Conductivity (OFHC), copper material. Based on the expected beam power from HCI the FC is designed for few hundred watts of beam power. The suppressor ring, which retains the secondary electrons on the cup, is made of SS 304 material. The FC is completely shielded by the 3 mm thick tantalum sheet. The linear movement of FC is controlled by a pneumatic cylinder, which provides the 60 mm strokes in the diagnostic box.

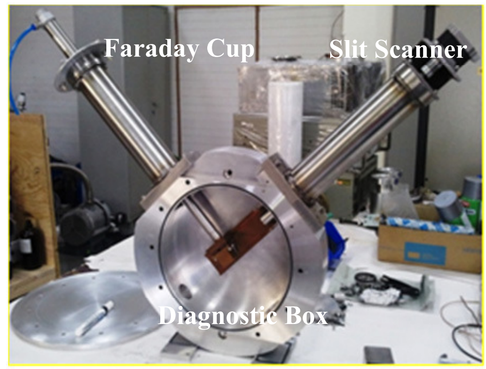

Figure1: Compact diagnostic box.

Figure 2: Faraday cup.

It can be used to measure the current of the order of few nanoamperes to hundreds of microampere current.

Slit Scanner

The slit scanner in Fig. 3 is fabricated indigenously for the measurements of beam positions and beam profiles in HCI beam line. It scans the beam in two transverse directions with the help of two 500 micron slits. The slits are made orthogonal to each other and moves linearly in such a way that they cut the ion beam in x and y directions. The linear motion of the slit scanner is done by a computer controlled stepper motor. The microcontroller programming and data processing have been done with the help of LabVIEW programs. It is possible to see the online beam profiles on the two dimensional graphs of the beam intensity versus the beam positions.

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Figure 3: Slit scanner.

Capacitive Pick-up

The compact diagnostic box will also consist of capacitive pick up for bunch length measurement at the entrance of DTL resonators in Fig. 4. This will be installed opposite to the Faraday cup. Once the Faraday cup will be taken out, the pick up will be moved in along the beam centre. The capacitive pick-up is designed for relative velocity (ß)~0.05 and it is under fabrication process. The time of flight will also be measured between the DTL resonators with the help of capacitive pick-up.

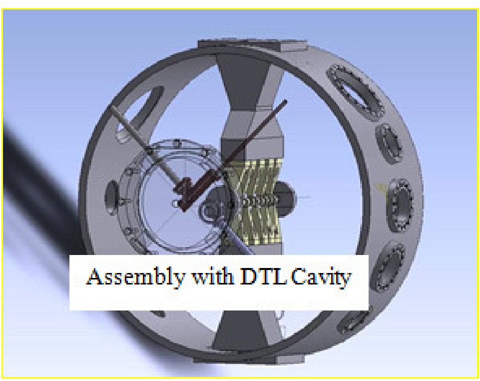

Figure 4: Design assembly of compact diagnostic box with DTL.

ONLINE BEAM TEST SET -UP

Diagnostic Box Installation in LEIBF

The prototype compact diagnostic box, along with the Faraday cup and slit scanner, were installed in the Low Energy Ion Beam Facility (LEIBF) at IUAC in Fig.5 to perform the online ion beam test and validate the various design parameters.

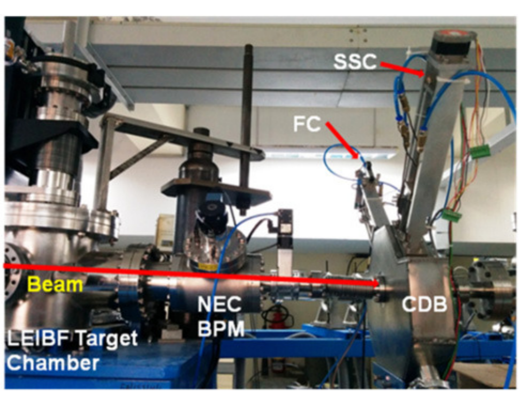

Figure 5: Prototype Diagnostic Box installed at IUAC LEIBF beam line.

The beam profile and current measured by the diagnostic system matched very closely to the one measured by the National Electrostatics Corporation (USA) made FC and BPM devices. The diagnostic system was further verified by the measurements of currents and beam profiles of the various ion beams such as N and O ion beams with different energy and currents. All the results demonstrated good agreement with those measured by standard devices confirming the operational aspect of the system.

Online Beam Test Set-up

A Keithely 6517 B electrometer is used to measure the ion beam current directly from the Faraday Cup. There is GPIB to USB connector, which connects the electrometer to CPU. The stepper motor controller was also connected to CPU by USB connector. The Faraday cup will give the current values and stepper motor provides the position information. The current signal from the Faraday cup can also be displayed on the control panel by using log amplifier. The linear motion of the slit scanner has been controlled by the stepper motor controller unit which is connected to a computer running the LabVIEW program in Fig. 6. When the scanner moves, FC collects the charged particles passed through the slits. It provides current signal and thus measures the ion beam current intensity vs the beam position.

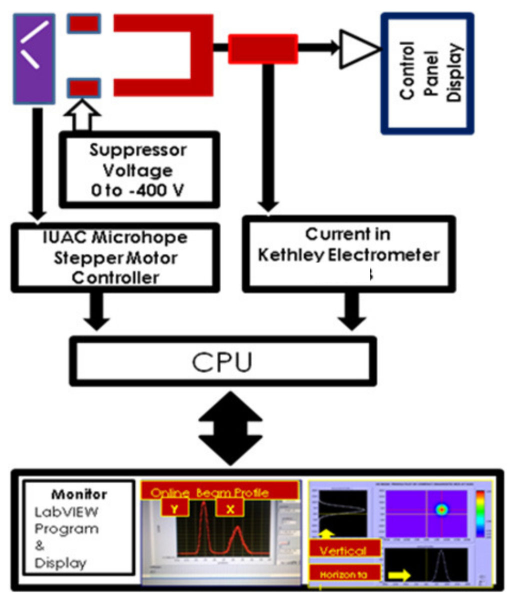

Figure 6: Electronic set up.

RESULTS AND DISCUSSION

The beam current and profile measurements of various heavy ion beams at different energy have been carried out to validate the design and fabrication of the Faraday cup and slit scanner. We have tested the Faraday cup and slit scanner by measuring the current and profiles of various ion beam viz. Nitrogen and Oxygen at different energy and current. The experimental details and its results are given below.

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Beam Parameters Measurements

The Faraday cup and beam profile monitor have been tested and verified with the following ion beams. (Table1).

Table1: Current Measurement by Faraday Cup

Ion Beam	Energy (keV)	Current (FC) (μA)	Current (NEC) (μA)
N^{1+}	250	72.5	74
N^{5+}	1250	1.3	1.3
O^{1+}	250	2.77	2.77
O^{5+}	1250	0.421	0.421

Nitrogen and Oxygen Ion Beam Test

The determinations of beam profiles through the slit scanner have been carried out for N and O ion beam in the material science beam line. The measurements of various types of the beams at various energies and current are really useful for the evaluation of the performance of the various optical devices installed into the beam line [4-8]. The results are shown in the following in Fig. 7.

The lower as well as higher currents were measured by the Faraday cup very accurately from tens of picoamperes to few hundreds of microamperes. Various ion beam profiles, obtained with the LabVIEW program, provide the digital signature of the charged particles distribution, i.e. the current intensity along the ion beam positions.

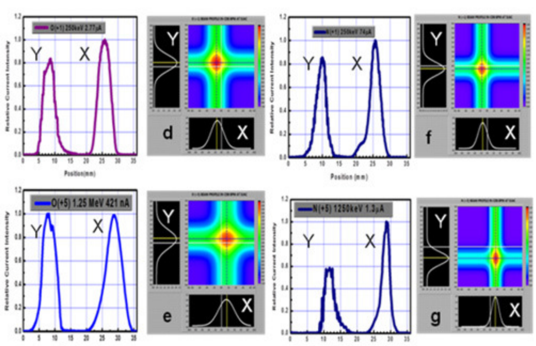

Figure 7: Beam profiles.

The experimental results provide the information not only on the beam current, profile and spot size but the beam positions also. The Oxygen and Nitrogen ion beam profiles along with their positions from the centre point of the beam line are shown above.

CONCLUSIONS

We have developed indigenously a very compact diagnostic system, which can replace any conventional beam diagnostic components in the beam line. The motivation behind the development of such devices came to investigate and avoid the beam losses in the low energy ion beam line section of an accelerating system. The low cost, high accuracy, high reliability and simplicity are the figures of merit of this system. This system plays a significant role in the current measurements and beam tuning to enhance the performance of accelerators by providing the good quality beam, especially at the entrance of each DTL cavities in the HCI accelerator system.

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REFERENCES

[1] A. Roy, Curr. Sci.76, 149(1999).

[2] G.Rodrigues, P.S.Lakshmy, Sarvesh Kumar, A.Mandal and D.Kanjilal, Rev. Sci. Instrum. 81, 02B713 (2010).

[3] R. Mehta, J. Sacharias, R.V. Hariwal et .al, Design Validation of IH Type Drift Tube Resonator at IUAC in ADS conference 2011, BARC, Mumbai, India.

[4] Valery Dolgashev et al, Appl. Phy. Lett. 97,171501 (2010).

[5] O.Kamigaito, M.Kase, N.Sakamoto,Y.Miyazawa, Eikezawa et al., Rev. Sci. Instrum.76, 013306 (2005).

[6] R.B. Fair, J. Phys. E: Sci. Instrum. 4, 35 (1971).

[7] Probyn B. A., J. Appl. Phys.D:Appl.Phys. 1, 457-65 (1968).

[8] Jacob L Phil, Mag. 28, 81-85 (1939) [1]Peter Fork, Lecture Notes on Beam instrumentation And Diagnostics, Joint University Accelerator School, 2008.

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