DESIGN, FABRICATION AND TESTING OF COMPACT DIAGNOSTIC SYSTEM AT IUAC

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Abstract

High Current Injector (HCI) [1] is an upcoming accelerator facility at Inter-University Accelerator Centre, New Delhi, India. This comprises 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 (QWR) cavities to accelerate heavy ions having $A/q \leq 6$. The compact diagnostic system consists of Faraday cup, slit scanner and capacitive pick up to measure the current, profile, position and bunch length of incident ion beam respectively. It is especially designed and fabricated to measure the beam parameters at the entrance of each of six IH-DTL resonators. The compactness is preferred to minimize the transverse and longitudinal emittance growth at the entrance of DTL resonators. 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 diagnostic system. Here we are presenting the detailed information about its design, fabrication and various test results.

DEVELOPMENT OF COMPACT DIAGNOSTIC SYSTEM

Compact Diagnostic Box (CDB)

A compact diagnostic chamber (Fig.1) is made of 12 mm thick stainless steel (SS-304) 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. 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. It has eight faces, in which two of them are orthogonal to each other and they have been designed specifically to mount the Faraday cup and slit scanner. The chamber was leak tested at the leak rate of 1×10^{-11} mbar.l/s. Without any separate pumping station, the vacuum of 1×10^{-7} mbar was achieved, but this can be further improved by adding a separate pumping station.

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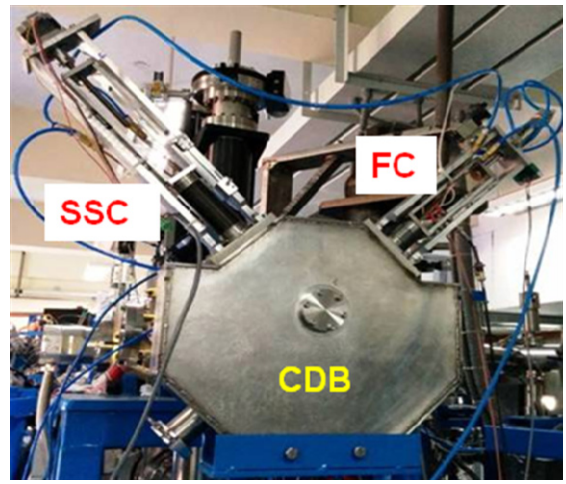

Figure 1: Compact Diagnostic Box.

Faraday Cup (FC)

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.

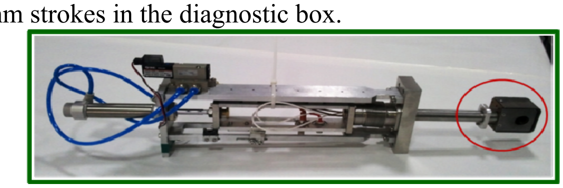

Figure 2: Faraday Cup.

It is a very compact design and can be used to measure the current of the order of few nanoamperes to hundreds of microampere current.

Slit Scanner (SSC)

The slit scanner (Fig. 3) is fabricated indigenously for the measurements of beam positions and beam profiles in HCI beam line. It scans the beam in both 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.

ISBN 978-3-95450-131-1

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.

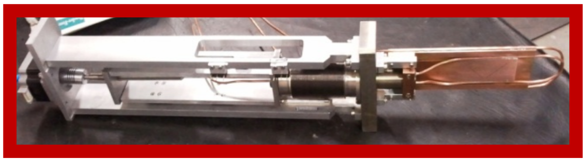

Figure 3: Slit Scanner.

It is possible to see the online beam profiles on the two dimensional graphs of the beam intensity versus the beam positions. The linear movement and position can also be controlled with two limit switches.

EXPERIMENTAL SET-UP FOR ONLINE BEAM TEST

Diagnostic Box Installation in LEIBF

HCI development is underway so the compact diagnostic box, along with the Faraday cup and slit scanner, was installed in the Low Energy Ion Beam Facility (LEIBF) at IUAC (Fig.4) to perform the online ion beam test.

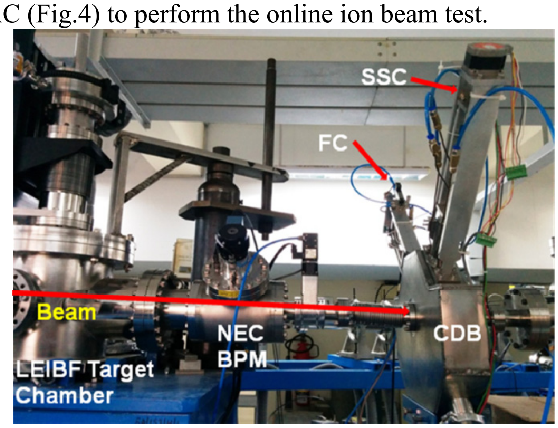

Figure 4: Diagnostic installed at IUAC beam line.

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. 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 (Fig 5).

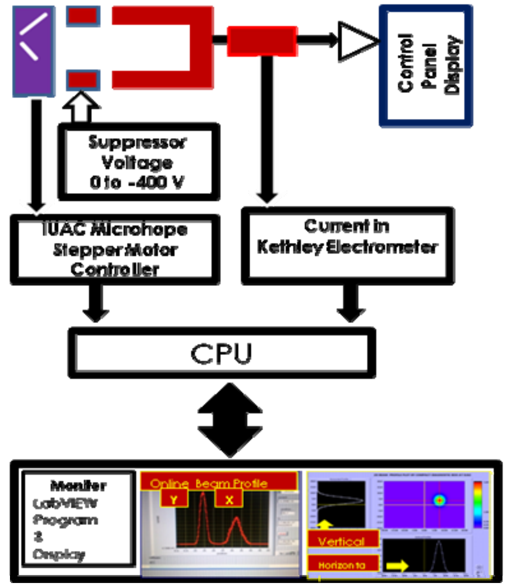

Figure 5: Electronic set up.

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.

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.

Beam Profile and Beam Position Measurements

The Faraday cup and beam profile monitor have been tested and verified with the following ion beams. (Table 1).

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

ISBN 978-3-95450-131-1

the various optical devices installed into the beam line [4-8]. The results are shown in the following figure (Fig.6).

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.

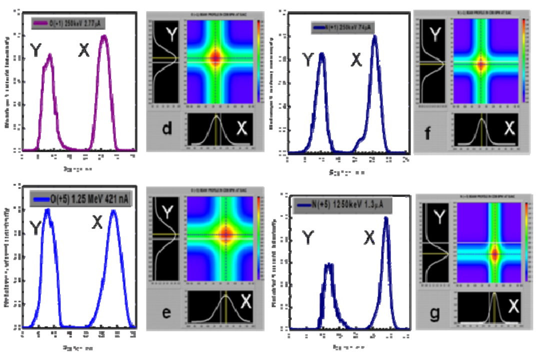

Figure 6: Beam Profiles.

The experimental results provide the information not only on the beam 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.

ACKNOWLEDGEMENTS

The author would like to acknowledge the IUAC workshop to provide the machining and welding facilities during the fabrication of complete diagnostic system. The author is also thankful to the Director, IUAC New Delhi for giving the permission for installation of diagnostic system and online testing with the various ion beams in LEIBF. Lia Merminga, R. Laxdal and Josef Holek from TRIUMF Canada are specially acknowledged for their support and fruitful technical suggestions.

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ISBN 978-3-95450-131-1