IMPROVEMENT IN BEAM TRANSMISSION THROUGH THE FOLDED TANDEM ION ACCELERATOR AT BARC

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Abstract

The 6 MV Folded Tandem Ion Accelerator (FOTIA) facility at BARC is operational since April, 2000 and accelerated beams of both light and heavy ions are being used extensively by various divisions of BARC, Universities, IIT Bombay and other R&D labs across the country for basic and applied research in the fields of atomic & nuclear physics, material science and radiation biology etc. Earlier, poor beam transmission through the 180^o folding magnet was a matter of concern for a long time. A systematic study for beam transmission through the accelerator was carried out and progressive modifications in folding magnet chamber, foil stripper holder and improvement in average vacuum level through the accelerator have resulted in large improvement of beam transmission leading to up to 2.0 micro-amp analyzed proton beams on target.

INTRODUCTION

As the FOTIA [1] is an upgraded version of the old 5.5 MV single stage Van-de-Graaff accelerator which was designed with lots of constraints due to existing building and infrastructure. The negative ions from SNICS source are bent through 90^o using a 70^o injector magnet followed by a 20^o electrostatic deflector into the vertical accelerating column. Inside the terminal, the ion beam pass through a thin carbon foil stripper and lose electrons and acquire positive charges. The resulting positive ions now are bent through 180^o by the magnet placed inside the terminal and then enter the high energy stage of acceleration. The beam is transported through series of diagnostic and corrective components and finally transported under UHV environment to experimental chamber in the beam hall through a five-port switching magnet. The beam hall has three operational beam lines.

Figure 1: FOTIA Column

BEAM TRANSMISSION STUDIES

Study of Folding Magnet Chamber

The Folding magnet plays a crucial role of selecting the required positive charge state. It can be observed (table 1) that the transmission through the 180^0 magnet in the terminal is very poor (less then 10%) and no other reason for this observation could be given except the small vacuum chamber size. In this study, we tried to find out the possibility of improving the transmission through 180^0 magnet by increasing the total air gap of the magnet.

Table 1: Typical Proton Beam Transmission through the accelerator before Modification at 2 MV Terminal

Location of Beam Current Measurement	Intensity
FC #1 (Total Current from Ion Source)	900 nA
FC #2 (Analyzed current)	300 nA
FC #3 (Injection in Machine)	270 nA
FC #4 (Entry port of Folding Magnet)	160 nA
FC #5 (Post 180^0 Magnet)	25 nA*
FC #6 (Pre-Analyzing Magnet)	18 nA
FC #7 (Post Analyzing Magnet)	10 nA
FC #8 (Pre-Switching Magnet)	10 nA
FC #9 (Before Scattering Chamber)	10 nA
FC #10 (On Target)	10 nA

* Beam entry to magnet needs to be changed for optimum transmission from FC#4 to FC #5.

The original 180^0 magnet was designed for maximum ME/q^2 of 10, with chamber size 9 mm x 14 mm and B_{max} =1.4 Tesla for a current of 100 Amp. Keeping amp-turns unchanged an exhaustive studies were carried out to get a reasonable yield of most probable charge states of Lithium, Boron, Carbon and Fluorine ions for whole range of terminal voltages. The air gap was increased from 14 mm to 20 mm to achieve B_{max}=1.08 Tesla and ME/q^2 =4.9. This resulted in around 10% increase in the beam transmission and hence it was concluded that chamber size is not the reason for the poor transmission.

Study of beam transmission for un-stripped ions through Folding Magnet

Effect of Injection Parameters

A systematic study was done for transmission of un-stripped (negative ion beams) through the folding magnet (Figure 2) for different set of injection parameters. The intensities of beam at different locations are shown in Figure 3.

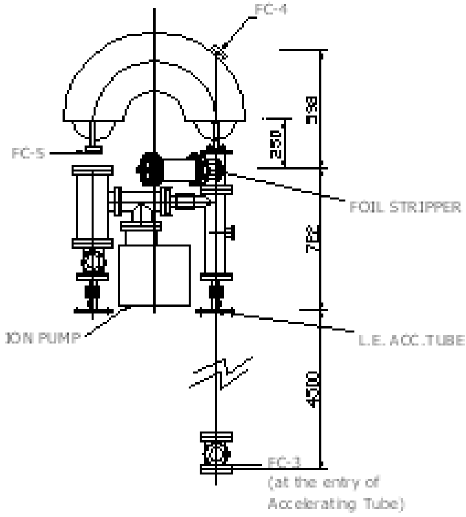

Figure 2: Layout of the Folding Magnet section

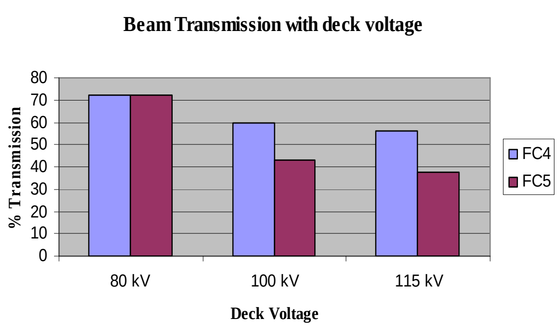

Figure 3: Percentage Beam Transmission wrt injection current for Un-stripped (H^-) Beam at 2 MV terminal

Effect of Stripper Size

The study of different stripper size (e.g. 10, 15, 20 mm and no holders) without carbon foils was carried out and the results are plotted in Figure 4. The transmission through bigger stripper size resulted in gradual increase in beam transmission for higher injection energies also.

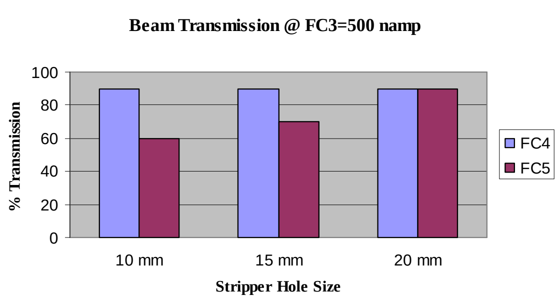

Figure 4: Percentage Beam Transmission wrt injection current (FC#3) for un-stripped (H^-) beam

Improvement in Vacuum in Folding Magnet

As the FOTIA beam lines have many narrow chambers for different magnets, accelerating tubes apertures etc., a distributed vacuum system [2] consisting of turbo pumps and Triode sputter ion pumps are used. The vacuum level in folding magnet area has been improved to the range of 10^{-8}-10^{-9} torr by providing additional turbo pump near analysing magnet. This has resulted in better beam transmission and minimum beam energy spreads.

OBSERVATIONS AND CONCLUSIONS

Based on all these investigations, the experimental data shows that there is a mismatch of physical axis and magnetic axis of the folding magnet which could be corrected by providing a pair of steerer used in dog leg configuration but due to space limitation this couldn't be implemented. The graphical representation of beam with respect to foil stripper for acceptable folding magnet axis is shown in the Figure 5, where it clearly shows that the acceptable beam axis is about 9 mm away from the physical axis of the tube and core of the beam was getting cut by the 5 mm wide steel frame. The problem has been resolved by adopting a modified stripper holder assembly which has minimum edge thickness and can accommodate bigger foil with supporting grid for making it self supporting. After this modification, the beam transmission has improved considerably and Proton beams up to 2 micro-amp has been delivered to users for irradiation experiments.

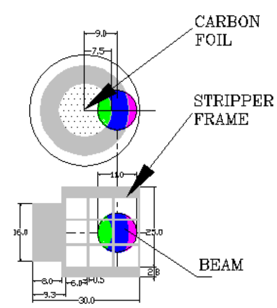

Figure 5: Beam position wrt holder and new foil holder

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