

## 6 MV FOLDED TANDEM ION ACCELERATOR FACILITY AT BARC

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### Abstract

The 6 MV Folded Tandem Ion Accelerator (FOTIA) facility is operational round the clock 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. The FOTIA (Figure 1) is an upgraded version of the old 5.5 MV single stage Van-de-Graaff accelerator (1962-1992). Since its commissioning in the year 2000, the poor beam transmission through the 180° folding magnet was a matter of concern. 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. Now the utilization of the beams from the accelerator has increased many folds for basic and applied research in the fields of

atomic & nuclear physics, material science and radiation biology etc. Few new beam lines after the indigenously developed 5-port switching magnet are added and the experimental setup for PIXE, PIGE, External PIXE, 4  $\pi$  neutron detector, Proton Induced Positron Annihilation Spectroscopy (PIPAS) setup and the general purpose scattering chamber etc have been commissioned in the beam hall. The same team has developed a Low Energy Accelerator Facility (LEAF) which delivers negative ions of light and heavy ions for application in implantation, irradiation damage studies in semiconductor devices and testing of new beam line components being developed for Low Energy High Intensity Proton Accelerator (LEHIPA) programme at BARC. The LEAF has been developed as stand alone facility and can deliver beam quickly with minimum intervention of the operator. Few more features are being planned to deliver uniform scanned beams on large targets.

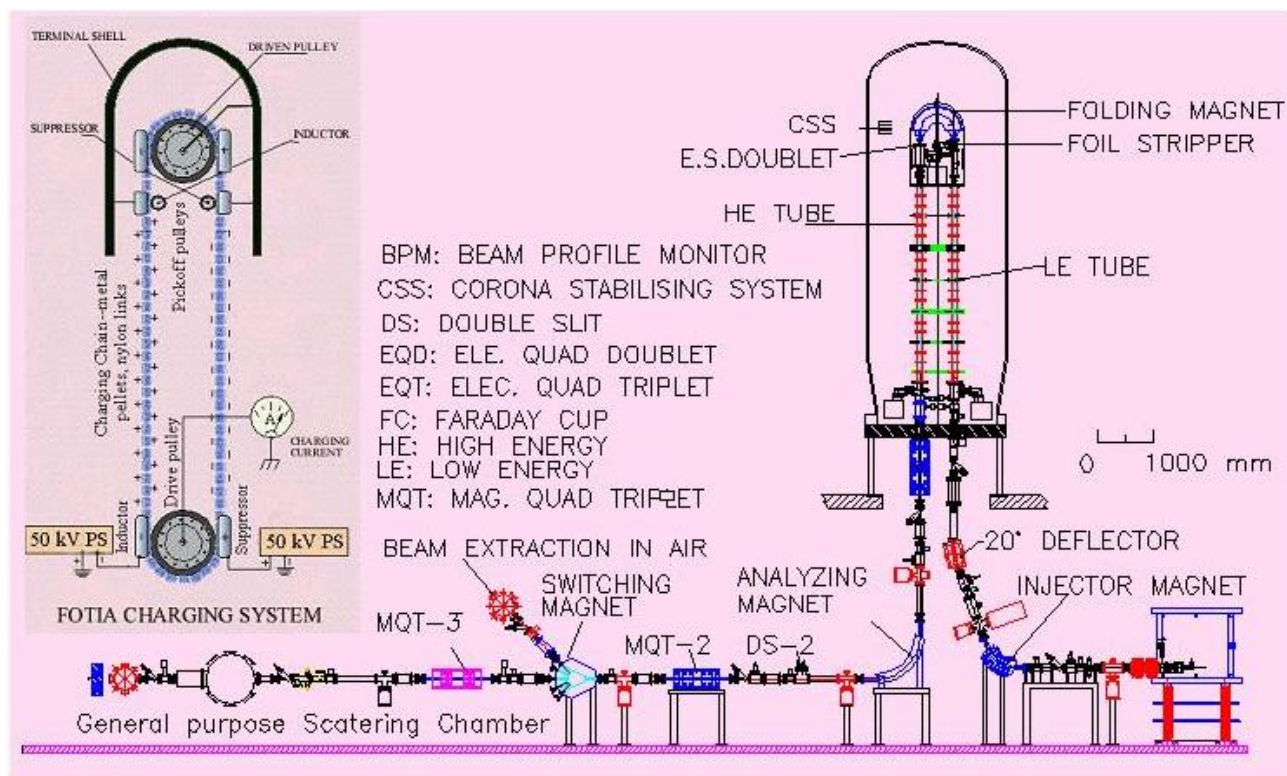


Figure 1: Schematic Layout of the Folded Tandem Ion Accelerator

## INTRODUCTION

The FOTIA [1] facility is designed and developed utilizing the expertise of scientists and engineers belonging to BARC and RRCAT, Indore. The facility was constructed using infrastructure of the Van-de-Graaff accelerator in the existing building. Most of the components like all bending magnets, electrostatic & magnetic steers, quadrupoles, beam line components and power supplies are indigenously designed and built. Over the period of last ten years the ion beams are being delivered to users and as parallel activity we continued up gradation for improving the accelerator performance and added many experimental setups for studies in basic and applied science.

## ROTATION OF ANALYSING MAGNET

Before the construction of new beam hall the experiments were carried out in old beam hall and in due course after getting possession of the new beam hall, the analyzing magnet which weighs approximately 2 tonnes was rotated using a specially designed turn table and jack assembly as shown in figure 2.

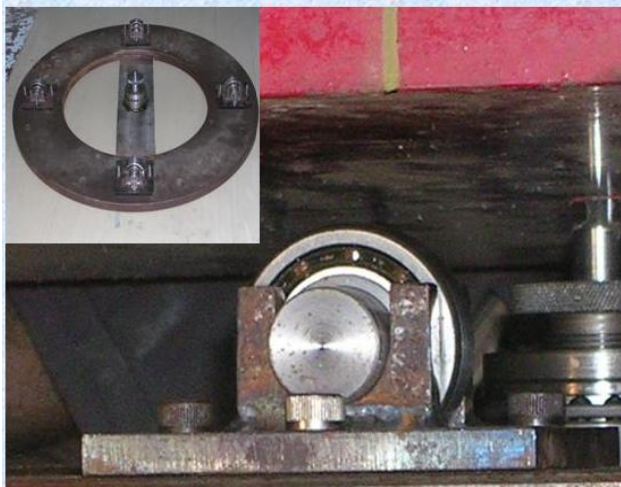


Figure 2: Turn table and jack assembly

## NEW MAGNET CHAMBER FOR FOLDING MAGNET

The Folding magnet plays a crucial role of selecting the required positive charge state. It was observed that the transmission through the  $180^\circ$  magnet in the terminal was very poor (less than 10%) and the reasons for this could be the small vacuum chamber size and hence a new vacuum chamber (Figure 3) of internal dimension 21 x 18 mm in place of 18 x 9 mm was designed and got fabricated in-house. The challenges, like very crucial tolerances, selection of proper welding sequence were involved. To achieve the tolerances following steps were involved.

1. Tack welding of adjoining components before full welding.

2. Measurements & Correction of concentricity and alignment after each tack welding.
3. Staggered welding and in case of misalignment, correction by controlled heating and guiding.
4. Concentricity of viewing ports w.r.t. entry/exit port is 1.6 mm over the length of 485 mm.
5. Weld joints tested with MSLD, leak rate less than  $1 \times 10^{-11}$  std-cc/sec.



Figure 3: Folding Magnet Chamber with view ports

After fabrication and testing of the chamber, it was installed in the existing magnet yoke with a spacer soft iron piece and observed that the beam transmission improved by about 5%.

## TRANSMISSION STUDIES

In order to improve the transmission further, a study of beam transmission for un-stripped ions through the folding magnet for different stripper size (e.g. 10, 15, 20 mm and no holders) and then effect of injection parameters were also carried out and the results are shown in figure 3.

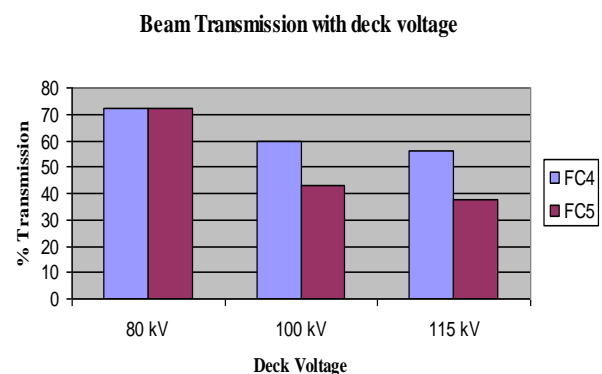


Figure 3: Beam Transmission vs Deck Voltage

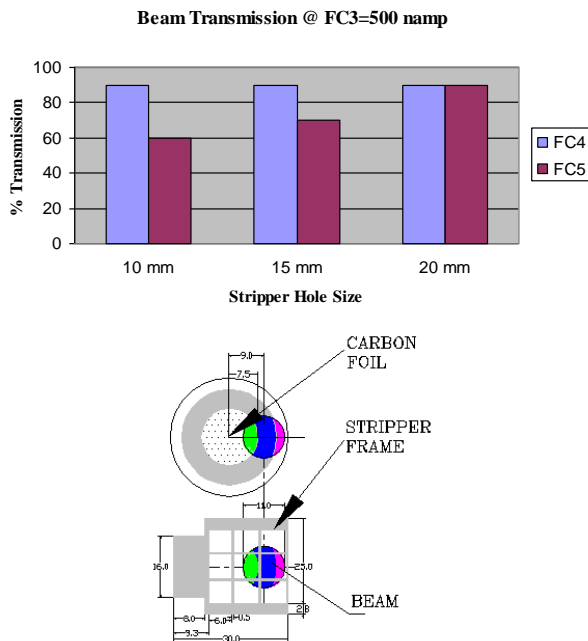


Figure 4: Summary of Beam Transmission with H and Beam position wrt holder and new foil holder

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 4, 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.

## EXPERIMENTAL FACILITIES

After analysing magnet the beam enters the beam hall where a 5-port switching magnet and 3 beam lines are installed (Figure 5). Following facilities are available for utilizing the beam from FOTIA after the in .

1. General purpose scattering chamber (80 cm diameter) with two rotating arms for detector mounting and arrangement for target movement linear as well as rotational.
2. Separate set up for PIXE, PIGE, Beam in Air for Radiation Biology, External PIXE (Figure 6).
3. Irradiation of samples at elevated temperature, PIPAS[2] (Figure 7)
4. Dedicated data acquisition system (LAMPS).



Figure 5: 5-port Switching Magnet and beam lines

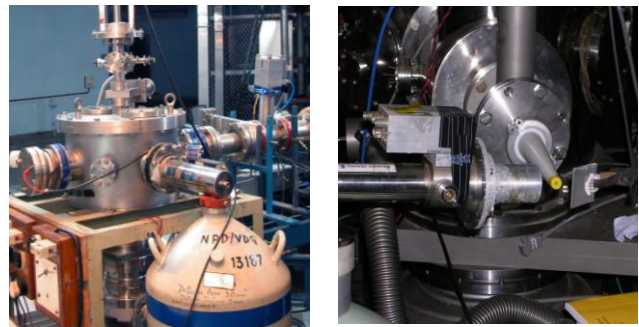


Figure 6: Set up for PIXE, PIGE and External PIXE

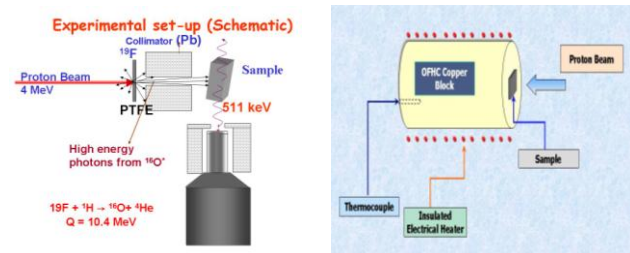


Figure 7: Experimental setups for PIPAS and Irradiation damage studies at elevated temperature.

## LOW ENERGY ACCELERATOR FACILITY (LEAF)

A Low Energy Accelerator Facility [3] (LEAF) is also in operation with several beams available to the users. The facility can deliver singly charged negative ion beams of energy upto 50 keV (figure 8). Beams of  $H^-$ ,  $Li^-$ ,  $C^-$ ,  $O^-$ ,  $Al^-$ ,  $Fe^-$ ,  $F^-$ ,  $Si^-$ ,  $S^-$ ,  $P^-$ ,  $Sb^-$ ,  $Ag^-$  and  $Au^-$  have been extracted and delivered to the users. Typical particle currents available on the targets are up to few micro amperes. Future plans include installing an electrostatic quadrupole triplet to focus the beam on target and a scanner to scan the beam uniformly on larger surface area and single button automated operation of the facility.



Figure 8: Low Energy Accelerator Facility

### UTILIZATION

Facility is running for last two years and has delivered various negative ion beams on the target. A list of extracted ion beams at 56 keV (50 kV acceleration Voltage + 6 kV cathode voltage) is presented in Table 1. Clusters of C<sup>-</sup> ion from C<sub>1</sub> to C<sub>25</sub> are extracted.

H<sup>+</sup> Implantation work was carried out to study the effect of implantation on the optical wave guide. A series of experiments with different ion beams and with varying energy are carried out to study the effect of implantation on the photoluminescence of GaAs quantum dots [4-6]. Experiments are carried out to study the effect of influence of Li<sup>-</sup> on the optical and electrical properties of the ZnO films [4]. Experiments have been conducted with the P<sup>-</sup> and B<sup>-</sup> ion beams to fabricate tunnel transistor by bombarding them on Si substrate.

Table 1: Extracted ion beams

Sample	Extracted Current	Beam	Analyzed Beam Current
TiH	10 $\mu$ A	H-	5 $\mu$ A
Graphite	90 $\mu$ A	C-	25 $\mu$ A
Fe <sub>2</sub> O <sub>3</sub>	28 $\mu$ A	O-	15 $\mu$ A
Silicone	20 $\mu$ A	Si-	8 $\mu$ A
LiF+Al	20 $\mu$ A	Li-	0.3 $\mu$ A
LiF+Al	20 $\mu$ A	F-	12.5 $\mu$ A
S	10 $\mu$ A	S-	2.3 $\mu$ A
AgI	30 $\mu$ A	I-	10 $\mu$ A
Pure Ag	5 $\mu$ A	Ag-	0.6 $\mu$ A
Pure Au	25 $\mu$ A	Au-	12.5 $\mu$ A
Sb	4.5 $\mu$ A	Sb-	0.2 $\mu$ A
P	15 $\mu$ A	P-	0.3 $\mu$ A
B + Ag	8 $\mu$ A	B-	80 nA

### CONCLUSION

Two ion beam accelerator facilities are operational in BARC campus in Van-de-Graff building, BARC Scientist and Engineers are most benefitted for carrying out multidisciplinary studies using ion beams from these facilities.

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