RECENT DEVELOPMENTS IN BEAM TRANSPORT SYSTEM AT IUAC

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Abstract

The beam transport system (BTS) is an important part of any accelerator development. The beam transport group at IUAC mainly takes care of (i) Ion Optical design of BTS from source to target at the experimental area (ii) Design and fabrication of different optical elements viz. Dipole ,quadrupole , steerer and scanner magnets (iii) Development of power supplies for the magnets iv) Development of High voltage power supplies for Electrostatic beam transport elements as well as Solid State detectors. The talk will cover the recent developments of BTS for Low Energy Ion Beam Facility (LEIBF), High Current Injector (HCI) and Phase II beam lines in beam hall-II. Developments of current controlled power supplies for various magnets at IUAC are described. Future developments of BTS for HCI at IUAC are projected.

INTRODUCTION

The beam transport system in any accelerator plays an important role in transporting ions from the source to the target or to inject ions from one system to another system. The acceptance of one system must match with the emittance of the preceding system. While designing the BTS the emittance of the ion source helps a lot to select proper dimension of the transporting elements. We have either measured the emittance of the beam coming from the source or used the emittance as quoted by the company while designing ion optics. The major tasks performed by the BTS group at IUAC are

i) ion optical design (ii) design of different electro magnets (iii) Fabrication and testing of the magnets(iv) designing layout of the BTS (v) development of power supplies for the magnets (vi) installation and maintenance of the whole system for successful operation of the accelerators. In this paper I describe different developments achieved in BTS during the last five years or so. The recent developments can be catagorised into following subheads:

1) Developments in Phase-II beam lines
2) Beam transport system of low energy ion beam facility (LEIBF)
3) BTS developments in HCI
4) Development of Power supplies

DEVELOPMENTS IN PHASE-II BEAM LINES

The zero degree beam line of PELLETRON in BH-I was extended to BH-II for augmentation of LINAC. The whole optical design from switching magnet in BH-I to target chambers for different beam lines in BH-II was simulated and layout was designed accordingly.. Seven quadrupole triplet magnets having maximum field gradients 23T/m and several steerer magnets were developed indigenously for these beam lines. The semicircular switching magnet having seven ports (0°, ±10°, ±25°, ±40°) in BH-II was designed as per beam rigidity expected from LINAC. . A scanning magnet [1] was developed for homogeneous irradiation of beams for material science beam line in phase-II. This whole system was installed as per ion optical design.

BTS OF LEIBF

A new LEIBF based on all permanent magnet ECR (NANOGAN) is being installed in new material science beam building. This facility will provide all kinds of ion beams ranging from a few keV to a few MeV for atomic - molecular and material science researches. The details of the facility is being presented elsewhere in this conference. The detail ion optical design as per building constraint has been performed using various codes TRANSPORT,GIOS and the layout has been planned accordingly. Several steerer magnets, electrostatic quadrupoles needed for this facility have been developed in-house. The special analysing cum switching magnet was designed for analysing and transporting in one of the three beam lines in the beam hall. The magnet was fabricated by DANFYSIK and tested in the factory. The specification of switching magnet is given in table 1.

Table 1: Specification of switching magnet

Bending Angles (deg.)	75, 90 , 105
Bending Radii (mm)	641.75, 529.1, 460
Pole Gap (mm)	65
B_{max} (T)	1.55 @ 240Amps
Entrance Angle (deg.)	29.05
Exit Angles (deg.)	15.95, 30.66, 43.09
Max. ME/q^2 (MeV. amu)	44.68, 30.37, 22.96
Momentum Resolution ($\delta p/p$)	$\approx 3.7 \times 10^{-3}$
Homogeneity ($\delta B/B$)	$\leq 10^{-3}$

The ion optical design and layout of the whole facility are shown in figures 1,2.

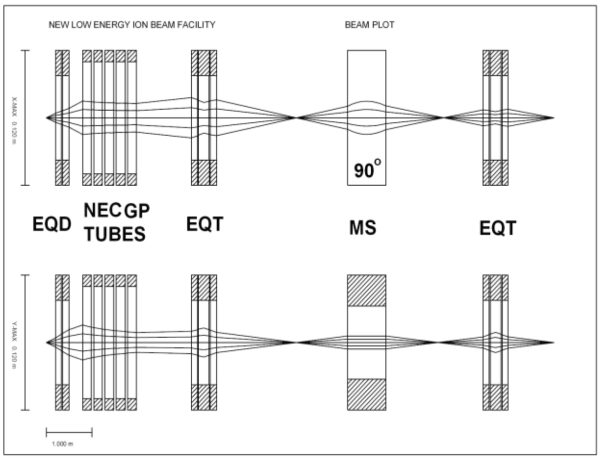

Figure 1: Ion optics for 90° beam line using GICOSY

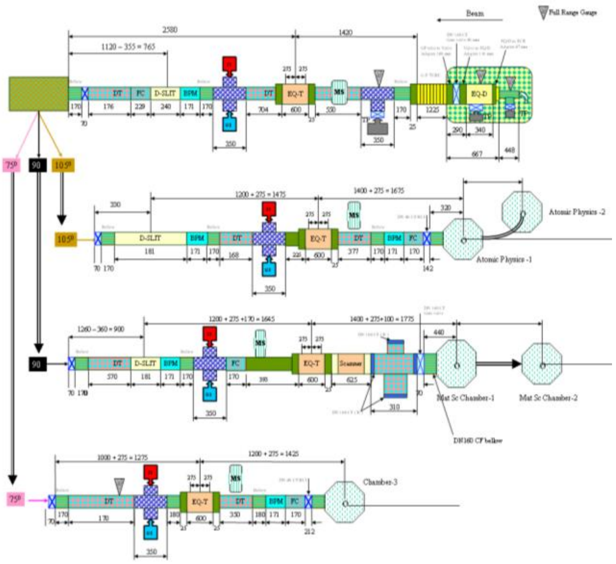

Figure 2: Layout of LEIBF

BTS FOR HCI

The HCI consists of an high temperature super conducting ECR, room temperature Radio frequency Quadrupole (RFQ) and Drift Tube Linac (DTL) to inject 1.8 MeVA high current (μA) beams into super conducting LINAC. The whole beam transport (~ 50 meters) is divided into three sections.

1) Low Energy Beam transport system (LEBT)
2) Medium Energy Beam Transport System (MEBT)
3) Medium High Energy beam Transport System(MHEBT)

LEBT

This extends from ECR to entrance of RFQ. The beam from ECR PKDELIS is optimised for A/q =6 at an extraction voltage 30kV. The extracted beam is mass analysed by an analysing magnet. To reduce the loading of the high voltage power supply biasing the high voltage platform and the accelerating tubes across the platform and ground due to extraction of multi-charged ions from HTS-ECRIS, the analysing magnet[2] having 80mm pole gap is placed on the high voltage platform to pre-select ions from the ECR source before acceleration from the high voltage platform. The magnet is air cooled and has been designed as a combined function magnet to achieve double focussing. The higher order corrections upto third order has been incorporated in the mechanical design. The vertical focussing is obtained by incorporating increasing sextupole field components at the entrance and exit of the magnet. This is achieved by having cylindrical pole shape at entrance and exit with negative radius of curvature. The horizontal focussing is achieved by introducing decreasing sextuple field component in the radial plane at the middle of the magnet. The specification of the magnet given in table1. The magnet was fabricated by Danfysik, Denmark. The test results of the magnet are given in table 2. A magnetic doublet has been placed before the magnet to increase its acceptance and to correct minor mismatch between specified and actual shim angles

Table 2: Specifications of the ECR analyzing Magnet

Maximum field	0.3 T
Bending radius	0.3 m
Bending angle	90^o
Air cooled	
Entrance, exit angle	$32.8^o \pm 0.5$
Entrance, exit pole shape	Cylindrical
Radius of curvature	-0.24 m ± 0.01
Pole profile	Approximate Rogowski
Side pole profile	Champhered
Pole gap	80 mm
Homogeneity	$B = B_o(1+n_1(x/□)+n_2(x/□)^2+n_3(x/□)^3+..)$
n_1	0
n_2	-0.7 ± 0.07
n_3	0.9 ± 0.09

Table 3: Measured results compared with specifications

Parameters	IUAC specifications	Model specifications	Measured value
Shim angle (°)	32.8 ± 0.5	32	31.7 ± 0.34
EFB radius (mm)	240 ± 10	250	255 ± 20
n_1	0	0	0
n_2	-0.7 ± 0.07	-0.694 ± 0.001	-0.67 ± 0.07
n_3	0.9 ± 0.09	0.873 ± 0.004	0.81 ± 0.15
n_4	0	-0.032 ± 0.046	-0.41 ± 2.49

The mass analysed beam is further energised by an accelerating column to 8 keV/u and focussed by an electrostatic quadrupole triplet placed at high voltage deck to the entrance of a single gap multiharmonic buncher which bunches the beam at the entrance of the RFQ. The beam from buncher is transported to the entrance of RFQ by a set of magnetic quadrupole lenses. The beam optics simulation using TRANSPORT code is shown in fig.

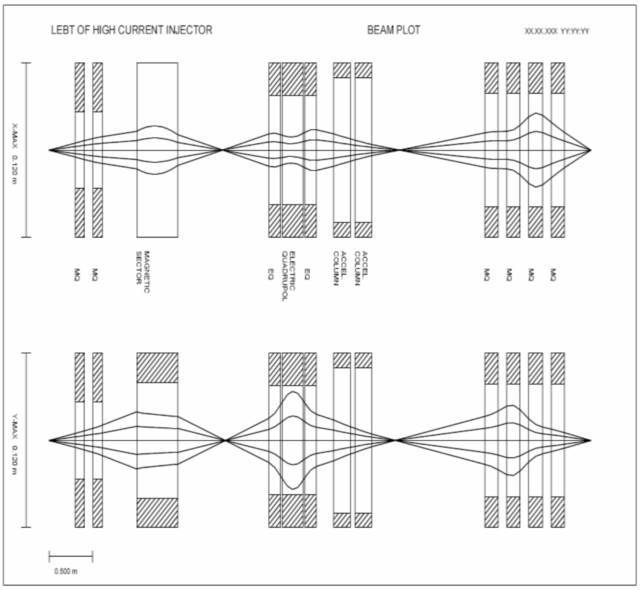

Figure 3 : Ion optics simulation of LEBT

MEBT

This section extends from RFQ -exit to entrance of DTL. The RFQ accelerates the beam to 180keV/u. The accelerated beam is transported to DTL by a set of quadrupole magnets. The ion optical simulation of this section is shown in figure.

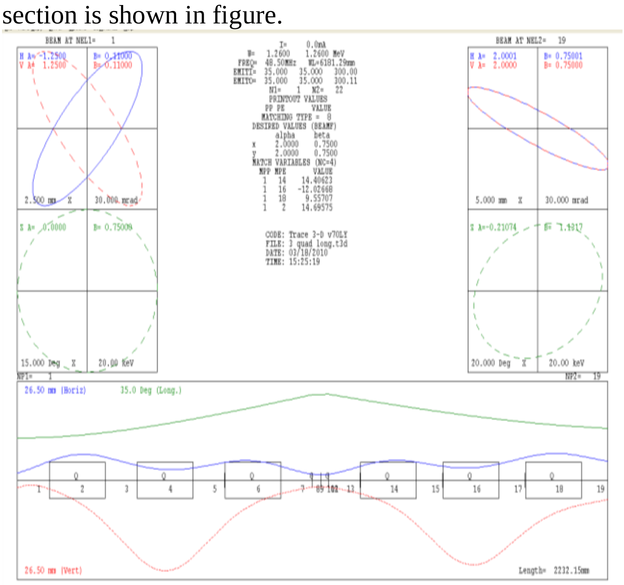

Figure 4: Beam optics of RFQ to DTL section using TRACE3D code

MHEBT

The MEBT matches the beam with DTL input requirements. DTL enhances the beam energy to 1.8 MeV/u to match with requirement of super buncher. MHEBT transports beam from DTL exit to the entrance of super -buncher in zero degree beam-line in BH-I. The overall layout of HCI demands a total bending of 360 °. So as to enter the beam into superconducting LINAC. To meet the design criteria, we have decided to design two achromat bends of 90 ° and one achromat bend of 180 °. The beam optics simulated using GICOSY for a 90° and 180 ° achromatic bends are shown in figures . The longitudinal beam optics using code TRACE 3D is as shown in Figures.4. The beam optics has also been verified by the multiparticle simulation code TRACK. The overall layout of the BTS is shown in figures.

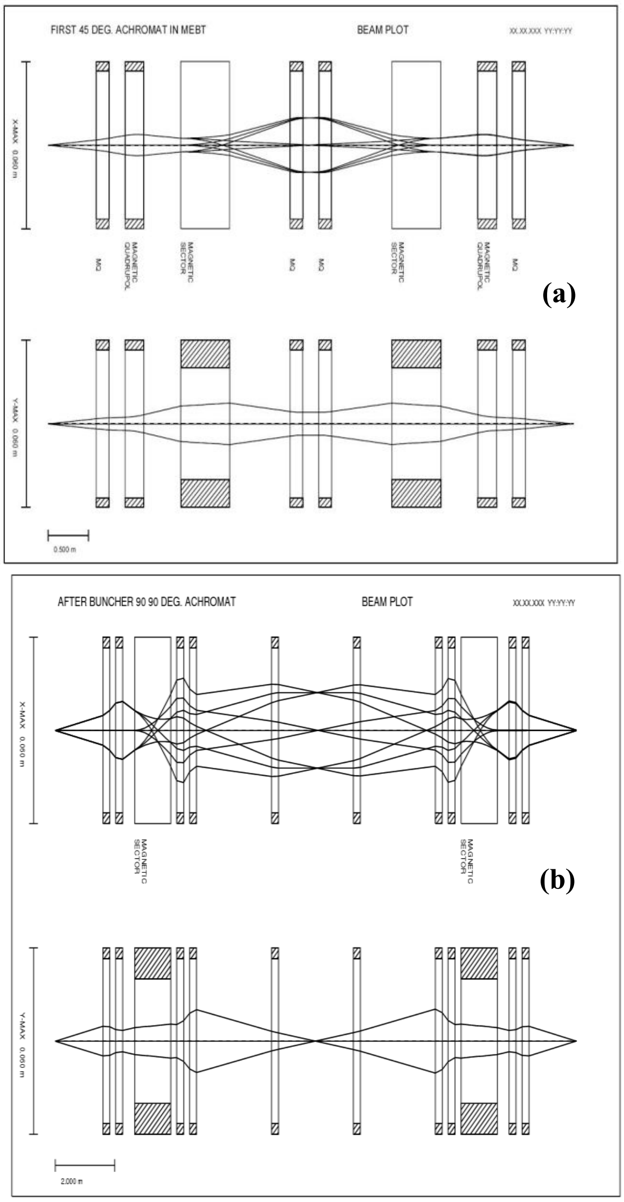

Figure 5: Achromatic transverse beam optics for (a) 90° (b) 180° bending section of MHEBT using GICOSY code

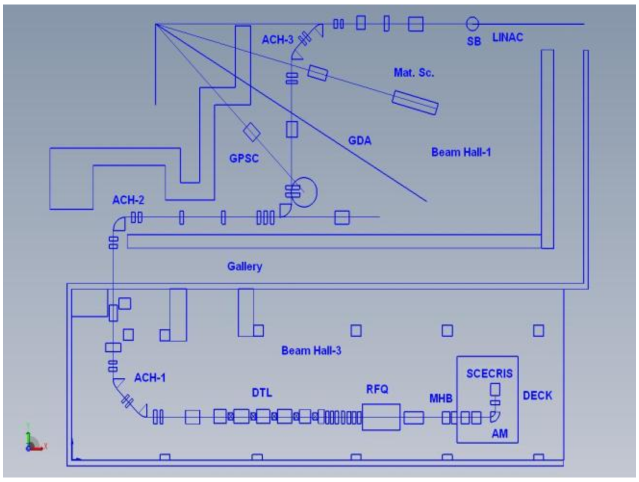

Figure 6: Layout of full HCI

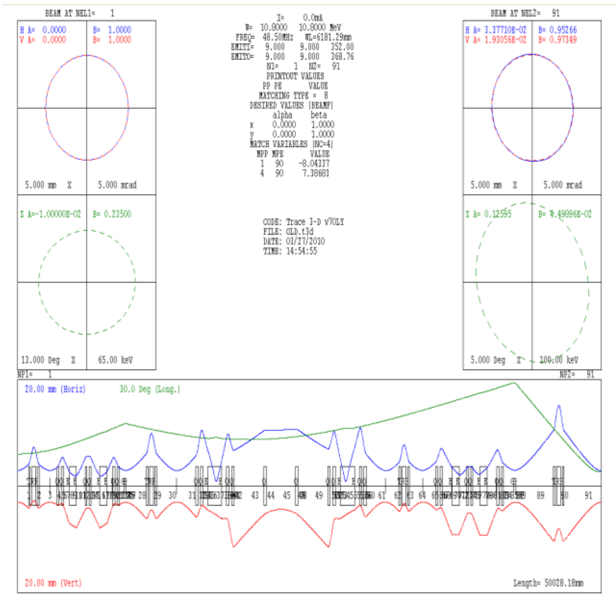

Figure 7: Beam optics of full MHEBT section using TRACE3D code

DEVELOPMENT OF POWER SUPPLIES

The power supplies for the magnets are current controlled and high stability ~ 10-50ppm. Many power supplies of different power ratings have been developed over the last few years. These are:

1) Bipolar power supplies for steerer magnets : 60V, 5A, 300 W, 20numbers
2) High current high voltage Power supplies for HYRA quadrupole magnets: 10-30KW, 5nos.
3) Bipolar AC Amplifier for Beam Scanning Magnets, 4nos
4) 1 KW (10V,100A) Switch Mode Power Supply for superconducting solenoid magnets,20 nos.
5) Low Power (500W) Air cooled power supplies for quadrupole magnets

Beside these, a large number of high voltage power supplies have been developed for INGA detectors and Atom source development. These are:

1) 3KV BGO Detector Bias Power Supply,40nos
2) 5KV HPGE Detector Bias Power supply,40 nos
3) 10KV High Voltage Power supply for atom source

Details of the power supplies are reported elsewhere in this conference. Specifications of some of these power supplies are described below;

Quadrupole power supplies for HYRA

Specifications:

- Power range : 10kW- 12kW
- Current range : 300A
- Voltage range : 32V and 42V
- Long term stability (8hrs) : 10 PPM
- Line regulation (10% slow): 3 PPM
- Output ripple : 20mV
- Ramp time : 10-100 sec.

Bipolar AC amplifiers for Scanning Magnet

Specifications:

- Output current range : ± (0-50A)
- Output voltage range: ± (0-60V)
- Scanning frequency range: 0.1 - 50Hz
- Input voltage: 415V, 3 phase
- RMS power : 1 KW
- Water cooled transistor Bank

Features:

- CAMAC / Local operation.
- Voltage and current regulation with fold back output limit.
- Back e.m.f protection.
- True regulated triangular wave output without crossover distortion.
- Necessary safety interlock to put-off load current if either interlock fails.
- Status indication of power supply on front panel as well as for CAMAC.

References

[1] A.Mandal, G.Rodrigues, S.K.Suman and Rajesh Kumar,J Acow,A large Area Scanning Magnet for Homogeneous Irradiation of Targets;, APAC-7 (2007)WEPMA002 , Indore, India.

[2] A.Mandal, G.Rodrigues, D.Kanjilal, Peter Brodt and Franz Bødker, NIMA583(2007)219.