ION OPTICAL DESIGN OF LOW ENERGY ION BEAM FACILITY AT IUAC

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Abstract

A Low Energy Ion Beam Facility (LEIBF) using fully permanent magnet ECR ion source (Nanogan) has been installed at Inter University Accelerator Centre (IUAC), New Delhi for fundamental research on Atomic and Molecular Physics, and Materials Science. The accelerator consists of an ECR ion source, 400kV accelerating column and an analyzingcum switching magnet with three beam ports at 75, 90 and 105degrees. The complete ion optics from ECR ion source to the target has been simulated using TRANSPORT and GICOSY ion optics codes. The ions from the ECR source are typically extracted at 15kV which are further accelerated by 400kV accelerating column (AC). The analyzing cum switching magnet has been designed to analyze different beams and to switch in a particular beam line. The beam is further transported to target locations using electrostatic quadrupole triplet. The details of ion optics and some preliminary results arepresented.

INTRODUCTION

A Low Energy Ion Beam Facility (LEIBF) has been installed at Inter University Accelerator Centre, New Delhi for fundamental research in low energy Atomic Physics and Materials science in addition to 15UD Pelletron [1] being operated for the last twenty years. The LEIBF is based on a fully permanent magnet 10GHzECR ion source (Nanogan) [2]which was procured from PANTECHNIK and was installed on 200kV high voltage platform providing beams from a few keV to a few MeV for last ten years. Due to limitations of the building and low acceptance of the analyzing magnet used earlier, extracted current and energy of beam was limited. To utilise the full potential of this source it has been installed now in a new building making it possible to place the source on a higher voltage (400kV) platform and to use a new large acceptance magnet for analyzing ions from ECR source. The present room is L shaped as shown in Fig 1. The layout of the accelerator has been made as per the geometry of the room. The ECR source is placed at one end on high voltage deck and the analyzing magnet is placed at 90^{o} bend of the floor. The analyzing magnet has been specially designed to analyze and switch to three beam lines at 75, 90 and 105deg. The object point of the magnet is ~5.0 metres away from the source. To transport multiply charged beams to such long distance from the source, an electrostatic doublet (EQD)anda triplet (EQT) quadrupoleshave been usedbefore and after the accelerating column respectively. The optics have been carefully designed to transport beams of various charge states and energies corresponding to deck voltage varying from 0 to 400kV at the object point of the magnet. The magnet analyzes and switches beam to the particular beam line. The complete layout has been done as per ion optical design and keeping provision of diagnostics and vacuum stations. This paper describes the complete ion optical configuration and hardware design of the magnet. The preliminary results of the operation of the accelerator are also reported.

ION OPTICAL DESIGN

The complete ion optics is described in following twosections:

The ECR source to Analyzing Magnet

All the quadrupoles are electrostatic since it is more efficient in low energy region than magnetic ones.The ion optics is based on the following input characteristics of the source.

Emittance = 100 π mm mrad,

Extraction Voltage = 15kV

Accelerating Voltage = 400kV

The starting object point of beam optics is 300 mm upstream the EQD. Instead of conventional Einzel lens, the EQD is used just after the source to increase the acceptance of the accelerating column. The EQD, accelerating column and EQT together focus the beam at the object point of the magnet. Different ion optical codes TRANSPORT [3], GICOSY [4] have been used for simulation. Since all the charge states are transported upto this point, the quadrupole fields are adjusted to focus the ions of particular charge state and energy at the object point of the magnet.The ions of other charge states get focussedat other points. A typical ion optical simulation in the Fig. 2shows the distribution of different charge states for a 10 kV extraction and 300 kV accelerating voltage when quadrupoles are optimized to focus Ar^{6+} at the object slit of the analyzing magnet. Because of this, the beam profile just before the slit becomes wide. To analyze the particular charge state, the slit width is reduced thereby improving the resolution at the image plane of the magnet.

Analyzing cum Switching Magnet

Instead of using a separate switching magnet, an analyzing cum switching magnet having three ports at 75, 90 and 105deg. have been designed to save space in the beam hall. The specifications of the magnet are given in Table 1. The gap of the magnet has been decided to accept the beam within 60% of the gap to avoid higher order aberrations. The maximum rigidity of the magnet is compromised to analyze lower charge state (1+) with low energy as well as higher charge states with higher energy. The entrance and exit angles have been optimized for 90° bend including gap effect to have a double focusing. The exit angles for 75° and 105° have been optimized to have double focusing. Since the double focusing image distance is different for different bending angles, being maximum for 75° due to weak focusing in radial plane, a quadrupole triplet is used along with magnet to have double focusing point.Finally the beam is focused to the target in the experimental chamber using anelectrostatic quadrupoletriplet lens. The whole ion optics from source to the target for 90°beam line is shown in Fig. 3. The whole layout of the accelerator is shown in Fig.1 and installed accordingly. All the components are remotely connected to control console for safe operation.

HARDWARE DESIGN OF THE MAGNET

Analyzing cum switching magnet is an H shaped dipole magnet having a gap of 65mm. The maximum ME/q^2 designed for 90°bend is 30MeV.amuwith bending radius 529mm and the corresponding maximum field value is 1.5T. The pole is designed to match the designed entrance and exit angles for 90° bend. The exit pole width is made much wider compared to entrance width to accommodate other two ports and to get proper homogeneity (~10^{-3}) for all bend angles. The radii for 75 and 105deg. bending angles are chosen as 642mm and 460mm. The exit periphery is designed to get exit angles for 75 and 105deg. bends as 17.3 and 42.9deg. The ampere-turn was calculated for B_{max}=1.5T and gap 65mm.The magnet was fabricated by DANFYSIK, Denmark. The 3D OPERA simulation codes of Vector Field were used to design the magnet.

TEST RESULTS

The magnet was tested for excitation up to maximum current of 240A and the field mapping of the magnet was done at the entrance and exit ends as well as middle of the magnet using a precision Group3 hall probe placed on a precision position scanner. The magnet parameters were calculated by analyzing field mapping data and compared with design values as shown in Table 1. All the parameters match well with design values. After installation, the helium leak checking of whole system is done thoroughly to achieve a vacuum of10^{-8}mbar. All the components have been checked for remote operation. In the preliminary test run, the oxygen gas is fed to ECR source with a RF power of 20Watts. The source is tuned for O^{1+} beam at 15 kV extraction and 200 kV acceleration potential and the analyzed beam currents for different charge states of oxygen in three beam lines are shown in Table 2. The X and Y beam profiles are shown in Fig. 4 for 75° beam line at the image plane of analyzing magnet and the installed facility is shown in Fig. 5. Further improvements in operation are in progress.

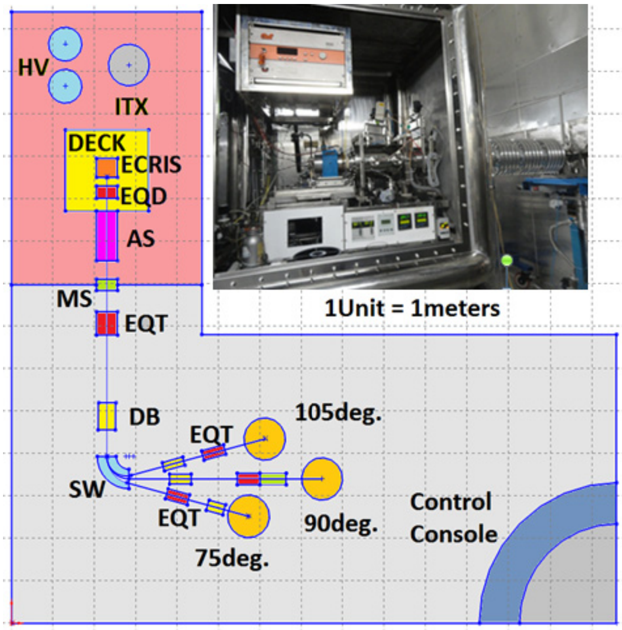

Figure 1: Layout of major components of LEIBF.

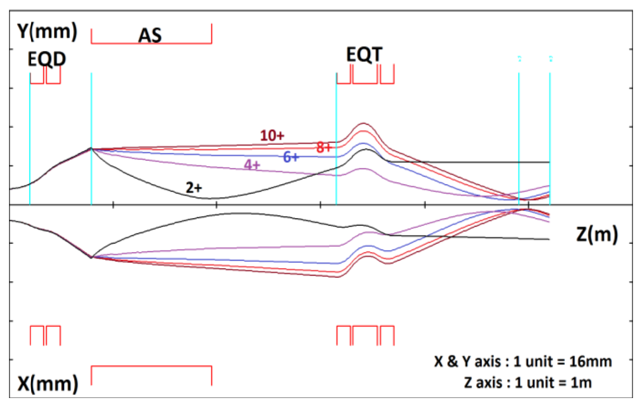

Figure 2: Beam envelopes for different charge statesof Ar ions with Ar^{6+} tuned at object slit of magnet.

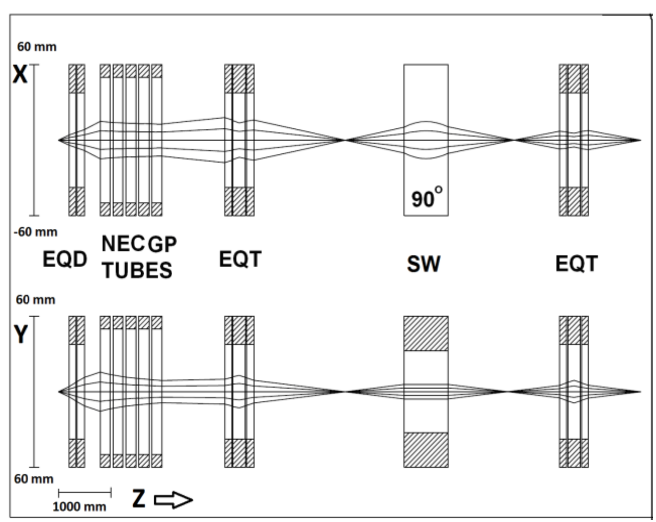

Figure 3: Beam Optics of full LEIBF using code GICOSY forAr^{6+}at 300 kV.

Table 1: AnalyzingMagnet Results

Parameters 75°,90°,105°	Design Values	Measured Values
B_{max} (T)	1.5 @ 240A	1.55 @ 240A
Entrance Angle(deg.)	29.1	29.05
Exit Angle (deg.)	17.3, 30.6, 42.9	15.95, 30.66, 43.09
Bending Radii (mm)	642, 529, 460	641.75, 529.1, 461.8
Homogeneity (center)	$1*10^{-3}$ over ± 40 mm	$7*10^{-4}$ over ±65 mm

Table 2: Measured Oxygen beam currents

Ion Species	Analyzed Beam Current		
	75°	90°	105°
O^{1+}	49.7μA	43.4μA	36.2μA
O^{2+}	6.67μA	3.32μA	8.64μA
O^{3+}	1.42μA	0.57μA	0.81μA
O^{4+}	0.29μA	0.14 μA	0.25μA
O^{5+}	14.9nA	15.7nA	15.0nA
O^{6+}	12.0nA	8.00nA	10.0nA

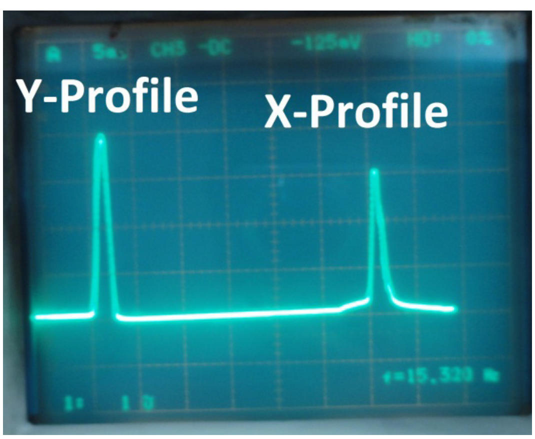

Figure 4: Beam Profiles in 75° beam line at the image point of anlyzing magnet

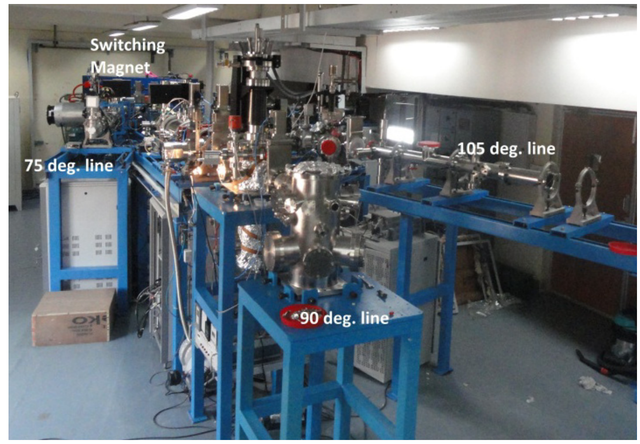

Figure 5: Installed LEIB facility

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