# START TO END SIMULATION OF HIGH CURRENT INJECTOR USING TRACEWIN CODE

Sarvesh Kumar, Abanimohan Mandal

Inter University Accelerator Centre, New Delhi, INDIA

## Abstract

High Current Injector (HCI) is an alternate injector to superconducting linac at IUAC in addition to pelletron. It consists mainly of high temperature superconducting ECR ion source (PKDELIS), radio frequency quadrupole (RFQ) and a drift tube linac (DTL). The ions of mass to charge (A/q) ratio of 6 are analysed initially and accelerated through RFQ and DTL to a total energy of 1.8 MeV/u. The different energy regimes connecting the accelerating stages are named as low, medium and high energy beam transport section (LEBT, MEBT and HEBT). The energy spread of beam increases from 0.02% at ECR source to 0.5% at the LINAC entrance. An ion beam of normalized transverse and longitudinal emittance of 0.3 pi mm-mrad and 3 keV/u-ns has been considered at the start for the simulation of ion optics using TRACEWIN code. The whole beam transport system has been designed using GICOSY, TRANSPORT and TRACE 3D codes piecewise and TRACEWIN code is used to simulate whole ion optics from start to end including acceleration stages such as RFQ and DTL. Simulation results shows that beam can be injected through LEBT, MEBT and HEBT into LINAC without significant emittance growth and beam loss.

## HIGH CURRENT INJECTOR

The ECR ion source [1,2,3] provides intense ion beams of high charge states which is the main requirement for nuclear physics experiments for better statistics and maximum energy gain from LINAC [4]. The beam optics calculations have been done piecewise [5] using different codes earlier and presently performed using TRACEWIN code [6] from start to end in envelope mode within framework of linear beam optics regime. A normalised longitudinal emittance of 3keV/u-ns and normalised transverse emittance of 0.3 pi mm-mrad has been assumed at the ECR ion source to design the whole system.

## LEBT SECTION

The LEBT section consists of an electrostatic einzel lens (EL) and an electrostatic quadrupole doublet (EQD) so that all the ions follow same trajectory independent of their mass which are analysed as mass to charge ratio of 6 using a large acceptance analysing magnet [7] (AM). These ions are followed by a combination of electrostatic quadrupole triplet (EQT) and electrostatic accelerating section (AS) to

transversely focus across the RF gap of a 12.125 MHz multiharmonic buncher. The input (i) and output (o) ion beam parameters for designing the individual LEBT, MEBT and HEBT section which connects the acceleration stages like high voltage DECK, RFQ [8] and DTL [9] are given in Table-1 where all twiss parmeters are in unit of mm/pi-mrad and all emittances (100%) are in unit of pi-mm-mrad.
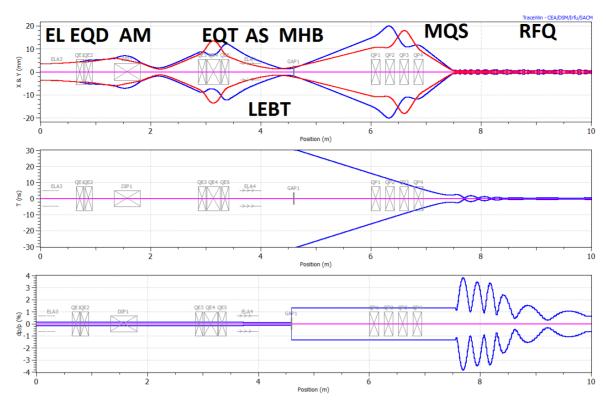
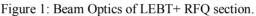Table 1: Ion Beam Parameters of Beam Transport Sections

| Parameters | LEBT | MEBT | HEBT |
|---|---|---|---|
| $\alpha_{xi}$, $\beta_{xi}$, $\varepsilon_{xi}$ | 0,1.0 0.3 | 0.62,0.05 0.46 | -0.44,0.98 0.46 |
| $\alpha_{xo}$, $\beta_{xo}$, $\varepsilon_{xo}$ | 1.72,0.14 0.46 | 2.2,0.53 0.46 | 0.14,0.84 0.38 |
| $\alpha_{yi}$, $\beta_{yi}$, $\varepsilon_{yi}$ | 0,1.0 0.3 | -0.59,0.22 0.3 | -0.1,1.1 0.3 |
| $\alpha_{yo}$, $\beta_{yo}$, $\varepsilon_{yo}$ | 1.73,0.14 0.3 | 2.2,0.45 0.3 | 0.02,0.97 0.3 |
| $\alpha_{zi}$, $\beta_{zi}$, $\varepsilon_{zi}$ | 0,22.5 1.31 | -2.2,1.1 1.36 | -9.1, 18.6 1.36 |
| $\alpha_{zo}$, $\beta_{zo}$, $\varepsilon_{zo}$ | -0.05,0.2 1.36 | -2.8,0.54 1.36 | 2.8,2.1 1.32 |
| $ME/q^2$ (amu.MeV) | 0.108 | 6.48 | 64.8 |
| E (MeV/u) | 0.003 | 0.180 | 1.8 |

These ions are bunched using a RF voltage of around 500V to the entrance of RFQ and transversely focussed using a set of four air cooled magnetic quadrupoles (MQS). The particles are bunched with a repetition rate of 83 ns and squeezed to a bunch width within 5 ns. The RFQ provides bunching, focusing to the injected ions from LEBT section and acceleration to an energy around 180 keV/u. The horizontal and vertical beam envelope for this section followed by RFQ section is shown in Fig. 1. The ion optical design of RFQ has been studied by TRACK code previously.

## MEBT SECTION

This section matches the beam from RFQ to DTL. It consists of a set of magnetic quadrupoles and a spiral buncher for transverse and time focusing at the entrance of DTL respectively. The ion optical design of DTL has been studied using LANA code previously.

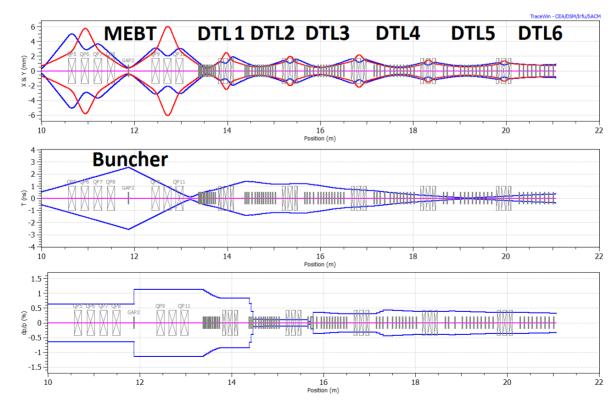Figure 1: Beam Optics of LEBT+ RFQ section.
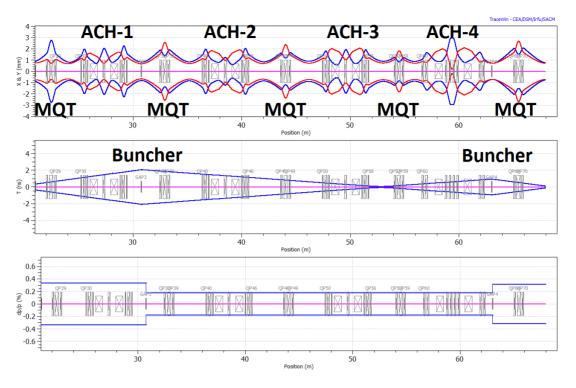


Figure 2: Beam Optics of MEBT+DTL section.

Figure 3: Beam Optics of HEBT section.

The energy spread rises less than 1% as the beam traverses from source to exit of DTL with full acceleration upto 1.8 MeV/u which matches to values obtained by LANA code. The beam envelopes for MEBT and DTL sections are shown in Fig. 2.

## HEBT SECTION

The HEBT section matches the beam from DTL exit to Superconducting LINAC and is very long section comparatively. It consists of four 90 deg. achromatic bends [10] to compensate the energy spread in the beam introduced from previous stages. The first three achromatic bends are identical in configuration and the last one is different due to geometrical constraints. All the dipole magnets are also identical in every achromat to make the beam tuning easier throughout the HEBT section. The achromatic bends marked as ACH-1, 2, 3 and 4 connected by magnetic quadrupole triplets (MQT). The beam envelopes in transverse planes, momentum spread and time width of the beam bunch are shown in Fig. 3. A 48.5 MHz spiral buncher is chosen at the image point of first achromatic bend to compensate the phase growth of beam bunch coming from DTL. Finally a 97 Mhz superconducting buncher placed at the image point of fourth achromat and bunches the beam at the LINAC entrance.

## CONCLUSION

The beam optics for whole HCI is being carried out from start to end using TRACEWIN code in envelope mode. The beam parameters matches well with values obtained earlier using TRACE 3D, LANA (for DTL) and TRACK

(for RFQ). The beam optics by code TRACEWIN will help the setup of beam optical parameters during operation of HCI. The installations of LEBT and RFQ are going on currently and the magnets for MEBT and HEBT section have been procured from Danfysik, Denmark.

## REFERENCES

[1]  D.Kanjilal et. al. Rev. Sci. Instrum. 77 (2006) 03A317

[2]  G. Rodrigues et. al. Rev. Sci. Instrum. **81**, 02B713 (2010)

[3]  G. Rodrigues et.al. Rev. Sci. Instrum. **83**, 033301 (2012)

[4]  S. Ghosh et. al. Phys. Rev. ST Accel. Beams 12, 040101 (2009)

[5]  A. Mandal et. al. 161, Proceedings of InPac 2013, VECC, Kolkata

[6]  http://irfu.cea.fr/Sacm/logiciels/index3.php

[7]  A. Mandal et. al. Nucl. Instr. and Meth. A 583 (2007) 219-227

[8]  Sugam Kumar et al., Proc. of InPAC-2011, IUAC, New Delhi

[9]  B.P. Ajith Kumar et al., Proc. of InPAC-2009, RRCAT, Indore

[10]  A. Mandal et. al. WEPPT006 Proceedings of Cyclotrons 2013, Vancouver, BC, Canada