HIGH CURRENT INJECTOR AT NUCLEAR SCIENCE CENTRE

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Abstract

A superconducting quarter-wave resonator based linac is being built to boost the energy of the beams available from 15 UD Pelletron tandem accelerator for experiments in Nuclear Physics, Material Sciences, Atomic Physics, Radiation Biology etc at the Nuclar Science Centre (NSC). A high current injector (HCI) is being designed as a parallel injector into the linac to provide higher beam currents. It will also provide some additional ion species like rare gas ions as well which are not available from the tandem. The HCI will consist of a high temperature superconducting ECR ion source placed on a high voltage deck that will provide the initial beams. These ions will then be accelerated to about 300 keV/u by a 48.5 Mhz radio frequency quadrupole (RFQ) accelerator (room temperature, about 4 m long). It is proposed to build a four rod RFQ with water cooling of the rods. The RFQ will provide focussing, bunching and acceleration in a single cavity, allowing the DC beam from the ECR to be injected into the linac after further acceleration. The RFQ is being designed for a mass to charge ratio of 7. The input energy of the ions will be about 5 keV/u and the final energy at the exit of the RFQ will be 300 keV/u . The aperture of the RFQ at the exit will be around 6 mm. The RF power requirement is expected to be 100 kW and due to CW operation the cooling of the rods is a critical point. The RFQ will be followed by a drift tube linac (DTL) section which will accelerate the beams to about 1 MeV/u for injection into the superconducting linac. Beam optics and RF simulation are underway for the design of the DTL. The paper will present the overall plans for the high current injector..

INTRODUCTION

Nuclear Science centre is an autonomous research centre established in 1985 under University Grants Commission for carrying out fundamental accelerator based research in Nuclear physics, atomic physics, material science, radio-biology etc. It has a 15UD pelletron installed in 1990 and is providing regularly various heavy ion beam to users from different universities and research institutes from all over India [1]. It can deliver DC as well as pulsed beam of pulse width 1-2 ns. With the available energy we can accelerate medium heavy ions upto ~ 2.5 MeV/u which is below coulomb barrier for most of the target- projectile combination. To go beyond coulomb barrier , the pelletron is being augmented to provide beam of 5MeV/u for medium heavy ions by installing a LINAC accelerator [2]. To attain high enegy from LINAC, the charge state of the injected beam should be high. The high charge state can be attained by passing the beam from pelletron through foil stripper which reduces the beam current. The pulse width of the beam needed for LINAC is 100-150 ps. The pulse beam (ns) from pelletron is further bunched to ~ps by a superconducting resonator placed before the entrance of the LINAC. Because of these two processes the beam current from pelltron after super-bunching is very low (~ a few nA) which poses a major hindrance for many experiments. Hence we need a High Current Injector to provide beam of high charge state as well as high current. In the present paper the design aspects of the proposed high current injector are presented.

DESIGN SPECIFICATIONS

The HCI will consist of a high temperature superconducting ECR ion source placed on a high voltage deck that will provide the initial beams [3]. These ions will then be accelerated to about 300 keV/u by a 48.5 Mhz radio frequency quadrupole (RFQ) accelerator (room temperature, about 4 m long) in order to take care of the good focussing properties of the RFQ at such low energies. Further acceleration up to 1 MeV/u before injection into the superconducting linac will be done using drift tube linac.

High temperature superconducting ECR ion source PKDELIS

We have developed and tested a HTS ECR ion-source in collaboration with PANTECHNIK,France which can deliver relatively high current (a few pμA) heavy ion beams for LINAC. Table 1. gives an idea of the extracted beam currents. It is capable of operating at 14 GHz and 18 GHz using high Tc superconducting axial coils and permanent magnet hexapole. Due to the large axial magnetic field the emittance of the beam is very large and poses a challenge in the design of Low Energy Beam Transport System (LEBT) to take account of space charge forces present in the multicharged beam extracted from ECR. The ions from ECR are first extracted around 30 kV and further accelerated using deck voltage, with a maximum allowable voltage of 350 kV. To reduce the loading of the high voltage power supply and space charge forces due to large multi-charged ions from ECR, a large acceptance analysing magnet will be placed on the high voltage deck to pre-select ions from the ECR source. The main design goals for the analysing magnet are large acceptance, minimum weight and reasonable mass resolution.

Extraction system

The ion optical calculations of the extraction system in the presence of the strong axial field produced by the HTS coils has been calculated using IGUN [4] assuming a total source current of 10 mA. The total extraction system comprises of the plasma electrode, puller electrode, focus electrode and a last electrode with the same potential as the puller electrode. The puller electrode is polarised to a negative potential of -20 kV in order to obtain better optics considerations.

Injector Analysing Magnet And Beam Transport

A 90^o injector magnet has been designed to select the particular ion and to eliminate unwanted ion species produced in ECR source [5]. This reduces the current loading of the high voltage power supply used to pre-accelerate the ions from ECR. The magnet has been designed for the following beam parameters : M/q = 10, emittance=200π mm.mrad,ME/q^2=0.3 amu.MeV, magnet rigidity Bρ=0.09 Tm. The design aim is to have minimum weight, good acceptance, reasonable mass resolution and no water cooling. To minimise weight, the radius of the magnet is taken to be 0.3m and B_{max} = 0.3 T. The gap of the magnet is taken to be 80 mm to match the large emittance of the beam. For point to point double focussing the mass resolution is $1.7x10^{-2}$ for a slit size of 10 mm. The beam optics has been calculated for point to point double focussing using TRANSPORT [6]. By including gap effect, the entrance and exit angles turns out to be 32.8^o for double focussing. To minimize higher order aberrations we have incorporated curvatures in the entrance and exit edges and field inhomogeneity in the radial plane. A first order calculation is shown in figure 1. and corrected higher order calculation upto third order is shown in figure 2. The beam optics up to the entrance of the RFQ and after RFQ are shown in figure 3 & 4. The layout of the beam hall showing the high current injector is shown in figure 5.

Radio Frequency Auadrupole Accelerator

It is proposed to build a four rod RFQ structure to be operated at 48.5 Mhz, a sub-harmonic frequency of the superconducting linac frequency. We have chosen the four rod structure instead of the four vane structure since the size of the resonator becomes relatively large at such low frequencies. In the case of the four rod structure, the machining of the electrodes becomes much simpler to handle, however, due to CW operation, the cooling requirements of the rods becomes a critical issue for a safe design since the RF power requirements are expected to be of the order of 100 kW. The RFQ will of course provide focussing, bunching and acceleration thereby allowing the DC beam having a maximum mass to charge ratio of 7 from the ECR source to be injected for bunching and further acceleration. Since the output energy of the ions from the source is expected to be of the order of 5 keV/u corresponding to typical extraction voltages of 30 kV, the final expected energy at the exit of the RFQ will be of the order of 300 keV/u. The aperture of the RFQ at the exit will be around 6 mm. The RFQ will be followed by a drift tube linac (DTL) section which will accelerate the beams to about 1 MeV/u for injection into the superconducting linac.

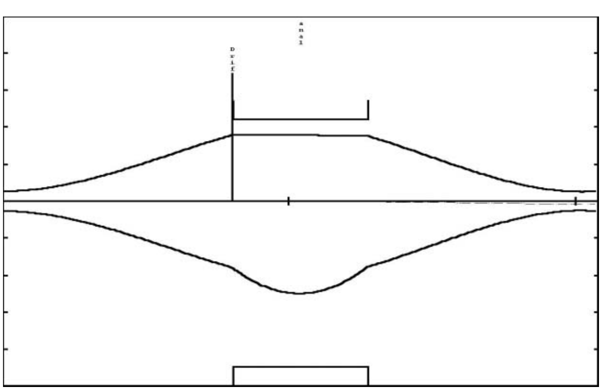
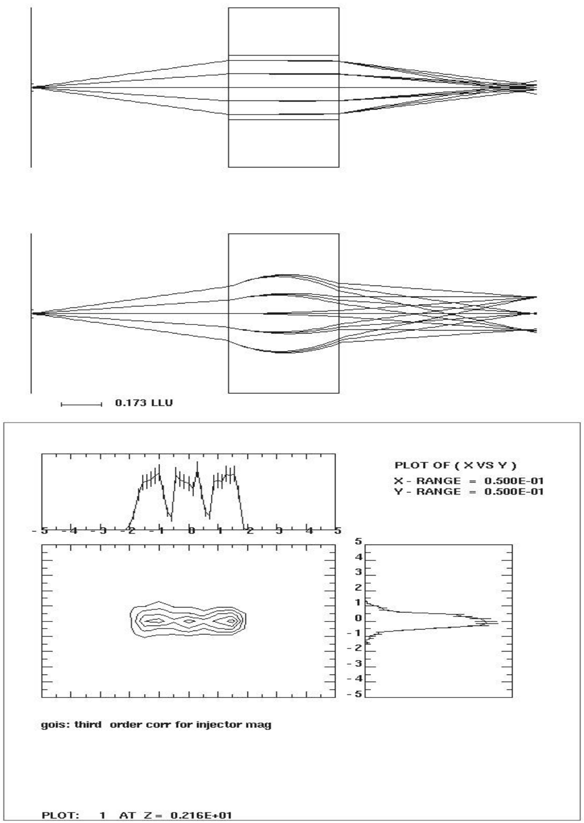


Figure 1: First order calculation (using TRANSPORT, upper: non- dispersive plane, lower: dispersive plane)



FIigure 2: Third order calculation with correction, mass dispersion of 1.5 %, using GIOS [7]

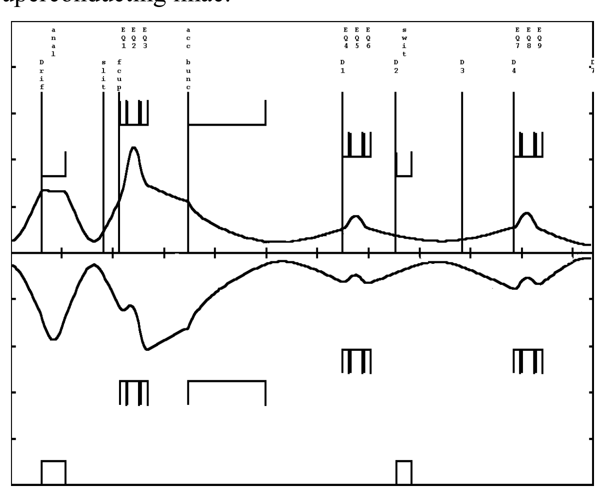


Figure 3: Beam envelope from ECR source upto RFQ entrance

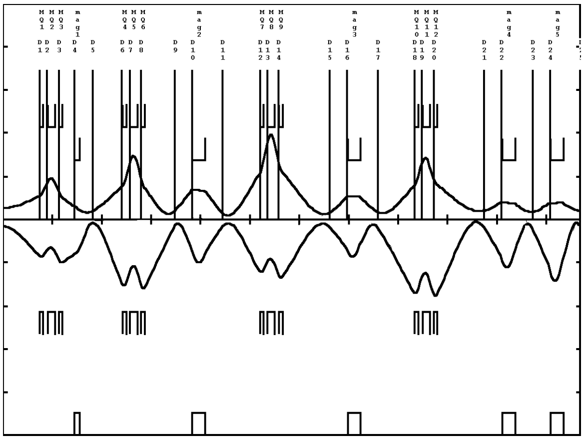


Figure 4: Beam envelope after the exit of the RFQ

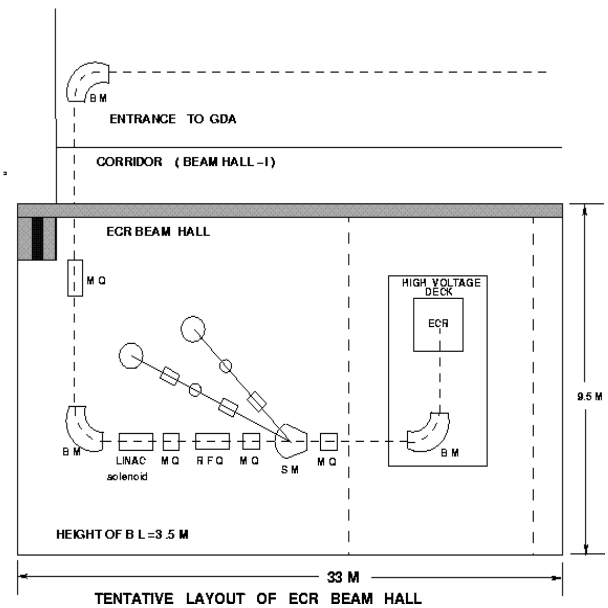


Figure 5: Layout of beam hall for the high current injection into superconducting linac

CONCLUSION

The proposed high current injector consisting of HTS-ECRIS, RFQ and DTL will replace the 15 UD Pelletron accelerator as an alternative injector to the superconducting linac.. It will enhance the beam current and energy of heavy ions for experiments related to nuclear physics, materials sciences, atomic physics.

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