

RARE ION BEAM FACILITY AT KOLKATA – PRESENT STATE OF DEVELOPMENT *

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Abstract

An ISOL (Isotope Separator On Line) post-accelerator type of RIB (Rare Ion Beam) facility is being developed at our centre. The facility will use light ion beams for producing RIBs using suitable thick targets. Also, development of an electron LINAC has been initiated with an eye to produce RIBs using the photo-fission route.

The RIBs will be ionized, mass separated and the RIB of interest will be accelerated using a heavy ion RFQ (Radio Frequency Quadrupole) followed by IH LINAC cavities.

The R&D efforts in various areas of this project will be discussed in this paper. Special emphasis will be given to the development of the RFQ and LINAC.

INTRODUCTION

An ISOL post-accelerator type of RIB facility is being developed at our centre [1]. A schematic layout of the facility is shown in Fig. 1. Light ions (p and α) from K=130 cyclotron will be used to produce RIBs using fusion-evaporation type of reaction or fission of heavy targets. In addition, a 50 MeV 100 kW SC electron LINAC is being developed at present to use photo-fission route of producing RIBs. The rare ions will be produced inside a thick target and ionised to 1^+ state in an integrated ion-source followed by a primary separation. The ions will be then fed into an on-line Electron Cyclotron Resonance Ion source (ECRIS) for high charge state ionization, mass separated and then accelerated in a Radio Frequency Quadrupole (RFQ) LINAC followed by a few IH cavities. The RFQ and first three IH cavities will accelerate the RIBs up to about 414 keV/u, charge stripped and further accelerated in three IH cavities up to about 1.3 MeV/u. Further acceleration using SC QWRs are being planned for the future. Fig. 2 shows the accelerator components that have been already installed and energised in the set up.

To facilitate on-going research activities, a beam switchyard has been made which can deliver RIBs up to about 29 keV/u using a shorter length RFQ. This dedicated research line is being installed at present.

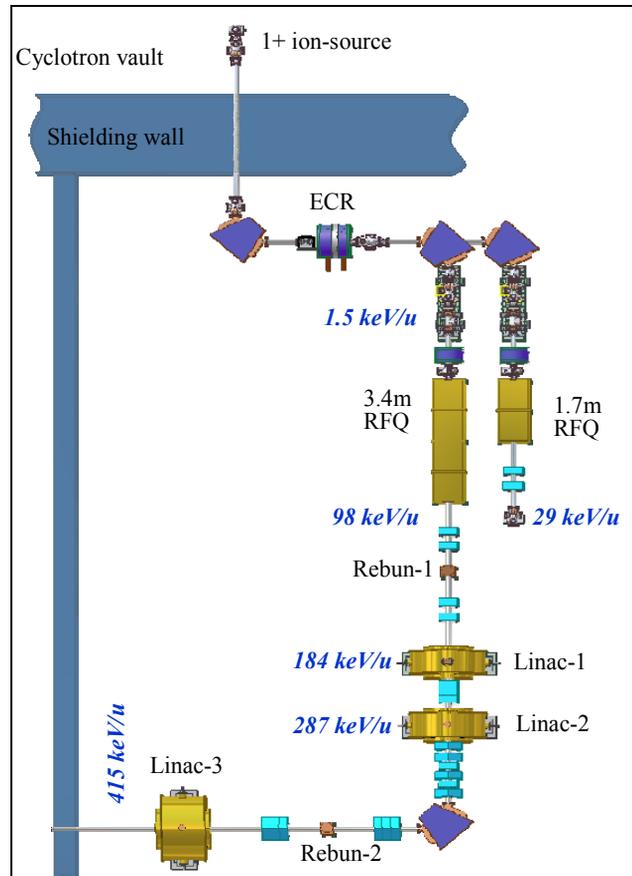


Figure 1: Layout of RIB facility.

DESCRIPTION OF RIB FACILITY

Target Ion-Source

The RIBs produced using thick targets will be diffusing out and enter in to an integrated ion source. Since diffusion rate increases with temperature, one usually selects refractory target compounds such as oxides and carbides for the target. Target materials can be deposited on Graphite matrices (RVCF fibres) that can withstand high temperature and have sufficient porosity to allow radioactive atoms to diffuse out [2]. Sintering & grain growth due to beam heating hinders the release of ions. Special efforts are being tried to reduce the rate of this process [3] in our target development program.

*This is a VECC-DAE project

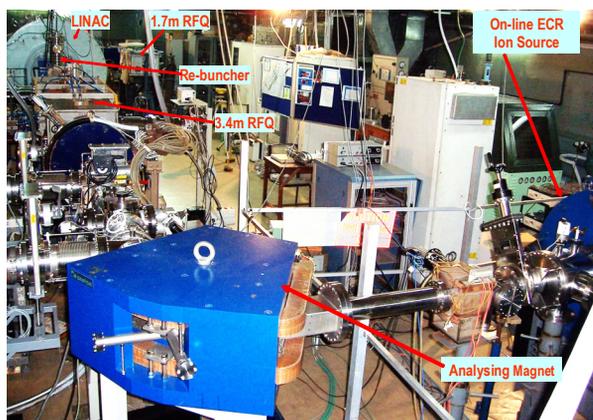


Figure 2: Presently installed accelerator components in RIB beam Hall.

No unique ion source exists which provides a long term solution for many elements in the harsh radiation and thermal environment close to the target. An ion source has already been developed which can work in high temperature surface ionisation mode or hollow cathode type arc discharge mode. The option of using an electron beam plasma ion source or specially made ECRIS is being explored at present. The low energy 1^+ ion beam from the first ion-source will be injected into the ECR ion source for higher charge state (n^+) production in the charge breeder.

The Charge Breeder

The rare ions have to be ionized to higher charge state ($q/A \geq 1/14$) with good enough efficiency for post-acceleration to higher energies. In the “two-ion source” concept the beams are ionized to 1^+ charge in the integrated target-ion source and then injected into the on-line ECRIS for further ionization to higher charge state n^+ .

The ions extracted from the integrated ion source will pass through a pre-separator, the 1^+ ion species of interest will be focussed to a small size and decelerated to very low energy for efficient capture within the ECRIS plasma [4]. To keep the ECR volume large we have chosen a 6.4 GHz on-line ECR ion source as the charge breeder. This ion-source has been operated for both gaseous and metallic beams using the MIVOC [5] technique in a stand-alone mode. Also for heavier ions, a charge breeder with ECR operating in 10+14 GHz dual frequency mode has been designed [6].

Low Energy Beam Transport

This section has the dual purpose of selecting the RIB of interest for further acceleration and tailor the beam within the acceptance ellipse of the RFQ. It consists of an Einzel lens, a dipole magnet (90 degree, 0.25 T), a solenoid magnet (30cm length, 0.65 T) and optimised drift distances. The ion optics of this low energy transport

line has been designed using the computer code TRANSPORT and COSY INFINITY. The dispersion and the magnification in the dispersive plane of 1.84 cm. and -0.88 respectively. The RFQ demands converging beam in both the planes and a reasonable match could be obtained.

The Heavy-Ion RFQ Linac

Radio Frequency Quadrupole Linac would be the first post accelerator of our RIB facility. It has been designed for $q/A \geq 1/14$ and input energy of 1.7 keV/u. The four-rod type RFQ is 3.4m long (vane length ~ 3.2 m) and operates at the resonance frequency of 37.8 MHz.

The development of RFQ has been done in phases. In the first phase we have developed a 1.7 m RFQ capable of accelerating beams up to 29 keV/u. This RFQ operates at a resonance frequency of 33.7 MHz. It has already been installed and operational since the year 2005. Transmission efficiencies of about 85% were measured for Ar^{4+} and other beams like $O^{2+,3+,4+}$ and $N^{3+,4+}$ through the RFQ. The details of this RFQ and results of beam tests are reported in ref [9]. This RFQ will be used in a dedicated beam line for material science research in near future.

The post-acceleration RFQ is almost identical to the RFQ mentioned above but is longer to achieve higher output energy of 98 keV/u. The resonant structure including the vanes, base plate and supporting posts is made from OFHC copper. The top cover (cavity) has been made from steel plated inside with copper. A photograph of the 3.4m RFQ during installation is shown in Fig. 3. In the preliminary test, beam transmission efficiency of 90% has been measured for O^{5+} . Further details about the RFQ system has been reported elsewhere [10].



Figure 3: The 3.4m RFQ post-accelerator.

Medium Energy Beam Transport

This section of the RIB system has been designed to match the RFQ beam with the longitudinal & transverse acceptance of LINAC-1. This section consists of a pair of quadrupoles placed before and after a 4-gap, 37.8 MHz re-buncher. The re-buncher has been already fabricated and installed. The frequency measured during low power tests are in good agreement with ANSYS simulation. The re-buncher has been energised up to 1 kW power in recent

tests. A photograph of the re-buncher during assembly is shown in Fig 4.



Figure 4: The Re-buncher during assembly.

The IH-LINAC Post-accelerators

After the initial stage of acceleration in the RFQ, the subsequent acceleration of ions will be done using IH cavities. Three such cavities would accelerate the 98 keV/u beam from RFQ to about 414 keV/u. The important parameters of the cavity are shown in Table 1. A photograph of the first cavity is shown in Fig. 5. The detailed design and measurement results of IH cavity has been reported elsewhere [11]. The first IH cavity has already been installed, powered up to 2.5 kW and beam acceleration tests are being carried out at present.

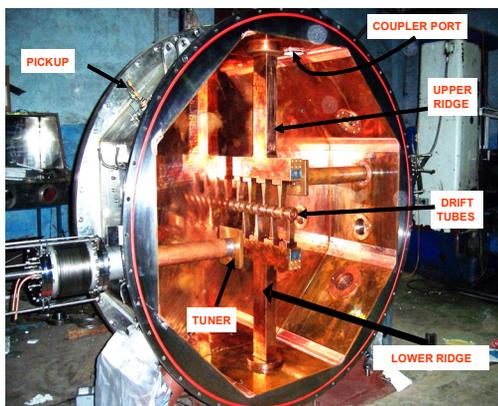


Figure 5: The first IH cavity during assembly.

SUMMARY & OUTLOOK

The status of ISOL post-accelerator type RIB facility development at our centre has been presented. A dedicated experimental line is being installed at present which will deliver stable heavy-ion beams of energy up to

29 keV/u at the end of the 1.7m long RFQ. The longer post-accelerator RFQ, re-buncher and first IH cavity have also been installed and beam tests are being conducted at present. The second IH cavity has been fabricated and its assembly is on progress at present.

The present RIB facility has been planned around the existing K=130 cyclotron. A programme to develop the front end of a 50 MeV, 100 kW super-conducting electron LINAC has been initiated in collaboration with TRIUMF which will be used for the production of neutron rich RIBs using the photo-fission route.

Table 1: Important Parameters of First Three IH Cavities

Parameter	IH-1	IH-2	IH-3
Frequency [MHz]	37.8	37.8	75.6
q/A	$\geq 1/14$	$\geq 1/14$	$\geq 1/14$
T _{out} [keV/u]	186.2	289.1	413.9
No. of gaps	9	10	17
Max. field [E _{Kil}]	1.4	1.3	1.4
Sync. Phase	-21.5	-25.6	-18
L _{Cavity} [m]	0.618	0.871	0.913
Accln. Gradient [MV/m]	2.13	1.79	1.99
Z [MΩm/m]	342	432	566
Q-value	13765	18963	16982
RF power	19.9	16.4	14.8

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