

RARE ION BEAM FACILITY AT VECC: PRESENT AND FUTURE *

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Abstract

An ISOL post-accelerator type Rare Ion Beam (RIB) Facility [1, 2] is being developed at our centre (Fig. 1). The RIBs will be produced by light ion induced fusion evaporation and also using photo-fission reaction in future. The primary reaction products will be ionized using two-ion source charge breeder. The possibility of feeding the primary reaction products directly to an ECR ion source using multi-stage skimmer and gas jet transport technique is being explored at present. An extended rod type heavy ion RFQ, one buncher and three IH cavities have been successfully commissioned. These accelerate stable beams up to about 414 keV/u. Three more IH cavities will increase the energy to about 1.3 MeV/u and SC QWRs will augment the energy thereafter. In the next stage of development, an Advanced National facility for Unstable & Rare Isotope Beams (ANURIB) has been envisaged. This green field project will deliver stable & RI beams from 1.5 keV/u to 100 MeV/u. This will have both ISOL type and PFS type facility. Neutron & positron beam based facilities will also be built around an electron linac.

PRODUCTION OF RIB

Light ion ($p \leq 30$ MeV, $\alpha \leq 80$ MeV) beams available from a K=130 room temperature cyclotron will be used as primary beams for the production of RIBs using thick targets. The RIB of interest will be ionised and separated from other reaction products. A two ion source technique consisting of a surface ioniser-ECR ion source combination or two ECR ion sources in cascade, where the first ECR is a permanent magnet free 1^+ source, will be employed depending on the RIB of interest. Also the possibility of feeding the reaction products directly to the second ECR source using a multistage skimmer system is being explored. The separation stage following the second ECR is a large acceptance (120π -mm-mrad) magnetic separator with a dispersion of about 2m.

A 50 MeV / 2 mA superconducting electron LINAC [3] is being developed in collaboration with TRIUMF, Canada which will be used to produce RIBs using photo-fission route.

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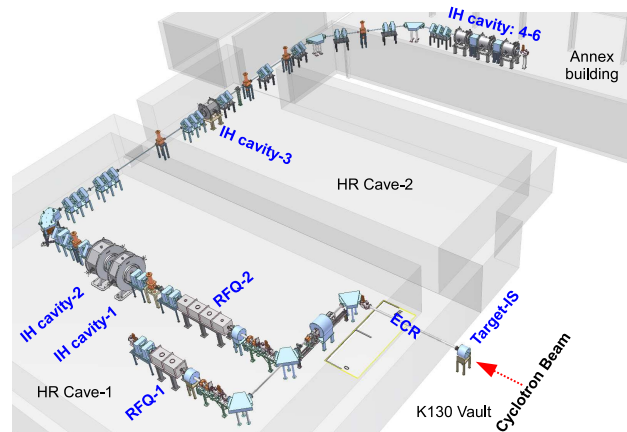


Figure 1: A three dimensional layout of the RIB facility at VECC.

POST-ACCELERATION OF RIB

The first stage of the post-acceleration is an extended rod type RFQ [4] designed for charge to mass ratio $q/A \geq 1/14$ and resonating frequency of 37.8 MHz (Fig. 2). The RFQ provides acceleration from 1.7 keV/u to 98.8 keV/u over a length of 3.4 m. The vanes, posts and the base plate of the RFQ have been machined from C10100 grade copper and they have internal cooling channels. The outer enclosure has been fabricated from steel (grade S30403) and electroplated from inside with copper. The power requirement of the RFQ is around 35 kW to produce a vane voltage of 54 kV. Typically 80% transmission has been achieved through RFQ. It is important to mention that the vanes of our RFQ make an angle of 45° with respect to horizontal(X) and vertical(Y) directions and as a result the X and Y motions of the emerging beam are coupled.

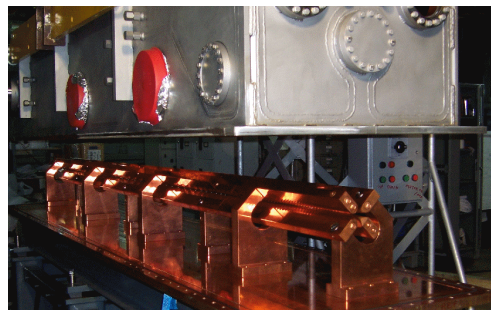


Figure 2: Heavy ion RFQ during installation.

The medium energy beam transport line between the RFQ and first IH cavity [5] uses a 37.8 MHz buncher and two quadrupoles on either sides of it for acceptance matching. The quarter wavelength structure has four gaps and consumes 6 kW power to produce a net bunching voltage of 60 kV.

The second stage of post-acceleration is done using three IH LINAC cavities - the first two operating at 37.8 MHz and the third one operating at 75.6 MHz (Fig. 3). The ions are accelerated in these cavities with a typical synchronous phase of -20° . The drift tubes, ridges and other internal components of the cavity have been fabricated from readily available C11000 grade copper. The octagonal shape cavities have been fabricated from explosively bonded copper with steel. During the initial commissioning stage, the three IH cavities have been placed in a straight line with quadrupole triplets in between the cavities for transverse focusing. Typical transmission through the three IH cavities is around 50% at present. These three IH cavities provide an acceleration up to 414 keV/u.

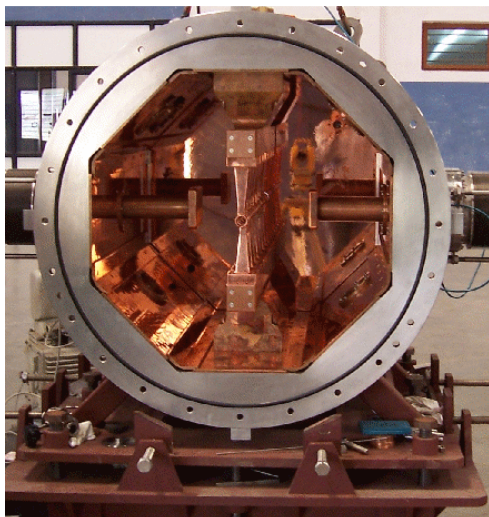


Figure 3: Third IH cavity during installation.

Due to space limitation at the installation site, which is an experimental cave of the cyclotron, three cavities would not be placed in a straight line finally. After the second IH cavity, there will be six quadrupoles followed by a 90° bend. The X-Y motions of the beam are decoupled before the bend. There will be two quarter wavelength 37.8 MHz bunchers for longitudinal matching of the beam - one before and one after the bend. The beam will pass through a meter long tunnel made in the concrete wall at the installation site and accelerated in the third IH cavity placed in the adjacent experimental cave. The nearly acromatic medium energy beam transport line [6] has a total of nine quadrupoles downstream of the bend to tailor the beam as required by third IH cavity.

The beam with $q/A \geq 1/14$ will pass through a charge stripper after the third IH cavity and the subsequent acceleration stages have been designed for $q/A \geq 1/7$. The

04 Hadron Accelerators

A19 Secondary Beams

fourth, fifth and sixth IH cavities have been designed assuming 0° synchronous phase (KONUS beam dynamics). The longitudinal focusing has been achieved using a negative synchronous phase cell at the beginning of the fifth and sixth cavities and the transverse focusing has been achieved using quadrupole triplets located in between the cavities. The beam energy at the end of the sixth cavity will be around 1.3 MeV/u. The fourth cavity is being fabricated at present. Further acceleration up to about 2 MeV/u will be done using superconducting quarter wave resonators which are being designed at present. Part of the analysing section after the charge stripper and the acceleration stages from fourth IH cavity onwards will be commissioned in a new building being built at present.

EXPERIMENTAL FACILITIES

RIB will offer enormous opportunities in all fields of accelerator based physics research for the next few decades. Development of associated experimental setup is therefore an integral part of RIB development. A beam switchyard has been commissioned recently after the ECR ion source which will allow experimentalists to use the stable and RI beams when commissioning is in progress in the main beam line. In the downstream of this line there is a RFQ capable of accelerating beams up to about 29 keV/u. This material science beam line also includes an experimental UHV chamber with ports for installation of in situ deposition and characterisation tools. Apart from this, set up for SEM, SPM, Mössbauer spectroscopy, positron annihilation etc. have been installed to utilise the opportunities with RIBs. A collinear laser spectrometer setup is being developed at present to study the hyperfine transitions and isotope shifts of atoms / ions. Also very sophisticated large area modular BaF2 detector array and neutron multiplicity detector array have been developed at our centre which will be gradually augmented depending on the experimental plans using RIB.

FUTURE PLAN - ANURIB

The ongoing development of a RIB facility at our centre has produced enough expertise in different fields of accelerator science and technology. This includes thick target development, ion source research, RFQ, IH cavities etc. in addition to our experience with cyclotrons for many years. The development of superconducting electron LINAC in collaboration with TRIUMF and superconducting cyclotron at our centre are helping us to gain experience in the field of superconducting RF cavities, magnets and cryogenics.

As a natural extension of the present RIB development a new proposal (Advanced National facility for Unstable & Rare Ion Beams - ANURIB; Fig. 4) has been placed for scientific scrutiny and financial sanction to the department. This will be a Greenfield project spanning over an area of 25 acre located about 5 km from the present campus.

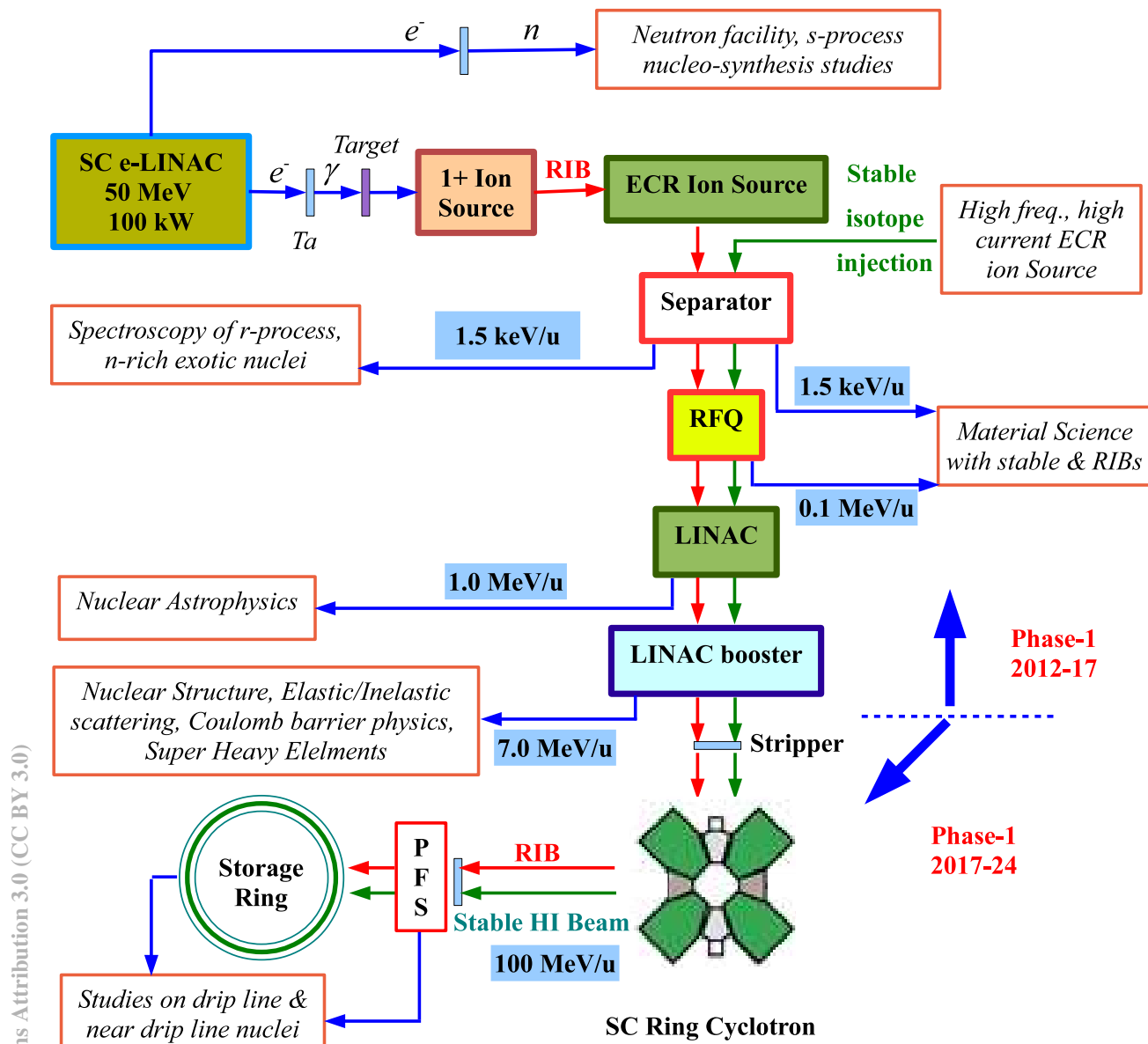


Figure 4: ANURIB project schematic : Accelerator facility & physics opportunities.

The primary accelerator for ANURIB will be the superconducting electron LINAC being developed with TRIUMF at present. The RIBs will be produced by photo-fission reaction and ionised by using two ion source ($1^+ \rightarrow n^+$) method. The RIB of interest will be selected in an isotope separator and accelerated in stages using RFQ, IH cavities and quarter wave resonators up to about 7 MeV/u. Linear accelerators in general have good transmission efficiency and therefore the same facility will be also delivering stable beams of high intensity. There will be option that RIBs and stable beams can be charge stripped after the linear acceleration stages and accelerated up to about 100 MeV/u using a superconducting ring cyclotron. At this energy the projectile fragmentation of stable and RI beams along with a Projectile Fragment Separator (PFS) will provide

interesting research opportunities for the study of drip line and near drip line nuclei.

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