THE PROPOSED RADIOACTIVE ION BEAM FACILITY AT THE CALCUTTA CYCLOTRON CENTRE

B. SINHA, A. CHAKRABARTI, A. BANERJEE, V. BANERJEE, S. BHATTACHARYA

Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Calcutta 64, India

P.SEN

Saha Institute of Nuclear Physics, 1/AF Bidhan Nagar, Calcutta 64, India

The production of radioactive ion beams (RIB) is a topic of great current interest. This will open up exciting areas of research on drip line nuclei and help us understand the origin and relative abundance of elements of the universe. However, the technology needed for obtaining accelerated RIBs of desired intensity and purity is extremely tricky and is one of the most challenging tasks for experimental nuclear physicists. The RIB facility at the VEC centre has been planned with the aim of accelerating ions of $q/A > 0.025$ to energies upto 1 MeV/u and would be of the ISOL post accelerator type. The present status of the activities in this direction will be presented.

1 Introduction

The plan to start R&D activities leading ultimately to the development of a low energy ISOL–post accelerator facility is almost an year old now. The choice for this particular type of RIB facility in preference to the PF type of RIB facility was guided by, among other considerations, e.g., of luminosity, purity, etc., by the presently available accelerator facility at VECC. The proposed RIB facility, schematically shown in fig.1, would be a light-ion facility accelerating ions of $q/A>0.025$ to energies upto about 1 MeV/u. The parameters are chosen to strike an optimum balance between the physics interest, cost and the R&D efforts involved in building such a facility.

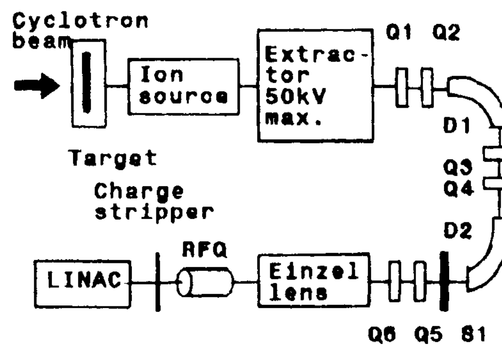

Figure 1: The proposed RIB facility at VEC centre

2 The major thrust areas in R&D activities

Keeping in mind the ultimate objectives, four major thrust areas for R&D studies have been identified. These are:

1. The study of production and release of radioactive nuclei of different elements from thick targets of different matrices and made from different grain sizes. Proton and α-particle beam from VEC accelerator would be used for the purpose.
2. Development of a new ECR ion source and modification of existing ISOL ion sources: The on-line single stage ECR ion-source is needed for obtaining higher efficiencies atleast for the gases. The existing ion source extractor assembly has to be also redesigned for extraction at higher voltages (50 kV instead of 30 kV present) and for pulsed beam extraction instead of continuous extraction.
3. Upgradation of the present ISOL facility to enhance the resolving power to atleast 10000 for the separation of isobars of light masses. This needs detailed beam optical design studies to fix the needed beam line optical elements.
4. To develop expertise for rfq design: The rfq needed for our purpose should be able to accelerate ISOL beam of $q/A>0.025$ and energy 2 keV/u to an energy of about 80 keV/u at its output. In the following paragraphs the present status of the activities in the above directions are described briefly.

3 Present status of activities

3.1 Design of the thick target production chamber

In order to achieve a secondary ion beam intensity in the range of 10^7 to 10^{10} pps, thick targets (few g/cm^2) have to be used. The production yields and release efficiencies of various radioactive products from thick targets have been studied by various groups [1,2]. Using the VEC accelerator a number of radioactive species are expected to be available as RIBs with intensities in the range of

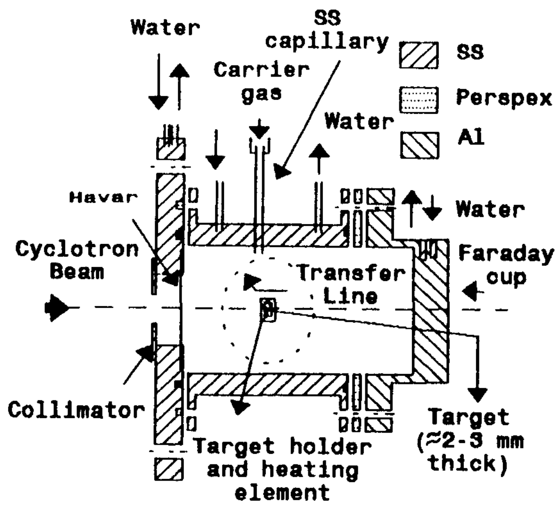

Figure 2: The target chamber assembly for VEC RIB facility

10^7 to 10^9 p/sec. Using the VEC accelerator a number of radioactive species are expected to be available as RIBs with intensities in the range of 10^7 to 10^9 p/sec. A few of them are listed in table 1. The list is surely going to increase manyfolds if appropriate thick targets for the production of other radioactive species can be made and efforts in this direction will be started soon. For efficient and fast release of the radioactive gases, the targets have to be heated to high temperatures (upto about 2500°K depending on the target) and a judicial choice of the target composition (refractory materials etc.), target matrix and grain size become important. The schematic diagram of the target chamber assembly for VEC-RIB facility is shown in Fig. 2. A beam intensity of upto 20 μA from the VECC Cyclotron would not heat the targets to desired high temperatures . Thus provision is kept so that temperatures upto 2000°K can be obtained by resistively heating the target holder using a 800 A/10 V power supply. The target chamber along with the transfer line is being fabricated.

3.2 Activities related to ion source and extraction

A new design of the ion source–extractor assembly for bunching of the ion beam has been completed. The necessary power supply for the above has been built. The present ISOL ion-source would be used for the initial test on the bunching capability and the extraction efficiency. If this can be achieved without significant loss of average intensity the duty cycle of subsequent post accelerators (rfq, linac, etc.) can be correspondingly reduced from cw to say, 20%. The design for a single stage ECR ion-source is being completed. A 6.4 GHz, 3kW Klystron generator

Table 1: Typical cross-section estimates (ALICE 85) for some of the radioactive nucleides to be accelerated in VEC-RIB facility. The beam energy of 20 MeV for protons and 50 MeV for α-particles were used for the computation of average cross-section.

Nuclei	Production Route	Target Material	σ_{Av} (mb)
^{11}C	$^{11}B(p,n)$	BN	48
^{13}N	$^{13}C(p,n)$	Graphite	70.5
^{14}O	$^{14}N(p,n)$	BN	5
^{15}O	$^{14}N(\alpha,p2n)$	BN	41
^{17}F	$^{14}N(\alpha,n)$	BN	7.5
^{18}F	$^{16}O(\alpha,pn)$	Al_2O_3	108
^{19}Ne	$^{19}F(p,n)$	LiF	20
^{27}Si	$^{27}Al(p,n)$	Al_2O_3	62
^{29}P	$^{29}Si(p,n)$	SiC^*	49
^{30}P	$^{31}P(\alpha,\alpha n)$	$Ca_3P_2^*$	73
^{34}Cl	$^{35}Cl(p,pn)$	$CaCl_2^*$	65
^{35}Ar	$^{35}Cl(p,n)$	$CaCl_2^*$	37

* Target preparation methods being explored.

has been procurred and installed for this purpose.

3.3 The design of the high resolution line

A very high resolving power of the order of 10000 or more can be acheived with two dipole magnets arranged in the dispersion additive mode [3]. The design of the beam optical system for VEC-RIB consisting of a number of quadrupoles, two dipoles and one einzel lens is being completed. The detailed design of one of the dipole magnets has been completed and the magnet is being fabricated.

3.4 Activities related to rfq development

The rfq for the RIB facility should be able to accelerate low β and low q/A heavy-ions and the optimum frequency range from the beam dynamical point of view lies in the range of 25 to 40 MHz. In this range of frequency the 4 rod $\lambda/2$ structure pioneered by the Frankfurt group [4] is the most convinient one from the point of view of the overall size, machinability, cost and other considerations. The rfq developmental activities at VECC is

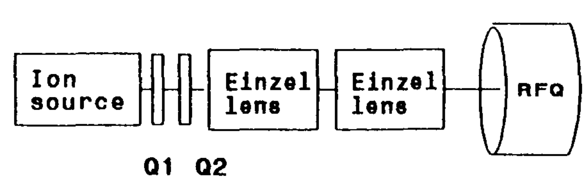

Figure 3: The proposed heavy ion implanter

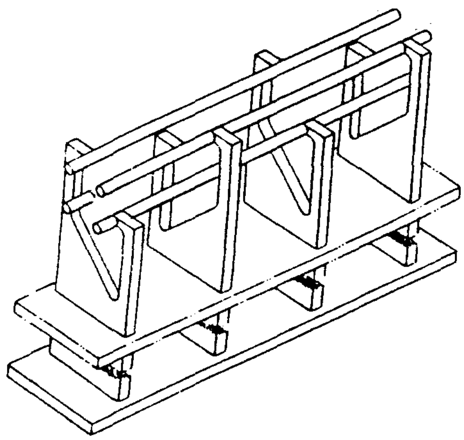

Figure 4: The rfq test structure

planned in two stages: first it has been decided to build an ion implanter with q/A >0.0625 and an output energy of 40 keV/u (fig.3). Subsequently the rfq needed for the RIB facility will be designed and fabricated in the second stage. A scaled down unmodulated 4-rod assembly has been designed (schematically shown in fig.4) to resonate over an expected frequency range from 85 to 140 MHz. The rf characteristics (frequency, Q and R_p values,etc.) and the longitudinal field distribution of this structure will be studied. The structure consists of 4 rods 500mm in length and having an aperture to radius of curvature ratio of 1.18. The 4-rods are supported by 4 equidistant posts of width 75mm and thickness 15mm. The distance between the posts is 145mm. The height of the post is variable(by adjusting the tuning plate's position) over a distance of 100mm. The designed value for the diameter of the tank housing the rod assembly is 390mm.

4 Summary

A modest level of activity has been initiated in the last one year at the VEC centre for R&D studies required for building a low energy (≈1MeV/u) RIB facility. The VEC-RIB facility is expected to deliver quite high intensity ($\approx 10^7 - 10^9$ atoms/sec) RIBs and the number of such beams could be quite large if proper efforts are directed towards the making of new thick targets. Study of release of radioactivities from these targets, development of ion soureces alongwith the development leading to beam pulsing, the design of a high resolution beam optical line injecting beam into rfq for further acceleration and the development of a low β, low q/A rfq are identified as the main technologically challenging areas where R&D activities should be concentrated.

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References

1. H.L. Ravn *et al*, Proc. of Accelerated radioactive ion beams workshop, Parksville, Canada, 1,94(1985).
2. P. Deckrock *et al*, Proc. of 2nd Int. Conf. on radioactive nuclear beams, Louvain-la-Neuve, 121(1991).
3. H. Wollnik, Proc. of workshop on the science of intense radioactive ion beams, Los Alamos, LA-11964-C, 186(1990).
4. A. Schempp, *Nucl. Instrum. Methods* **50**, 460 (1990).