ECR HEAVY ION SOURCE AND EXTERNAL INJECTION SYSTEM FOR THE CALCUTTA VARIABLE ENERGY CYCLOTRON (VEC)

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ABSTRACT

A compact room-temperature ECR heavy ion source alongwith its external injection system is in an advanced stage of development at the Variable Energy Cyclotron Centre (VECC). Both stages will be initially energized using 6.4 GHz microwave power. The source will facilitate acceleration of heavy ions from the K= 130 cyclotron at the Centre. Design aspects of the source and the injection line and the present status will be discussed.

1. INTRODUCTION

The Variable Energy Cyclotron (VEC) at Calcutta is operating continuously since end of 1981 with a hot cathode light ion PIG source. Sometime ago it was decided that VEC should be equipped with external ECR heavy ion source to meet the pressing demand of heavy ions from the cyclotron. After making survey[1-5] of the working ECR sources ,the following guiding features were drawn . It should be a compact two stage room-temperature source enclosed in iron yoke. Iron yoke in the form of a cylinder will be utilised also for source alignment and restricting the X-rays emanating from the source. It was also decided that a sextupolar stabilizing field will be provided in the second stage, and commercial microwave generator will be used as power source.

2. DESIGN

Schematic diagram of the source is shown in fig 1. The second stage design is almost similar to that of the Compact (CP) ECR source of MSU[6-8]. The entire source is enclosed in a 25 mm thick iron cylinder acting as the yoke to capture the return flux. Four sets of coils, C_1, C_2, C_3 and C_4, generate the resonance and mirror fields in both the stages. Sextupolar magnetic field generated by permanent magnets M alongwith the mirror field produce a B-minimum configuration in the second stage.

Stage 1 plasma chamber S1 is made of 94 mm internal diameter copper pipe and has a 20 mm diameter quartz tube along the axis where microwave discharge takes place. RF power is fed in this stage parallel to the axis. The second stage plasma chamber S2 is made out of a solid oxygen free high conductivity(OFHC) copper billet. This chamber has an internal diameter of 108 mm and length 345 mm. The chamber is water cooled and has slots for mounting the $SmCo_5$ magnet bars externally i.e. outside the vacuum. Three radial ports are provided for vacuum gauge, alternative RF line and oven connections.

Heavy ions are extracted from the aperture on the emitting plasma electrode at positive voltage of about 10 kV.The extractor electrode voltage can be varied from 0 to -5 kV. Two 152 mm diffstak type pumps will be used to pump first stage plasma chamber and extraction chamber and cryopumps will be used beyond the extraction region. Second stage will be pumped, mainly, by the plasma itself. Additional pumping will be provided through the apertures on the plasma elctrode from the extraction side. The specifications of the source are given in table 1. Some details of various components of the source are given below:

2.1 Microwave

For the present appliication, 6.4 GHz has been chosen to be the resonance frequency for both the stages. It has been planned to use a single 6.4 GHz,

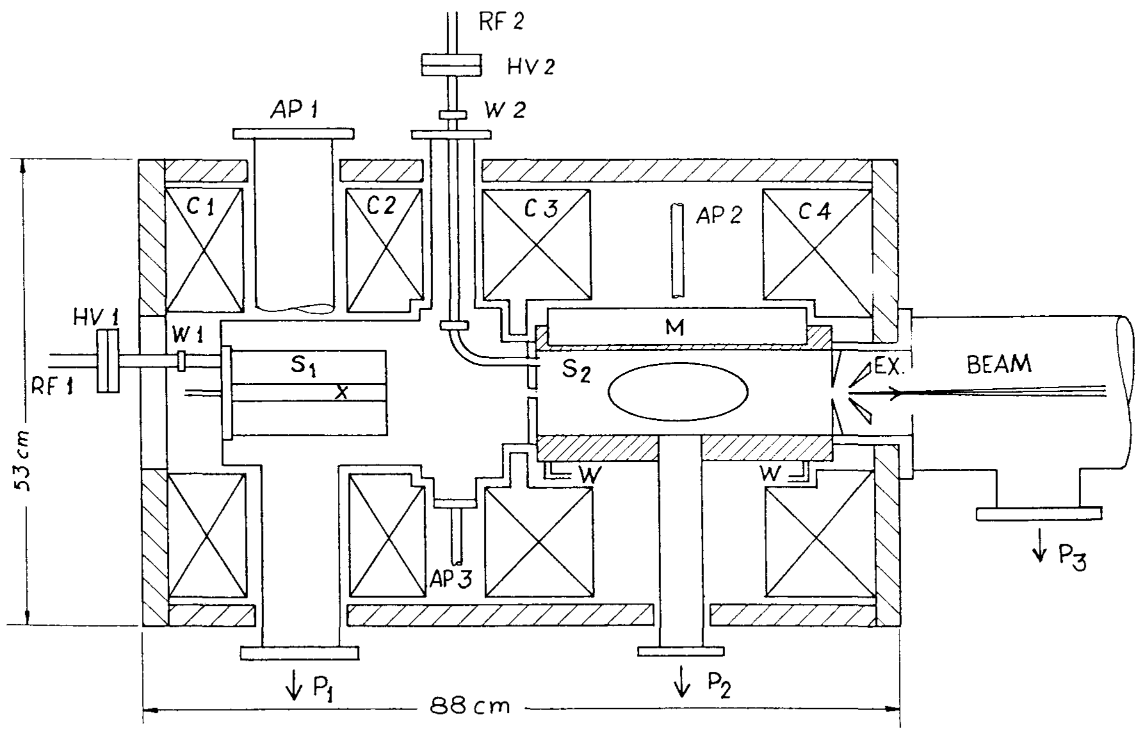

Fig. 1: *Layout of the VEC ECR source. RF: microwave power feed, HV: high voltage isolators, W: microwave window, S1: stage 1, S2: stage 2, C: solenoid coil, M: sextupole magnet, AP: additional ports, P: pumping ports.*

Table-1.

i.	Length of the source	88 cm
ii.	Outer diameter of the yoke cylinder	53.6 cm
iii.	Number of solenoid coils	4
iv.	Frequency of operation	
	-Stage 1	6.4 GHz
	-Stage 2	6.4 GHz
v.	Plasma chamber diameter	
	-Stage 1	94 mm
	-Stage 2	108 mm
vi.	Sextupole magnets	
	-Length	305 mm
	-Field diameter	118 mm
	-Field on the pole tip	4 kG
vii.	Estimated solenoid power	
	-For 6.4 GHz operation	25 kW
	-For 10.0 GHz operation	52 kW

3 kW microwave generator and feed both stages by a power divider. RF is injected in both the stages parallel to the axis, although provision has been kept for radial injection in the second stage.

2.2. Magnetic field

As is common with most of the conventional ECR sources, two types of magnets are used. One type is the solenoid magnets and the other is $SmCo_5$ permanent magnets for the sextupolar field. Four solenoidal coils C_1,C_2,C_3 and C_4 generate the required resonance field of 2.29 kG and also the mirror fields in both the stages. The sextupolar $SmCo_5$ magnet in the second stage alongwith the solenoid magnet produces a B - minimum configuration in this stage.

2.2.1. Sextupole magnets: Each 305 mm long sextupolar bar is made up of five individual blocks of size 61.0 mm x 38.1 mm x 50 mm, having a residual magnetism of 9 kG magnetized along the 50 mm dimension. Sextupole field diameter is 118 mm Calculated field plots for the sextupole are shown in fig.2. Curve 1 in this figure corresponds to the radial field along the radius going into the centre of a pole and curve 2 along the radius going between the two adjacent poles.

2.2.2 Solenoids: Four coils C_1,C_2,C_3 and C_4 comprise of double wound double layer pancakes made from 6.3 mm square hollow copper conductor. The conductor is insulated by kaptan tape during winding.

Finished pancakes have an epoxy cast layer which gives them a circular shape with the outer diameter matching the internal diameter of the yoke cylinder of 486 mm

There are two types of pancakes as shown in table 2:

Table-2.

Pancake type	I.D. (mm)	O.D. (mm)	Number of turns/layer	Thickness (mm)
A	19Ø	475	21	14.8
B	24Ø	472	17	14.8

Fig 3 gives an example of the solenoid fields obtained using POISSON code with these coils.The lower curve corresponds to 6.4 GHz operation for both stages and the upper one corresponds to the 1Ø GHz operation. It is also possible to generate falling field configuration in the first stage as shown in the fig.4. It has also been planned to apply a bias voltage to the first stage plasma in the falling field case.

3. INJECTION LINE

The ECR source will be located in the high bay area over the shielding planks above the cyclotron as can be seen in the fig.5. The injection line[8] will utilize only magnetic elements. LM1 and LM2 are magnetic lenses to match the ECR extracted beam to the injection line. The 9Ø° charge state analysis system has two identical unit cells. Its transfer matrix has -I value in (x,x') as well as (z,z') planes. The charge state analysis is done at 2Ø cm downstream the quadrupole QT4. Further transport of the beam to the centre of the cyclotron is carried out, telescopically, using magnetic lenses LI1-4 and, subsequently, by LI5. An electrostatic mirror inflector inflects the beam into the median plane. Beam line vacuum will be near $1Ø^{-7}$ torr.

4. PRESENT STATUS

As in the middle of April 1989, the coil winding for 27 pancakes is over and orders for the solenoid power supplies have been placed. Two 6.4 GHz, 3kW(cw) microwave generators have been received from M/s Varian, USA. Iron Yoke cylinder has been rolled and is undergoing machining. One 25Ø mm diameter oxygen free copper rod has been received from MSU for making the second stage plasma chamber. Vacuum system for the source has been purchased. Permanent magnet blocks are expected to arrive anytime from Julich. Fabrication of the injection line

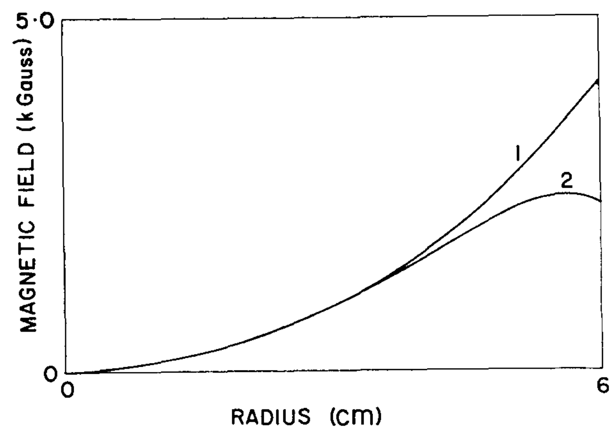

Fig. 2: Radial fields due to sextupole magnet. Curve 1: along the radius going into a pole centre; Curve 2: along the radius going between two adjacent poles.

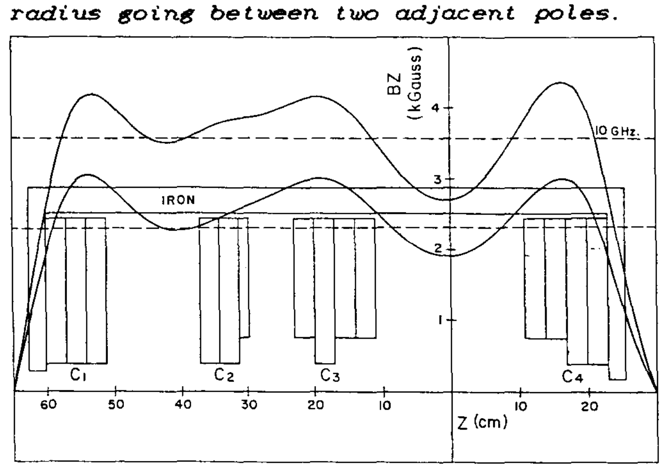

Fig. 3: Axial magnetic field of the solenoidal coils. The upper curve corresponds to 1Ø GHz operation and the lower to 6.4 GHz operation.

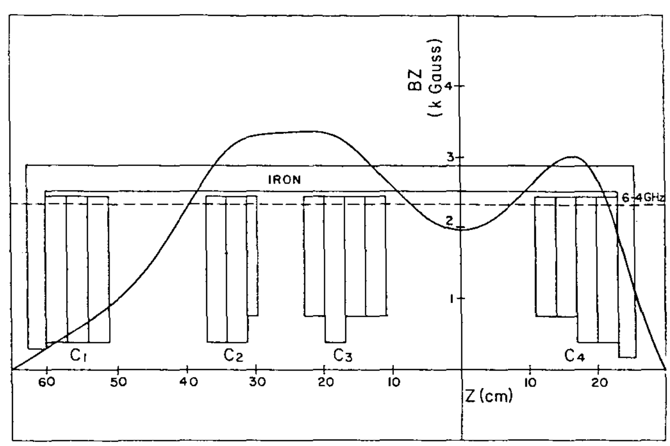

Fig. 4: Axial magnetic field of the solenoidal coils with gradient configuration in the first stage for 6.4 GHz operation. Excitation current in coil C_1 is zero in this case.

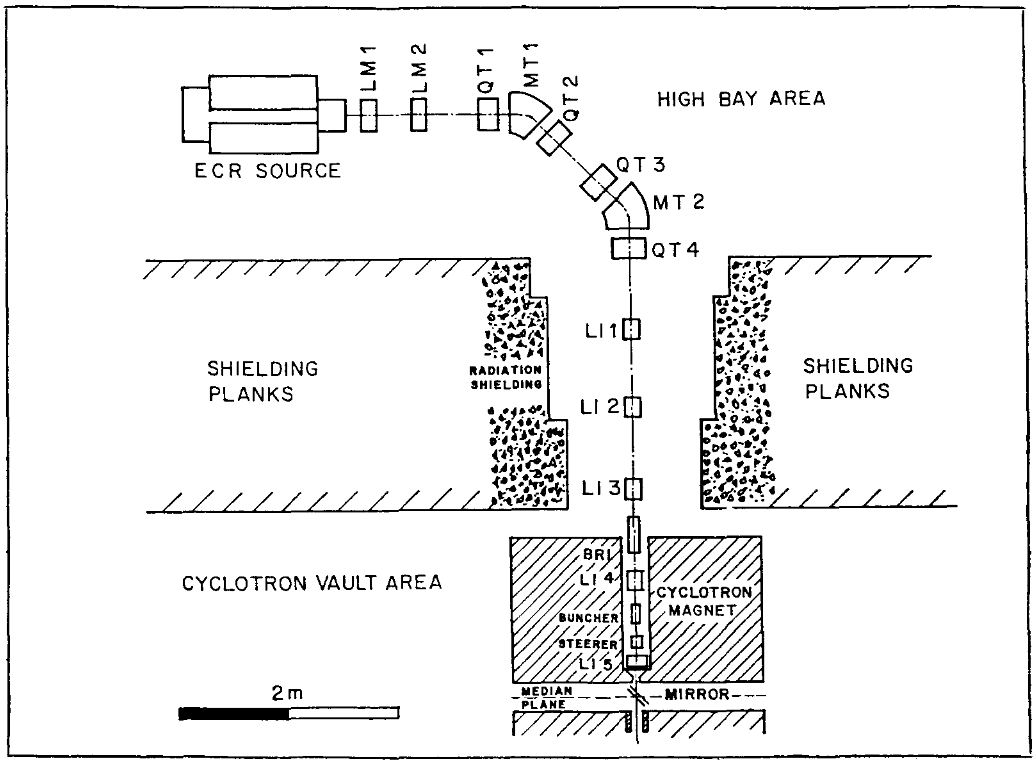

Fig. 5: Layout of the external injection line from the ECR source into VEC. LM, LI: Magnetic lenses, QT: quadrupole magnets, MT: dipole magnets, BRI: beam rotator solenoid. Charge state analysis is done 20 cm downstreamthe exit ofquadrupole QT4.

components just upto the 90° bend is underway. We hope to start testing of the source sometime early next year.

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