THE ELECTRON CYCLOTRON RESONANCE ION SOURCE AT VARIABLE ENERGY CYCLOTRON CENTRE, CALCUTTA

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Abstract

Characteristics of the 6.4 GHz two stage ECR ion source developed at Variable Energy Cyclotron Centre is presented. A few modifications which have been incorporated to improve source performance are highlighted. The source will facilitate acceleration of light heavy ions with the existing K = 130 (224 cm diameter) Variable Energy Cyclotron. Multiply Charged Heavy Ion (MCHI) beam from the source will also be utilised for atomic physics studies. Oxygen beam has already been used for ion implantation studies. The external injection system under development is nearing completion.

1. Introduction

The Variable Energy Cyclotron (VEC) having K = 130 is under regular operation at our centre since 1981. Only light ion beams of alpha, deuteron and proton are being routinely accelerated in the cyclotron using the existing PIG light ion source. The development of a two stage Electron Cyclotron Resonance (ECR) heavy ion source [1-3] was started from the end of 1987, and made operational in the middle of 1991.The present source has been developed based on the design [4] concept of the 6.4 GHz single stage compact (CP) source of MSU.

2. Ion Source

2.1 Description

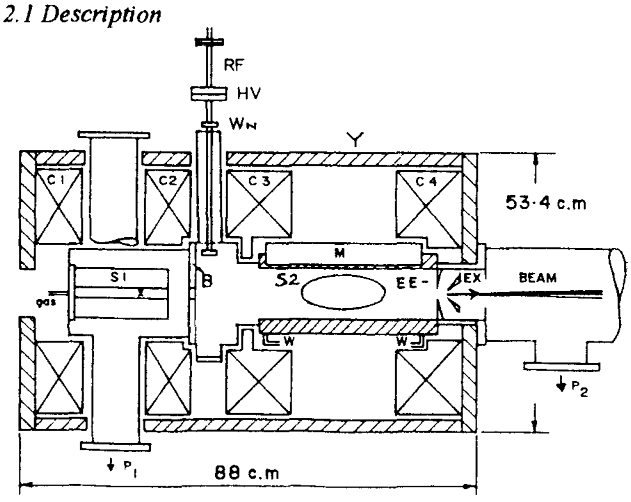

Fig 1. Schematic diagram of VEC ECR ion source . Y - Iron Yoke, C1 - C4 - Mag. coils, S1 - Stage -1, S2 - Stage 2, M - Sextupole, WN - Window, W - Water line, P1 - P2 Pumps, EX - Extractor, B - Baffle plate, EE - Emission electrode.

The VEC ECR ion source is [5,6] a room temperature, two stage source, as shown in Fig 1 schematically. The first stage consists of a copper cylinder of 9.4 cm inner diameter. The first stage has a 2.0 cm diameter quartz tube within which the first stage discharge takes place. The second or main stage consists of a copper cavity having 10.8 cm inner diameter. The second stage is water cooled and is fitted with 30 cm long $SmCo_5$ sextupolar magnet which generates the radial stabilising magnetic field of this stage. The pole tip field of sextupole is 4 kgauss and field diameter is 11.8 cm. Microwave power is directly fed only to the second stage from a 3 KW 6.4 GHz commercial microwave generator. First stage receives a fraction of microwave power leaking from the second stage through a 2.0 cm diameter hole on the baffle plate B in between the two stages. The first and second stages are enclosed in a 2.5 cm thick iron cylinder. Four coils C1-C4 comprising 27 pancakes generate the axial magnetic fields for the two stages. The pancakes are made of 6.3 mm square hollow water cooled copper conductors. Although the coils are

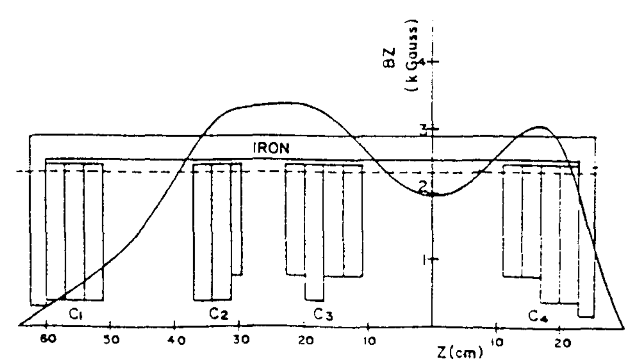

Fig 2. Axial Magnetic field of the solenoidal coils with gradient configuration in the first stage for 6.4 GHz operation. Excitation current in coil C1 is zero in this case

designed to provide mirror fields in the two stages, the first coil has not been operated so that stage one has a falling field configuration (Fig 2) instead of a mirror distribution Extraction system is similar to that of CP source at MSU. Puller electrode is placed 2.5 cm away from the ion emission electrode EE and its potential can be varied within 0 to -3 Kv. The source is biased positively within 8 to 10 Kv.

Two 600 liters/sec diffstak type pumps are used to pump stage - I vacuum chamber and the extraction chamber. Pressures attained in these chambers are 1.8×10^{-7} and 1.4×10^{-7} Torr respectively. Second stage is pumped from extraction side through three slots and 8 mm diameter extraction hole on the copper ion emission electrode. Cryopump and turbomolecular pumps have been used to pump the entire beamline[7] upto the cyclotron.

Heavy ion beam produced in the ion source pass through two glaser lenses and an analysing magnet to a faraday cup placed inside a diagnostic chamber. The analysing magnet is a 90° dipole magnet with 29° edge angle at entry and exit. The magnet has a pole gap of 8.6 cm. Widths of object and image slits have been set to 2 cm and are placed 89 cm away from the dipole magnet entry and exit points during regular operations.

3. New modifications.

Recently a few modifications (Fig 3) have been made in the source. While operating the source it was

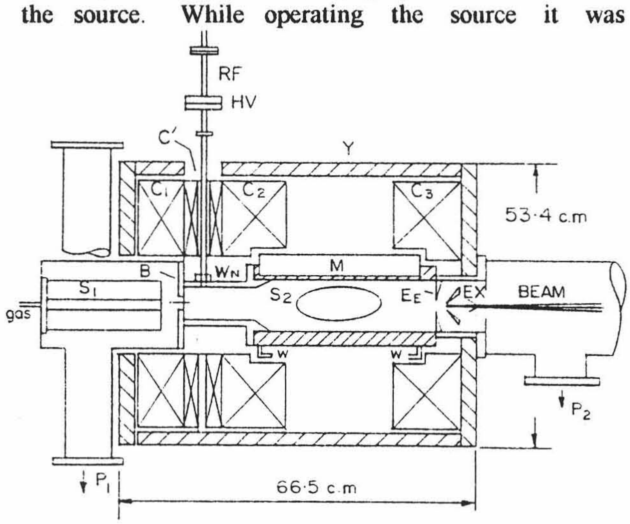

Fig 3. Schematic of modified ECR.
Y-iron yoke, C1-C3 - Mag. coils, S1 - Stage one, S2 - Stage two, M - Sextupole, WN - Window, W - Water line , P1 - P2 - Pumps, Ex - Extractor, B - aluminum baffle plate, EE - Aluminum emission electrode

experienced that the injection side magnetic field was inadequate and for better results, this mirror field required to be increased. To do that more pancakes have been packed at the microwave injection side. Since the source is operated in the falling field configuration, the coil C1 (Fig 1) was not used. Pancakes from this coil have been utilised to increase the field (Fig 4) in the injection side.

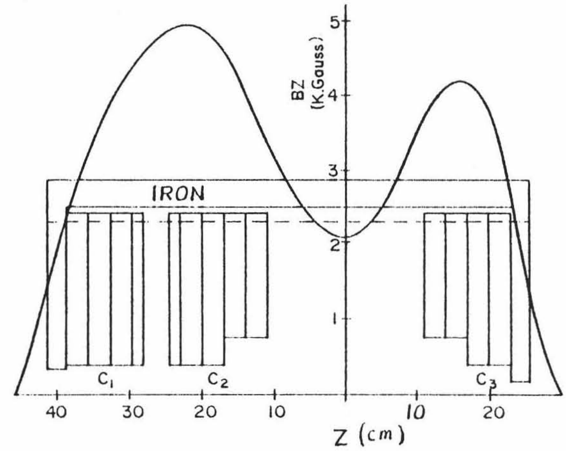

Fig - 4. Axial magnetic filed distribution after adding extra coil.

Another modification has been made by using aluminium electrodes in the plasma chamber. This is based on the recent report[10] that aluminium plasma chamber is a superior material as an emitter of cold electrons in the discharge which are essential to enhance the rate of high charge state ion production. To get this benificial effect at least to same extent, extraction side copper emission electrode and the stainless steel baffle plate between the stage - 1 and stage - 2 have been replaced by those made of aluminium. As it is time consuming to make a new second stage with aluiminium the same copper plasma chamber has been retained.

4. Axial Injection System

The axial injection system[8] is shown schematically in Fig .5. After analysing magnet the beam is passed

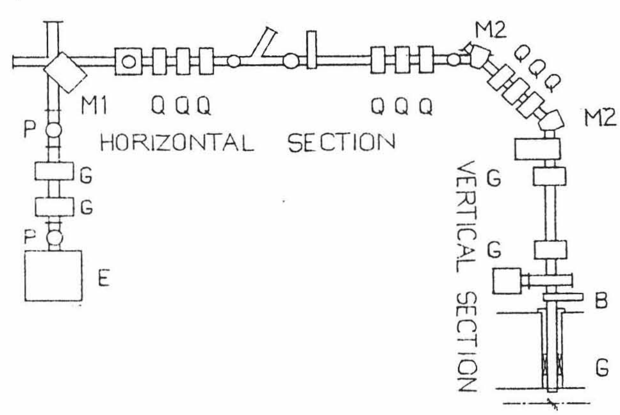

Fig. 5. Schematic diagram of Injection line
E - ECR ion source, P - Pump, G - Glaser, M1 - Analysing magnet, M2 - 45^{0} bending magnet, B - Buncher, I - Inflector

through a matching section comprising two quadrupole triplets in the horizontal line. The beam is then bent vertically down by a system comprising two 45° magnetic dipoles and three quadrupole magnets inbetween. In the vertical section the beam passes through two glaser lenses before entering into the cyclotron magnet yoke. The old 22.5 cm plug at the top centre of the magnet yoke has been changed to make passage for the beam and focusing elements. The third glaser lens is placed inside the new 22.5 cm iron plug. The beam is finally inflected into the cyclotron using a electrostatic mirror inflector.

5. Results and discussions

The results presented here [9] are for the ECR source before making the recent modifications. The results after modification will be available soon. The source is operated with gases like oxygen, nitrogen, neon and argon. Fig. 6 shows a spectrum of oxygen charge states. tuned for O^{6+}

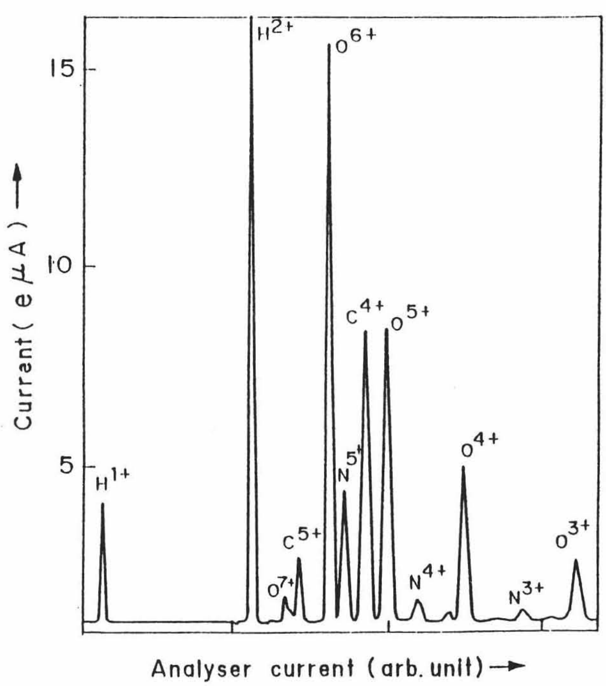

Fig 6. Spectrum of Oxygen charge states, tuned for O^{6+}

Fig. 7 shows spectrum of argon charge states tuned for Ar^{11+} Table - 1 shows typical values of currents of some MCHI beams. Current was found to increase with R.F power (Fig 8) and is quite stable. With the new modifications it will be possible to operate the source from middle of October 1995. It is hoped that with the use of aluminium electrodes and higher injection side field a considerable improvement will be achieved in source performance. Based on recent findings [11,12] that high B mode operation even at 6.4 GHz frequency, there is a remarkable improvement of source performance, We have plan to modify the source accordingly in near future.

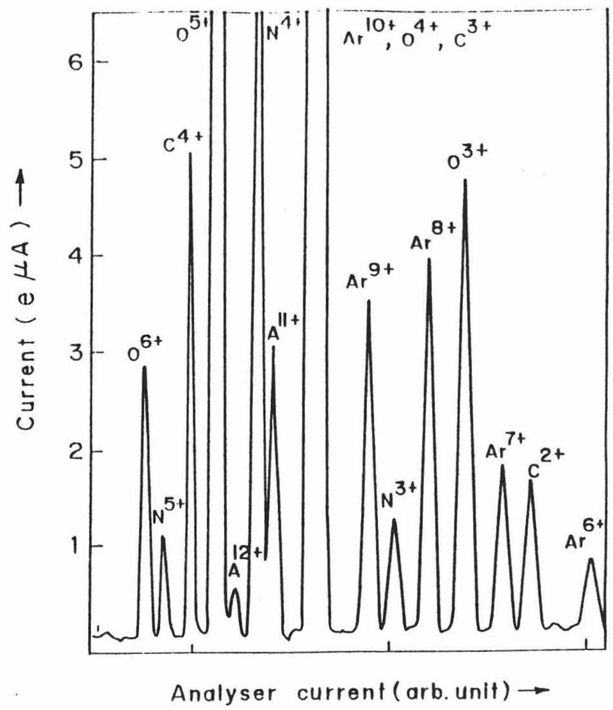

Fig 7. Spectrum of Argon charge states, Tuned for Ar^{11+}

charge states	currents (eμA)	charge states	currents (eμA)
O^{4+}	65	Ne^{5+}	30
O^{5+}	27	Ne^{6+}	8
O^{6+}	15	Ne^{7+}	3
O^{7+}	1.2	Ne^{8+}	0.7
N^{4+}	25	Ar^{8+}	21
N^{5+}	12	Ar^{9+}	10
N^{6+}	1.0	Ar^{11+}	3

Table - 1 Currents of various charge states

As regards injection of ECRIS beam into the cyclotron the final phase of coupling work will start in the shut down period starting from November 1995. By this time however MCHI beam from ECR Source has been utilised for implantation studies and sputtering experiments. A few atomic physics groups are preparing for atomic physics studies using ECRIS beam.

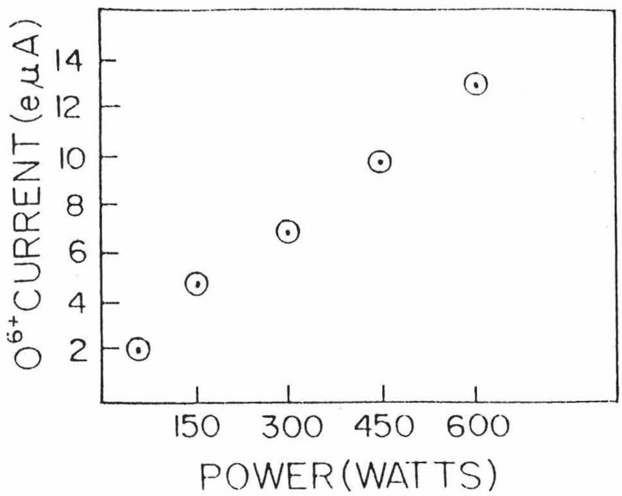

Fig 8. Ion beam current variation with RF power

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