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Development of 14.5 GHz Electron Cyclotron Resonance Ion Source for Muti-charged Ion Beams

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1. Introduction

Ion sources to make multi-charged ion beam based on the electron cyclotron resonance (ECR) principle [1, 2] have played major role in the advancement of the knowledge of atomic and nuclear physics and in many areas of applied science and technology. Since the final energy of an ion beam is directly proportional to the charge of the ion during acceleration, a premium is placed on ion sources which are capable of generating very high charge state ion beams for use at accelerator-based research facilities. Recently in KAERI a 14.5 GHz ECRIS (Electron Cyclotron Resonance Ion Source) has been designed and is being fabricated to produce multi-charged ion beams for medical applications in a cyclotron. The design results, fabrication status, and future plan will be presented in this topic.

2. ECRIS Design and Component Fabrication

2.1 ECRIS System Design

A layout of the designed ion source is shown in Fig. 1. The important design goal is to produce C^{6+} ions with a current revel of several tens of microampere. Table 1 shows the summarized design parameters of the design.

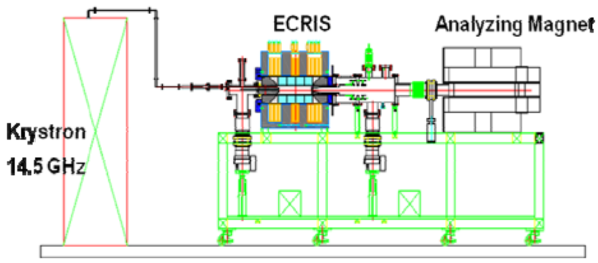

Fig. 1 The designed 14.5 GHz ECRIS in KAERI.

Table 1 Summary of the ECRIS Parameters.

ECR Frequency	**14.5 GHz**
RF Power	**2.0 kW**
B_{ECR}	**0.52 T**
B_{inj}	**1.7 T**
B_{ext}	**1.1 T**
B_{rmax}	**1 T**
R_{inj}	**3.3**
L_{ECR}	**90 mm**
V_{plasma}	**85 cm^3**
$ID_{chamber}$	**68 mm**
$L_{chamber}$	**320 mm**
I_{C6+}	**75 uA**

2.2 Hexapole Magnet

A strong and long-life hexapole magnet for the ECR ion source [3] has been designed and fabricated. The size of the outer diameter and the number of the sector of the hexapole are optimized with the help of a 3-dimensional field calculation code. And to make a strong and long-life magnet against the magnetic stresses on the hexapole, a sector is designed with a multi-layered structure, which has different magnetic materials depending on the strength of the magnetic stresses. The fabricated one is shown in Fig. 2.

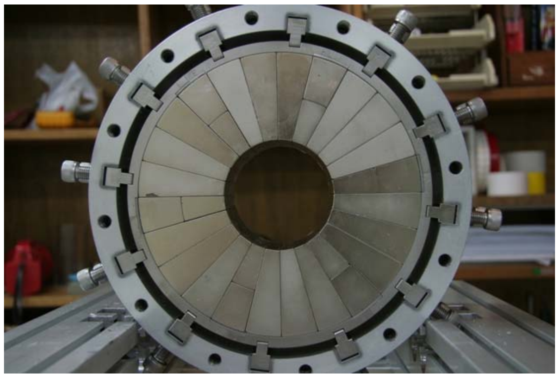

Fig. 2 A fabricated hexapole magnet.

2.3 Solenoid Coils for Axial Field

Three different set of coils are designed to make a proper shape of axial field in the ECRIS as shown in Fig. 3. The mirror ratio is controlled by a trim coil. To make a strong mirror field in the entrance and exit of the ion source, yoke volume is maximized in the chamber. Fig. 4 shows the calculated result of the axial field depending on the coil currents.

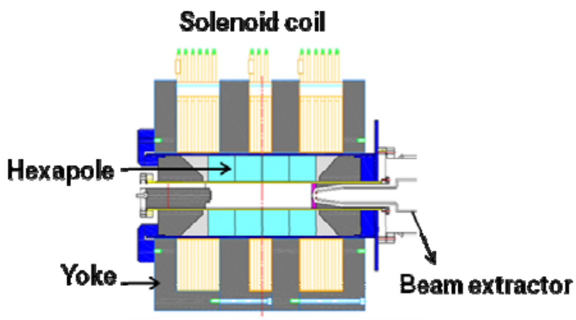

Fig. 3 Structure of solenoid coils and yokes.

2.4 Plasma Chamber and Vacuum System

An ECR plasma chamber is designed and fabricated as shown in Fig. 5. To make an Al cylinder structure in the plasma region, Al and stainless steel are brazed and proper cooling channel is fabricated around the chamber. Al cylinder has a role of secondary electron source, and help to increase the ion density in the ECR plasma. A biased electrode is installed to control the ECR region actively. Two TMP systems which are at the gas inlet port and at the beam extraction port will be installed to make a high vacuum.

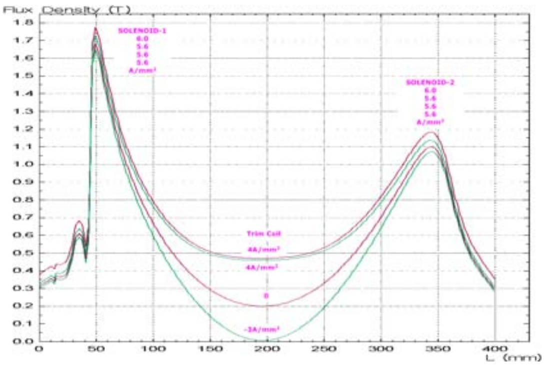

Fig. 4 Axial field configuration in the ECR chamber.

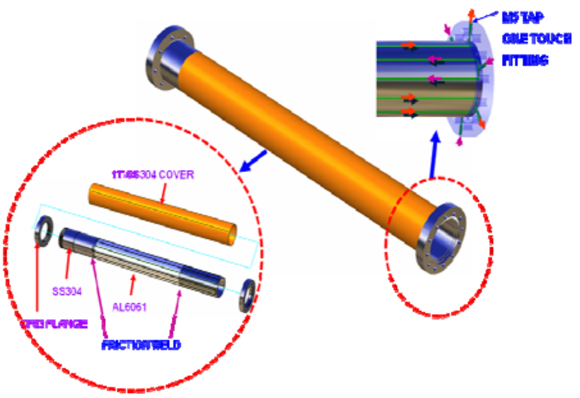

Fig. 5 Structure of the ECR plasma chamber.

2.5 RF System

A 2 kW 14.5 GHz Klystron (bandwidth 85 MHz) system is prepared to make ECR plasma. The RF transport system consists of RF switch, dummy load, circulator, tuner, DC breaker, vacuum windows, and WG18 waveguide components. The RF system is in ground potential, and it is isolated from high voltage through 35 kV DC breaker. RF wave is launched in parallel with the direction of axial magnetic field.

2.6 Beam extraction system

To cover the wide range of mass number and charge state ion beams a movable electrode is designed. Decel electrode is not installed because its optics effect is very small, and the back scattered electron could be a source of electron in the chamber. Einzel lens is necessary to make effective beam transport system as shown in Fig. 6. The operation voltage of the Einzel lens is similar with the beam extraction voltage.

2.7 Beam Diagnostics System

Two faraday cups and an analyzing magnet is prepared for the beam diagnostics. The specification of the bending magnet is as follows;

- Max. field 0.139 T
- Bending radius 400 mm
- Bending angle 90 °
- Pole gap 45 mm
- Double focusing

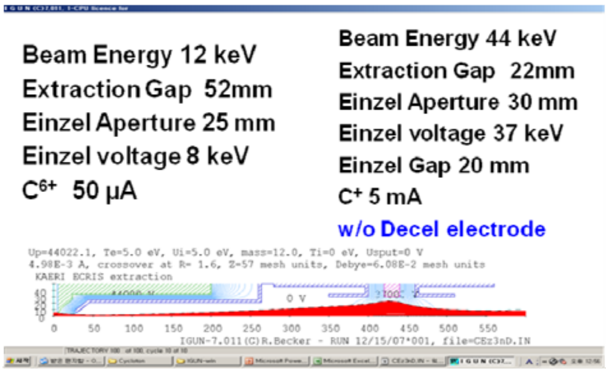

Fig. 6 Design result of the beam extraction system.

3. Conclusions

The fabrication of 14.5 GHz ECRIS for multi-charge ion beam extraction would be finished soon in KAERI. But the optimization of the operation condition to increase the beam current and the number of the charge state would be more important than fabrication.

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