Design of the compact permanent-magnet ECR ion source

J. Y. Park[ab*], J. K. Ahn[a]
H. S. Lee[b], M. S. Won[b], J. H. Yoon[b], J. P. Kim[b], J. S. Bae[b], J. K. Bang[b]
[a]*Pusan National University*
[b]*Korea Basic Science Institute(Busan Center)*
[*]*Corresponding author: jinyongp@pusan.ac.kr*

1. Introduction

Electron Cyclotron Resonance Ion Sources (ECRIS) for multiply charged ion beams keep regularly improving and expanding since the pioneer time of R.Geller and his coworkers about twenty years age[1]. It has been widely utilized in a variety of research areas ranging from atomic and nuclear physics to material sciences. Because of the unique capability of producing highly charged ion beams, the ECR ion source has become increasingly popular in heavy-ion accelerators where the principle of acceleration sensitively depends on the charge-to-mass ratio (q=M) of the injected positive ion beam.

The potential usages of beam based research development is still developing and there are plenty of rooms to be part of it. On the basis of ECR ion source technology, we will explore possible applications in the field of plasma technology, radiation technology, plastic deformation, adding more and new functionality by implantation, MEMS applications, developing new generation mass analysis system, fast neutron radiography system, etc.

2. Design of ECR ion source

ECR ion sources can be classified into two different types; with electromagnets or with only permanent magnets. Advantages of all-permanent magnet type ECR ion source are simple power supply, simple cooling system, low cost of operation and compactness of total size. We plan to develop the 2.45GHz ECR ion source with all-permanent magnet. ECR ion source use two types of magnetic fields referred to as mirror and hexapole magnetic fields[2-7]. The mirror fields axially confine the ECR plasma while the hexapole fields radial confine it. A schematic view of the all-permanent magnet ECR ion source is presented in Fig.1. It consists of 3 kind of permanent magnet. Two ring magnets at side with inner radii of 40 mm, outer radii of 100 mm and thicknesses of 30 mm are used to make a mirror magnetic field. Hexapole magnet with inner radii of 30 mm, outer radii of 50 mm and thicknesses of 150 mm is used to make a radial magnetic field. Center ring magnet with inner radii of 80 mm, outer radii of 100 mm and thicknesses of 20 mm provides a flat magnetic field at the center region to make of “volume-type” ECR Ion Source. The magnetization of each permanent magnet is shown in Fig.1.

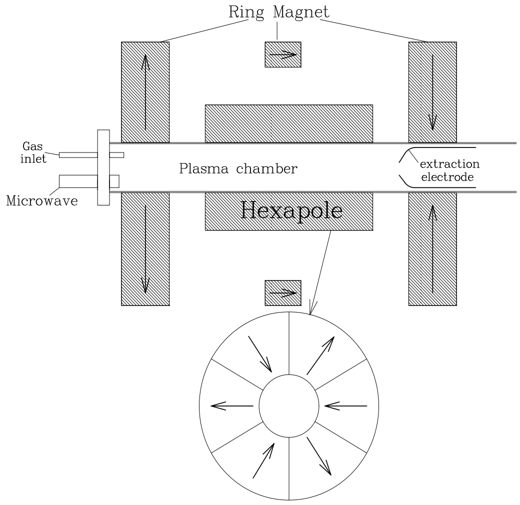

Fig. 1. Schematic view of Prototype of ECRIS at 2.45 GHz

The magnetic structure was designed based on computer simulation calculated with TOSCA (OPERA-3D). Fig.2. illustrates the mirror magnetic field, B_z, along the asymmetry axis(at r = 0). Red line represent the mirror field of “volume-type” ECR ion source with center ring magnet in place while blue line represent the surface mirror field without center ring magnet. Black line is ECR resonance magnetic field of 875 G formed by 2.45GHz microwave.

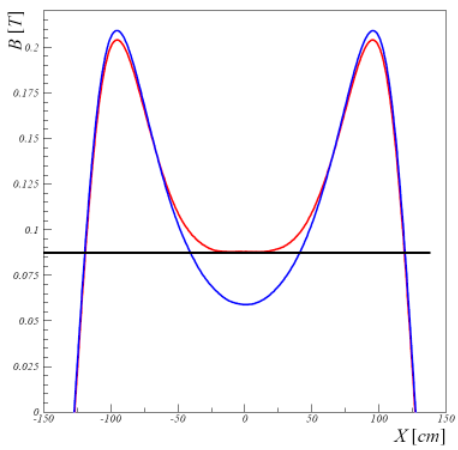

Fig.2.Calculated axial magnetic field profiles for volume (red) and surface (blue) ECR configuration.

Table I lists typical parameters of the KBSI-ECR compared with those of other all-permanent ECR. The KBSI-ECR has better mirror ratio (B_{ratio}) with low Radio Frequency (RF) as comparing.

Table I : Typical parameters of KBSI-ECR compared with those of other ECR.

	RF [GHz]	B_{max}[T] B_{min}[T]	B_{ratio} (B_{max}/B_{min})	Power [W]	HV [kV]
NANOGAN	10	0.8 0.34	2.24	100	25
NANOGAN2	14.5	0.88 0.373	1.70	200	19
TUNL	2.45	0.1 0.05	1.14	310	0.45
LAPECR2	14.5	1.28 0.43	2.47	450	25-30
LECR2	14.5	1.5 0.39	2.47	1100	25
KBSI-ECR	2.45	0.23 0.0875	2.63		

We plan to extract various heavy ions by using KBSI-ECR and accelerate these with Van de Graaff accelerator. Fig.3. shows the schematic view of radioactive ion beam line.

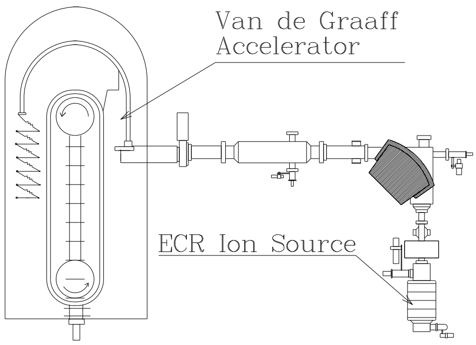

Fig.3. Schematic view of radioactive ion beam line with KBSI-ECR ion source and Van de Graaff Accelerator.

3. Ion beam facility based on ECRIS at 28GHz

Figure 4 shows the schematic view of the fast neutron beam line at Korea Basic Science Institute(KBSI). It consists of ion source, RFQ accelerator, heavy ion accelerator (DTL), target system and so on. The fast neutron beam is provided by the heavy ion, $^{7}Li^{q+}$, which interacts with hydrogen target. This heavy ion is provided by the 28GHz superconducting ECRIS and accelerated by RFQ and DTL acceleration system. The magnetic fields inside of gas chamber are formed from superconducting magnet to generate maximum magnetic field around 4T because the 28GHz microwave corresponds to 1T.

The ECR ion source based beam facility shall assist the research and development efforts in NT, ST, BT, and nuclear science field by providing reliable heavy ion beam. In addition, the knowledge obtained from this project can be utilized to develop instruments such as 13 nm lithography system, port inspection system, ion engines, ion implantation system, etc. Furthermore, the technology for developing ECR ion source can be used step stone for all kinds of heavy ion accelerator as a primary incident energy source.

4. Conclusions

We performed magnetic field design of the "volume-type" ECR ion source in resonance with a microwave frequency of 2.45 GHz. The magnetic system in the present ECR ion source consists of two ring magnet for the mirror field, hexapole magnet for radial field and center magnet for flat-B field. We plan to measure magnetic field and make the ECR ion source at 2.45GHz.

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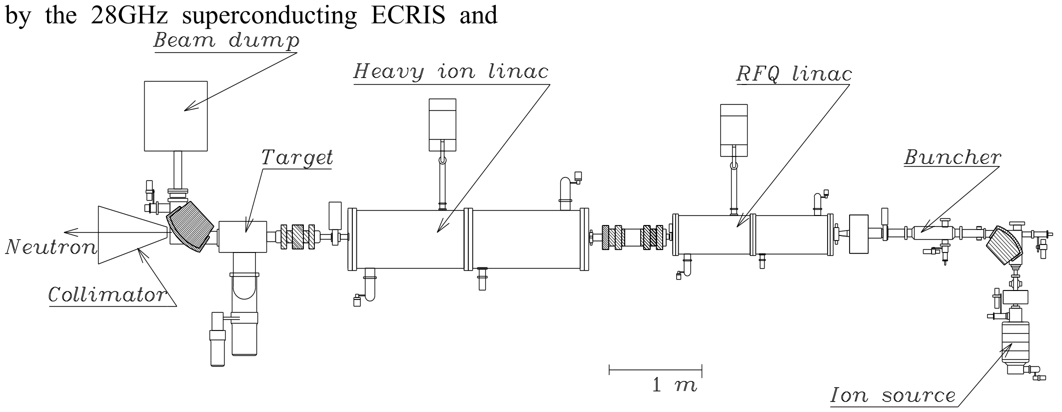

Fig.4. Schematic view of the low-energy heavy-ion accelerator for fast-neutron production.