The 12th Symposium on Accelerator Science and Technology, Wako, Japan 1999

Beam Generation Test for HYPERNANOGAN and Modification of 18GHz ECR Ion Source at JAERI Takasaki

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Abstract

A new ECR ion source was installed in a cyclotron system at the Takasaki site of Japan Atomic Energy Research Institute. Test operation was carried out using inert gases, and some metals by means of a micro oven, rod insertion, and sputtering. Ions of inert gas with M/Q=2 were accelerated with the 'cocktail beam acceleration technique'. An 18 GHz ECR ion source in development was modified to improve the magnetic field distribution. Performance in generating highly charged ions has significantly rised as a result. This paper reports preliminary operation results of the new ECR ion source and summarizes development of ECR-18.

1 Introduction

An ion source is a key device for ion accelerators in order to meet requirements from various research fields on ion species and beam energy over a wide range. When the AVF cyclotron was constructed in 1989, it was equipped with OCTOPUS to generate a heavy ions from gaseous materials. As the researches progress, demands for highly charged heavy ions keep increasing. We started development of an 18-GHz ECR ion source (ECR-18) in 1994. A new ECR ion source H-ECR (HYPERNANOGAN manufactured by PANTECHNIK s.a., shown in Fig.1) was installed in the cyclotron system in March, 1999 to supply metallic ions. A full permanent magnet source (MINI-ECR) [1] was also developed for an electrostatic accelerator, and is now in a 400 keV ion implanter for ion acceleration test to realize MeV implantation. With these ECR ion sources, we are pushing forward with efficient use of the facilities and beam time as well as expanding ion species and a beam energy range.

2 H-ECR

The new ECR ion source H-ECR was installed with a new injection line. The source is a single stage plasma device capable of producing highly charged ions of low mass ions and intermediate charge states of high mass ions. The source is equipped with two different system to supply solid materials; furnace for low melting point metals (Li, Ca, Pb, Ag, etc.) and a sputtering device for high melting point metals and compounds (Ta, W, Mo, etc.). Two insulated coils, with independent power supplies, generate a high field gradient from 0.4 to 1.1 T, along the axis of the plasma chamber. The source operates at a frequency of 14.5 GHz with a maximum microwave power of 2.0 kW. A Glaser lens was adopted as the first focusing element because of very intense extracted beams. All the focusing elements in the injection line are solenoid lenses. The specification of the H-ECR is listed in Table 1. and Figure 2 shows the schematic layout of ion sources before the injection line.

Charge state distribution Ar ion was obtained with careful tuning as shown in Fig. 3. The intensities at all charge states are comparable to the nominal values and they are more than 5 times as high as OCTOPUS.

Ions of He^{2+}, C^{6+}, N^{7+}, O^{8+}, Ne^{10+}, $^{36}Ar^{18+}$ with M/Q=2 were individually generated and accelerated by the cyclotron. For cocktail beam acceleration for M/Q=2, Ne^{10+} was the heaviest ion generated by OCTOPUS. Since beam current of $^{36}Ar^{18+}$ was too low to measure, accelerated ions were directly detected with a plastic scintillator. Estimating from count rate and beam attenuation, $^{36}Ar^{18+}$ beam current from the cycloton was order of 0.1 epA. Detail of this experiment is described in elsewhere in this proceedings [2] [3].

Generation of Pb and Ta ion was preliminarily made to examine an oven and an elemental wire insertion method, respectively, and Pb^{22+} of 2.0 eμA and Ta^{28+} of 6.0 eμA were observed. The M/Q spectra are shown in Fig. 4. Generation of La ions was examined using LaB_6 rod by means of insertion and sputtering. Intensity of La ion was dependent on a support gas. We tried He, O_2 and Ar as support gases. The O_2 was best for insertion method. In case of sputtering method, La ion was observed for only O_2 support gas. Note that the cyclotron may accelerate Pb ions because the acceleration condition of M/Q<6.5 is hardly achievable. The source will begin to supply ion beams to the cyclotron early next year after developing various metallic ion generation using an oven, a rod insertion and MIVOC method [4].

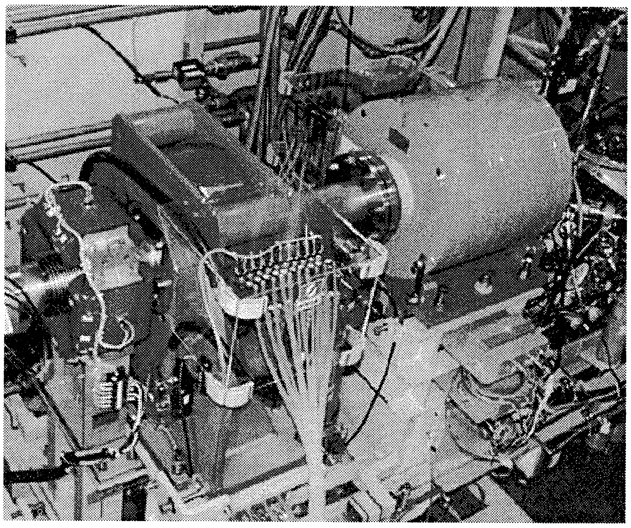


Fig. 1 A new ECR ion source HYPERNANOGAN and Glaser lens.

Table 1 Specification of H-ECR.

microwave frequency	14.5 GHz
maximum microwave power	2 kW
number of mirror coil	2
maximum coil current	1100 A
maximum mirror field strength	1.3 T
multipole permanent magnet	sextupole

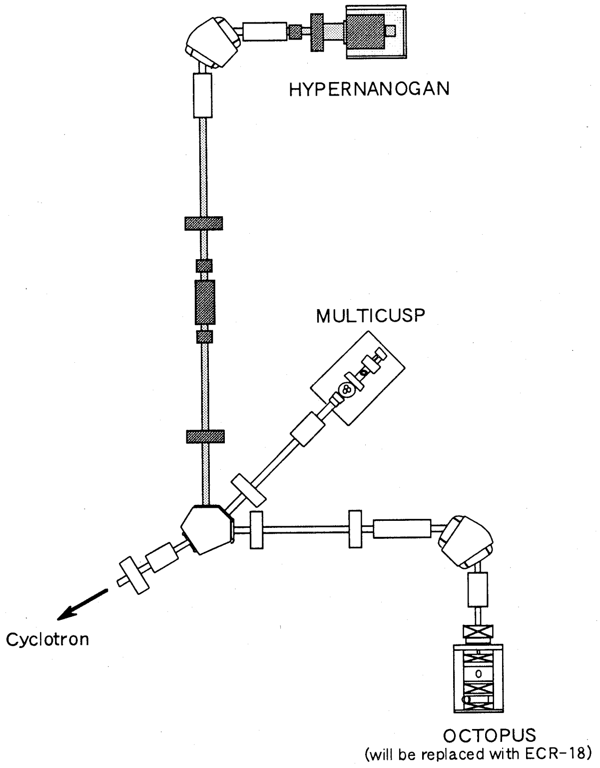


Fig. 2 Schematic layout of ion sources before the injection line.

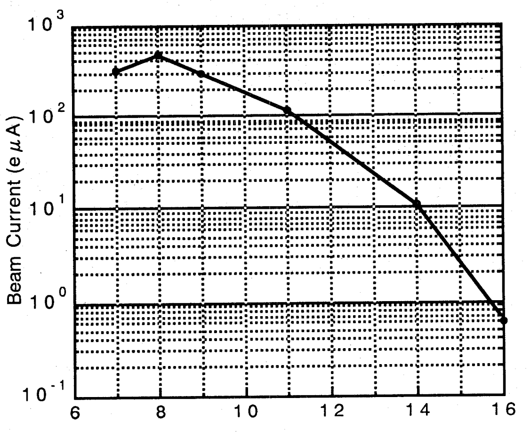
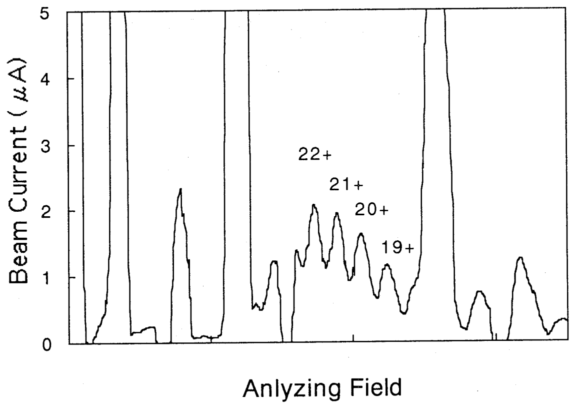


Fig. 3 Charge state distribution of Ar ion for H-ECR.

(a) Lead



(b) Tantalum

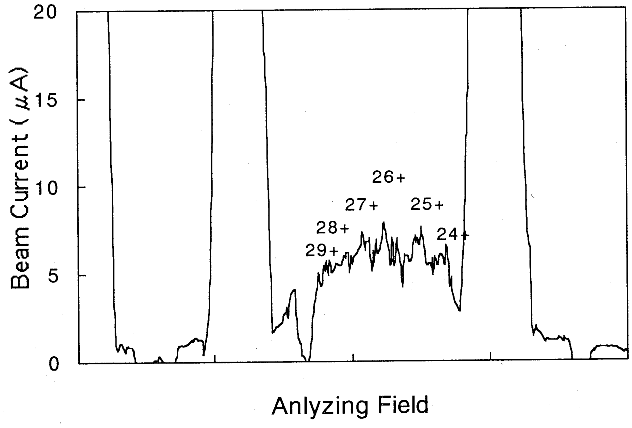


Fig. 4 M/Q spectra for Pb (a) [by means of a furnace] and Ta (b) ions [sputtering device].

3 ECR-18

This source has a solenoid coil in order to vary a mirror ratio in a wide range. A solenoid coilis mounted between the mirror coils [5]. At a mirror ratio about 2, which is optimum to generate highly charged ions, a small bump appeared between the mirror field peaks in the original magnetic field profile as shown in Fig.5. The source performance in generating highly charged ions improved after minor changes, and the maximum charge state of Ar ion was 16+ with 2 enA beam current. Some of observed phenomena may be peculiar to this field profile with the bump;

(1) An aluminum liner on the plasma chamber wall (copper) enhanced the beam at high charge states by factor 2 or 3, but a bias probe had little effect.

(2) After tuning the source to maximize specific charge state intensity, increasing solenoid coil current resulted in decreasing intensity at high charge states.

We assumed that the plasma was divided into two regions by the bump and the larger bump weakened their connection. Under this assumption, electrons fed from the bias probe into a region on the microwave-injection side (region I) might not be easy to move to the other region (region II) from which ions were extracted. On the other hand, the aluminum liner surrounding the whole plasma could supply electrons into the both regions and increase electron density. This hypothesis agrees with the phenomenon (1) because the maximum and the average charge states increase with electron density. Electron flow from the region I to II might be further obstructed by the bump growing with increasing solenoid coil current, which explains the phenomenon (2).

As a result of a field calculation with a code of TOSCA, it turned out that the bump could be removed simply by halving the solenoid coil length and the gap between the mirror coils. The source redesign and the axial field profile are shown in Fig.5 together with the original ones. After the modification, test operations were made with the aluminum liner and the bias probe. The charge state distributions of Ar ions before and after the modification are compared in Fig.6. Intensity of Ar^{16+} increased by three orders of magnitude.

We are planning to replace OCTOPUS with ECR-18 after stable operation of H-ECR is realized in combination with the cyclotron.

References

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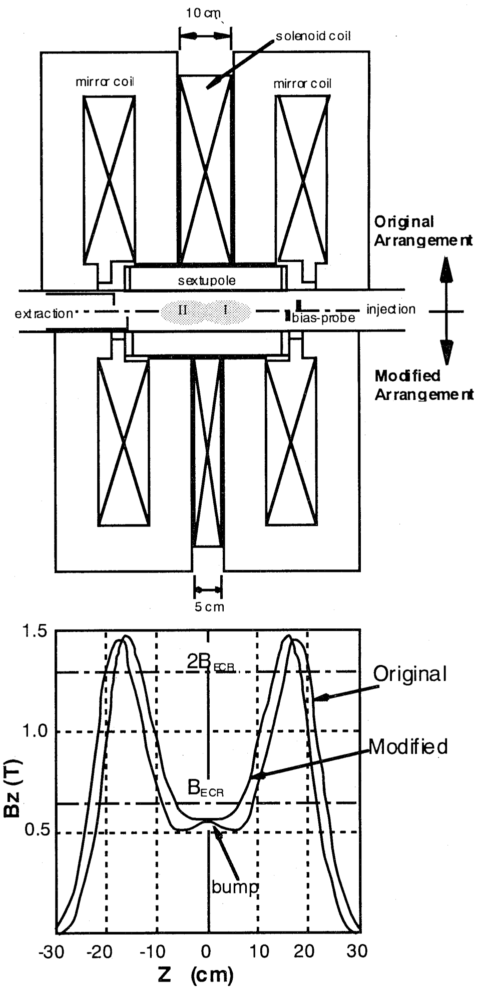

Fig. 5 Modification of the solenoid coil and the axial magnetic field profile of ECR-18. The image of the divided plasma is illustrated in the plasma chamber.

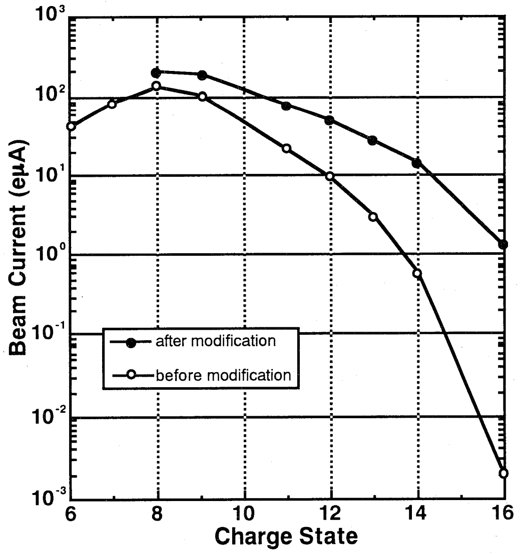

Fig. 6 Improvement in charge state distribution of Ar ions by the ECR-18 modification.