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MANUFACTURE OF THE 6-10 GHZ COMPACT ECR ION SOURCE WITH A VARIABLE PERMANENT MAGNET MIRROR

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Abstract

A new small size ECR ion source working in 6-10 GHz is manufactured and now under the first test. This source is made of permanent magnets only, and its total weight is about 40 kg. Its remarkable features are continuously variable axial mirror field, comparatively large inner diameter of the plasma chamber and radial multiport windows for an RF injection and a plasma viewing. The variable field is realized by a continuous replacement of the mutual position of two ring magnets on the beam axis. The design, manufacture, experimental setup and introductory beam test for this new source are reported shortly.

1. Introduction

Until quite recently, as for a very compact ECR ion source with permanennt magnet only, there was "NANOGAN" alone in the world[1]. But now, such kind of sources are in manufacturing at several insitutes[2]. Usually, typical measures of these sources are within tens of kg in total weight and roughly within ϕ200mm×200mm in outer dimension.

However, these compact sources have commonly a few problems to be improved. First, the confining magnetic field is fixed in almost cases and hard to change continuously for the fine tuning of an extracted ion beam. Second, when the source size is reduced as possible as small, the inner size of the plasma chamber is also apt to shrink corespondingly. Third, in addition, both a local heating by the microwave power which is not absorbed into the plasma and the reduced size of the plasma chamber give rise to a hardness of an effctive cooling of the source. Considering these problems, we have developed a new compact ion source with a variable axial mirror field and with a large size ratio of the plasma chamber compared to the outer total size. Its outline will be described below.

2. Design Parameters and Structure of the Source

Tab.1 shows main parameters of our new ion source. Especially remarkable points are as follows:

(1) The inner diameter of the plasma chamber is set to ϕ60mm. This is the largest value in several same order compact sources in the world (Usually, its order is ~ϕ30mm). In order to produce a multiply-charged ion beam as possible as high, it is desirable that the inner diameter of the plasma chamber is over several times larger than the anode hole diameter.

(2) The confining magnetic field can be changed continuously by a replacement of two radially magnetized ring magnets on the beam axis (one is magnetized to inner direction and the other outer direction). As a result, the axial mirror ratio can be controlled continuously for an optimization of the extracted beam.

(3) A few quartz windows are mounted in the radial direction into the plasma chamber. These are used for the microwave port and also as a viewing port. Furthermore, it is also possible to inject the microwave power from such multiports, simultaneously. It can be considerd that the radial injection method of microwave power is not necessary inferior to an axial one[3].

(4) The total volume of the permanent magnet parts are considerably decreased than the other compact sources. By this reason, our new source is made with very small expense. Its volume is a very important measure for compactness, lightness and economy of a source.

(5) Considering that if this source is used for the injection to an ion accelarator(such as linac or cyclotron), the beam hole diameter is set to ϕ2-4mm, which is relatively smaller than many usual cases.

The total weight of the source amount to about 40 kg and the plasma chamber is cooled with pure water. The photograph and sectional views of the new source are shown in Fig.1 and Fig.2 respectively. These design concept and technology are mainly based on a succeeding experience of development works for the 2.45GHz compact ECR ion sources in INS[4].

3. Magnetic Field Configuration of the Source

The confining magnetic field distribution is shown in Fig.3. The solid and broken line denote the simulated results by the POISSON code and circled points are measured results. The used magnetic material is a neodymium alloy with a maximum BH-product of 46MGOe(NEOMAX-46). The simulated results agree with the measured one within accuracy of 3%.

As for the axial mirror field, if the ring-to-ring distance is selected properly to a given microwave frequency, the required ECR field is sufficiently realized within the axial region in the plasma chamber corresponding to 6-10GHz one. On the other side, the radial ECR field is formed always(that is, independent of the ring-to-ring distance, in the first order approximation) inside the wall of the plasma chamber within the range of 6-10GHz. Very roughly speaking, the maximum distance between two ring magnets (=130mm) corresponds to the 6 GHz operation and minimum distance (=90mm) to the 10GHz operation.

Therefore, to a certain given frequency, the extracted beam can be optimized by a fine adjustment of the initial position of these two ring magnets on the beam axis. Since these ring magnets are jointed by a cylindrical yoke with the dimension of ϕ190×ϕ220×190 mm^3 and sectupole magnets are surrounded also by this yoke, a leakage flux to the radial direction is extremely reduced. Further, as the extractor electrode is made of a mild steel, the axial mirror field is formed more effectively than in case of a non-magnetic material.

As in Fig.3, a very strong inverse magnetic field is formed in the gas-supporting side on the beam axis. Generally, if a microwave power is injected from this axial direction, this feature limits to the effective absorption to a plasma. But in our case, the microwave power is injected from the radial direction of the chamber, then the problem does not become seriously.

A more detailed discription on these field configuration is given in our other report[5].

4. Experimental setup

The constructed ion source is set into the injection transport system of the INS-SF Cyclotron. A 45° bending magnet of the transport line is used as the ion analyzer. The distance from the ion source to the analyzer is 1827 mm, which is relatively longer compared to an usual setup. Then, in order to arrange the focusing condition and to realize the calculated beam envelope, an einzel lens, a collimator and a Q-triplet are installed between them. A typical example of the beam trace is given in Fig.4. The simulation was carried out by the GIOS code. In this choice, about 50 of the mass resolving power are realized.

The ion source is exhausted by a 300 l/s turbo molecular pump through both a radial side port of the plasma chamber and the axial anode elctrode hole. The no-loaded pressure and the working one is 2.1×10^{-6}Torr and $3\text{-}5\times10^{-6}$Torr at the beam-extractor side respectively.

The microwave power is injected into this ECR ion source from the proper microwave system for the large ECR ion source of the SF-Cyclotron. This microwave source is a klystron amplifier and the operating frequency is fixed at 6.1 GHz. Therefore, a 10GHz operation and a variable frequency performance are not scheduled in the first beam-extraction test.

5. Summary

A new type of a very small size ECR ion source has been made using permanent magnets only.

(1) The inner diameter of the plasma chamber is set to ϕ60mm. This value is the largest size among those kind of compact sources in the world, at present.

(2) Its confining fields can be changed continuously by a replacement of the radially magnetized ring magnets.

(3) Since the volume ratio of magnets to a whole of the source is fairly reduced, the cost reduction for making the source is realized drastically, too.

(4) Based on the experience for manufacture of this new source, a further advanced version can be designed.

Now the beam extraction has started up. By a very introductive adjustment, about 600μA of a total beam is extracted from an anode hole of ϕ5mm at 10 kV, when the input RF power is 80 W. But in order to produce the multiply-charged ion beam effectively, there are a few tasks to be done as follows : (1)production of electron source as a first stage,(2)optimization of the relative axial position of the anode to the peak magnetic field, etc. These problems will be handled hereafter.

Ackowledgements

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References:

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2) Proc. of the 12th International Workshop on ECR Ion Sources; INS-J-182(1995)
3) E. Tojyo, Y. Ohshiro, M. Oyaizu and Y. Shirakabe: INS-Rep.-1103(1995)
4) E. Tojyo, Y. Ohshiro, M. Oyaizu and Y. Shirakabe: Proc. of the 11th International Workshop on ECR Ion Sources; KVI-Report 996; p.234-238(1993)
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Table 1
Design Parameters of the 6-10 GHz Compact ECRIS

Input microwave frequency	6-10	GHz
Input microwave power	≦200	W(C.W.)
Beam voltage	≦30	kV
Normalized emittannce	~0.5π	(desired)
Beam hole diameter	2-4	mmϕ
Inner dimension of plasma chamber	>ϕ60×70	mm^3
Outer dimension of body	ϕ220×230	mm^3
Dimension of ECR surface	6GHz: ϕ=44,L=50 mm	(B=2.14kG)
	10GHz: ϕ=52,L=65 mm	(B=3.57kG)
Dimension of ring magnets	ϕ60×ϕ140×30	mm^3
	ϕ20× ϕ80×30	mm^3
Stroke of ring magnets	20mm (gas injection side)	
	20mm (beam extraction side)	
Dimension of bar magnets	6-25×25×60	mm^3
Variable mirror ratio	3.1-5.0(gas injection side)	
	2.0-3.0(beam extraction side)	
Total weight	40	kg

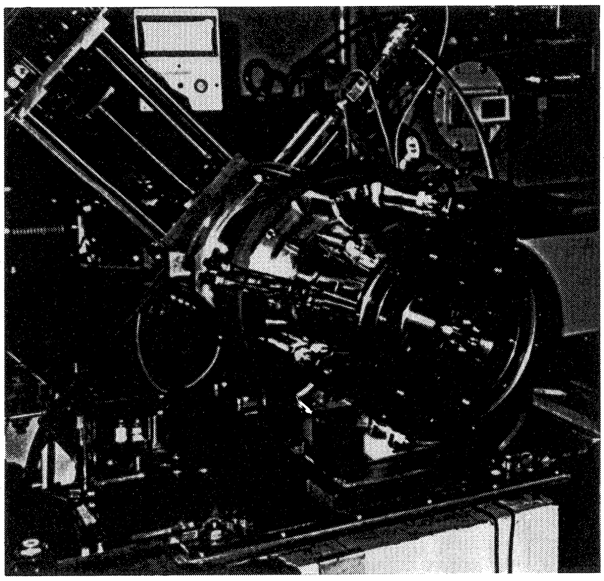

Fig.1 Photograph of the ion source

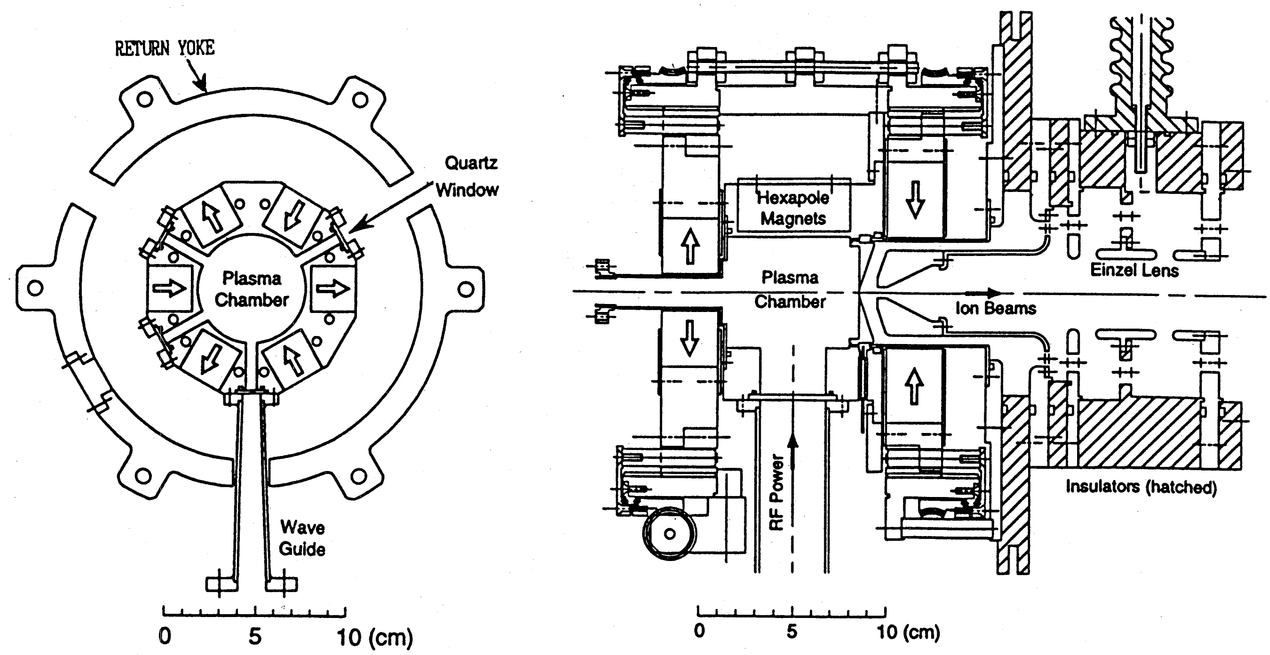

Fig.2 Sectional views of the ion source

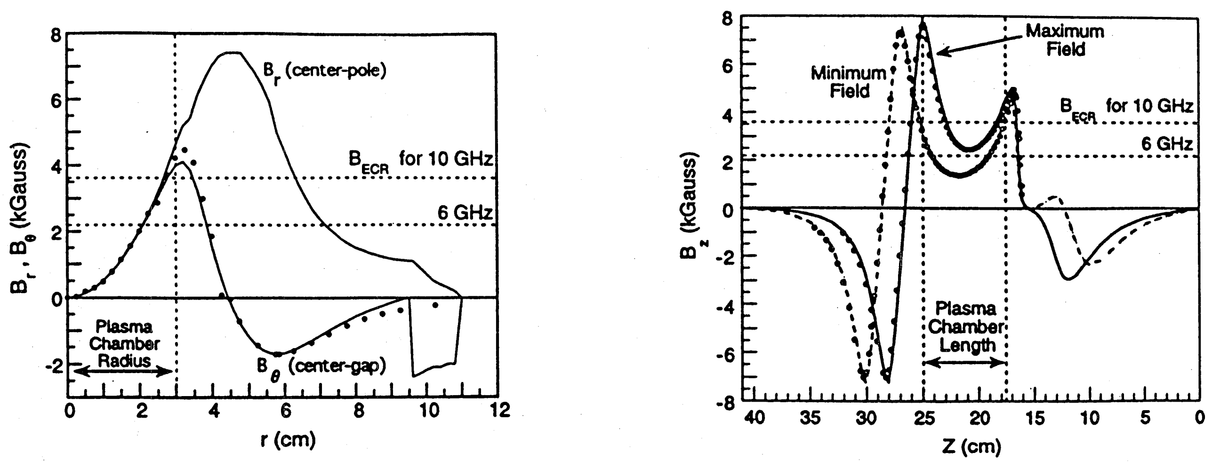

Fig.3 Magnetic field configurations of the ion source

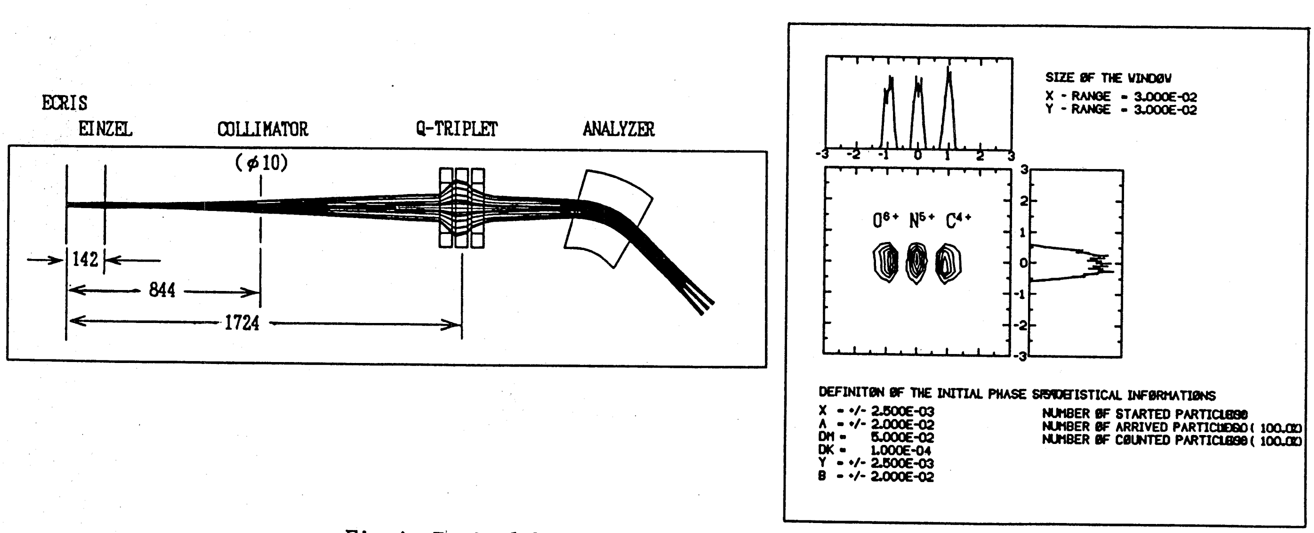

Fig.4 Typical beam trace in the test stand