第23卷 第11期
1999 年11月

高能物理与核物理
HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS

Vol.23, No.11
Nov., 1999

A Single Charge State ECR Ion Source

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Abstract A compact 2.45GHz electron cyclotron resonance ion source (ECRIS) for high beam current of single charge state has been built at Institute of Modern Physics. A mixed ion ($H_1^+ + H_2^+ + H_3^+$) beam current of 90mA is delivered from a single aperture of ϕ6mm with rf power 600W at extraction voltage 22kV. This paper introduces the source structure, the magnetic configuration, the test results and the relation between the magnetic configuration and total beam current. In addition, the magnetic configuration is also compared with that of the other 2.45GHz ECR ion sources built in different laboratories. Finally, some conclusions are presented.

Key words electron cyclotron resonance, magnetic configuration, total beam

1 Introduction

Without cathode, ECR ion source can work steadily for very long time with high ionization efficiency, strong ion current and lower beam emittance. ECR ion source can produce multiply-charged ion beams at different magnet condition and microwave power. This machine whose purpose is used in medical treatment with neutron is built for Lanzhou university. The neutron is obtained with tritium target bombarded by deuterium ion. This source is a prototype of the deuterium source.

2 Layout of the ECRIS

The schematic view of the ECR ion source is presented in Fig. 1. The design involves one plasma stage only. The copper plasma chamber with diameter of 7cm and length of 7cm is a double walled to accommodate cooling water. A tapered ridged waveguide section, which has a three-stub tuner to allow tuning for an optimum match of the microwave power to the plasma, guides the microwave into the plasma chamber through a window which is composed of double layer ceramics. Permanent magnets are used to produce the required magnetic field distribution. Meanwhile in order to adjust the magnetic field finely for the maximum beam current, three auxiliary coils are used. The extraction system consists of three electrodes

Received 4 May 1999

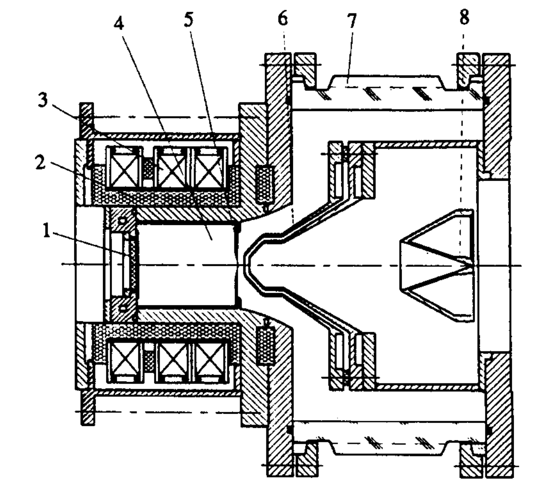

Fig. 1 Schematic of ECRIS

1 microwave window, 2 permanent magnets, 3 solenoids, 4 plasma chamber, 5 plasma electrode, 6 puller electrode, 7 ground electrode, 8 ceramics, 9 Faraday cup.

(accel–decel type). the gaps among the plasma electrode, the puller electrode and the ground electrode are 5mm and 4mm, respectively. The aperture of the plasma electrode is 6mm. The aperture of both puller electrode and ground electrode are 7mm. The beam is measured by a Faraday cup with biased voltage of negative 90V to suppress the second electrons emission.

3 Magnetic Configuration

The static magnetic fields required for ECR is given by

$$B = f_{ce} / (2.8 \times 10^{-2}), \quad (1)$$

where B is in mT and f_{ce} is in gigahertz. Thus the typical magnetic fields in the ECR zones normally lie between 87.5mT and 1000mT when the radio frequency (rf) is in the range 2.45—28GHz[1]. When the frequency is 2.45GHz, the resonance magnetic field strengths B is 87.5mT. In fact, one finds three different types of overdense ECR ion source at 2.45GHz with different magnetic field strengths B. In the first type, $B = B_{ECR}$ (low field model with 87.5mT). In the second type, $B \approx 1/3 B_{ECR}$ or $1/2 B_{ECR}$. In these sources B can be lower than B_{ECR} everywhere inside the plasma. In the third type, $B > B_{ECR}$ (high field model with 93mT)[1]. Because we use the Nd–Fe–B permanent magnet to produce the required magnetic fields, the strengths B can not be adjusted in large range. Therefore, the low field model with 87.5mT and the high field model with 93mT were tried in our test. The typical field distributions are presented in Fig. 2.

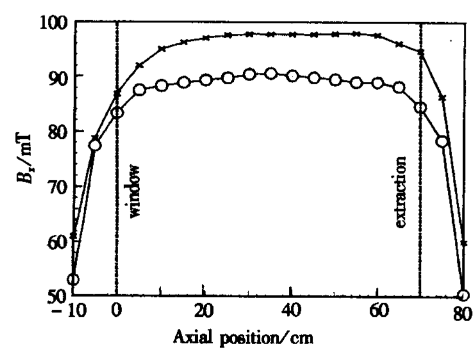

Fig. 2 Axial magnetic fields distribution

The positions of the microwave window and the extraction aperture are shown as dashed line. × high field model with 93mT, ○ low field model with 87.5mT.

4 Result of Experiment

By using the low field model with 87.5mT, at microwave power of 600W, extraction high voltage of 22kV, a biased voltage −5kV, gas consumption of 2—3sccm, a mixed ion beam current ($H_1^+ + H_2^+ + H_3^+$) of over 90mA has been extracted. The corresponding density is 318mA / cm^2. By using the high field model with 93mT, keeping the other conditions the same, a mixed ion beam current ($H_1^+ + H_2^+ + H_3^+$) of 72mA has been extracted. The beam density is about 255mA / cm^2. With regard to this result, the total beam current gotten by using low field model with 87.5mT is more than that by using high field model with 93mT. We think it may be caused by two reasons: (1) The distance between the microwave windows and ECR point at the injection region is not tuned well. This distance has something to do with microwave power absorbed by plasma. (2) There is a contradiction between the ion extraction and the plasma confinement. In addition, during the test we find that the magnetic field distribution is slightly different at low and high microwave power.

5 Comparison of the same type ECR ion source

At present, there are a few 2.45GHz ECR ion sources which have achieved strong ion current in the world. For instance, (1) The source built by Los Alamos National Laboratory could produce the total beam current ($H_1^+ + H_2^+ + H_3^+$) of 130mA and the beam density is 224mA / cm^2. The use of two solenoids produce required magnetic configuration. The magnetic configuration is shown in Fig. 3[2]. (2) The source built by Chalk River Laboratories could achieved the total beam current ($H_1^+ + H_2^+ + H_3^+$) of 95mA and the beam density is 484mA / cm^2. Two

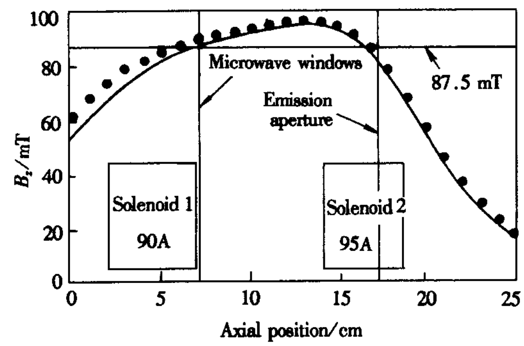

Fig.3 Measurement of the proton source axial magnetic field and comparison of its magnitude at the entrance (microwave window) and exit (emission aperture) positions

Within errors, the resonant magnetic field of 87.5mT at 2.45GHz occurs at both locations

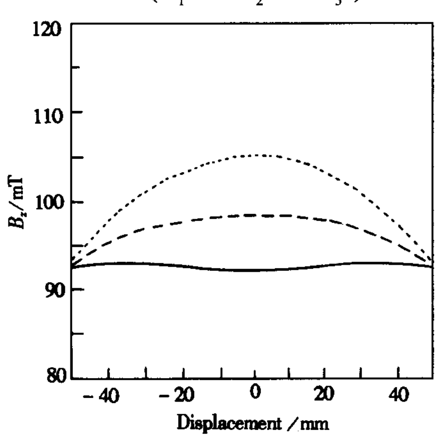

Fig.4 Magnetic induction on the axis the plasma chamber for various centre-to-centre solenoid spacing with the solenoids centred on the plasma chamber

The plasma electrode is at 50mm and the microwave window is at −50mm.

······79mm, – – – 104mm, ——130mm.

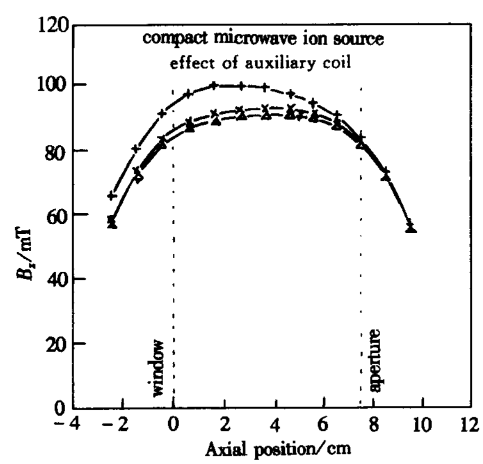

Fig.5 Axial magnetic field profile for various coil currents

The position of the microwave window and the extraction aperture are shown as dashed lines.

Δ I_c=−1A, +I_c=8A, ×I_c=0.

solenoids are used to produce the required magnetic configuration. The magnetic configuration is shown in Fig. 4[3]. (3) The source built by Chalk River Laboratories could produce the total beam current ($H_1^+ + H_2^+ + H_3^+$) of 60mA and the beam density is 306mA / cm^2. In this source, permanent magnets is used to produce the required magnetic fields. The magnetic configuration is shown in Fig. 5[4].

6 Conclusion

Form above mentioned five magnetic configurations and our operating experience, we think it is necessary to satisfy with two conditions in order to get strong ion current. (1) The strengths **B** at both the injection point and the extraction point are 87.5mT or 93mT. (2) The axial magnetic fields are approximately 87.5mT or 93mT from the microwave windows to the extraction point.

In addition, the strengths *B* at injection point and extraction point are corresponding. In other word, while the magnetic field at the injection point is 87.5mT or 93mT. The magnetic field at the extraction point should be also 87.5mT or 93mT.

We thank the colleagues in the institute for their enthusiastic help in technologies and equipment during the ion source tuning.

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单粒子态 ECR 离子源

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摘要 介绍了一台2.45GHz电子回旋共振(ECR)单电荷离子源的磁场场形，以及它和总束流的关系. 并且比较了国际上现有的几台同类型离子源的磁场场形. 由此得出了关于2.45GHz ECR离子源磁场场形的一些结论.

关键词 电子回旋共振 磁场场形 总束流

1999-05-04收稿