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A NEW 18 GHz ECR ION SOURCE FOR CYCLOTRON AT CIAE

B. Tang†, B. Q. Cui, L. Zhang, R. G. Ma, G. Guo, Y. F. Wang, H.N. Chen, Y. T. Li, Y. J. Ma, L. Sui
L.H. Chen, China Institute of Atomic Energy, Beijing 102413, China
C. Qian*, ‡, L. T. Sun, P. Zhang, W. Lu, L. B. Li, J. D. Ma, Z. H. Jia, X. Z. Zhang
Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
Y. T. Li, College of Nuclear Science and Technology, Fundamental Science on Nuclear Safety and Simulation Technology Laboratory, Harbin Engineering University, Harbin 150001, China

Abstract

In order to meet the requirements of ion beam for the single event effect experiment, the ion source needs to supply ion beams of N, Ne, Si, Ar, Fe, Kr, Xe, and so on for the cyclotron. The most effective way to increase the energy of the cyclotron is to increase the charge state, and the Kr ion charge state reaches 22+ while the Xe ion charge state reaches 35+. A new room-temperature Electron Cyclotron Resonance (ECR) ion source operating at 18 GHz has been developed and assembled at China Institute of Atomic Energy (CIAE). This new ECR ion source is based on the Lanzhou Electron Cyclotron Resonance ion source No.5 (SESRI-LECR5) developed at Institute of Modern Physics (IMP). The magnetic confinement of the new ECR ion source is realized by the axial mirror field provided by two set of room temperature pancake coils while the radial hexapole field is supplied by a permanent magnet hexapole. A dual-sputter disk injection component was designed for the production of metallic cocktail ion beams. This paper will give the detailed design of this ion source, and some preliminary highly charge state ion beam production results will also be presented.

INTRODUCTION

A heavy ion cyclotron (K=120) [1] has been rebuilding at CIAE. The cyclotron is a versatile machine，
which is employed for the production of protons, deuterons, alpha-particles and heavy ions in the variable energy The energy of proton is variable at 10-72 MeV, the maximum current intensity is 200 eμA , the deuterium ion energy is variable at 10-65 MeV, the alpha ion energy is variable at 20-130 MeV, and the heavy ion energy is 120- MeV * Q^2/A (Q and A are the charge state and mass number of accelerated ions respectively). For heavy ions, the energy of the ion beam extracted by the accelerator is proportional to Q^2. It is very important to improve the charge state of the ion beam to improve the maximum beam energy accelerated by this accelerator. The original injector of the accelerator is a 10 GHz CAPRICE 1 Tesla ECR ion source was developed in 1992 [2]. The charge state that can be generated for heavy nuclide particles is low. For example, the charge state of Kr can only reach 18+, while the charge state of Xe can only reach 27+. Therefore, the development of a new ion source with the ability to produce higher charge state ion beam, is necessary to meet the requirements of the basic and application research of heavy ion, such as the research of low energy nuclear physics, single particle effect, ion radiation damage and so on.

THE LAYOUT OF THE INJECTOR

The original 10 GHz ion source injector was equipped below the cyclotron. The horizontal ion beam is injected into the vertical section through a 90-degree electrostatic deflector and enters the central hole of the magnetic pole under the cyclotron. Two sets of triple quadrupole lens matching beam envelope are set in the vertical section, and finally injected into the cyclotron through an electrostatic deflector (mirror) for acceleration.

The new 18 GHz high charge state ECR ion source injector is set directly below the original 10 GHz ion source injector, as shown in Figs. 1 and 2. According to the requirements of cyclotron, the maximum high voltage of the ion source is 20 kV, and the total ion beam is about 5 emA. Magnetic elements are used on the beam line to reduce the influence of space charge effect on the ion beam. A solenoid lens is set behind the ion source to match the change of ion beam angle under different extraction voltage conditions to meet the requirements of the optical envelope of the dipole magnet. The dipole is a dual-focusing magnet with a deflection radius of 500 mm and the deflection angle is 90 degrees, and the mass resolution is better than 60.

A set of triple quadrupole lens is set behind the dipole magnet, and the analyzed ion beam is matched into the electrostatic deflector and injected into the vertical beam line of the original injector. The large radius electrode plate of the electrostatic deflector is movable. When the beam is supplied by the new injector, the large radius electrode plate of the electrostatic deflector will be move out, and then the ion beam can pass through the electrostatic deflector. Two XY magnetic guides are also set on the beam line to correct the ion beam transmission direction.

ION SOURCE

A high performance room temperature ECR ion source was proposed for various ion beams injection. According to the scaling laws of an ECR ion source [3, 4]. Its design is based on SESRI-LECR5 [5] parameters and optimized for the magnetic field of the SECRAL operating at 18 GHz [6]. Compared with a superconducting ECR ion source, a room temperature 18 GHz ECR ion source has the advantages of more accessible construction, lower cost, and more convenient maintenance.

* contributed equally to this work
† tangb364@126.com
‡ qianc@impcas.ac.cn

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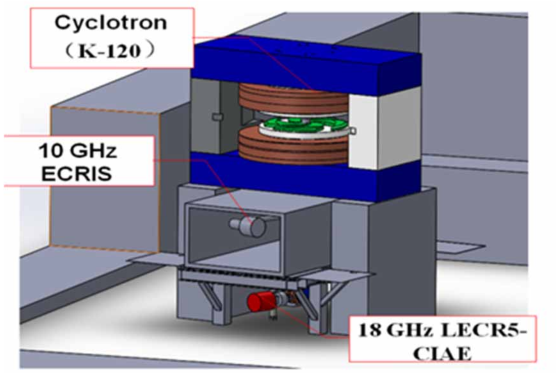

Figure 1: Layout of the cyclotron system.

Figure 2: The picture of the new injector.

As shown in Fig. 3. The axial magnetic field to achieve a mirror field uses two coils that injection and extraction coils. It is advantages to tuning on the electron temperature through the magnetic gradient at resonance. Besides, the magnetic field at the injection side is reinforced by a thick iron plug that obtains a high-B mode magnetic profile. The axial field of 2.6 T at the injection is achievable, as shown in Fig. 4. A hexapolar system gives the radial magnetic field. The optimum configuration for such a system is given by the so-called Halbach array composed of 36 block permanent magnets (88 mm inner diameter, 188 mm outer diameter, and 320 mm long). Using the higher remanence material N50M NdFeB (Br=1.407 T, Hc=-1043 kA/m) improves the radial magnetic field strength, and uses higher polarization coercivity material N48SH NdFeB (Br=1.386 T, Hc=-1011 kA/m) solves the self-demagnetization problem in the six critical magnetic segments. The radial magnetic field at a chamber wall of 1.2 T is achievable, and the large and long plasma chamber (80 mm in diameter and 340 mm long) allows a long lifetime for the ions to produce high charge states. Table 1 presents the parameters of the LECR5-CIAE ion source.

The gas inlet system of the ion source is equipped with four gas inlet pipes, each of which is independently adjustable by a needle valve, and can inject various gases into the ion source, simultaneously. At the same time, a dual-sputter disk injection component is designed for the production of metallic cocktail ion beams to meet the experimental requirements of single event effects research (Fig. 5).

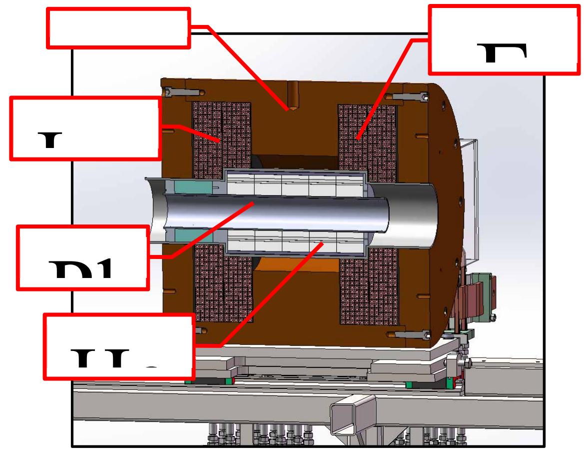

Figure 3: Layout of the LECR5-CIAE ion source.

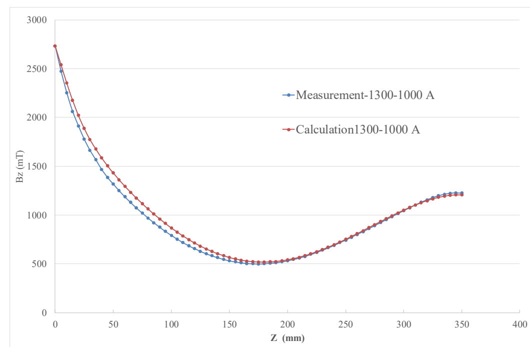

Figure 4: The calculated and measured magnetic field.

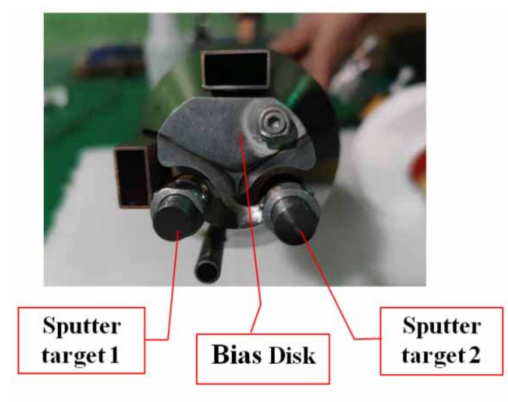

Figure 5: Injection component.

Table 1: The Parameter of the LECR5 Ion Source

Parameter	Value
Microwave frequency (GHz)	18
Maximum power(kW)	2.0
Binj (T)	2.6
Bext (T)	1.4
Brad (T)	1.2
Mirror Length (mm)	340
Plasma chamber D (mm)	80
Maximum HV(kV)	30

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FIRST BEAM EXPERIMENT

A large number of experimental studies on ion beam generation have been carried out, and the ion beams of elements such as silicon, oxygen, nitrogen, neon, krypton, xenon, etc. have been produced. The high voltage of the ion source reaches 25 kV, which is better than the design value of 20 kV. The beam generation methods for different forms of elements are studied. For gaseous elements, such as oxygen, nitrogen, neon, etc., gas intake is used. For solid elements, silicon uses the gaseous compound of SiH_4, while iron, tantalum, etc., uses the sputtering method. The typical beam intensity is shown in Table 2, in which the Fe^{15+} ion beam reaches 6 eμA with sputter target. $^{84}Kr^{22+}$ ion beam reaches 6.8 eμA with nature Kr gas. $^{129}Xe^{35+}$ion beam reaches 1.1 eμA. All are better than the acceptance index. The mass spectrometry of the Kr ion beams and the mixture beams of Ne, N and Ar are shown in Figs. 6 and 7, respectively.

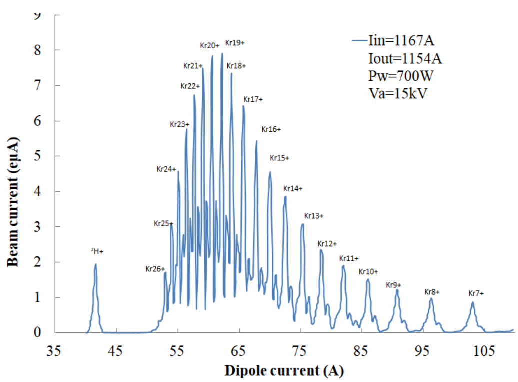

Figure 6: The ^{nat}Kr ion beam.

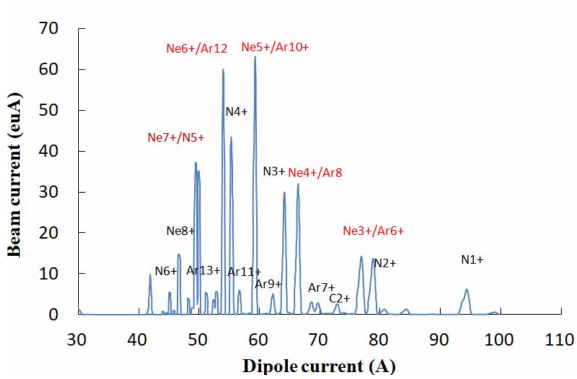

Figure 7: The mixture beams of Ne, N and Ar.

Table 2: Typical Beam Current

Beam	Beam Current (eμA)
$^{14}N^{4+}$	95
$^{20}Ne^{6+}$	75
$^{28}Si^{8+}$	15
$^{40}Ar^{12+}$	29
$^{56}Fe^{15+}$	6
$^{84}Kr^{22+}$	6.8
$^{129}Xe^{35+}$	1.1

CONLUSION

A new room-temperature ECR ion source operating at 18 GHz have been developed at CIAE. The preliminary tests show that the ion source has the ability to produce silicon, oxygen, nitrogen, neon, krypton, xenon single or mixed cocktail beams. In the later stage, further research will be carried out, and the experimental research on the acceleration and extraction of cocktail beam by the accelerator will be carried out in cooperation with the cyclotron.

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