THE INSTALLATION OF THE 28GHZ SUPERCONDUCTING ECR ION SOURCE AT KBSI

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Abstract

In 2009, a 28 GHz superconducting electron cyclotron resonance (ECR) ion source was developed to produce high currents, diverse heavy ion charge state for the compact heavy ion linear accelerator at KBSI (Korea Basic Science Institute). The aim of this study was to generate a high current, and fast neutrons for interacting a heavy ion with the proton target. The fabrication of the key parts, which are the superconducting magnet system with the liquid helium re-condensed cryostat, the 10 kW high-power microwave considering for optimum operation at the 28 GHz ECR Ion Source, were completed in 2013. The waveguide components were connected with a plasma chamber including a gas supply system. The plasma chamber and ion beam extraction were inserted into the warm bore of superconducting magnet. In this paper, we present the current status of the installation of an ECR ion source and report on the test results for ECR plasma ignition.

INTRODUCTION

The compact linear accelerator employing the 28 GHz ECR ion source was developed at KBSI [1]. The practical purpose of the KBSI accelerator is to produce fast neurons for the high-resolution radiography technology. We have been fabricating a 28 GHz superconducting ECR ion source to deliver high intensity beams of highly charged heavy ions into the radio frequency quadrupole (RFQ) and the drift tube linear accelerator (DTL). To fulfill this target, accelerated ^{7}Li ions need to interact with a hydrogen gas jet at an energy of a few MeV/u, which then generate high-intensity fast neutrons at forward angles. The 28 GHz superconducting ECR ion source was developed in 2009. The design of each component of the ECR ion source was completed in 2010. The individual components were assembled in 2011. Very recently, a 28 GHz superconducting ECR ion source has been installed, as shown in Figure 1. In this article, we present information regarding the components required for the ion source in details, and the experimental setup for the first plasma ignition.

THE SUPERCONDUCTING MAGNETS

The superconducting magnet system is comprised of 3 mirror solenoid coils and a hexapole magnet [2, 3]. The inside diameters of the hexapole magnet and solenoid coils are 207 mm and 442 mm, respectively. Two kinds NbTi superconducting wire was used for the magnet system. A higher current density NbTi wire was selected for the winding of hexapole magnet, respectively. The copper/NbTi ratios were 4.9 for the solenoid coils and 2.32 for the heaxpole magnet. The superconducting magnets have an operating margin of about 30% away from the critical current, according to the design values. Figure 2 shows a schematic drawing of the superconducting magnet system.

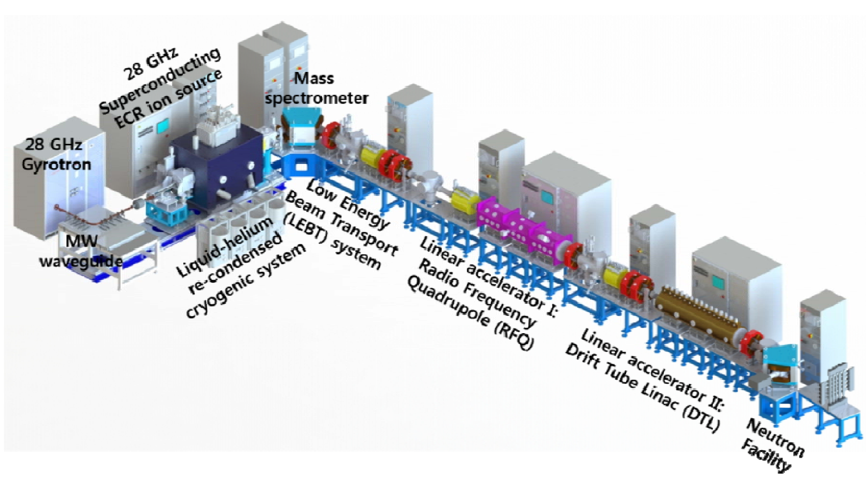

Figure 1: Schematic view of the heavy ion accelerator with the 28 GHz superconducting ECR ion source.

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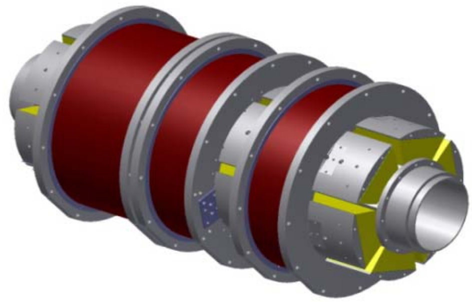

Figure 2: Layout of the superconducting magnet system.

The three solenoid magnets were assembled with stainless steel pipe. Step-type racetrack coils were placed around the aluminum bore tube. We inserted titanium wedges at the interfaces of each coil, to provide azimuthal compression. The ends of the hexapole magnet are fixed with a stainless steel metal clamp, in order to support the large radial electromagnetic force.

Figure 3 shows the layout of the cryogenic system. The cryogenic system for superconducting magnet operates at 4.2 K with liquid helium, and was designed to operate in a closed loop mode Additional liquid helium is not needed to be transferred during operation because a helium recondenser is used to maintain a constant liquid level. The four recondenser units are installed at the top of the liquid helium vessel and linked with the cryocoolers. They liquefy the helium gas and it then drops by gravity. The helium recondenser controller monitors (HRC-100) control the pressure in the vessel to maintain the level of the liquid helium inside of the cryostat within a target value. It was demonstrated that the cryogenic system is capable of achieving appropriate recondensing performance through long time experiments[4]. Even when the superconducting magnet is in full operation, there is no changes in the liquid helium level. Based on the experimental results for the superconducting magnet and cryogenic system, we concluded that the superconducting magnet system is now ready for the plasma ignition.

PLASMA CHAMBER

The plasma chamber is also shown in Figure 3. The chamber length and its diameter are 500 mm and 150 mm respectively and is made of a stainless steel (SUS316L) material. The cooling water channel (>5 L/min) is located at each end side of the plasma chamber wall. The electrode and chamber for ion beam extraction was designed so as to be retractable in the case when maintenance work is needed. The two turbo molecular pumps are installed under the injection and extraction boxes. The chamber is pumped by the capacity of 1100 L/sec for the realization of ultra-high vacuum level (~ 10^{-8} Torr). If plasma ignition occurs in the chamber, the generation of a large amount of X-rays would be predicted. It is generally reported that the X-rays would be as a heat load for a cryogenic system. Such an unexpected heat load would affect cryogenic performance. Therefore, a simulation with regard to the generation of X-rays was carried out and considering the likely effect of X-rays on shield thickness[5]. We plan to wrap the plasma chamber with a 2 mm thick tantalum sheet to reduce the effect of X-rays and to also employ a Kapton sheet for electrical insulation.

MICROWAVE SYSTEM

The microwave are initially delivered from a gyrotron with 28 GHz, 10 kW at a TE02 mode through a circular waveguide (WC128). In order to avoid damage arising from reflected power, the security and detection system are located in front of the gyrotron. For safety reasons, it is necessary to protect the devices and personnel. One 90-degree corrugated bend and three linear waveguides are connected to deliver the microwave power from the gyrotron to the plasma chamber.

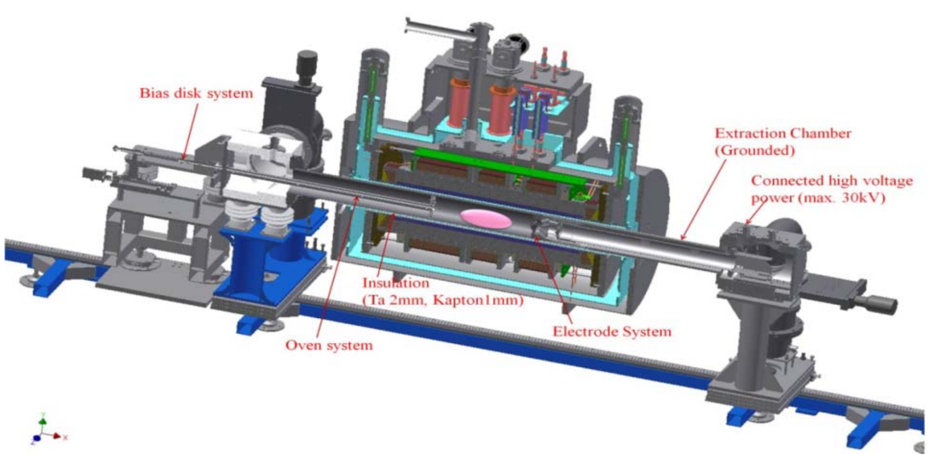

Figure 3: Layout of the cryogenic system and plasma chamber.

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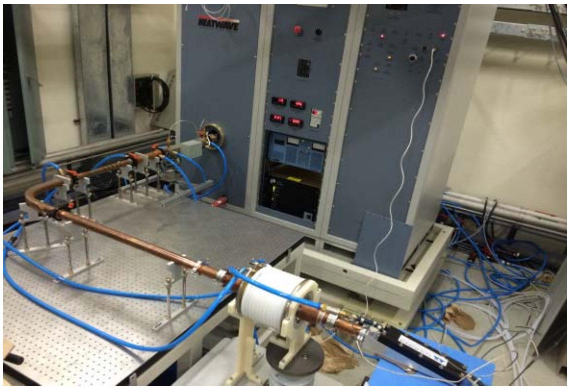

Figure 4: The 28 GHz microwave transmission line from gyrotron to ECR ion source.

The waveguide system is connected in series with the following components as shown in Figure 4 and 5. We measured the values of microwave power at each component using a self-developed dummy load. 2 kW of microwave power was generated and delivered to the waveguide components. The results are listed in Table 1. As shown in the table, most of the microwave power was measured at several location. Compared to out power from the gyrotron, most of power was delivered and consumed at the dummy load. This also means that the output of gyrotorn (2 kW) was not forwarded completely to the waveguides but the deviation (reflected power) appeared to be negligible. It was observed that the output frequency variation at 28 GHz was from 27.9740 GHz to 27.9893 GHz and the frequency fluctuation was found to be below 0.1 %.

Table 1: Forward microwave power at each

Location	Component	Measured Power[kW]
Default	Gyrotron + Directional coupler: (A)	1.9
1	(A) + Mode Converter : (B)	1.88598
2	(B) + Mode Filter : (C)	1.89102
3	(C) + 90° bend: (D)	1.88598
4	(D) + DC Break	1.87658

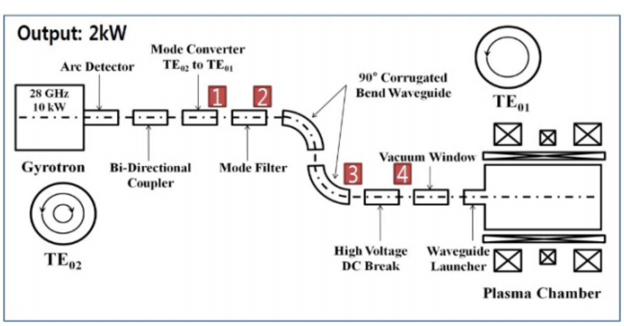

Figure 5: The 28 GHz microwave transmission line from gyrotron to ECR ion source.

PLASMA IGNITION

As we reported above, the majority of the parts(superconducting magnet with liquid helium cryostat, plasma chamber, microwave system and so on) were ready for plasma ignition. For the initial ignition, Ar gas was prepared for the experiment. After injecting Ar gas into the plasma chamber, the vacuum changed from a few of 10^{-8} Torr to 10^{-6} Torr. We carried out the experiment under normal condition for the superconducting magnet because the training of the entire magnet has not finished yet. The axial magnetic field is about 2.3 T at the injection area, and 2.1 T at the extraction region. A radial magnetic field of 1.3 T on the plasma chamber wall was used for the initial plasma ignition. According to the magnetic field distribution, we limited the microwave power to less than 1 kW. Figure 5 shows the Ar gas plasma after applying the gyrotron operation power. It can be seen that the typical ECR plasma was shaped like a star, which was mainly caused by the hexapole magnet field.

We already installed the extraction part for producing the ion beam. In the next step, we plan to extract and transport the ion beams through the LEBT beam line during this year. Ion beam current and intensity will be measured at the diagnosis chamber with various tools (slits, wire scanner faraday cup and so on).

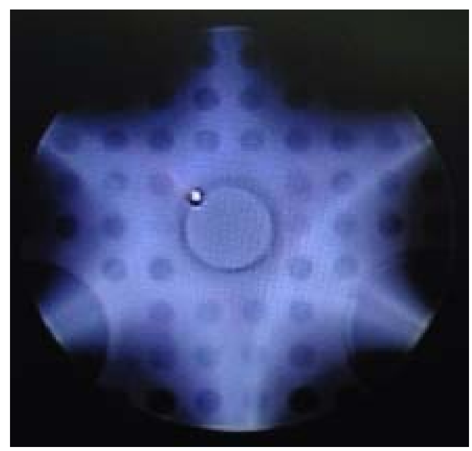

Figure 6: Picture of Argon plasma ignition.

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REFERENCES

[1] J. -H. Yoon et al., Rev. Sci. Instrum., 83 (2012), 02A315.
[2] B. S. Lee et al., Rev. Sci. Instrum., 83 (2012), 02A347.
[3] J. Y. Park et al., Rev. Sci. Instrum., 85 (2014), 02A928.
[4] S. Y. Choi et al., Rev. Sci. Instrum., 85 (2012), 02A315.
[5] J. Y. Park et al., Rev. Sci. Instrum., 85 (2014), 02A948.

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