THE DEVELOPMENT STATUS OF COMPACT LINEAR ACCELERATOR IN KOREA

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Abstract

The establishment of a compact linear accelerator is in progress by Korea Basic Science Institute. The main capability of this facility is the production of multiply ionized metal clusters and the intense beams generation of highly charged ions for material, medical and nuclear physical research. To generate the intense beam of highly charged ions, we started to develop an Electron Cyclotron Resonance Ion Source (ECRIS)[1] using 28 GHz microwaves. For ECRIS, the designing of a superconducting magnet, microwave inlet, beam extraction, and plasma chamber were in progress. The nominal axial design fields of the magnets are 3.6 T at injection and 2.2 T at extraction; the nominal radial design field strength at the plasma chamber wall is 2.1 T. We already installed 28 GHz gyrotron with 10 kW and tested dummy cooling system. In this paper, we will report the current status and a further plan of compact linear accelerator using a 28GHz ECRIS.

PROTOTYPE 2.45 GHz ECRIS

We are now developing the compact linear accelerator to the year of 2013. The compact linear accelerator offers many advantages including a low cost, compact, less power consuming, and user-friendly system because of small installation space. A prototype 2.45 GHz ECRIS[2] applying permanent magnets, which is shown in Figure 1, was developed at 2009 for the basic research of engineering design of 28 GHz ECRIS. The ECR plasma was obtained using Ar gas.

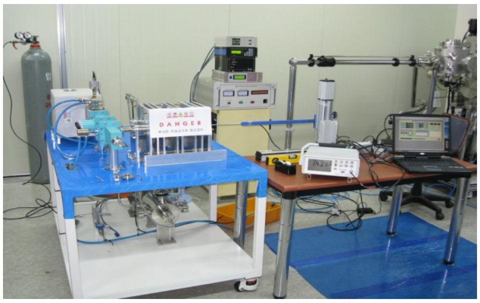

Figure 1: A prototype 2.45 ECR ion source.

We have made a Langmuir system to measure an electron temperature of plasma for the calculation of ECR plasma density. The measured electron density was 9.09 eV and calculated ECR plasma density was $1.235\text{x}10^{11}$ cm^{-3}.

MICROWAVE SOURCE FOR 28 GHz ECRIS

The installation and performance test of 10 KW, 28 GHz gyrotron were finished. The gyrotron works well in the power range between 1 kW and 10 kW. Figure 2 shows the power consumption in a dummy load as a function of an output power from gyrotron. A measured frequency range was 15.3 MHz (27.9893~27.9740 GHz), which is an acceptable error range.

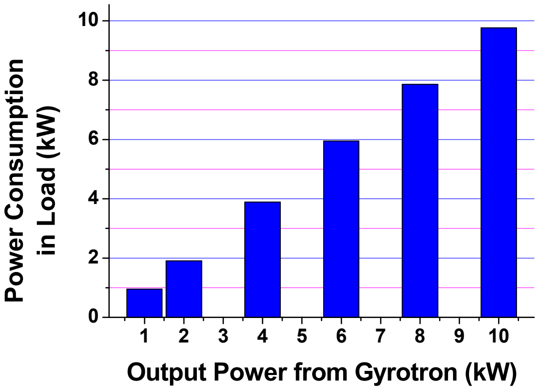

Figure 2: Power consumption in a dummy load as a function of an output power from gyrotron.

Figure 3 shows a status window of 28 GHz gyrotron operation program when RF output changes form 4 kW to 6 kW. Blue and red lines in the figure indicate setting and measured value in the real time, respectively. In the left figure, the increment of beam voltage and the decrement of main magnet current were observed as variation of output setting value from 4 to 6 kW. Also, the output power is changed simultaneously, as shown in right figure.

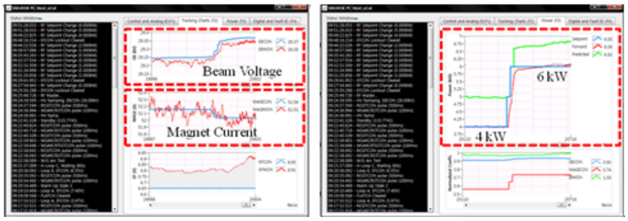

Figure 3: A status window of 28 GHz gyrotron operation program when RF output changes form 4 kW to 6 kW.

A high voltage DC break was developed to couple the microwave source and ECR plasma chamber. The outline of 28 GHz, 10 kW microwave system to ECR plasma chamber is depicted in Figure 4.

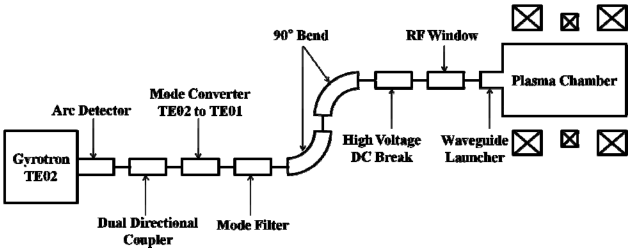

Figure 4: Outline of 28 GHz, 10 kW microwave source to ECR plasma chamber.

MAGNET DESIGN FOR 28 GHz ECRIS

The design of superconducting magnets for 28 GHz ECRIS is shown in Figure 5. The nominal axial design fields of the magnets are 3.6 T at injection and 2.2 T at extraction; the nominal radial design field strength at the plasma chamber wall is to be 2.1 T. We started the winding of 3 solenoids and hexapole magnets using OK 78 and OK 35 NbTi wire[3-5]. We are trying to reduce an X-ray heat load to obtain higher beam energy. A detailed magnet design may refer at poster TUP 155.

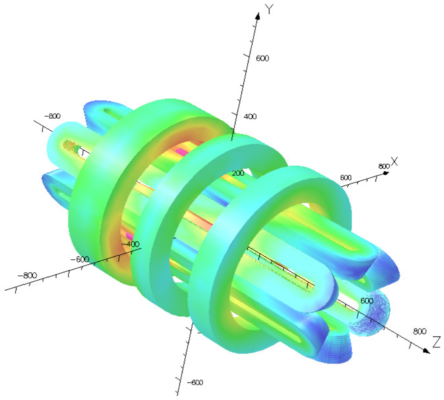

Figure 5: A design of superconducting magnet.

The cooling system for superconducting magnet was examined with a hexapole magnet model that wound with cu alloys wire. It is same size as real hexapole superconducting magnet. The one magnet model of six was installed in the cryostat then cooled down using 4 cryocoolers. The magnet model was chilled by conduction cooling method and no cryogen was consumed in this cooling test. The temperature was observed using 17 temperature sensors (CERNOX), which are represented in Figure 6. The temperature stabilized below 6 K and it took below three hours.

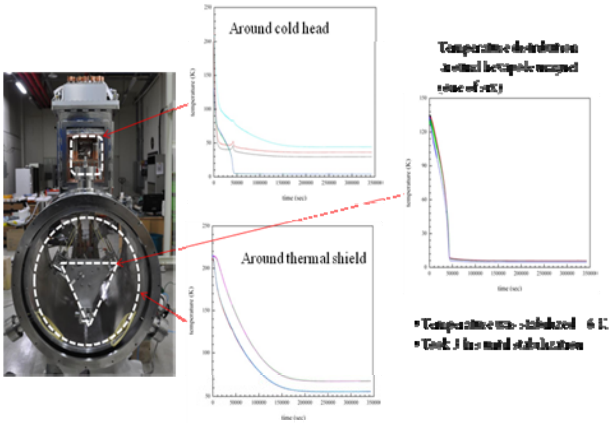

Figure 6: Cooling performance test using a part of hexapole magnet model wound with cu alloys.

To verify the heat capacity and the effectiveness of conduction cooling path to the magnets, a transient heat test was also carried out. For this we installed the cartridge heater (25 and 50 ohm) as a heat source at the bottom of the magnet model. Transient heat was controlled using temperature controller (Model 340, Lakeshore) and applied through heater. We tested several heat ranges and the results of external heat input about 50 W is shown in Figure 7. The heat propagated from the heater location so that one can see a clear increase of the temperature in magnet model. Valuable cooling parameters were deduced from measured data.

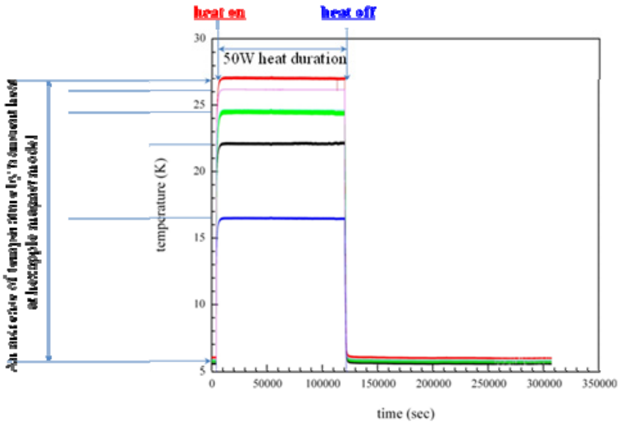

Figure 7: Temperature variation by external heat of 50 W.

NEUTRON RADIOGRAPHY SYSTEM

The end part of our compact linear accelerator is a fast neutron radiography system. The beam flux and energy for a neutron radiography system were calculated by an equation (1), where, Y is a neutron yield, F_{Li} is a beam flux, ρ is a density, N_A is an Avogadro constant, A is atomic number, L is a target length, and σ is a cross section of target.

$$Y_n = F_{Li} \times \rho \frac{N_A}{A} \times L \times \sigma \tag{1}$$

The needed fast neutron flux is 5.3 x 10^{13}/s for Li^{3+} beam current of 1 mA at a beam energy about 2 MeV/u.

FUTURE WORKS

Our compact linear accelerator will be installed at 2013 if an ample budget would be secured. In this year, the development of 28 GHz ECRIS will be finished. Designing of acceleration parts including RFQ, and DTL would be under study, simultaneously. Then, we will move to the neutron radiography system, which is our first goal.

REFERENCES

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