DEVELOPMENT OF LARGE APERTURE FARADAY-CUP FOR LEBT OF KHIMA

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Abstract

Since an aperture of a low energy beam transport line of the KHIMA is quite large, 100 mm, to minimize an uncontrolled beam loss, large aperture Faraday-cup with the diameter of 100 mm is installed to measure the beam current from the electron cyclotron resonance ion source (ECR-IS) and to identify the ion species using analyzing magnet. The suppression ring was designed to reduce the repelling electrons for an accurate measurement. The Faraday-cup has the cooling channel with the heat capability of 100 W to recover the heat from the ion beam for safety during the operation. In order to reduce the noise propagation from the cooling channel, the cooling channel was insulated with the cup. In this presentation, we show the physical modeling, mechanical aspect for design the large aperture Faraday-cup, and the result of in-beam test with the ECR-IS in KHIMA.

INTRODUCTION

The Korea Heavy Ion Medical Accelerator(KHIMA) project was launched to establish a high energy heavy-ion particle based cancer therapy technique in Korea and to perform the patient treatment using a carbon beam. The accelerator part consist of the low energy beam transport (LEBT) line, radio frequency quadrupole (RFQ) accelerator, interdigital H-mode (IH) drift-tube linac (DTL), medium energy beam transport line, synchrotron, and high energy beam transport line [2]. It can provide a low intensity proton and carbon beams with an energy in the range of 110 to 430 MeV/u for carbon beam and in the range of 60 to 230 MeV for proton which corresponds to the water equilibrium beam range of 3.0 to 27.0 g/cm^2 [3]. In the low energy beam transport (LEBT) line of the KHIMA project, it has several beam diagnostics to confirm the beam quality from the electron cyclotron resonance (ECR) ion source. The wire-scanner (scanning wire) has the two wire, which was installed perpendicular to each other, to measure the horizontal and vertical beam profile and central orbit simultaneously. The slit is used to eliminate unwanted beam from the ECRIS and to measure the emittance by the slit scanning method. The AC current transformer (ACCT) and Faraday-cup are used to measure the beam current for the pulsed beam and DC beam, respectively. The chopper is installed to control the pulse width for the multi-turn injection in the ring. The number and position of the diagnostics in the LEBT line is shown in Fig. 1.

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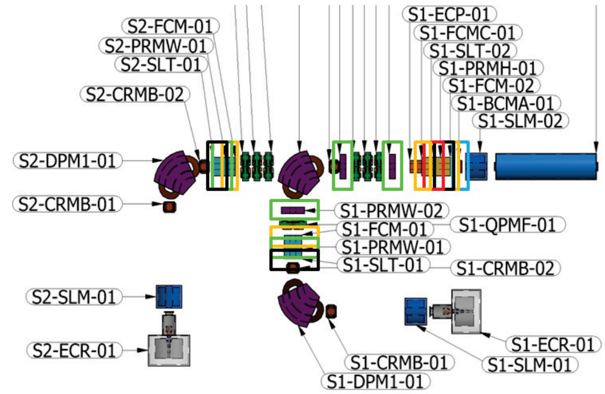

LEBT

label	BD type	number
□	Profile grid(harp) H&V	1
□	Scanning wire H&V	5
□	Slit H&V	3
□	Faraday cup (AC/DC/Chopper)	4
□	ACCT	1
	Chopper	1
	LEBT TOT.	**15**

Figure 1: Position and number of diagnostics in LEBT line of KHIMA.

FARADAY-CUP DESIGN

In the LEBT line, it has a large aperture Faraday-cup to confirm the transmission rate of the beam line by measuring a beam current at each section [1].

Mechanical Foundation Concept

Since the diameter of the vacuum chamber in the LEBT beam line is 100 mm, the aperture of the Faraday-cup should be larger than 100 mm to avoid the destruction of the signal line and high voltage line for the suppression ring by hitting the beam on the line. It is also important to avoid the activation of the element which is significant to increase the machine maintenance time. The cup surface has the angle of 45 ° to achieve the angle of reflection inside the cup. The Faraday-cup has the guide on the flange to reduce the mechanical vibration while the cup is moving. The cup was made of copper to increase the heat transfer to the cooling channel and to reduce the secondary electron yield from the 100 keV proton beam. The pneumatic actuator was adopted. Since the beam power from the carbon and proton beam with the beam current of up to 0.3 mA and the beam energy of 8 keV/u is 29 W, the Faraday-cup has the water cooling

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channel. The position and size of the cooling line was optimized to recover the heat up to 100 W from the Faraday-cup surface. The schematic drawing of the designed Faraday-cup is shown in Fig. 2.

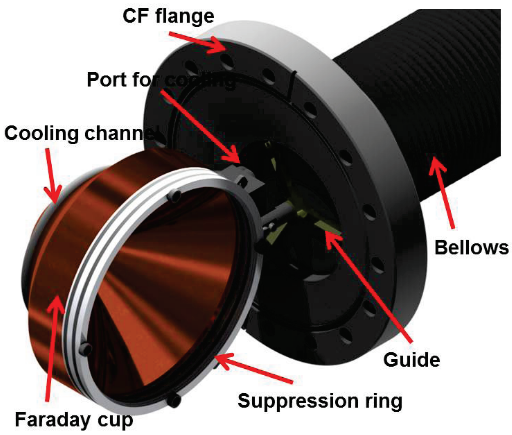

Figure 2: Schematic drawing of designed Faraday-cup.

Suppression Ring Part

In order the suppress the repelling electron, the two suppression rings were installed at the entrance of the Faraday-cup and the ceramic insulator was also installed between two rings to prevent the electrical discharge between them. The ceramic structure was optimized to reduce the possibility of the electrical discharge by increasing the path length between two suppression rings. The thickness of the ceramic ring is 1 mm and three insulators which has different diameter were installed. The schematic drawing of the suppression rings and ceramic insulator is shown in Fig. 3.

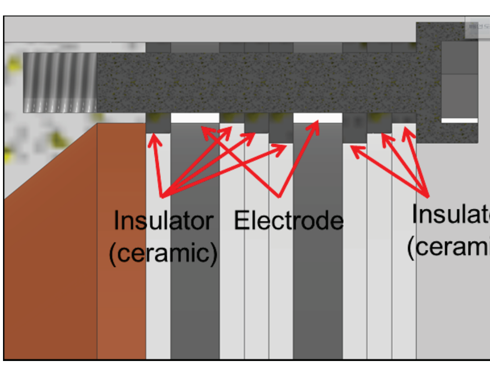

Figure 3: schematic drawing of the suppression rings with thickness of 2 mm and ceramic insulator with thickness of 1 mm.

From the Ref [4, 5], the repelling electron energy from the 100 keV proton beam is less than 100 eV and the cross section is decreased by a factor of about 20 at the 30 eV. The voltage on the suppression ring was determined to prevent the electron escape up to 100 eV. The electric field distribution with symmetric and asymmetric potential is calculated using CST [6]. The suppression voltage was assumed up to 1 kV. The 2-dimensional field map and field distribution along the central line of the Faraday-cup with the 1 kV suppression voltage are shown in Fig. 4

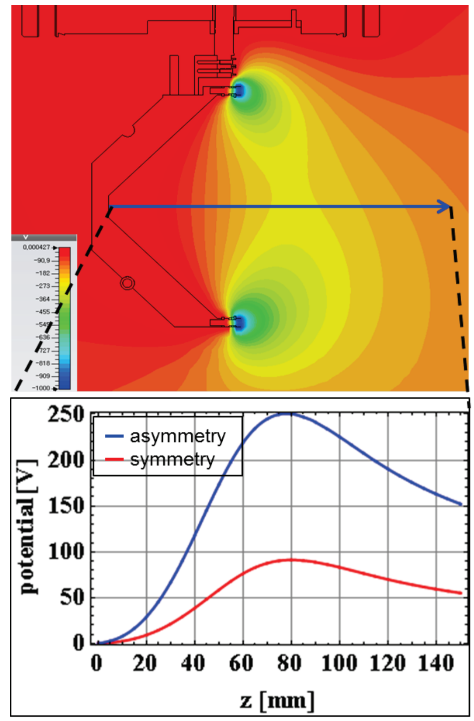

Figure 4: 2-dimensional field map and field distribution along the blue line (central line of Faraday-cup) with 1 kV suppression voltage.

The maximum electric potentials with the asymmetry (1 kV to 0 kV) and symmetry (-500 V to 500 V) pattern are 250 V and 80 eV, respectively. The asymmetric pattern gives the higher electric potential and then it was adopted. To prevent the electron escape with the energy of 100 eV, the required voltage on the suppression ring is about 400 V.

Cooling Channel Part

The Faraday-cup has the water cooling channel which can recover the heat up to 100 W from the cup surface. The cooling channel and the cup are made of copper to increase the efficiency of the heat transfer. The cooling channel should be insulated electrically from the cup by using the insulation material because the noise from the water flow in the cooling channel can cause the beam current measurement error. The general insulation material such as the alumina ceramic and PEEK, however, has lower thermal conductivity. Then the aluminum nitride, which has the thermal conductivity of 180 W/mK, was adopted. The holder which is made of the aluminum nitride wrapped the cooling channel and it is connected to the cup. The detail drawing of the cooling channel part is shown in Fig. 5.

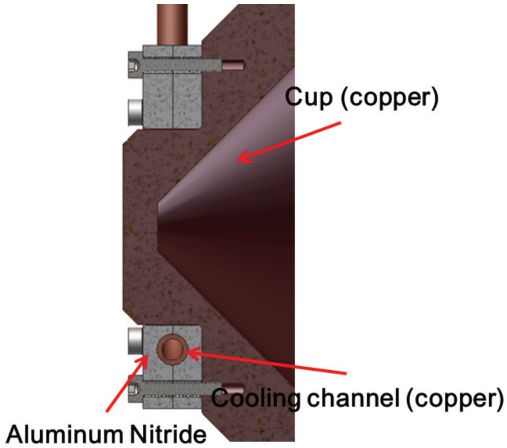

Figure 5: Detail drawing of cooling channel part.

Based on the thermal conductivity and structure, the diameter and path length of cooling channel, pressure drop, and the temperature variation were calculated. The main parameters for the cooling channel is listed in Table 1

Table 1: Main Parameter for Cooling Channel.

Parameter	Unit	Value
Cooling capability	W	100
Channel material		Copper
Channel diameter	mm	4.35 mm
Path length	mm	137
Water flow	liter/min	2.9
ΔP, ΔT	bar, °C	0.05, 0.5

FABRICATION AND BASIC TEST

The Faraday-cup was fabricated on the domestic company, ITS [7], and the leakage test of cooling channel was performed with the pressure of 7 bar. The leakage was not observed during the 30 min test. The picture of the leakage test is shown in Fig. 6.

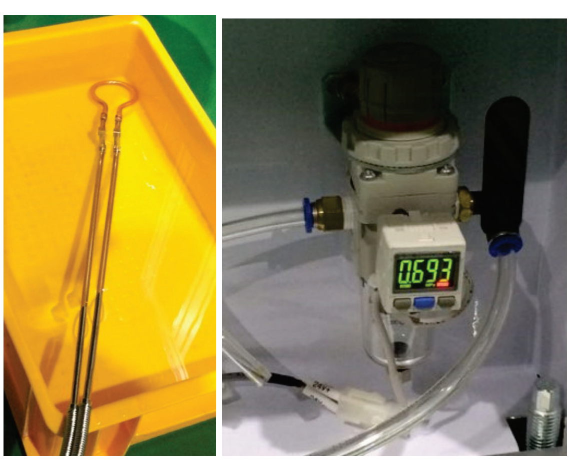

Figure 6: Picture of leakage test of fabricated cooling channel.

The Faraday-cup was fully assembled and the pneumatic actuator test was performed. The performance was verified. The picture of the fully assembled Faraday-cup is shown in Fig. 7.

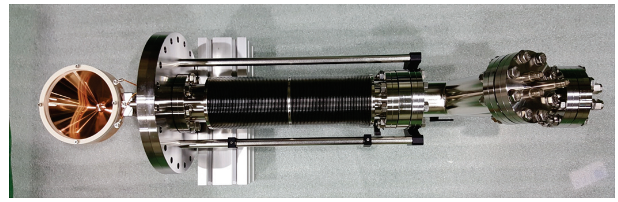

Figure 7: Picture of the fully assembled Faraday-cup.

The module for the data acquisition has two candidates. The beam test with the low energy ion beam, 8 keV/u, from ECR-IS will be performed at this year.

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CONCLUSION

The mechanical and electromagnetic design of the large aperture Faraday-cup, which will be installed in the low energy beam transport line of KHIMA, was performed to reduce the escape of repelling electron and to recover the heat from the cup surface. It was fabricated based on the design values and the laboratory tests, such as the leakage test of cooling channel, the assembly test with pneumatic actuator, were performed to confirm the performance. The severe leakage is not observed and it is well working. The beam test with the low energy ion beam, 8 keV/u, from ECR-IS will be performed at this year.

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