DESIGN OF RF SYSTEM FOR COMPACT AVF CYCLOTRON*

J.H. Oh, B.N. Lee, H.W. Kim, J.S. Chai#
Accelerator and Medical Engineering Lab. , SungKyunKwan University, Suwon, 440-746, Korea

Abstract

RF system is one of the most important parts for producing good and efficient accelerator system. The ion beam will be derived by a K100 SSC (Separated-Sector-Cyclotron). 8 MeV SF(Sector-focused) Cyclotron which produces 8 MeV proton beam is used as injector of K100 SSC cyclotron. In this paper, we designed RF system including RF cavity. The total specification of system is on the following. The frequency of this RF system is 70 MHz coaxial type cavity. Also we applied 4th harmonic, dee voltage of 50KV. We simulated the RF system using commercially available simulator, CST Microwave studio.

INTRODUCTION

A design research about RF system of 8MeV cyclotron was recently conducted. This cyclotron produce 1 mA proton beams at 8 MeV for K100 SSC. The high-intensity beam will be derived to SSC of above 1 mA. Then this extracted beam of this cyclotron goes to ISOL target

This paper mainly describes a development study of 8 MeV injector Sector-Focused cyclotron RF system. RF system is designed to have a few thousand of Q value with resonance frequency of 74.33MHz which based on the magnet design. Because of the limitation caused by magnet, we satisfied the condition of λ/2 by adjusting stem, liner, gap of Dee and so on. H^- particles having 24KeV for average energy are safely supplied in middle plane of poles through inflector and accelerated from central region by 50KV Dee voltage. Then accelerated particles having same angular frequency by isochronous magnetic field are ejected from final extraction stage with 8MeV energy. 3D modelling process was done by 3D CAD system, CATIA P3 V5 R18 [1] and analyzed by CST-MWS. By repeating this process, we completed the fully satisfied design.

RF SYSTEM DESIGN

The RF system has total 4 vertical stems. [2] Before designing this RF system, magnet design was preceded. Almost parameters of whole size are decided from magnet design. Material of RF Cavity is OFHC copper to get electric conductivity better and not affect magnetic field intensity. OFHC copper (model name : NBM C11000) has good electric conductivity($5.91\times10^{7} S/m$) compare with electric conductivity of normal copper ($5.8\times10\ S/m$) .

Dee angle is 40° which is located both of valleys. Total length of each dee is about 30cm. Cavity is coaxial type which has λ/2 resonant mode:

$$\lambda = \frac{c}{f} \quad (1)$$

Where c is the light velocity and f is frequency of RF system. Supposed resonance frequency of RF system is 70MHz, the wavelength, λ, is 4.28m. We set the length of whole inner conductor to half-wave length for resonance mode of λ/2. Based on this, the length of the stem which becomes an inner conductor is set to 36.5 cm.

This value, 36.5 cm, is applied for magnet design and the length of inner conductor approaches to 2.14 m, the value of half-wave length through 4 stems.

The radius of outer conductor is 40 cm based on the size of magnet. Liner is designed to have 39 cm height along the valley gap and exactly fit into the valley. Then the outer conductor which has 7.5 cm for radius is constructed by a hole in the valley of magnet. Particles are accelerated in E-field formed by two 5cm length dummy dees attached at both sides of outer conductor.

Table 1: Specification of RF system for 8MeV Cyclotron

Parameters	Values
Resonant Frequency	74.33MHz
Harmonic Number	4^{th}
Dee Voltage	50kV
Resonant mode	λ/2
Material	OFHC Copper
Pole radius	0.40 m
Hill/Valley gap	0.03 / 0.39 m
Dee angle	40°
Number of Sector/Dee	4 / 2

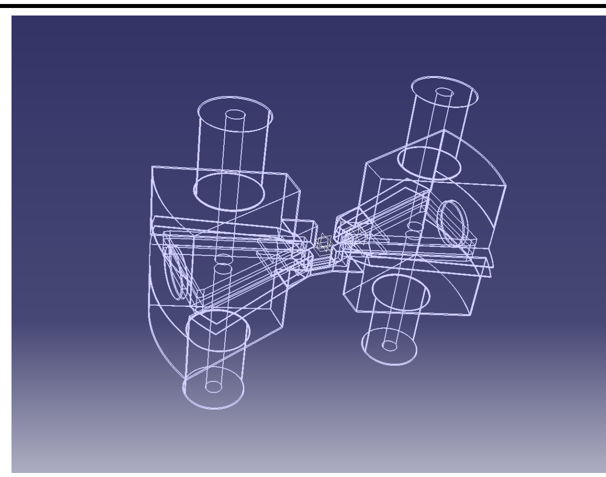

Figure 1: Wireframe of RF cavity basic model

*Work supported by Ministry of Education, Science and Technology, Republic of Korea and Department of Energy Science and School of Information and Communication Engineering of SungKyunKwan University
#jschai@skku.edu

RF SYSTEM SIMULATION

CST Microwave studio is one of special tool for 3D electromagnetic of RF system. [3] It can show E-field and H-field in the 3-dimensional. To optimize 70MHz RF frequency, various method is used. Especially, the stem position and shape is a primary key to decide resonant frequency and field distribution.

We suppose that the frequency is strongly influenced by the thickness of stem. Besides, it also affects Q value so the optimization of stem thickness is very important. If thickness of stem is so thin, the stem would be melted by RF power and Q value is decreased.

On the contrary to this, the frequency becomes higher with thick stem.

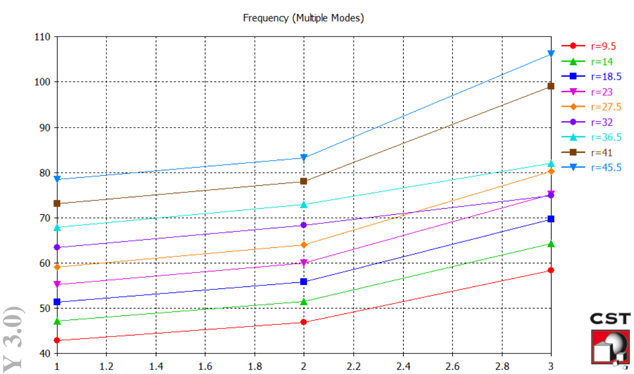

Figure 2: Frequency range following the radius of stem.

In Figure 2, vertical axis is resonance mode at each frequency and horizontal axis is RF frequency (MHz). The 'r' is radius of vertical stem. In this study, mode 3 is chosen due to suitable field distribution. So we optimized the stem figure and location as shown in Figure 3.

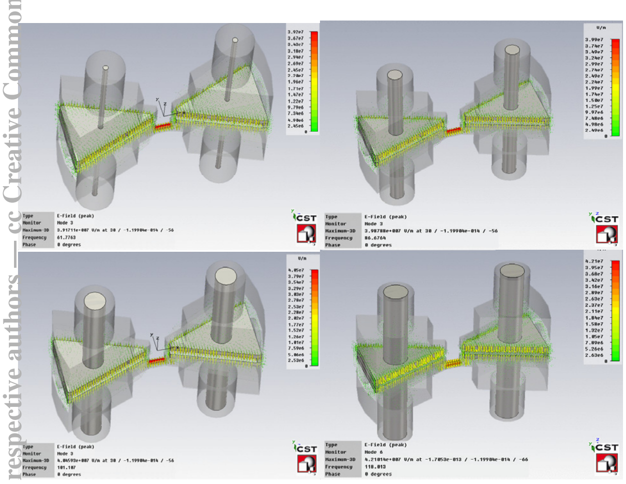

Figure 3: Frequency optimizing process.

By an optimization process, the radius of stem was decided to 2cm and the electric and magnetic field of final model was shown in Figure 4,5.

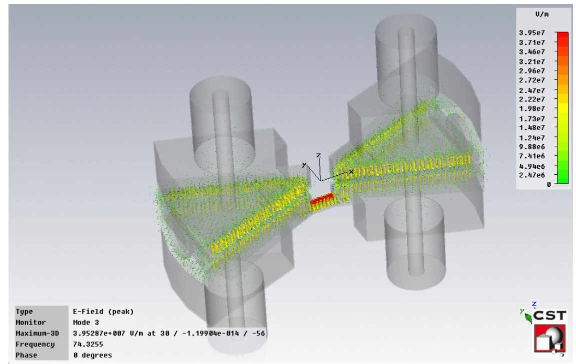

Figure 4: Electric field distribution.

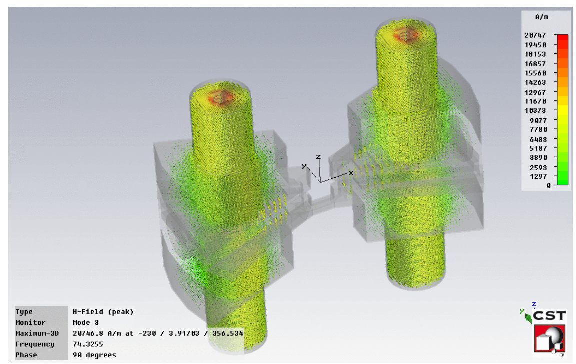

Figure 5: Magnetic field distribution

The resonant frequency of this RF system is 74.33MHz. H^- particles are accelerated by E-field direction which occurred to dee from dummy dee or opposite direction. A marginal error of frequency with targeted value can be adjusted by fine tuner.

We can calculate the Q value of resonant mode using Micro Wave Studio, CST. The equation for the calculation is shown below. [4]

$$Q = \frac{2\pi \cdot Stored\_Energy}{Energy\_Consumed\_per\_period} = \frac{2\pi \cdot f \cdot W}{P_{rms}} \quad (2)$$

Applying the method, the Q value of this RF resonator calculated by MWS is 5981.

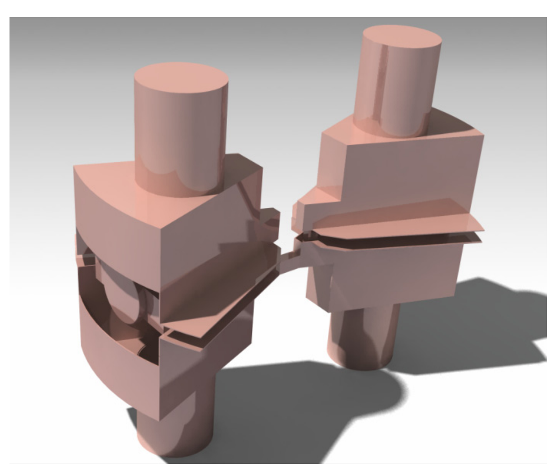

Figure 6: Final RF cavity design using CATIA V5

SUMMARY

This paper has explained the features of 8 MeV injector cyclotron RF cavities. we could acquire the optimal Q value and resonant frequency after iterated simulation many times. Designed cavity has proper RF frequency and Q value. Marginal error of RF frequency will control by RF tuner next process. It is expected that full conception design of 8 MeV cyclotron, included magnet, RF system ,etc, will be finished in November,2010

REFERENCES

[1] Dassualt Systems, FR.
[2] I.S. Jung, "Design of the RF SYSTEM FOR A 30 MeV Cyclotron", EPAC'06, June 2006, Edinburgh, WEPCH080.
[3] Computer Simulation Technology, Germany, http://www.cst.de.
[4] C.Pagani, "Cyclotron Cavities",CERN 92-03, CAS, April 1991, Oxford, UK