DESIGN OF THE RF SYSTEM FOR A 30MEV CYCLOTRON*

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Abstract

Lab. of Accelerator Development(LAD) in Korea Institute of Radiological & Medical Sciences(KIRAMS) developed a 13MeV medical cyclotron, named by KIRAMS-13, for Positron Emission Tomography(PET) in 2001. Now, KIRAMS-13 has spread to the provinces through the national project, "Development of Cyclotron and FDG Synthesis modules." But, there is just one cyclotron for Single Photon Emission Computed Tomography(SPECT) in Korea, which is made by IBA, Belgium. If any problem is happened, we should shut off the cyclotron until an engineer fixes them. So, we decide to develop a 30MeV cyclotron, named KIRAMS-30, which has high-performance compared with existing commercial cyclotrons and will install this machine to radioactive isotopes production and research in Advanced Radiation Technology Institute(ARTI). In this paper, we design a RF system, such as cavity, power coupler, and so on. At design of RF components, we consider mechanical stability, RF heating and cooling, arcing and low maintenance. We simulate the RF system of KIRAS-30 with CST Microwave Studio(MWS) and present simulation results.

INTRODUCTION

KIRAMS is developing a 30MeV cyclotron' called KIRAMS-30 and plans to be installed at ARTI, Jeongeup in late 2006. ARTI will make use of KIRAMS-30 for radioisotopes production, industrial application, food and agriculture fields. The final object of design is that 30MeV beam energy, 300μA beam current, and dual beam extraction. We also consider easy operation, remote control and monitoring system.

The RF system of KIRAMS-30 has vertical cylindrical stems just like other commercial cyclotrons. The power coupling method is capacitive coupling. In this paper, we describe the simulation results of KIRAMS-30 RF system with MWS.

RF SYSTEM

KIRAMS-30 accelerates a negative hydrogen ion and extracts proton. To accelerate the H^- beam to 30MeV, 0.8 T·m magnet and vacuum level under 10^{-6} torr are needed. Almost material of the RF system is OFHC copper to reduce out-gassing and not influence the magnetic field intensity. The RF system needs cooling mechanism to reduce RF heating and power loss. The RF specifications are shown in Table 1.

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Table 1: Specification of RF system

Parameters	Values
Resonant Frequency	63.96 MHz
Harmonic Number	4th
Dee Voltage	(nominal) 50kV
Resonant Mode	λ/2 mode
Matching Impedance	50 Ω
Material	OFHC copper
Hill/Valley Gap	0.03 / 0.62 m
Hill/Valley Angle	48 / 42 degree
Number of Sector/Dee	4 / 2

In KIRAMS-30, the dee capacitance is calculated to be C_{dee} = 25 pF. The cavity is approximated to be a lossless coaxial line with characteristic impedance Z_0, a capacitance C_{dee} being added at one end and the other end being short. We estimate the length of the coaxial-line part used with the elementary transmission line theory. The impedance looked at a point x into the capacitance side is given by

$$Z(x) = Z_0 \frac{1 - Z_0 \omega C_{dee} \tan\left(\frac{x\omega}{c}\right)}{j\left[\tan\left(\frac{x\omega}{c}\right) + Z_0 \omega C_{dee}\right]} \quad (1)$$

Where c is the light velocity and $\omega = 2\pi f_{rf}$. At $x = L$, the transmission line is shorted and we have $Z(L) = 0$, thus,

$$L = \frac{c}{\omega} \tan^{-1}\left(\frac{1}{Z_0 \omega C_{dee}}\right) \quad (2)$$

The characteristic impedance of a coaxial line is given by[1]

$$Z_0 = \sqrt{\frac{\mu}{\varepsilon}} \frac{1}{2\pi} \ln\left(\frac{b}{a}\right) \quad (3)$$

Where *b* is the inner radius of the outer conductor and *a* is the outer radius of the inner conductor. Let's assume that *b*=0.276m, *a*=0.09m. Taking the value of 63.96MHz for f_{rf}, the length of the coaxial part is *L*=0.664m.

RF Simulation

The RF system is designed with CST MWS which is a special tool for the fast and accurate 3D electromagnetic simulation of high frequency problems[2]. We already decided resonant frequency and calculated the elementary parameters of RF structure. Figure 1 shows the basic model of RF system.

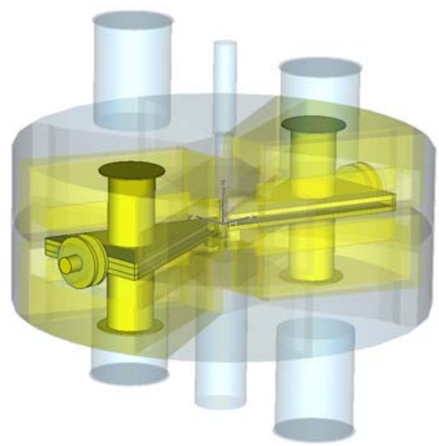

Figure 1: Basic model of KIRAMS-30 RF system.

According to the stem position, field distribution and resonant frequency are changed. The optimum process of the stem position is presented in Figure 2.

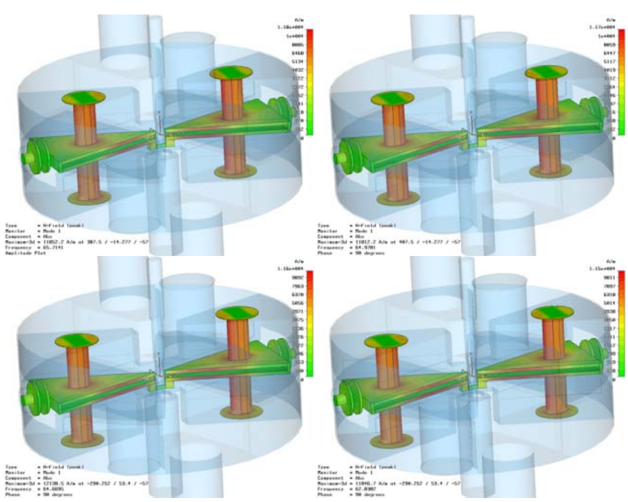

Figure 2: The optimum process of the stem position.

The electric and magnetic field distribution of a final model are shown in Figure 3 and 4.

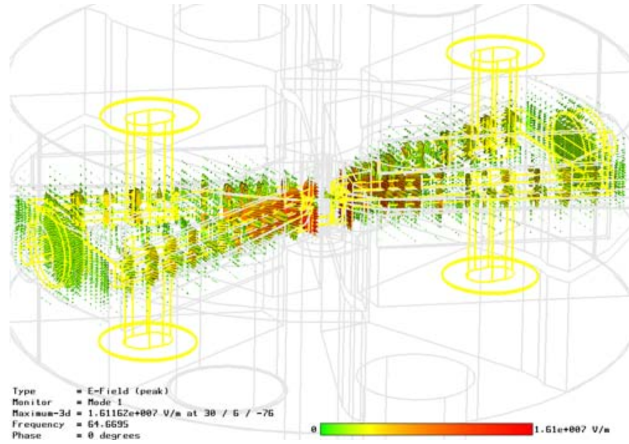

Figure 3: Electric field distribution.

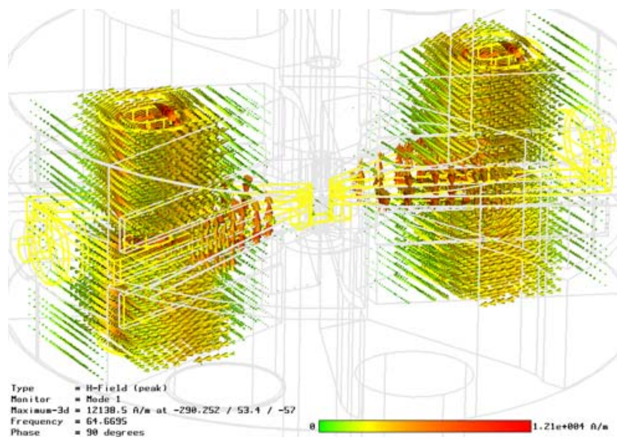

Figure 4: Magnetic field distribution.

The resonant frequency is 64.6695MHz and Q value is 6529, those are calculated with MWS. The difference of the resonant frequency between simulation and defined values is due to simplify inner structure of a cyclotron. A margin for error should be covered with frequency tuning range. Figure 5 shows the frequency tuning range as fine turner is moved.

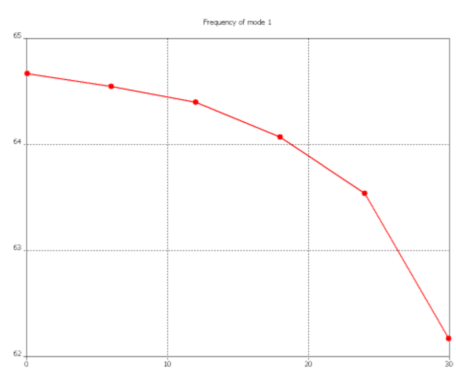

Figure 5: Frequency tuning range.

Mechanical Drawing of RF System

At mechanical drawing of RF components, we consider following factors[3].

- Mechanical stability
- RF heating and cooling

- Arcing and multipacting
- Low maintenance
- Low cost

The cross-section view of the designed RF system is shown Figure 6.

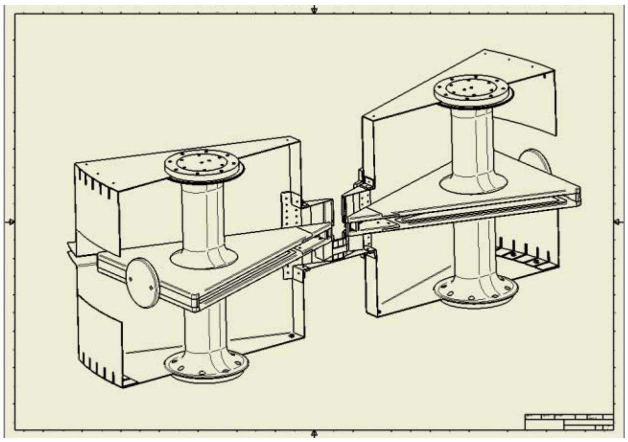

Figure 6: Cross-section view of the RF system.

CONCLUSION

A 30MeV cyclotron, KIRAMS-30, has been developed by LAD in KIRAMS. The RF structure is being manufactured by DooWon Ltd. and low power controller is being designed by Pohang Accelerator Laboratory (PAL)[4]. It is started to install KIRAMS-30 at ARTI in late 2006. The following are magnet shimming, vacuum test, RF power test, etc. We will finish installation until February, 2007.

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