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A Design of RF System for KIRAMS-13

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Abstract

At the Korea Institute of Radiological and Medical Sciences(KIRAMS), The design study of a 13MeV cyclotron for Positron Emission Tomography(PET) had been developed at 1999. The KIRAMS-13(13MeV medical cyclotron in KIRAMS) has been improved for regional cyclotron center. The magnet design was changed to reduce electric power consumption. We shortened the length of a pole gap by 20mm, and reduced about 67% of electric power consumption. So, we had to consider the RF system design as a result of changing magnet design. But, main RF parameters, such as resonant frequency, RF power, dee structure, cavity structure, and so on, were not changed to reduce cost and time of production. For satisfying these preconditions, we only redesigned the liner and the center block. In the paper, we describe the RF simulation results focused on the change of structures and the progress being made in production work for regional cyclotron

1. Introduction

Because of design problems associated with heavy reliance upon movable control rods (CRs), soluble boron (SB) has been introduced as one of the major control features in all modern PWR designs. The uniform distribution of SB at the proper concentration throughout the core minimizes the need for CR insertion and the consequent spatial distortion of the core power distribution. However, since many drawbacks due to the use of SB had been identified in spite of its satisfactory performance, the elimination of SB reactivity control from the

PWRs had been studied to offer a number of attractive features, including:

At the Korea Institute of Radiological and Medical Sciences(KIRAMS), The design study of a 13MeV cyclotron for Positron Emission Tomography(PET) had been developed at 1999. Increasing desire for an uninterrupted, reliable, low cost and timely supply of the isotopes to regional customer has prompted obtaining a 13MeV cyclotron for PET applications. This project is supported by the Ministry of Science and Technology(MOST) of the government.

The magnet design of KIRAMS-13 for regional cyclotron center was changed to reduce electric power consumption. Pole gap is reduced by 20mm and Number of coil turns is 16*19. So, electric power consumption is reduced by 67%[1]. As a result of the magnet design, the RF system design is also changed to satisfy existing RF parameters. But main RF parameters and components were not changed to reduce production cost and time.

In this paper, we describe the RF simulation and mechanical drawing of KIRAMS-13 for regional cyclotron center.

2. Fundamental RF System

KIRAMS-13 accelerates a negative hydrogen ion. For efficient accelerating, vaccum level is maintained under 10^{-6} torr. Material related with the RF system must be manufactured with diamagnetic body to not influence the magnetic field intensity. The RF system needs cooling mechanism because power loss is changed into heat. RF constituent elements are shown in Table 1[2].

Table 1: RF constituent elements

Resonant Frequency	77.3 MHz
Harmonic Number	4^{th}
Dee Voltage	40 kV
Cavity Shape	Coaxial Type
Resonant Mode	λ/2 fundamental mode
Matching Impedance	50Ω
Material	OFHC copper & Diamagnetic material
Cooling Capacity	30 kW
Pole Gap	12cm
Hill Angle	43.5 degree
Valley Angle	46.5 degree

2.1. Fundamental RF System

The RF resonator system is designed with CST MicrowaveStudio(MWS) which is a specialist tool for the fast and accurate 3D EM simulation of high frequency problems. The RF system is conceptually similar to the LC resonator circuit, where the resonant frequency is given by

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

where L is the inductance and C is the capacitance. In the calculation, we set f to be 77.3MHz, which is the fourth harmonic of the revolution frequency of a beam. Two 39° dees are located in two valleys. Total length of each dee is 50cm. The distance between the dee and the liner is 3.4cm. Applied voltage is 40kV. The MWS model of the RF dee and the resonator is illustrated in Fig.1.

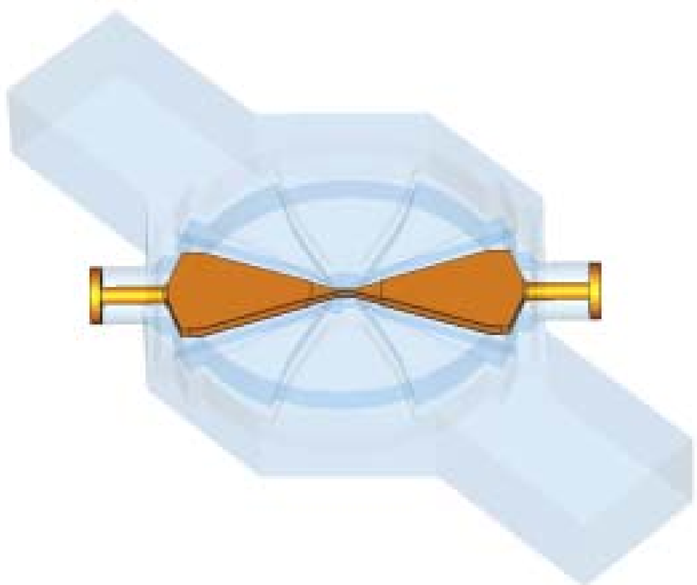

Figure 1: MWS model of RF system.

Vector distribution of electric field is shown in Fig. 2. Since electric field is formed vertically to dee edges, it is adequate to accelerate ion beam.

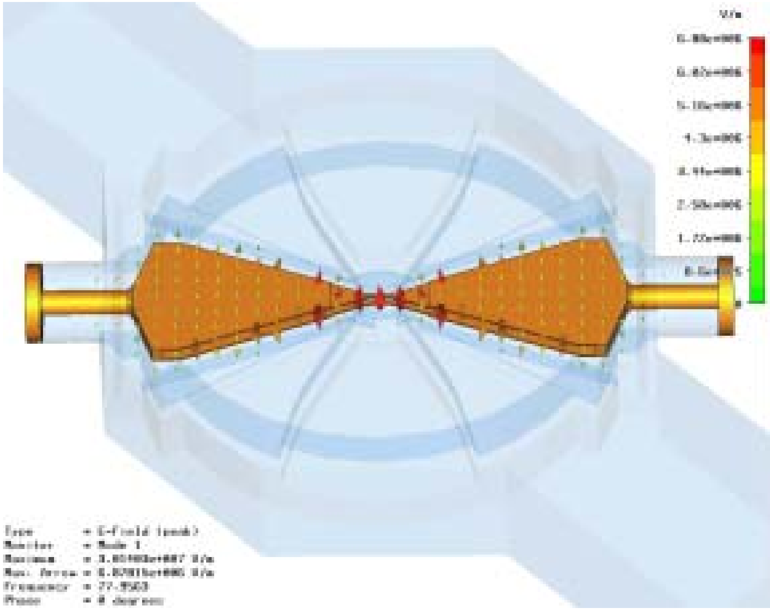

Figure 2: Vector distribution of electric field

Magnetic field is shown in Fig. 3. Magnetic field is distributed around dee stem. Therefore, ion beam movement is not interfered by magnetic field.

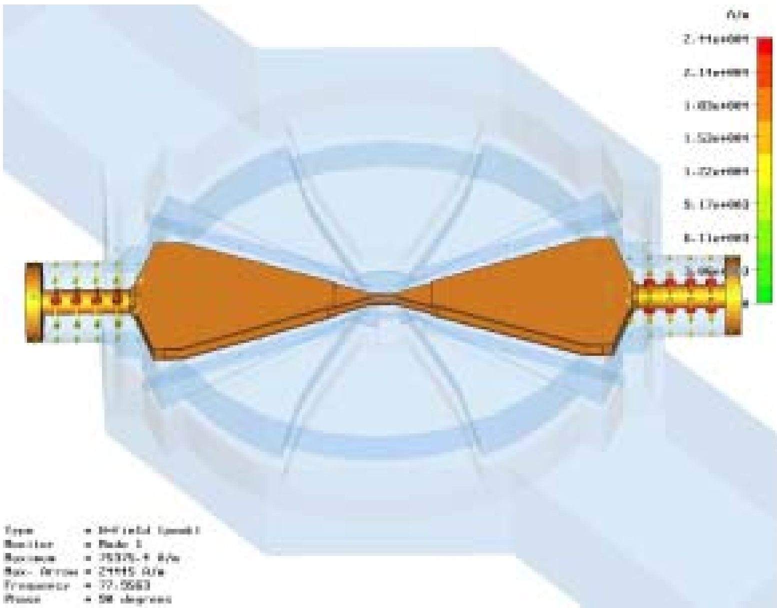

Figure 3: Magnetic field distribution

The resonant frequency is 77.9MHz calculated with MWS. Difference between simulation and calculation is due to omit some parts such as RF fine tuners and simplify inner structure. Q value is 4465.

The principle role of power coupler is RF power transmission to the cavity. The coupling is inductive and the total RF power is 30kW.

The simulation model of power coupler is shown in Fig. 4 and s parameter is shown in Fig. 5.

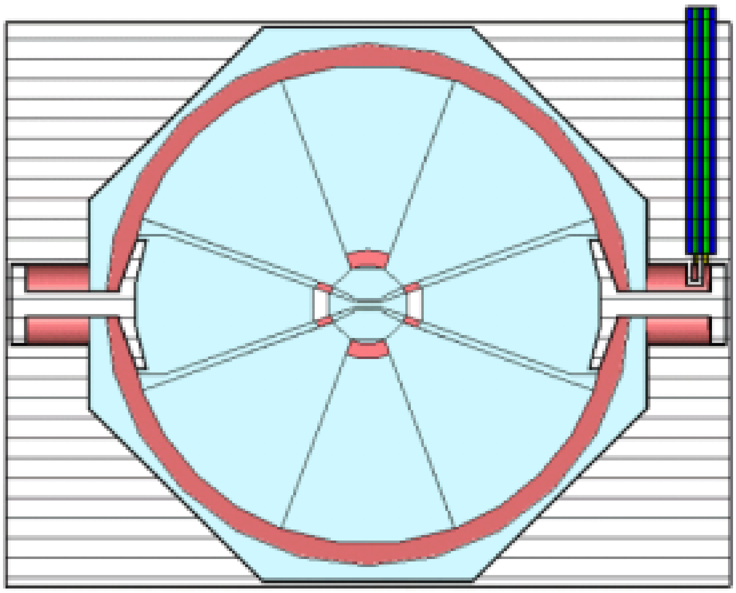

Figure 4: Simulation model for power input characteristic analysis.

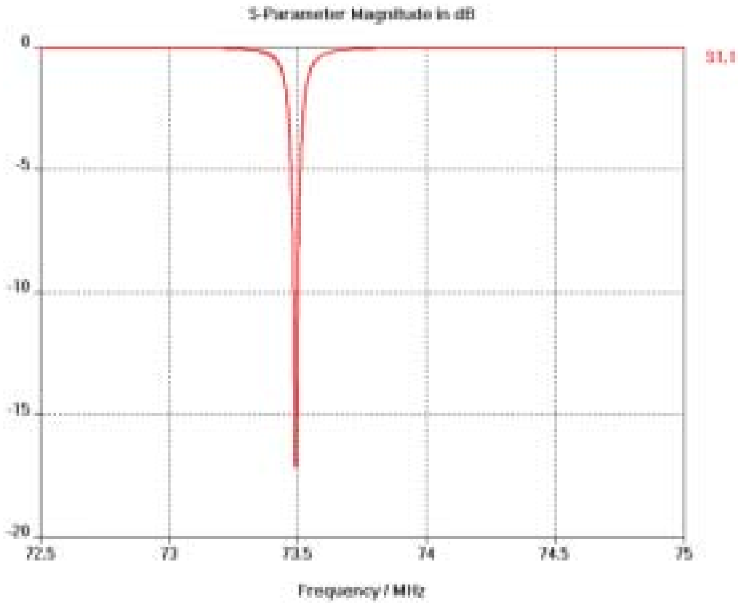

Figure 5: S11 graph

2.2. Mechanical Drawing of RF Components

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

- Mechanical stability

- RF heating and cooling
- Arcing and multipacting
- Low maintenance
- Low cost

RF components are under extreme stresses due to charging inducing by the high RF power passing through.

The mechanical drawings of RF components are illustrated in Fig. 6~10.

Figure 6: Dee.

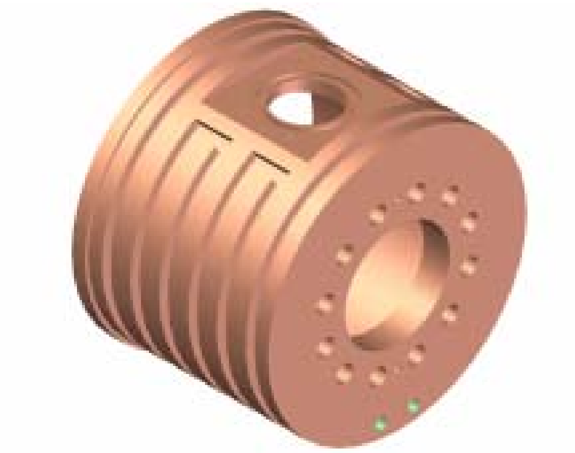

Figure 7: Internal part of the cavity.

The dee and the cavity are used with the original KIRAMS-13 design to reduce production cost and time.

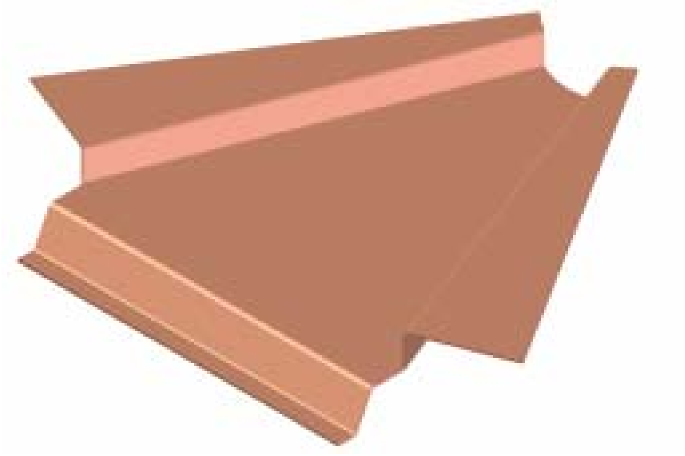

Figure 8: Liner.

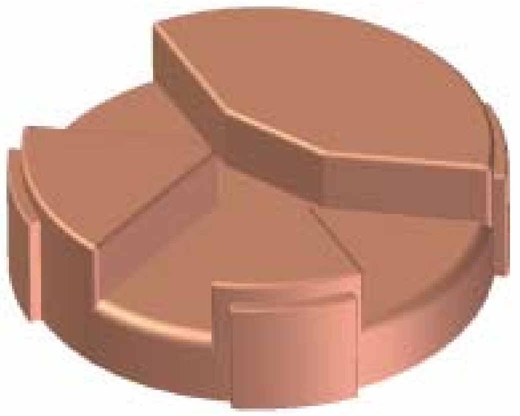

Figure 9: Center block

The liner and the center block design are modified to tune the resonant frequency to 77.3MHz and optimize beam trajectory[4][5].

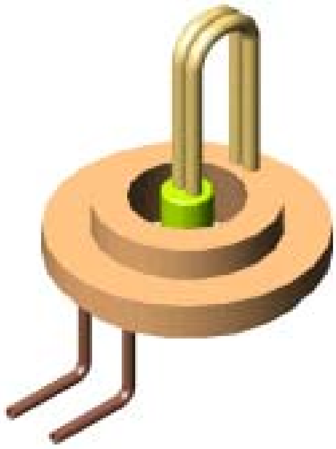

Figure 10: Coupler.

In the coupler, RF heating and multipacting are the most serious problems. So, the sufficient cooling capacity are reflected in mechanical design.

3. Conclusions

RF design studies for the regional cyclotron center have been in progress to improve the efficiency of KIRAM-13. Currently, we finished the designs of RF components and are manufacturing them.

When completed in 2004, the regional cyclotron center will serve to produce short-lived radioisotopes and diagnose incipient cancer with PET.

4. References

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