Design of KIRAMS-13 RF System for Regional Cyclotron Center

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1. Introduction

The KIRAMS-13 has been improved for regional cyclotron center for the last five years. The magnet design was changed to reduce electric power consumption. The length of a pole gap was shorted by 20mm and number of coil turns was increased to 16x19. So, electric power consumption of magnet system was reduced about 67%. And the magnetic field influenced the central region design because the beam trajectory was changed. But, main RF parameters, such as resonant frequency, RF power, dee structure, cavity structure, and so on, were not changed to reduce production cost and time. Consequently, we had to consider the RF system design as a result of changing the magnet design and the central region design. For satisfying these preconditions, we only redesigned the liner and the central region of KIRAMS-13.

2. Design of Magnet System & Central Region

Isochronism of KIRAMS-13 was achieved by placing a few side shims, as well as by slightly varying the vertical gap, along the radius of the cyclotron [2]. To reduce electric power consumption, we redesign magnet system. The parameters related to magnet system are shown in Table 1.

Table 1: Magnet Specification

Parameters	First Model	Second Model
Dimension (m^3)	1.9x1.2x1.08	1.96x1.3x1.21
Weight (tons)	14	18
Bmax (T)	1.92 at hill 0.84 at valley	1.99 at hill 0.9 at valley
No. of Coil Turns	8x18	16x19
Excitation Current (A)	466	135
Power (kWatt)	36	12

OPERA-3D was used to design and calculate the magnet and the magnetic field was measured using a Hall probe. The average magnetic field of the first model and the second model is shown in Fig 1.

The central region of KIRAMS-13 cyclotron is composed of an internal ion source of cold cathode PIG type, the central dee as a puller, and guides. The electric field distribution in the central region has been numerically calculated from an electric potential map produced by the program RELAX3D. The magnetic field distribution has been measured experimentally [3].

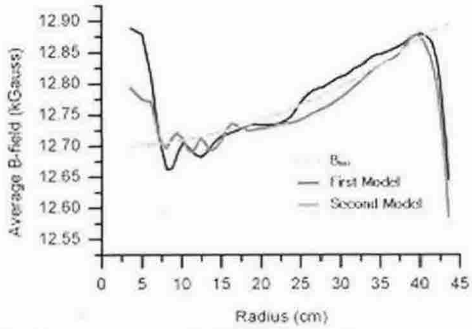

Figure 1: Average magnetic field along the average radius of the beam.

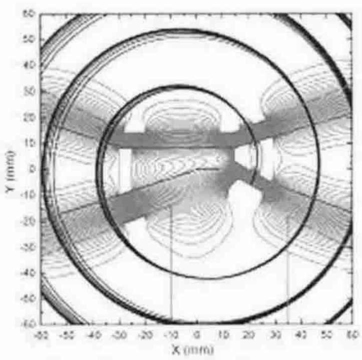

Figure 2: The resultant beam trajectories.

3. 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 caused by heat.

3.1 RF Simulation & Experimental Results

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. 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.

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.

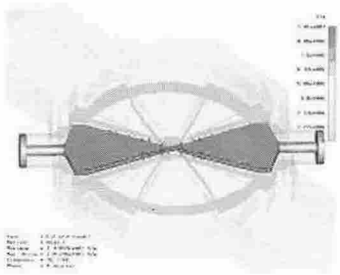

Figure 3: Vector distribution of electric field

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

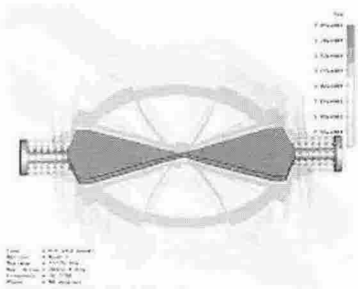

Figure 4: Magnetic field distribution

The resonant frequency is 76.7MHz 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.

We measure S11 parameter and impedance with network analyzer. These results are shown in Figure 5, 6.

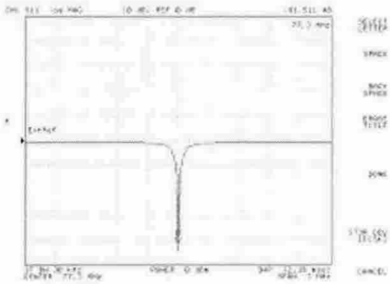

Figure 5: S_{11} parameter

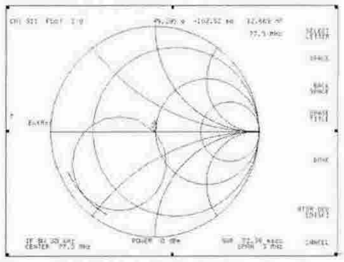

Figure 6: Magnetic field distribution

3.2 Mechanical Drawing of RF Components

At mechanical drawing of RF components, we consider following factors [4].

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

Main RF parameters were not changed to reduce production cost and time and we had to consider the RF system design as a result of changing the magnet design. For satisfying these preconditions, we only redesigned the liner and the central region of KIRAMS-13.

The mechanical drawings of liner and central region are illustrated in Fig. 7~9.

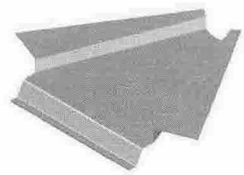

Figure 7: Liner.

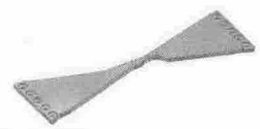

Figure 8: Central Part of Dee.

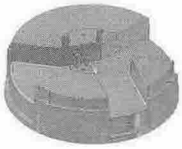

Figure 9: Center Block.

4. Conclusion

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.

References

[1] Seung Hwan Shin, "Design of a magnet and measurement of magnet field and study of central region design for 13 MeV PET cyclotron," APAC 2004, Gyeongju, March 2004.

[2] S. H. Shin, Other, "Measurement and Analysis of a 13MeV Cyclotron Magnetic Field", APAC 2004, Gyoengju, March 2004.

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[4] Yoon Kang, "Coupler Electromagnetic Design," HPC Workshop, TJNAF, 2002.