# DESIGN OF KIRAMS-13 RF SYSTEM FOR REGIONAL CYCLOTRON CENTER

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*Abstract*

At the Korea Institute of Radiological and Medical Sciences(KIRAMS), the design study of a 13MeV cyclotron(KIRAMS-13) for Positron Emission Tomography(PET) had been developed in 2001. The KIRAMS-13 has been improved for regional cyclotron center. The magnet design was changed to reduce electric power consumption. We shorted the length of a pole gap by 20mm and increased number of turns from 18x8 to 16x19 [1]. So, electric power consumption was reduced about 67%. However, main RF parameters were not changed to reduce production cost and time. So, 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. In this paper, we describe the RF simulation and experimental results focused on the change of structures and the progress being made in production work for regional cyclotron center.

## 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.

## THE MAGNET SYSTEM

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 redesigned the magnet system. The parameters related to the 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 |
| B (T) at 13MeV | 1.92 at hill<br>0.84 at valley | 1.94 at hill<br>0.79 at valley |
| No. of Coil Turns | 8x18 | 16x19 |
| Excitation Current (A) | 466 | 145 |
| Power (kW) | 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.

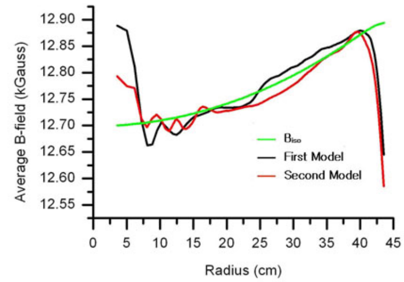


Figure 1: Average magnetic field along the average radius of the beam.

## DESIGN OF THE CENTRAL REGION

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]. The geometry of the central region has been tested with the computations of orbits carried out by means of the acceleration beam tracking method. The optical properties and acceleration characteristics in the central region were studied by using the information obtained from the beam tracking code and beam traces obtained experimentally. Figure 2 shows the beam trajectories with the conventional beam tracking code.

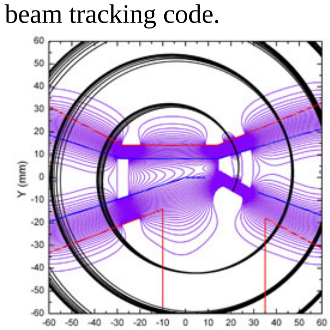


Figure 2: The resultant beam trajectories.

## FUNDAMENTAL RF SYSTEM

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

Table 2: RF constituent elements

| | |
|---|---|
| Resonant Frequency | 77.3 MHz |
| Harmonic Number | $4^{th}$ |
| Dee Voltage | 45 kV |
| Cavity Shape | Coaxial Type |
| Resonant Mode | $\lambda/2$ fundamental mode |
| Matching Impedance | 50Ω |
| Material | OFHC copper<br>& Diamagnetic material |
| Cooling Capacity | 30 kW |
| Pole Gap | 12cm |
| Hill Angle | > 30 degree with radius |

### *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 3.9cm. Applied voltage is 45kV.

Vector distribution of electric field is shown in Fig. 3. Since electric field is formed vertically to dee edges, it is adequate to accelerate ion beam.

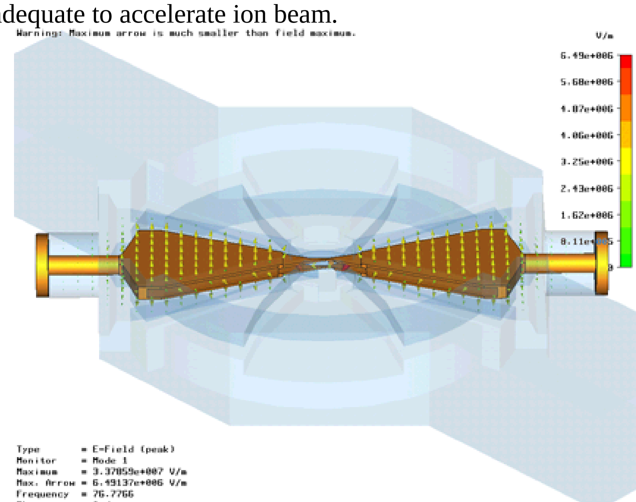

Figure 3: Vector distribution of electric field

Magnetic field is shown in Fig. 4. Magnetic field is distributed around dee stem. Therefore, ion beam movement is not interfered by magnetic field.

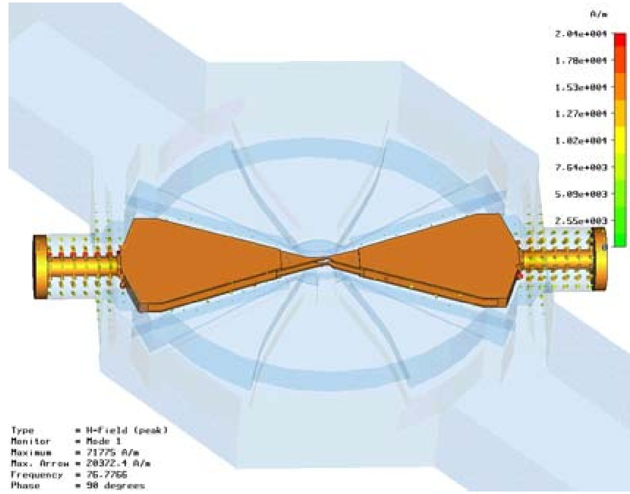

Figure 4: Magnetic field distribution

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 and material properties. The Q value is 4465.

We measured $S_{11}$ parameter and impedance with network analyzer. These results are shown in Fig. 5, 6.

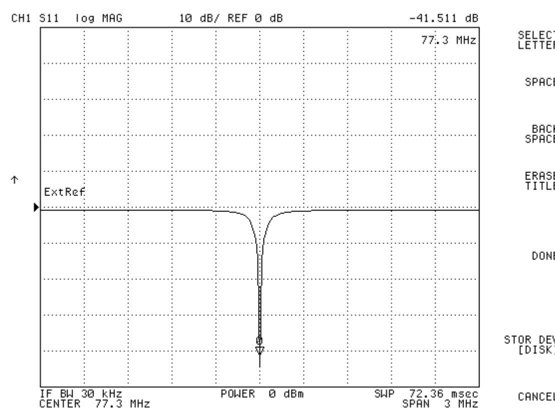


Figure 5: $S_{11}$ parameter

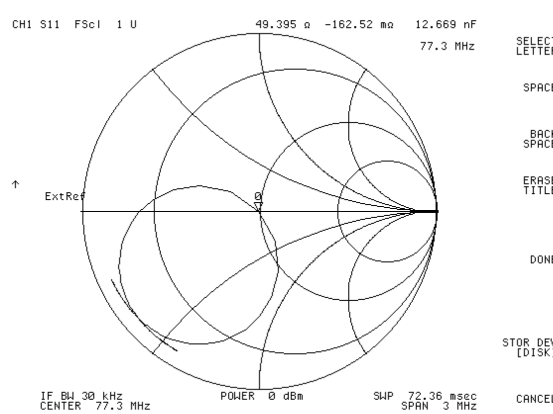


Figure 6: Smith Chart

### *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.

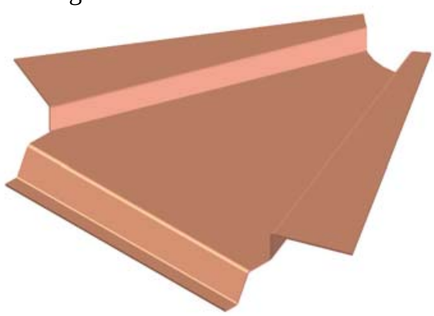

Figure 7: Liner.

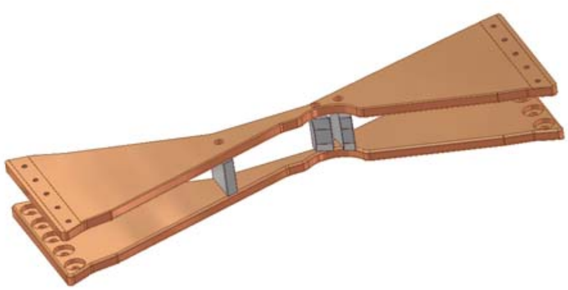

Figure 8: Central Part of Dee.

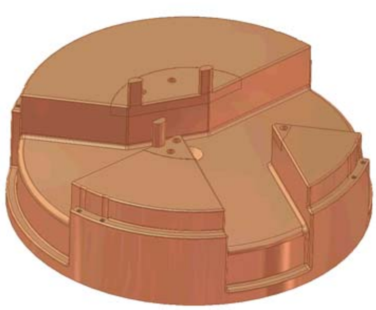

Figure 9: Center Block.

## 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.

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