Design of RF coupler for KIRAMS-13
(Korea Institute of Radiological & Medical Sciences-13)

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Abstract: KIRAMS-13, the first medical cyclotron developed by domestic technique, is used to produce radio-isotope such as ^{18}F whose life time is relatively short through test operation. For high-power operation of charged particle accelerators, the power coupler must withstand enormous stresses due to charging induced by high RF power passing through. High-power RF testing with peak power in excess of 30kW has been performed on prototype power coupler for KIRAMS-13 normal conducting cavities. CST MICROWAVE STUDIO(CST MWS) is used for fundamental RF Design, and power coupler is manufactured according to fundamental power coupler design requisite. The qualification of the couplers has occurred for the time being only in a limited set of conditions as the available RF system and control instrumentation are under improvement.

Keywords: power coupler, cyclotron, cavity, microwave studio

1. INTRODUCTION

Various power couplers have been used in cyclotron cavity structure of existing accelerator facilities. The power couplers are under extreme stresses due to charging induced by the high RF power passing through[1]. The power coupler for KIRAMS-13 normal conducting cavities must be able to transfer up to 30kW peak power[2].

Three prototype couplers have been manufactured and preliminary testing has occurred at Cyclotron Application Laboratory (CAL). The testing was done using 30kW, 77.3MHz RF Amplifier, with vacuum, arc, thermal interlocks and dee voltage monitors provided for protection.

In this paper we present the simulation, experimental results and mechanical drawing used in the designed power coupler.

2. FUNDAMENTAL RF SYSTEM DESIGN

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

Table 1 RF constituent elements.

Harmonic number	4
Resonant Frequency	77.3MHz
Dee Voltage	40kV
Cavity Shape	Coaxial Type
Resonant Mode	λ /2 fundamental mode
Impedance	50Ω
Vacuum Level	$\leq 10^{-6}$ Torr
Material	OFHC copper & Diamagnetic material
Cooling Capacity	10~30 kW

2.1 RF dee simulation

RF dee is designed with CST MWS which is a specialist tool for the fast and accurate 3D EM simulation of high frequency problems[3]. MWS model of RF dee resonator is shown in Fig. 1.

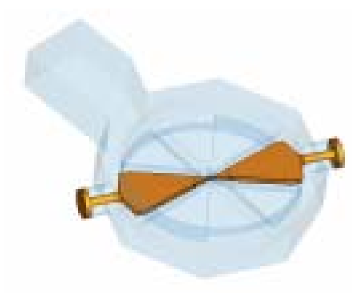

Fig. 1 MWS model of RF dee resonator

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.

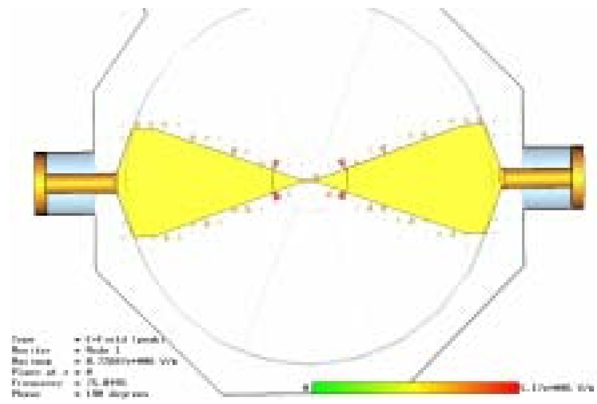

Fig. 2 Vector distribution of electric field

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

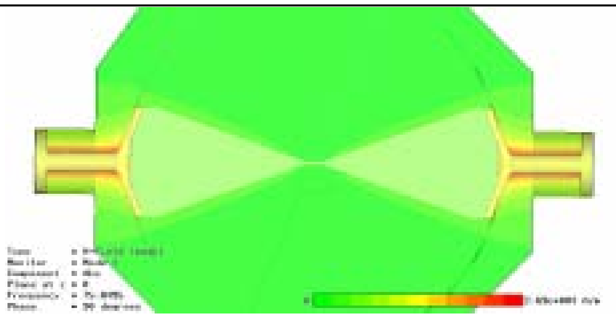

Fig. 3 Magnetic field distribution

Resonant frequency of RF dee resonator is 75.84MHz calculated by MWS. Difference between simulation result and calculated resonant frequency is due to omit some parts like RF fine tuners and simplify inner structure. Q value is 5282, but it doesn't consider RF coupling effect.

2.2 Power coupler Design

Principle role of power coupler is RF power transmission to the cavity. At coupler design, we consider following factors[3].

(1) Low RF reflection and transmission losses with cavity
(2) Low cost
(3) Mechanical stability
(4) RF heating and cooling
(5) Arcing and multipacting
(6) Low maintenance

MWS model of prototype power coupler for KIRAMS-13 is shown in Fig. 4. In this model, cooling part is omitted for reducing simulation time. Mechanical drawing is shown in Fig. 5.

Fig. 4 MWS mode of prototype power coupler

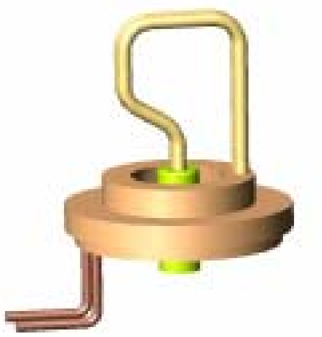

Fig. 5 Mechanical drawing of prototype power coupler

S parameter is shown in Fig. 7. At resonant frequency, S_{11} parameter is -17dB. From Fig. 8, overcoupling is shown. But impedance can be matched as we rotate the power coupler.

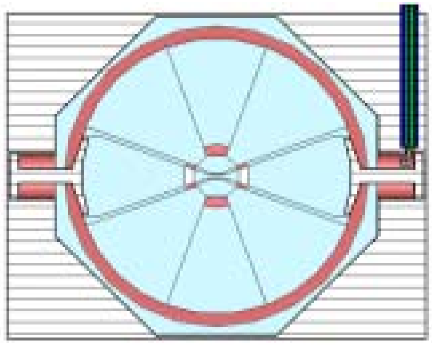

Fig. 6 Simulation model for power input characteristic analysis

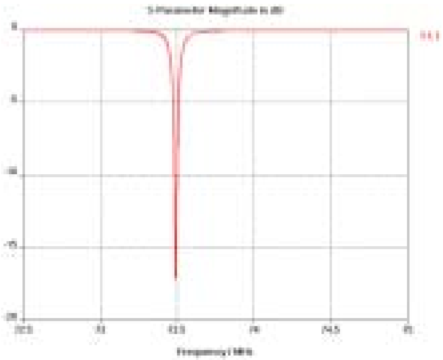

Fig. 7 S_{11} graph

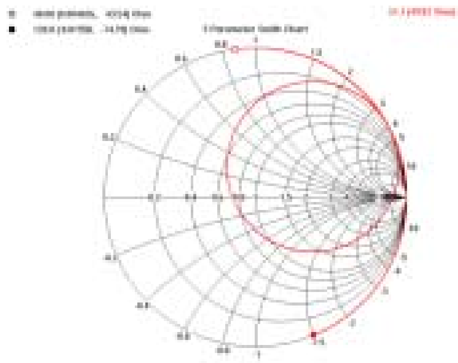

Fig. 8 Smith chart

3. TESTING RESULTS

An RF system consisting of a 77.3MHz 30kW RF amplifier connected via a transmission line to cyclotron used to transfer the RF power through the power coupler.

Manufactured prototype power coupler is shown in Fig. 9.

Fig. 9 Prototype power coupler

Using network analyzer, resonant frequency, return loss, and input impedance are measured. These results are shown in Fig. 10, and 11.

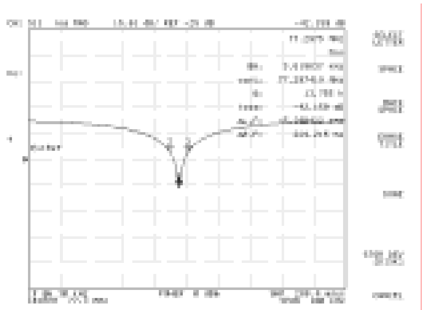

Fig. 11 Measured return loss (S_{11} graph)

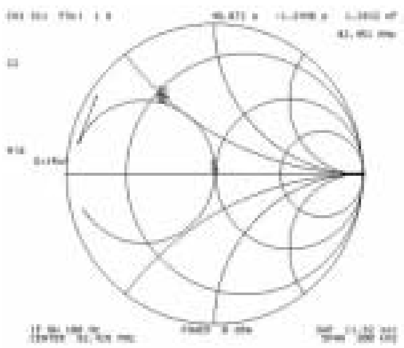

Fig. 12 Measured input impedance

Resonant frequency is 77.3MHz. Return loss is 42dB. The input impedance is 50Ω. From these results, calculated and simulated results are matched with experimental results.

4. CONCLUSIONS

A series of simulation and tests were performed on the prototype power coupler. Peak power levels, about 30kW, were achieved without RF heating problems. But multipacting and ripple are occurred occasionally when RF duty cycle is increased to 100%. The work will continue to extend the tests to inject full duty cycle.

5. ACKNOWLEDGEMENTS

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