The superconducting cyclotron RF system R&D

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1. Introduction

IMP is presently developing a 10MeV Superconducting Cyclotron(IMP-MK90) for the nuclear pore membrane production and research purpose. (The cyclotron parameter see Tab.1).The RF system comprises two separated resonators driven by independent amplifiers to allow for the phase and amplitude modulation technique to be applied for beam intensity modulation. The cyclotron works on 4th harmonic with Dee's voltage 70kV frequency 37MHz. According to the physical requirements of the superconducting cyclotron, the cavity is designed to be vertical 1/2 wavelength line structure. The RF system preliminary design has been completed.

2. The cyclotron and RF system design specifications

On the basis of the physical design requirements, the relevant physical parameters shown in Tab.1.

Tab.1 The basic parameters of the cyclotron

Type of cyclotron	
Heavy Ion	$^{40}Ar^{12+}$,$^{86}Kr^{26+}$
Axial injection with ECR ion source Split beam with either Septum Magnet or QWR cavity	
Beam current	>3euA
Beam energy	10MeV/u
RF system parameter	
Resonant Frequency	37MHz
Dee Voltage	60-80KV
Dee Angle	33°
Extraction Radius	750mm
Injection Radius	35mm
Phase Stability	≤±0.5º
Amplitude Stability	$\leq 1\times10^{-4}$
Frequency Stability	$\leq 1\times10^{-6}$
Magnet	
Magnet Coil	~300kAT
Maximum magnetic field	2.75T
Magnet Weight	~90 tons
Production Lines	
Multi-purpose Line	1 line
Industrial line	3 line with beam split

Fig.1 The cyclotron structural model

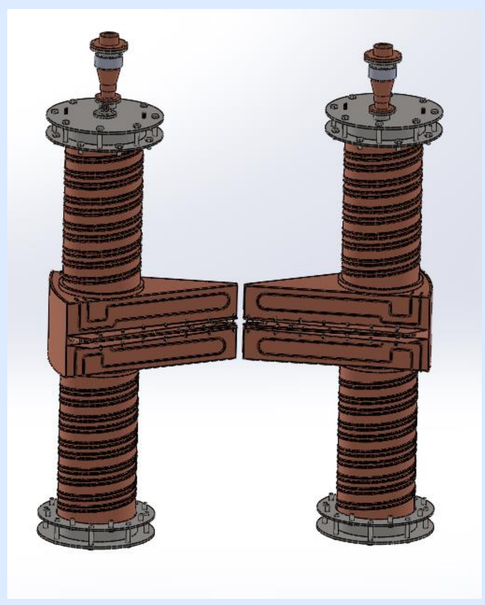

Fig.2 The RF cavity structural model

2.1 RF structural simulation results with CST

According to the structure parameter, the three-dimensional model is founded with CST. The simulation results show that the resonant frequency is 37.05MHz, Q value is 7259 and power loss is 18kW. The voltage distribution along the radius is shown in Fig.3.

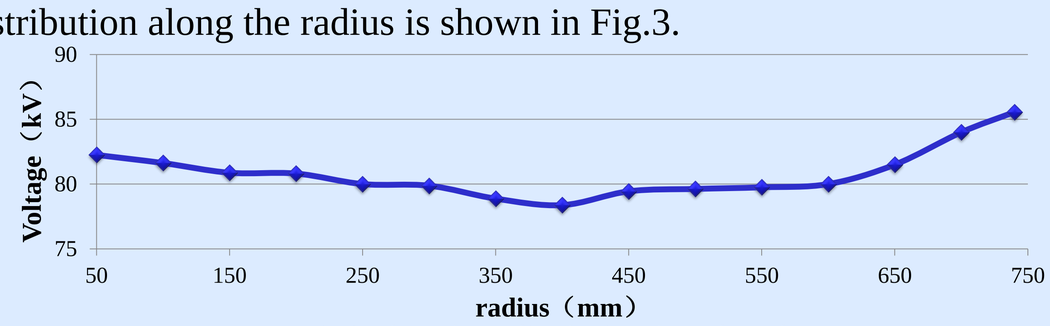

Fig.3 The Voltage distribution along the radius

Electromagnetic field simulation results show in Fig.4.

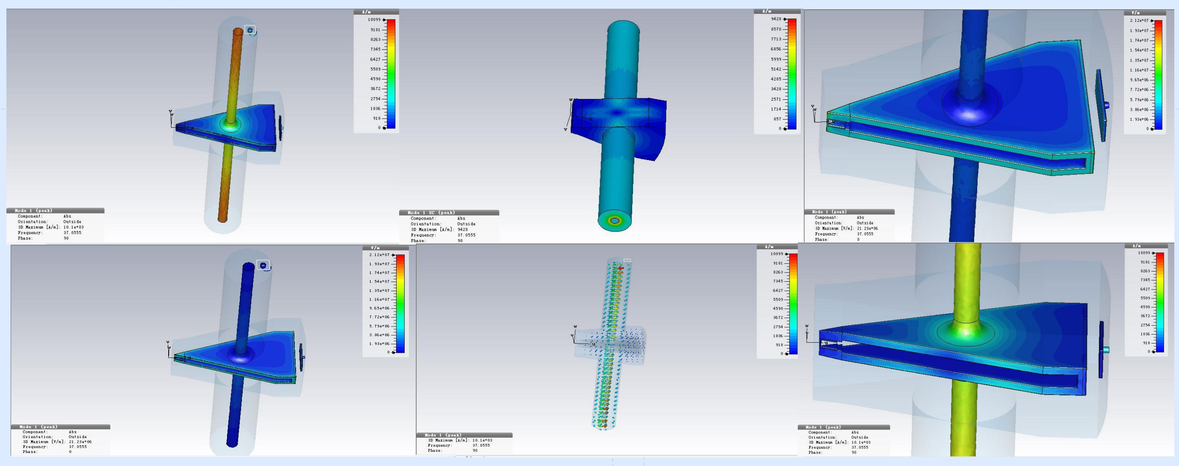

Fig.4 Electric field distribution, magnetic field distribution and surface current distribution

2.2 The tuning design of the RF cavity

The fine-tuning loop has been designed to meet the dynamically tuned requirements. the coarse-tuned with capacitor plate.The fine-tuning parameter shows in Tab.2.

Tab.2 The fine-tuning parameter

Parameter	Value
Tuning range (kHz)	120
Tuning resolution(Hz)	100
The rotation angle of the tuning ring（°）	90
Backlash Tolerance（°）	0.1

2.3 The coupler design of the RF cavity

The coupler has been designed to be inductor coupler.The coupler maximum testing power is 30kW，Maximum power consumption on coupler is 0.5%，Maximum reflection power on coupler is 1%.

3 The sawtooth wave buncher design

The design of buncher adopts small signal harmonic synthesis and wide band amplification and matching transmission. The buncher parameter shows in Tab.3.The principle is shown in Fig.5. the RF system block diagram.

Tab.3 The sawtooth wave buncher parameter

Parameter	Value
Frequency (MHz)	37
Effective duty cycle	>60%
Buncher voltage(kV)	1.6
Linearity error	<1%

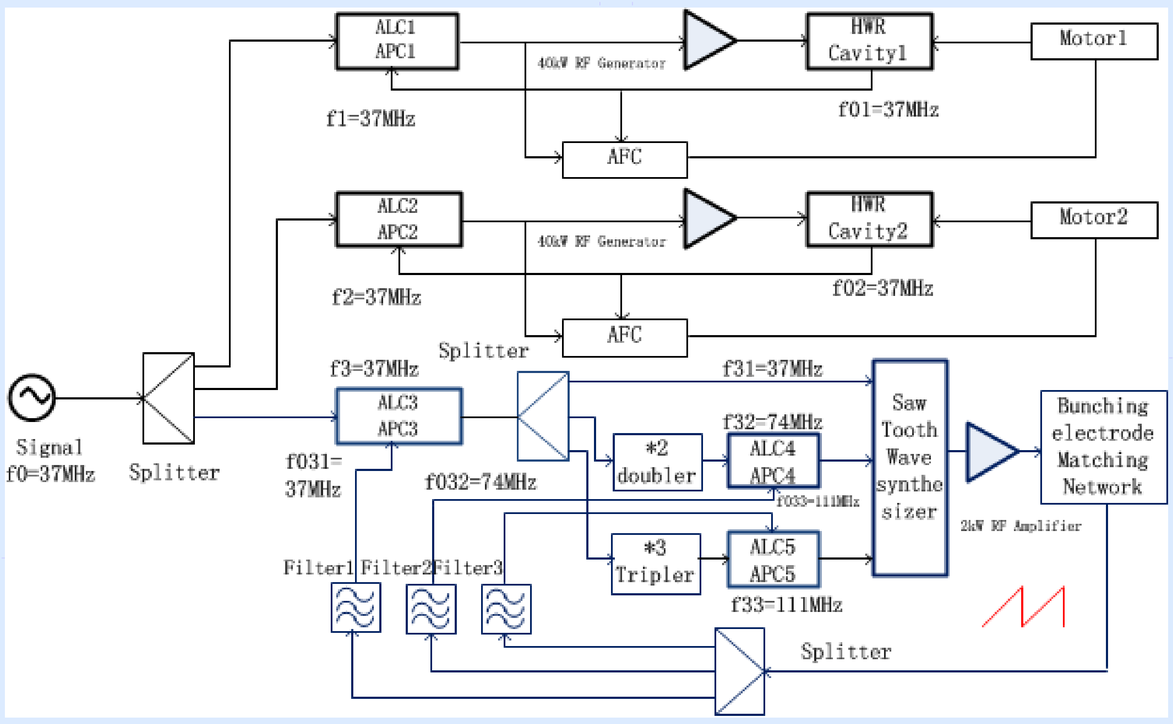

Fig.5 the block diagram of RF system composition

The paper introduce the RF design of the 37MHz superconducting cyclotron cavity and RF system, including RF cavity simulation, the geometry structure of DEE is optimized repeatedly for the ideal voltage distribution ,the buncher designing scheme and parameter etc.

The next step is to carry out the system optimization design, including the system cooling design coupling, and tuning optimization design, and the radio frequency splitter beam design, and the system engineering transformation work.

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