ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-MOPB03

THE SUPERCONDUCTING CYCLOTRON RF SYSTEM R&D*

Xianwu Wang†, Xingli Jiang, Yong Qiao, Zhe Xu , Institute of Modern Physic, Lanzhou, China

Abstract

IMP is presently developing a 10MeV Superconducting Cyclotron (IMP-MK90) (see Fig. 1) for the nuclear pore membrane production and research purpose [1-5]. The cyclotron parameter see Table 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 (Fig. 2).

Figure1: The cyclotron structural model.

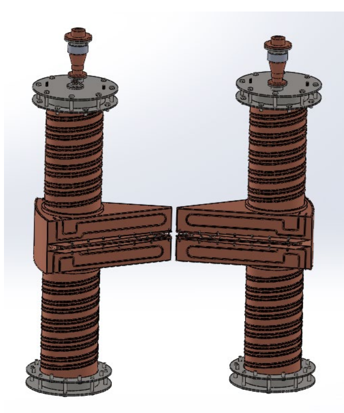

Figure 2: The RF cavity structural model.

THE CYCLOTRON AND RF SYSTEM DESIGN

On the basis of the physical design requirements, the relevant physical parameters shown in Table1.

Table 1: RF System Specifications

■ **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	≤±0.5°
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

RF STRUCTURAL SIMULATION RESULTS WITH CST

According to the structure parameter, the three-dimensional model is founded, simulated and analyzed with CST. By changing and optimizing Dee's angel, stem dimension, stem height and position etc. parametrics of structure, The simulation results show that the resonant frequency is 37.05MHz, Q value is 7259 and power loss is 18kW. The voltage along the radial gap of Dee is from 82.25 kV in the center of Dee to 85.56 kV in the radius of Dee Extraction. The voltage distribution is uniformly rising along the radial gap of DEE. As shown in Fig. 3. The results shows that the voltage characteristics along the radius basically depend on the the position and diameter of the inner stem, and the Dee's angle. The electric field and magnetic field distribution map of the cavity are shown in Fig. 4 and 5. Surface current distribution result show in Fig. 6.

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 . The fine-tuning parameter shows in Table 2.

* Work supported by IMP
† email address: wangxw@impcas.ac.cn

ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-MOPB03

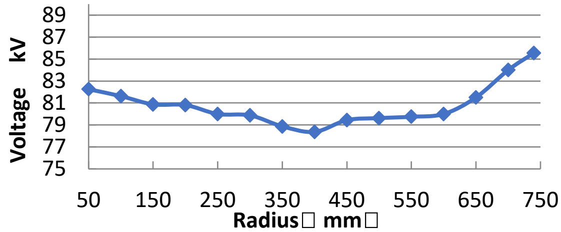

Figure 3: Voltage distribution along radius.

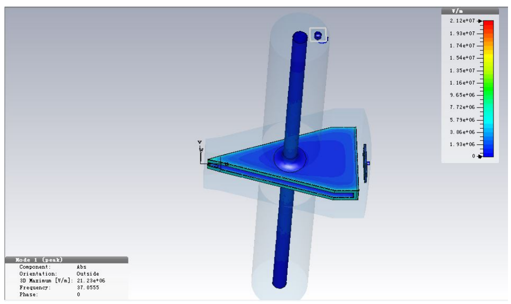

Figure 4: Electric field distribution.

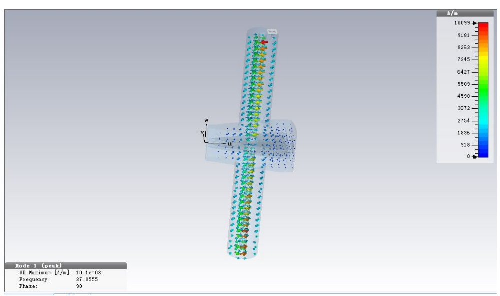

Figure 5: Magnetic field distribution.

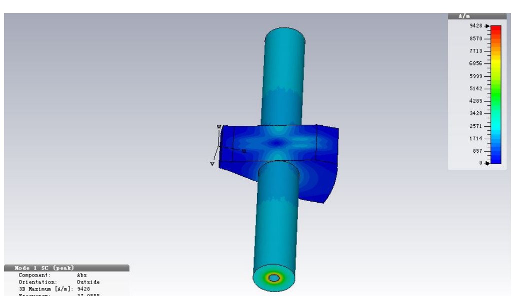

Figure 6: Surface current distribution.

Table 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

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%.

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 Table 3. The principle is shown in Fig. 7. the RF system block diagram.

Table 3: The Sawtooth Wave Buncher Parameter

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

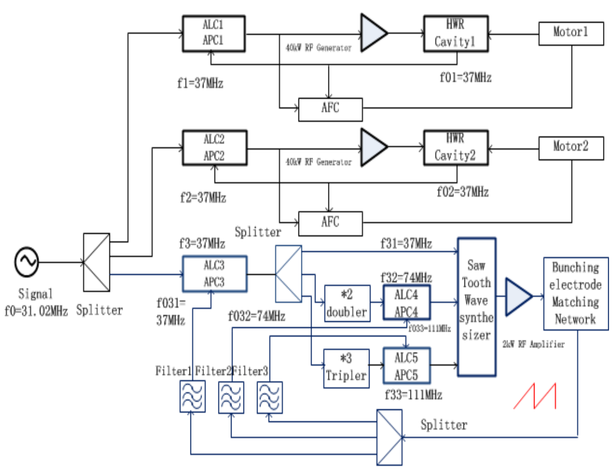

Figure 7: the block diagram of RF system composition.

CONCLUSIONS

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.

REFERENCES

[1] S. Shin, J. Lee, B.-N. Lee, D. Ha, H. Namgoong, Development of the RF cavity for the SKKUCY-9 compact cyclotron, Nuclear Instruments and Methods in Physics Research A, 795, 2015, pp.276-283.

ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-MOPB03

[2] H.S. Song, H.W. Kim, B.N. Lee, J.H. Oh, J.S. Chai. Design Of Rf Cavity For Compact 9 Mev Cyclotron. *In Proceeding of IPAC 2011*, San Sebastian, Spain, pp.151-153.

[3] Y. Jongen, M. Abs, W. Kleeven, S. Zaremba, A.A. Glazov, S.V. Gurskiy, O.V. Karamyshev, G.A. Karamysheva, N.A.Morozov. RF Cavity Simulations for Superconducting Cyclotron C400. Physics of Particles and Nuclei Letters, Vol.8, No.4, 2011, pp.386-390.

[4] V. Sabaiduc, G. Gold, B.Versteeg, J.Panama. Resonator system for the best 70 Mev cyclotron. *In proceedings of Cyclotrons 2013,* Vancouver, Canada, 2013, pp.153-155.

[5] V. Afzalan, H. afarideh, R. Azizi, M. Ghergherehchi, J.S. Chai. Design and simulation of cavity for 10 MeV compact cyclotron. *In Proceedings of Cyclotrons-2013,* Vancouver, Canada. 2013, pp.200-202.