

# DESIGN AND SIMULATION OF CAVITY FOR 10 MeV COMPACT CYCLOTRON

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## Abstract

RF system is known as one of the most vital parts to produce the efficient accelerator system [1]. In this paper, the RF system and cavity of 10 MeV AVF (Azimuthally Varying Field) Cyclotron for radioisotope production are designed. The Cyclotron works on 4th harmonic with Dee's voltage of 50 KV. In order to supply the expected accelerating voltages RF power coupling and RF tuner has been considered. The RF system is simulated using commercially available simulator, CST Microwave Studio code. In contrast the geometry of cavity is optimized to achieve suitable Q value in desired frequency. Since the factors are non-ideal during the fabrication process, the actual Q value of cavities is estimated.

## INTRODUCTION

This paper mainly describes a development study of cavity for 10 MeV AVF cyclotron. The cyclotron is being designed for producing short-life isotope, such as F-18 for Positron Emission Tomography (PET). The AVF cyclotron will be injected by penning ion source (PIG) for getting F-18. Because of the limitation caused by magnet, we satisfied the condition of  $\lambda/2$  by adjusting stem, liner, the gap of Dee, etc. Cavity is designed to have a few thousands of Q value with resonance frequency of 69MHz, which is based on the magnet design. In addition, in order to obtain a good Q value in desired frequency, geometry of cavity is optimized.

CST studio suite offers a lot of options for parametric design. This structure has defined when some objects which relatives to each other change simultaneously. The model of the cavity is designed by this code has many parameters like Dee's angel, valley gap, stem dimension, etc. Parametric geometry of structure can change easily in order to determine the optimum geometry of cavity [2]. 3D modeling was investigated by using Solid Works program to study the non-ideal factor during the fabrication process [3].

## RF CAVITY DESIGN

### General Concept

The geometric model of the double gap delta cavity housed inside the valley of the magnetic system of cyclotron; so the structure of the RF system is double gap  $\lambda/2$  coaxial type resonator. This structure is useful for

compact cyclotron because they are suitable for applications where a special radial voltage profile (along the acceleration gaps) is desired [4].

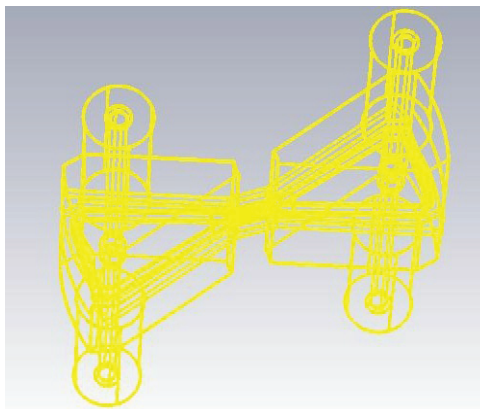


Figure 1: Wire frame of cavity.

The RF system specifications of 10 MeV RF cavity are shown on table 1. Material of RF Cavity is OFHC copper to get better electric conductivity. In addition, this material does not affect magnetic-field intensity. Using the CST Microwave Studio, a parametric model of the resonator was created (Figure 1). Dee's angle is  $35^\circ$ , which are located in both of valleys. Total length of each Dee is about 42cm. Total lengths of Dees, hill gap (3cm), and stem reaches  $\lambda/2$  in rough design and Dee's radius is 35cm. 4th harmonic mode has been adopted, and length of Dee's gap corresponds to the hill gap.

Table 1: 10 MeV Cyclotron RF System Specifications

Parameters	Values
Energy	10 MeV
Pole radius	0.45m
Extraction radius	0.40m
Hill / Valley gap	0.03 / 0.48m
Number of cavities	2
Cavity angle	40 degrees
Dee angle	35 degrees
Dee voltage	50 kV
Harmonic mode	4
Resonant frequency	69 MHz

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### Coupling and Tuning

We chose capacitive coupling for coupling power to the cavity because the double gap coaxial type cavity has an inner conductor. The advantage is variable capacity that is more reliable than a variable inductive loop. Cavity will have a capacitive coupled power input connected to a rigid coaxial line. The active tuning system must be designed to bring the cavities to the frequency initially to compensate for detuning because of temperature variations due to RF heating [5]. In the other side of cyclotron, cavity has a tuner similarly controlled by external motor for fine-tuning of the cavity frequency.

### SIMULATION

RF geometry was developed in the CST STUDIO SUITE for adjusting stem, liner, the gap of Dee, etc. An optimal stem design will be important and several iterations of modelling might be needed. It is better to simulate cavity by advanced 3D RF design tools.

In order to achieve the suitable mode for accelerating particles the structure of cavity was simulated. Electric field of cavity causes the particle acceleration is shown in Figure 2.

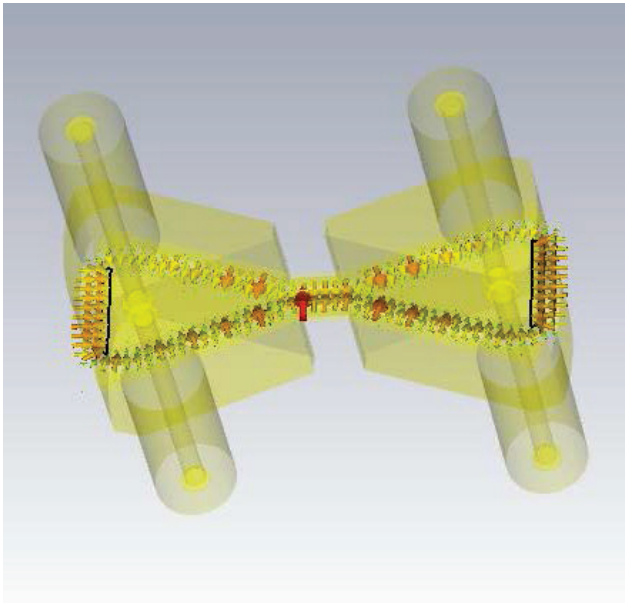


Figure 2: Electric field distribution in median plan.

In this study, mode 1 is chosen due to suitable field distribution in the median plane. Total lengths of Dees, hill gap (3cm), and stems are optimized in order to have the maximum Q-value in desired frequency. To obtain the size of the stems, we should design parametric geometry of cavity to study the effect of stem dimension changes on the frequency and Q-value of cavity. Effect of stem dimension changes into the Q-value in desired frequency is shown in Figure 3. Maximum Q value calculated by MWS CST is 6497.

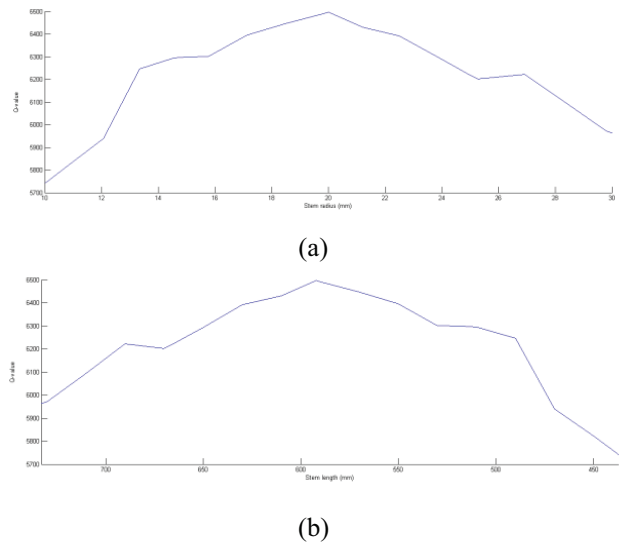


Figure 3: (a) Effect of the stem radius and (b) stem length change into the Q-value.

Final 3D modeling was done by using Solid Works program. The resonator stems, Dee plates and liner thickness was designed by considering standard-size copper components, which are closed to the obtained size for the optimum Q-value with consider the limitation caused by magnet.

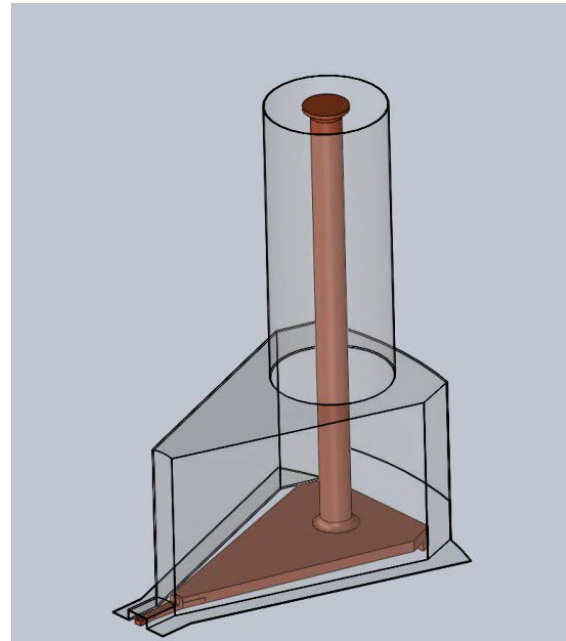


Figure 4: 1/4 model of designed cavity.

1/4 model of designed cavity is shown in Figure 4 consists of the copper resonant structure and an enclosing vacuum box which defined by the valley gap.

Electric field and magnetic-field distribution is shown in Figure 5 and 6. In fact, Q value calculated by MWS CST is 6284.

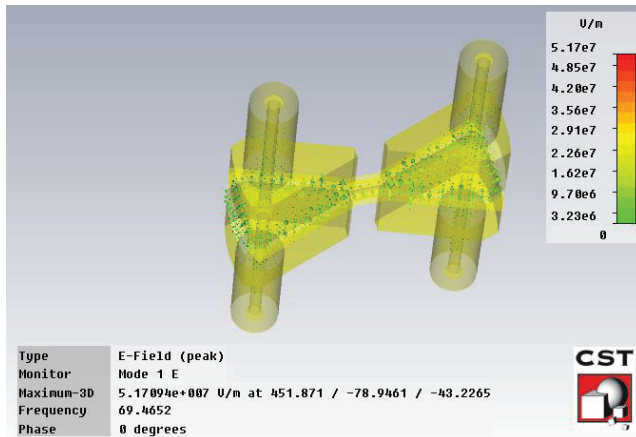


Figure 5: Electric field distribution in the cavity.

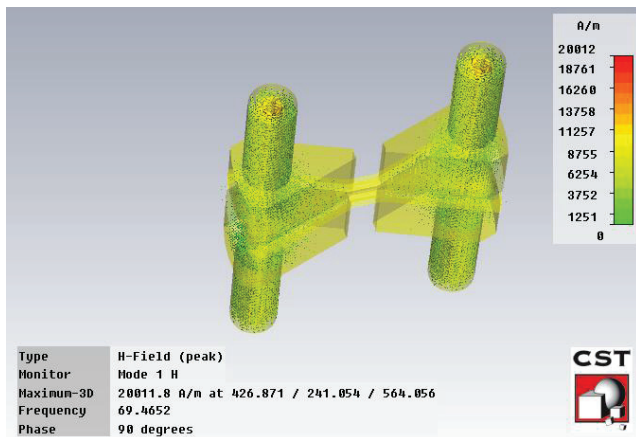


Figure 6: Magnetic field distribution in the cavity.

## CONCLUSION

This paper has explained the features of 10 MeV AVF cyclotron RF cavities. We could acquire the optimal Q value and resonant frequency after iterated simulation. Designed cavity has proper RF frequency. To reduce construction costs the resonator parts are made from standard-size copper components.

## REFERENCES

- [1] John J. Livingood, *Principles of Cyclic Particle Accelerators* (D. Van Nostrand, 1961).
- [2] CST Microwave Studio manual, (2011).
- [3] <http://www.solidworks.com>
- [4] P. K. Sigg, RF for Cyclotrons, CERN-2006-012, (2006).
- [5] Y. Jongen et al, "RF CAVITY SIMULATIONS FOR SUPERCONDUCTING C400 CYCLOTRON," MOPCP061, Proceedings of CYCLOTRONS 2010, Lanzhou, China.