DEVELOPMENT OF HIGH POWER ELECTRON ACCELERATOR FOR INDUSTRIAL APPLICATIONS

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Abstract

The high power electron accelerator (FANTRON-I) for industrial applications is under development at Seoul National Uinversity. Coaxial cavities with circular and nonagon shape for cold test are designed, fabricated and tested to investigate electromagnetic properties and manufacturing methods. Several tuning methods are proposed and being tested. FANTRON-I RF system consists of oscillator, solid state amplifier, two stage tetrode amplifiers and all of them except the last one are fabricated. In this paper, the system configuration of the FANTRON-I and the test results are presented.

1 INTRODUCTION

The high power electron accelerator (FANTRON-I) for industrial applications especially for the purpose of substitution for chemical treatments is under development at Seoul National University[1]. The characteristics of FANTRON-I are its accelerating mode using TM010 mode of coaxial cavity and X-ray target[2]. Because FANTRON-I uses TM010 mode in coaxial cavity, the electron beam has three dimension motion. Beam dynamics study for the three dimensional beam motion of FANTRON-I is being carried out and optimized now[3]. The conceptually designed FANTRON-I is presented in Fig. 1. The operating frequency of FANTRON-I is 159.41 MHz, and the diameter of the cavity is about 2.4 m. Because of the large size and its mode characteristic, several cavity shapes are considered for easy fabrication, low cost and good performance. Coaxial cavities with circular and nonagon shape are mainly considered, designed, fabricated and tested. As shown in Fig. 1, the two coaxial cavities are located in the vacuum vessel. Therefore the cavity need not withstand the atmospheric pressure, and need only to confine the electromagnetic energy. RF system of FANTRON-I consists of oscillator, solid state amplifier and two stages tetrode amplifier. The 100 W solid state amplifier is fabricated, tested and 10 kW first stage tetrode amplifier is being fabricated. The main specification of FANTRON-I is presented in Table 1.

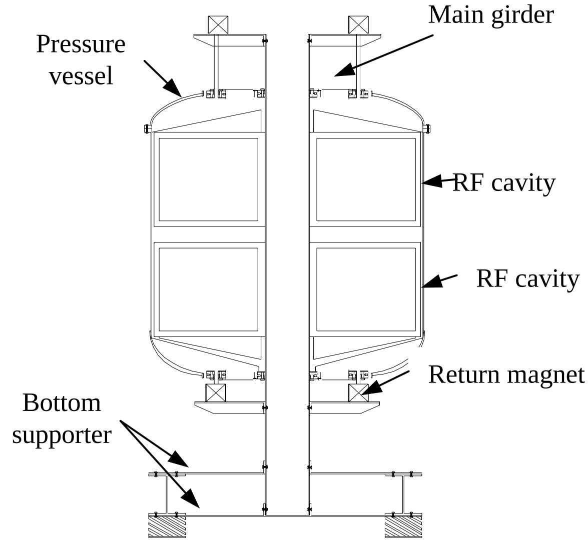

Figure 1. FANTRON-I layout

Table 1. FANTRON-I parameters

• Electron beam energy	10 MeV
• Electron beam power	100 kW CW
• Cavity parameter	
Number of cavities	2 ea.
Resonant frequency	159.41 MHz
Shunt impedance	2.4 MΩ
Quality factor	51500
• Required RF power	220 kW
• Acceleration scheme	$1.5\beta\lambda+0.5\beta\lambda$
• Number of bending magnet sets	16 ea.
• Maximum magnetic flux density	0.158 T

2 FANTRON-I CAVITY

2.1 Cavity Shape

As stated above, several cavity shapes are considered for easy fabrication, low fabrication cost and also good electrical performance. Coaxial cavities with circular and nonagon shape shown in Fig.2 are mainly considered and analyzed. The calculation results of electrical parameter are shown in Table 2. OPERA-3D code is used to calculate electrical parameter[4]. As presented in Table 2, there are no differences between two cavities.

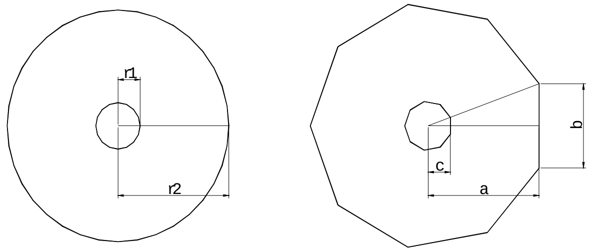

Figure 2. circular(left) and nonagon(right) shape cavity

Table 2. Electrical performance comparison

Shape	f (MHz)	Q	Ra (ohm)
Circular	159.50	51720.1	2412789
nonagon	159.41	51504.2	2409758

2.2 Circular Shape Coaxial Cavity

Small size circular shape coaxial cavity for cold test to check the electrical performance was fabricated and tested[5]. TM010 mode in circular shape coaxial cavity could be measured and the measured Q and R/Q values were about 78 % of design value. The uniformity of electromagnetic field and heat dissipation in the circular shape coaxial cavity are very good but when it is needed to disassemble a cavity, the joints dissipate large amount of heat because of the TM010 mode characteristic of coaxial cavity.

2.3 Nonagon Shape Coaxial Cavity

As shown in Table 2, the electrical performance of the nonagon shape coaxial cavity is almost equivalent to that of circular shape coaxial cavity but the uniformity of electromagnetic field and heat dissipation at the cavity wall are not so good as to that of circular shape coaxial cavity which are shown in Fig. 3 and Fig. 4 respectively. But the field can be considered enough uniform in small areas in which electron beam is accelerated, and for easy fabrication, low fabrication cost, nonagon shape coaxial cavity is considered as FANTRON-I cavity.

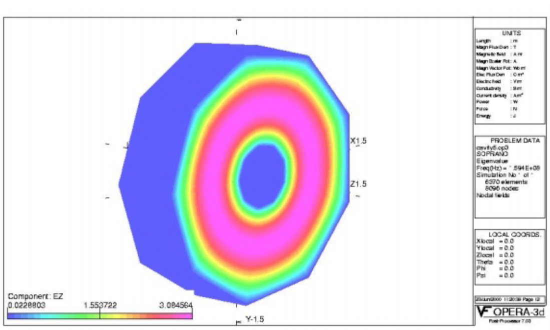

Figure 3. Axial electric field distribution of nonagon shape coaxial cavity

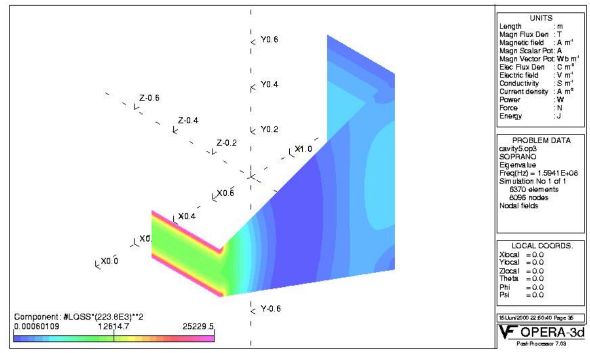

Figure 4. Heat dissipation distribution at the cavity wall

To fabricate the nonagon shape cavity, stainless steel (316L) plates are machined, bended and TIG welded to STS frame and 9 subsection assembled together by bolting. After the cavity is fabricated, the STS cavity is copper plated. Two subsection assembled together is shown in Fig. 5

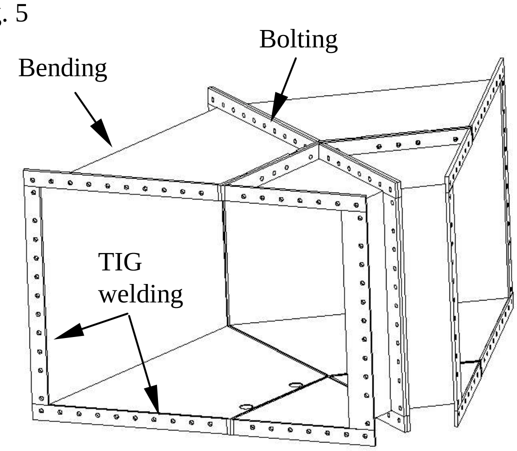

Figure 5. Two subsection assembly of nonagon cavity

2.4 Nonagon Shape Cavity Cold Test

The real size nonagon shape coaxial cavity was fabricated and cold tested before copper plating. The fabricated cavity is shown in Fig. 6. Slater perturbation theory was used to measure the R/Q value[6]. Network

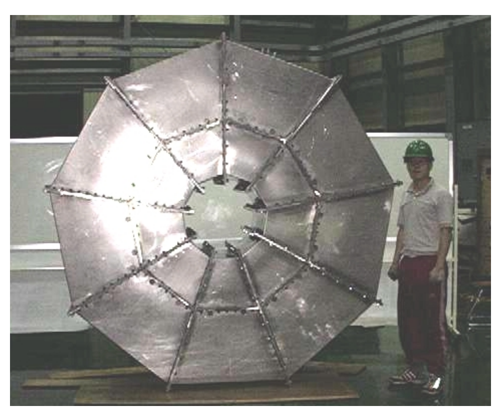
Figure 6. Real size nonagon shape cavity

analyser (HP 3752 C) measures the frequency shift due to the perturbation induced by the dielectric bead (20 mmΦ, alumina) . The measured values are compared with design values in Table 3. Quality factor(Q) and shunt impedance(R) values are about 79 % of the design value.

Table 3. Nonagon shape cavity (before copper plating) cold test result

	Design value	Measured value
f (MHz)	159.4100	159.8615
Q	9564.1	7460.2
R (ohm)	722133.0	577494.1

2.5 Cavity Tuning

Cavity tuning method by pushing and pulling the cavity wall is considered. Three side tuning using this method provide efficient tuning for the nonagon shape cavity. The frequency shift due to the displacement of the cavity wall is calculated using OPERA-3D code and presented in Fig. 7.

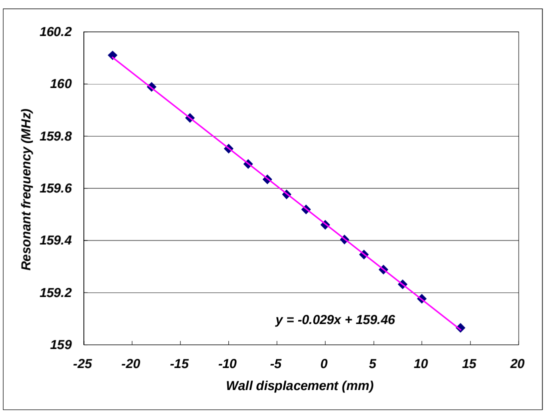

Figure 7. Cavity tuning data

3 RF SYSTEM

The FANTRON-I accelerator use tetrode as a main RF amplifier and RF system consists of cascade amplification stages. 100 W solid state amplifier was fabricated, tested and 10 kW amplifier using tetrode is being fabricated. The 100 W solid state amplifier is presented in Fig. 8.

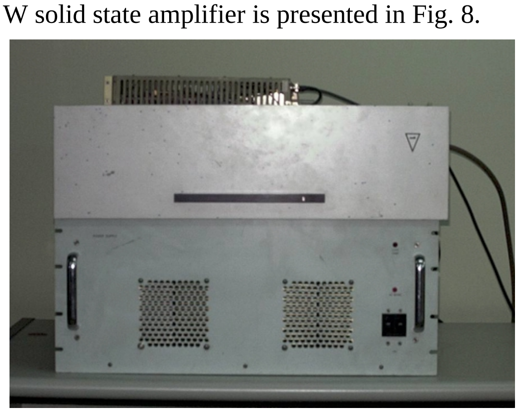

Figure 8. 100 W solid state amplifier

4 CONCLUSION AND FUTURE WORKS

The nonagon shape coaxial cavity was selected as a FANTRON-I cavity and designed, fabricated and tested. It shows a good electrical performance and provides easy fabrication method and low cost. Field distribution and HOM characteristics should be measured to check the nonagon shape cavity electrical performance. Tuning experiment according 3 side tuning method should be performed to check its validity. Thermal and mechanical analysis resulting from non uniform cavity heat disspation should be analyzed.

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