SINGLE PASS ACCELERATION EXPERIMENT USING COAXIAL CAVITY

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Abstract

The high power electron accelerator (FANTRON-I) for industrial applications is under development at Physico-technology laboratory, KAPRA (Korea Accelerator and Plasma Research Association). To validate the acceleration scheme, single pass acceleration experimental setup using nonagon shape coaxial cavity has been installed. The experimental setup consists of an electron gun, coaxial cavity, bending magnet, beam diagnostic and dump chamber, RF amplifier, vacuum and cooling system. A Rogowiski type gun with Th-W wire filament was used as an electron gun and produced 20 kV, 0.8 mA electron beam. A 159.41 MHz, 3 kW RF system consists of an oscillator, 100 W solid state amplifier and 3 kW tetrode amplifier. The bending magnet composed of main and supplementary magnet for weak focusing was designed, fabricated and tested. In this paper, the test results of the acceleration system components using nonagon shape coaxial cavity are analyzed and the design status of FANTRON-I are presented.

1 INTRODUCTION

A 10 MeV, 100 kW electron beam accelerator using TM_{010} mode in the coaxial cavity mainly for the purpose of sterilization and food irradiation is under development [1]. It uses a nonagon shape coaxial cavity and bending magnet composed of main and supplementary magnet for the beam focusing [2][3]. To validate the acceleration scheme and understand the characteristics of the components of the acceleration system, low energy electron beam acceleration system was designed, fabricated and installed. Each component such as electron gun, nonagon shape cavity, bending magnet and RF system was tested and compared with designed value.

2 LOW ENERGY ELECTRON BEAM ACCELERATION SYSTEM

The specifications of the acceleration system are presented in Table 1 and the schematic diagram of the experimental setup is shown in Fig. 1. As shown in Fig. 1, it consisted of two accelerating sections and one bending section. Not all the cavity inner space was evacuated by vacuum pump, but only along the beam transport section by ceramic tubes inserted into the cavity beam holes. The electron beam could be dumped either after one acceleration or two accelerations by bending magnet. It used a nonagon shape cavity with bare stainless steel surface on which copper is not plated – copper plated nonagon shape cavity will be used for 10 MeV. The low energy gain in Table 1 is due to the stainless cavity and low RF power.

Table 1. Specifications of low energy electron beam acceleration system

Parameter	Specification
Beam energy	30 keV
Beam current	0.8 mAdc
Initial beam energy	20 keV
RF frequency	159.41 MHz
RF power	3 kW
Number of cavity	1

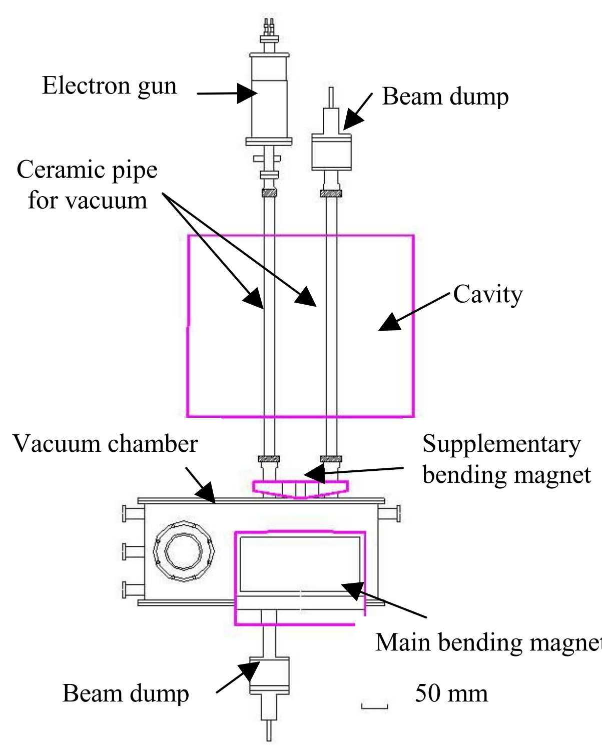

Fig. 1. Schematic diagram of acceleration system

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2.1 Electron Gun

The Rogowiski type electron gun was designed, fabricated and tested. As is well known, Rogowiski type electron gun consists of a cathode, a spherical control electrode, and a cylindrical anode with an outer radius that is smaller than the radius of curvature of the control electrode [4]. A 0.76 mmΦ W98/Th2 wire was used as a cathode. In the temperature limited operation region, electron current of 0.8 mA could be extracted at 20 kV applied voltage.

2.2 Cavity

A nonagon shape cavity was designed, fabricated and tested. The results of the cavity cold test which measured the electric field distribution using bead perturbation method are shown in Fig. 2 and the comparison between the calculated and measured value are summarized in Table 2.

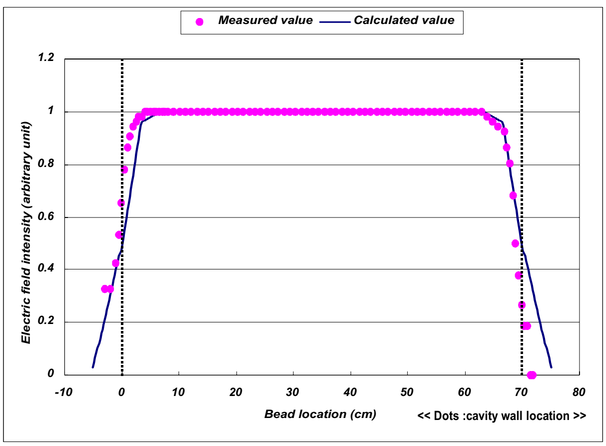

Fig. 2. Electric field distribution along the beam hole

Table 2. Comparisons between calculated and measured cavity parameters

Parameter	Calculated value	Measured value
Resonant frequency	159.410 MHz	159.878 MHz
Unloaded Q	9820	7291
Shunt impedance	754698 Ω	590863 Ω

From the bead perturbation test, TM_{010} mode in the nonagon shape coaxial cavity could be confirmed and the electric field distribution had little difference from circular shape coaxial cavity. As shown in Table 2, the measured frequency is about 400kHz higher than calculated value because of the fabrication errors (especially bending error of the stainless steel) of the cavity but the degradations of Q and shunt impedance are 74 % and 78 % respectively which are the typical values of the general cavity.

The cavity tuning method to push and pull the three side cavity walls was simulated and the results are shown in Table 3.

Table 3. Tuning effect measurement

Parameter	Frequency tuning effects
Calculated value	-0.0291 MHz/mm
Measured value (14mmΦ circular contact)	-0.0145 MHz/mm
Measured value (90 mm× 90 mm rectangular plate contact)	-0.0186 MHz/mm

In Table 3, when the cavity walls were pushed inward, the direction of displacement was selected minus. As shown in the Table, it seemed that the calculated value were overestimated because the cavity wall was bent in circular shape when pushed by the tuner. Tuner with large contact area was more effective for tuning the cavity.

The effect of ceramic insertion into the two beam holes of the cavity lowered the resonant frequency about 300 kHz in both calculation and measurement case but had little influences on the cavity parameters such as unload Q.

2.3 Bending Magnet

The bending magnet consists of main and supplementary magnet for focusing purpose, The design parameters are shown in Table 4.

Table 4. Design parameters of bending magnet

Parameter	Main magnet	Supplementary magnet
Pole piece angle	178 °	10 °
Pole piece rotation angle	11 °	0 °
Gap size	50 mm	50 mm
Magnetic flux density	36.1 gauss	21.5 gauss
Magnetomotive force	161 AT	97 AT

The calculation results of the bending magnet using OPERA3D code [5] and the fabricated magnet are shown in Fig. 3, and Fig. 4 respectively. The current density of the coil of each magnet was limited below 1 A/mm^2 , there the coil could be cooled by natural convection. The magnetic flux density profile of the magnet was measured using 3D gauss meter (Lakeshore,460) and the result of main magnet is shown in Fig. 5. The results showed that the difference between the calculated and measured value was within 3 % for the main magnet

2.4 RF system

The RF system consisted of oscillator, 100 W solid state amplifier, 3 kW tetrode amplifier, and power transmission line. The whole acceleration system including RF system is shown in Fig. 6

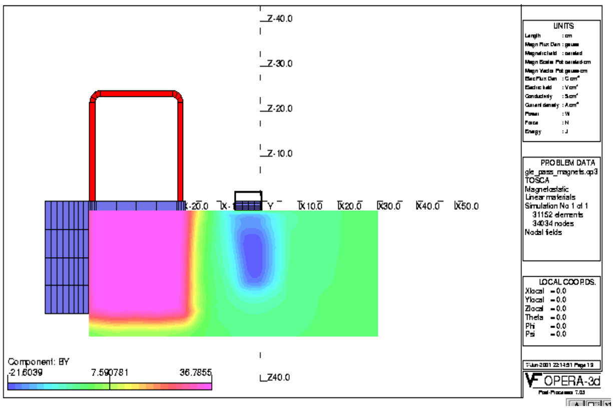

Fig. 3. Calculated magnetic flux density profile

Fig. 4. Fabricated magnet

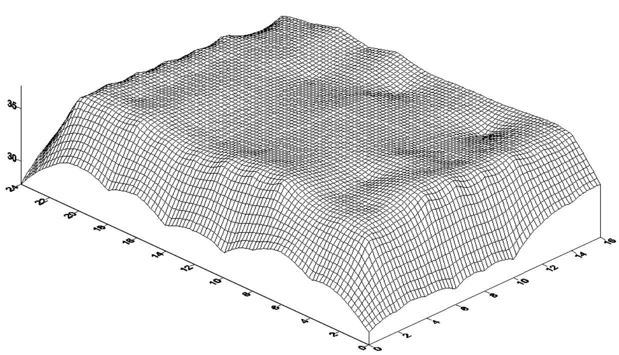

Fig. 5. Measured magnetic flux density profile

3 CONCLUSIONS AND FURTHER WORKS

A low energy electron beam acceleration system using TM_{010} mode in the coaxial cavity was designed, fabricated and the study on the characteristics of its components was carried out. The cavity characteristics and its tuning effect were measured and compared with calculated values. From the cold test results, it was known that the electrical characteristics of the nonagon shape coaxial cavity were agreed well with the 3-D calculated value. The rigorous analysis about the fringing field region is necessary for the proper focusing effect. The acceleration experiment is going to be performed to validate the whole acceleration scheme.

Fig. 6. Low energy acceleration system

4 REFERENCES

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