AN ALUMINIUM RF CAVITY FOR THE RING CYCLOTRON PROJECT

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ABSTRACT

An aluminium RF cavity was constructed for the RCNP ring cyclotron and preliminary power test was done. The RF cavity was successfully excited by a power amplifier which has been developed for the cavity. Cavity voltage above 200kV was achieved in the preliminary test.

INTRODUCTION

The RCNP ring cyclotron project has been outlined elsewhere.[1] Fig. 1 shows the layout of the ring cyclotron. The single gap H_{101} mode cavity is equipped with a movable tuner plate to cover the proposed frequency range. This cavity has frequency independent voltage distribution and be able to produce phase compression ratio of around 3. Detailed structures of the cavity were determined on the basis of model studies. The characteristics of the RF system are given in Table 1.

MECHANICAL DESCRIPTION OF THE CAVITY

Schematic drawing and photograph of the cavity is shown in Figs. 2 and 3. Walls of the cavity are made of 50mm thick pure aluminium (A1070), and welded each other. The cavity is reinforced by ribs made of anticorrosion aluminium alloy (A5052). Walls will be cooled with demineralized water. The mechanical structure itself is rigid enough and needs no additional support. A stock, the tuner plate which are shown in Figs. 1 and 2 are covered with oxigen free copper. The copper of the stock and the tuner plate is sustained by stainless steel and aluminium structures. An anti stock electrode is also made of oxgen free copper. A space between the stock and the anti sotck electrode forms acceleration gap. The gap is 100 mm at the injection radious and 250 mm at the extraction one. The tuner plate slides on the stock to vary the

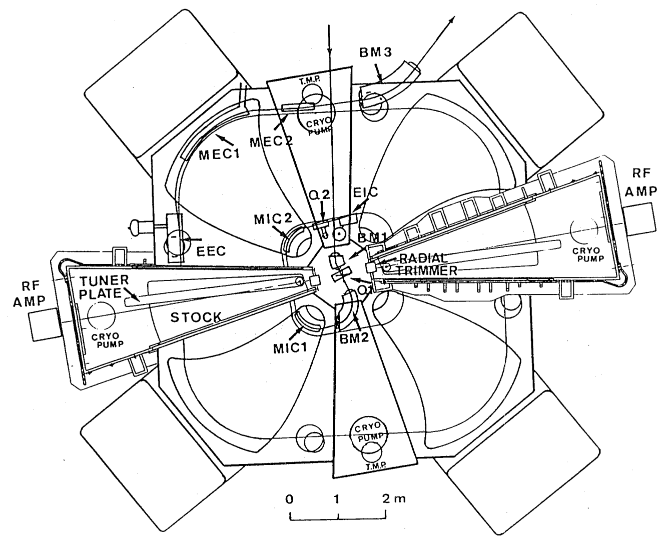

Fig. 1. Layout of the ring cyclotron.

Table 1
Characteristics of the RF system

RF frequency	20 ∿ 33 Mhz
Harmonic No.	4, 6, 8, 12
Phase compression ratio	∿3
RF peak voltage	500 kV
RF power	200 kW/cavity
No. of cavities	2

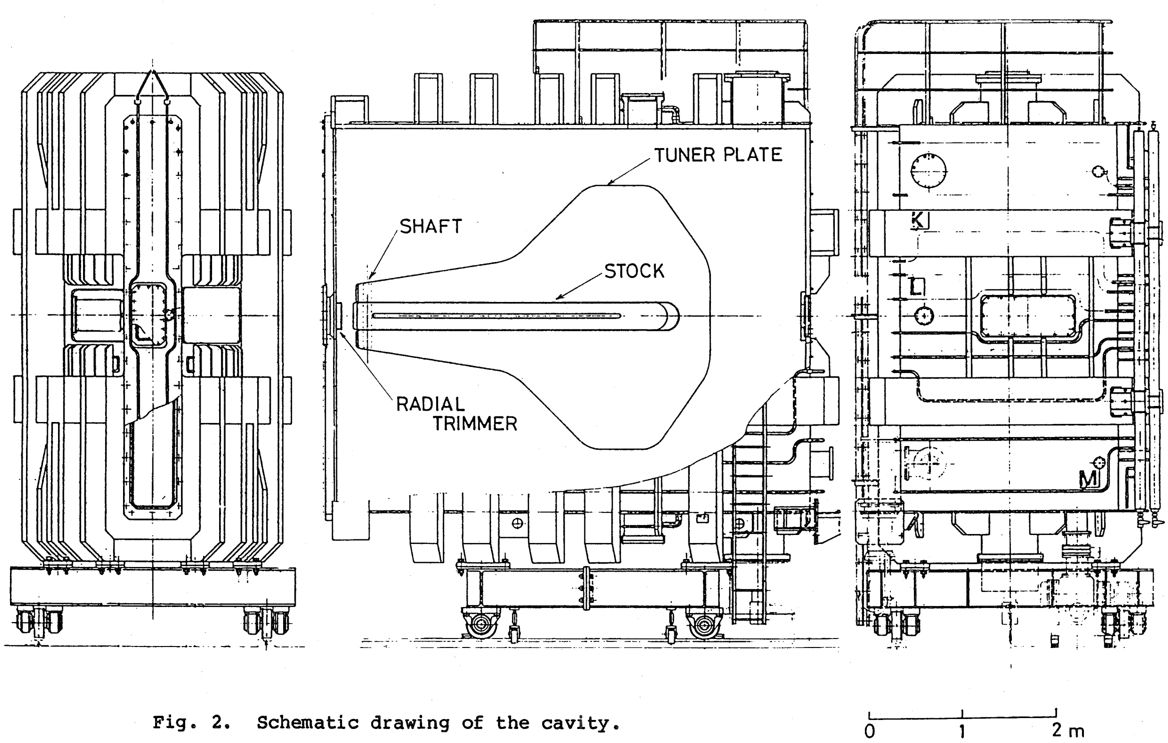

Fig. 2. Schematic drawing of the cavity.

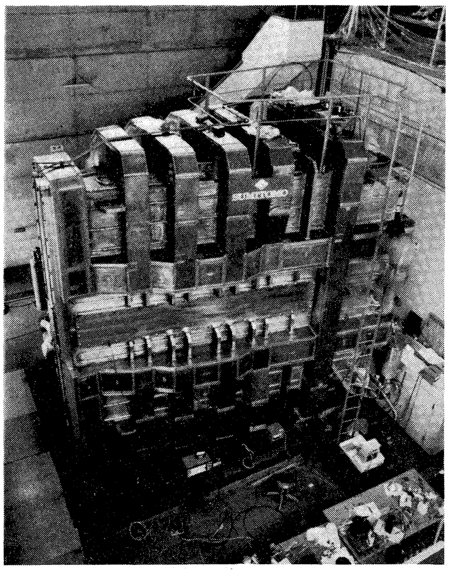

Fig. 3. Photograph of the cavity

resonant frequency. A rack and pinion system rotates the tuner plate around a shaft. The rack is set on the stock. The pinion is driven by a stepping moter which is set inside the tuner plate. Cooling water of the tuner plate and power of the stepping motor are supplied turough the shaft. Water cooling tubes are soldered inside the tuner plate and the stock. Electrical contact between the stock and the tuner plate is performed by silver-plated Be-Cu contact springs shown in Fig. 4. The springs are 0.6 mm in thickness. Copper-clad aluminium plates are welded at contact between the cavity and copper components. The cavity will be evacuated down to 1×10^{-5} Pa by a 22 in. cryogenic pump and a 10 in. diffusion pump.[2]

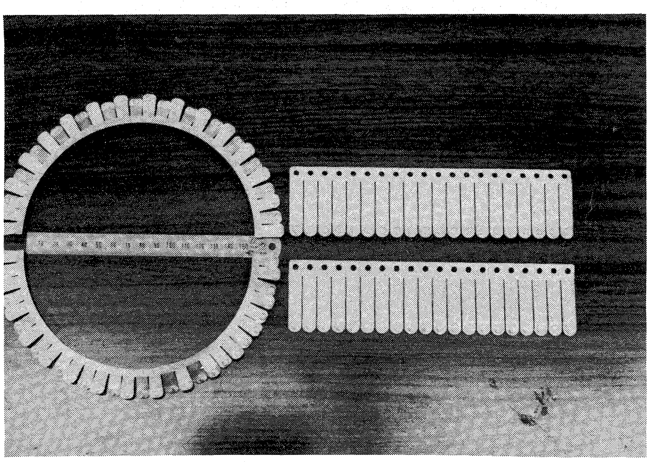

Fig. 4. Photograph of Be-Cu contact springs.

RF CHARACTERISTICS OF THE CAVITY

The final RF characteristics were investigated on a 1/10 scale model study. Several modifications were made to correct the frequency range, power reduction and voltage distributions for a new version of the proposal of the ring cyclotron project[3]. Resonant frequencies for various modes of the cavity were investigated as shown in Fig. 5. There are seven resonances below 100 MHz. The resonant frequency range of H_{101} mode is 22 $\sim$33 MHz. Fig. 6 shows measured Q value of H_{101} mode. Because of lower conductivity of aluminium comparing with that of copper, RF power loss is larger than that of copper by 30%. The maximum RF power loss of the cavity is estimated to be 200 kW for 500 kV at 33 MHz.

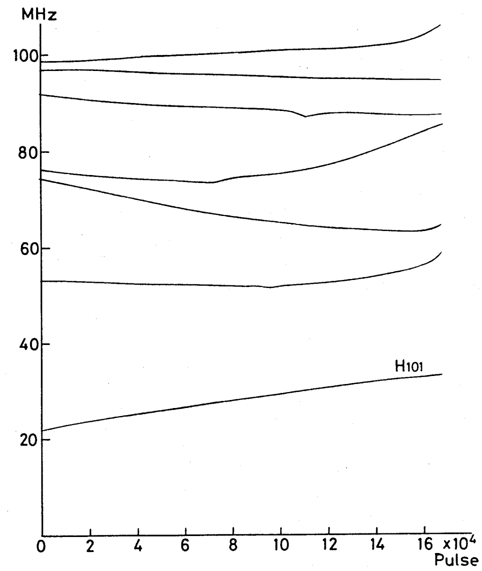

Fig. 5. Resonant frequencies of the cavity vs. position of the tuner plate.

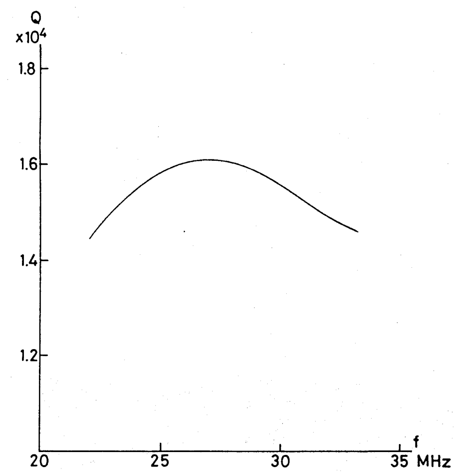

Fig. 6. Q value of H_{101} mode resonance vs. frequency.

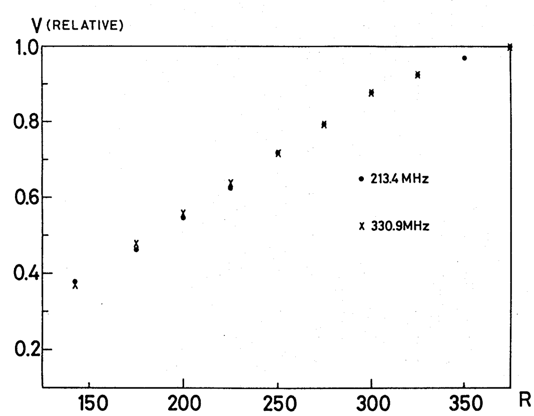

Fig. 7. Voltage distributions of the 1/10 scale model.

The relative gap voltage of the 1/10 scale model were measured with a perturbation method. The measured voltage distributions along acceleration gap are shwon in Fig. 7 for two resonant frequencies. The voltage distributions show radially increasing shape and no frequency dependence. These voltage distributions can produce phase compression ratio of around 3. The voltage distributions are able to be varied with the radial trimmer shown in Figs. 1 and 2.

RF POWER AMPLIFIER

An RF amplifier was developed to excite the cavity up to 500 kV. A tetrode (RCA 4648) is used for the amplifier. Maximum output RF power of the amplifier is 200 kW. An input circuit of the amplifier consists of a quarter wave-length coaxial line with a sliding short. The input circuit is damped by 50Ω terminating resistor. An inductive power feeder is adopted for a coupling between the power amplifier and the cavity. An output capacitance of the power tube is 85 PF, and a self inductance of the couling loop is ∿0.5 μH. A coupling circuit was designed to cancel effects of these reactances. Fig. 8 shows an equivalent circiut for output circuit of the amplifier. The characteristics of the H_{101} mode resonance are expressed in lumped constants. C, L_m and C_c are adjusted to obtain desired resonance frequency and plate inpedance with a well centered circle on complex plane[4]. A water cooled vacuum variable capacitor is used for C_c. Photograph of the power feeder is shown in Fig. 9.

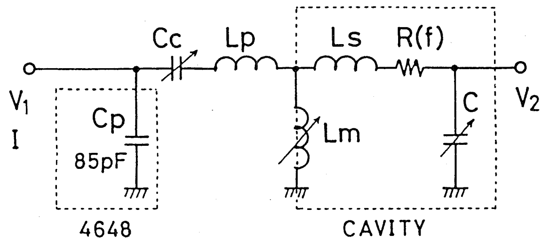

Fig. 8. Equivalent circuit of the output circuit of the RF system.

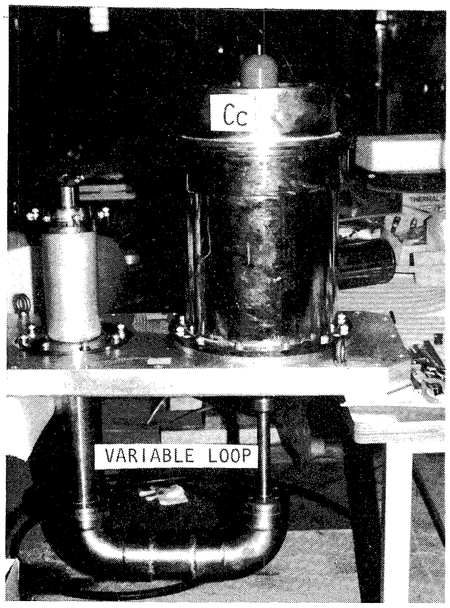

Fig. 9. Photograph of the power feeder.

POWER TEST

The cavity was successfully excited by the amplifier at 22.5 MHz, 25.2 MHz and 30.5 MHz. After 50 hours ageing, the cavity generates voltage more than 200 kV. The RF power is supplied with pulse mode operation. Figs. 10 and 11 show typical wave form of cavity voltage under and above multipactoring voltage, respectively. The vacuum of the cavity was $2 \sim 8 \times 10^{-4}$ Pa above multipactoring voltage. Output RF power at 25.5 Mhz, 180 kV was 59 kW. The full power test of the cavity is in progress.

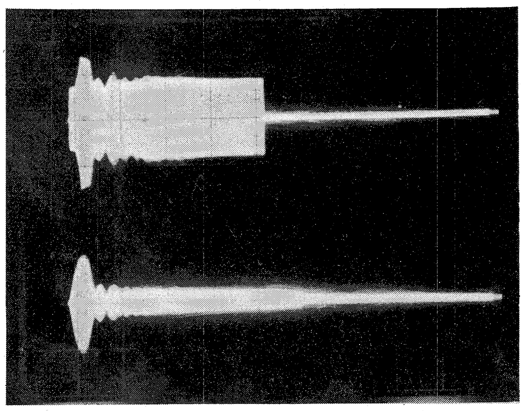

Fig. 10. Typical wave form of the cavity voltage under multipactoring.
Upper; G_1 voltage: 100 V/div.
Lower; Cavity voltage: 18 kV/div.
Horizontal: 50 μs/div.
f = 30.5 MHz

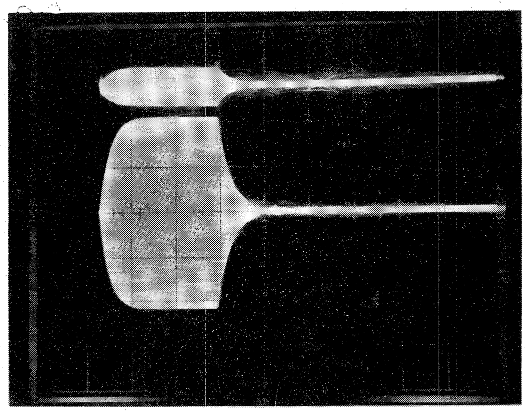

Fig. 11. Typical wave form of the cavity voltage above multipactoring voltage.
Upper; Anode voltage: 20 kV/div.
Lower; Cavity voltage: 75 kV/div.
Horizontal: 0.5 ms/div.
f = 25.5 MHz

REFERENCES

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4) T Saito et al., RCNP Annual Report (1981) p.227.