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ACCELERATION SYSTEM FOR THE RCNP RING CYCLOTRON

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Abstract

A variable frequency H_{101} mode single-gap cavity has been made for the RCNP ring cyclotron. The frequency range is 22 to 33 MHz. Radially increasing voltage distributions of the acceleration system produce beam phase compression ratio of about 3. The cavity was excited up to 270 kV at 33 MHz in a preliminary test. A 20 inch cryopump evacuated the aluminium cavity chamber down to 1×10^{-7} Torr.

Introduction

An intermediate energy ring cyclotron (K=320, $E_{p\ max}$ = 300 MeV) has been proposed as a new accelerator facility at RCNP, Osaka University.[1] The aim of this accelerator is to get high quality beams of protons and light ions for precise nuclear studies in high resolution. In the proposed system, the energy spread of the beam from the injector cyclotron is precisely compensated by using new method of flat-topping without flat-topping deceleration. It is essential for the method to realize proper phase compression in the ring cyclotron. Fig. 1 illustrates the layout of the ring cyclotron.

A single-gap acceleration cavity with a capacitive tuner plate has been made which covers the designed frequency range of 22~33 MHz. The cavity produces phase compression ratio of about 3 by radially increasing acceleration voltage distribution which is independent of frequency.

The cavity chamber is made of pure aluminium welding structure. The choice of the aluminium has several advantages such as non magnetic property, high thermal and electric conductivities, fast decay time of induced activity as well as good machinability and economical construction cost, compared with copper-clad stainless steel structure. The main characteristics is listed in Table 1.

Cavity

The cavity chamber was made of high conductivity pure aluminium (A1070). The vacuum tight chamber was welded with double groove joint by automated MIG machine. The chamber is reinforced by rib arrays of anti-corrosion aluminium alloy (A5052) to withstand an atmospheric pressure. The flanges of the chamber were machined and grooved by milling machine after correction of the welding deformation. The inner surface of the aluminium chamber was polished by 250 mesh buff, degreased and rinsed with a neutral detergent.

The rotatable tuner plate slides on a stock to change the resonant frequency, as shown in Fig. 2. The edge of the stock forms an acceleration electrode. The drive of the tuner plate is made along a rack mounted on the stock periphery with pinion system by a stepping motor which is set inside the tuner plate. The copper skin of the tuner plate and the stock is sustained by aluminium and stainless frameworks. Silver plated Be-Cu contacts with silver head carry RF current between the stock and the tuner plate. A copper-clad aluminium is used to contact between the copper skin of the stock and the aluminium chamber. Fig. 3 shows the photograph of the cavity and the mounted RF power amplifier.

The cavity 25 m^3 in volume is evacuated by a 20 inch cryopump mounted on the top of the chamber down to 10^{-7} Torr as shown in Fig. 4. A 10 inch diffusion pump with a cold trap has been used as an auxiliary pump system.

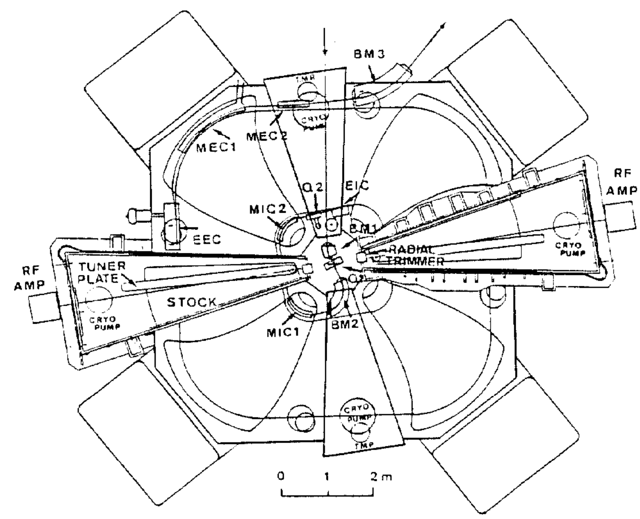

Fig. 1. Layout of the ring cyclotron.

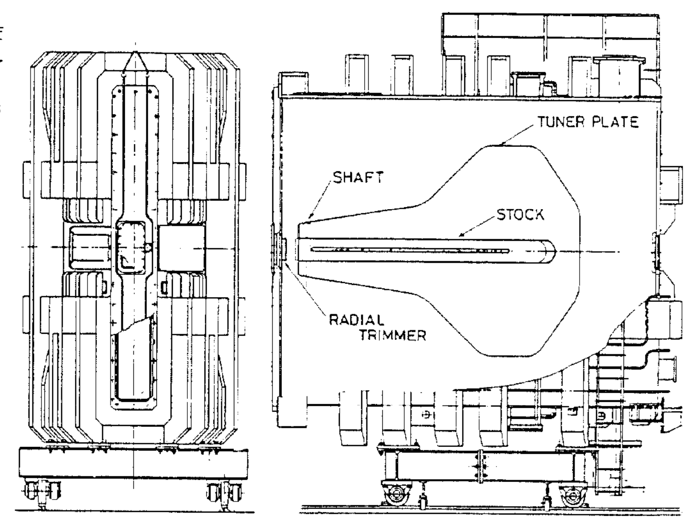

Fig. 2. Schmatic drawing of the cavity.

TABLE 1

Characteristics of the cavity

Dimension	length 5 m height 4 m
Frequency	22 ~ 33 MHz
Phase compression ratio	~3
RF Peak Voltage	500 kV
RF Power	200 kW

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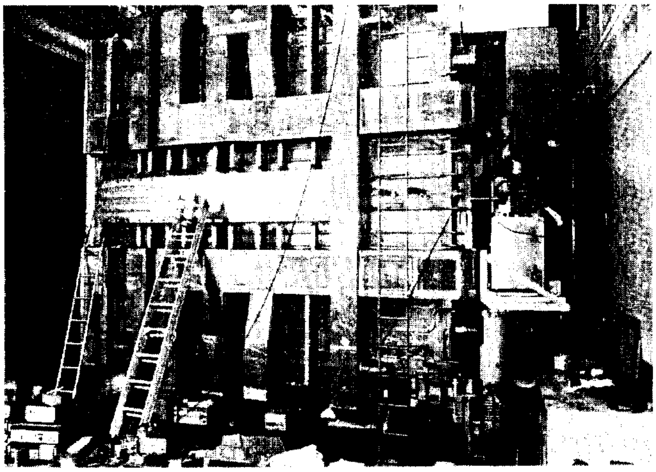

Fig. 3. Photograph of the cavity, RF power amplifier mounted on the chamber.

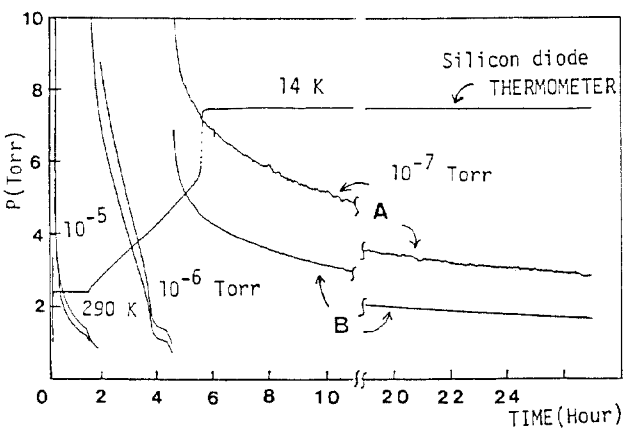

Fig. 4. Typical pumping down chart.
A: 5m from cryopump.
B: 2.5 m from cryopump.

RF Characteristics

The RF characteristics of the cavity were investigated on a 1/10 scale model study. Resonant frequencies were measured for various modes of the cavity below 100 MHz. Seven resonant modes were observed there.[2] The resonant frequency and Q value of H_{101} mode resonance are shown in Fig. 5. The RF power loss of the cavity is estimated to be 200 kW for maximum gap voltage (500 kV) at 33 MHz.

The gap voltage distributions were measured from injection through extraction radius with a simplified perturbation method. A thin rod perturbator made of acrylic resin was inserted into the acceleration gap through the beam aperture in 40 mm height. The cross section of the rod is 5 mm in thickness, 39 mm in height and the length is long enough to cross the acceleration gap. The frequency shift caused by the perturbator was measured. The sensitivity of this method was calibrated at several points with a conventional perturbation method.[3]

This simplified method is very useful to study the effect of a radial trimmer, since we can measure the voltage distributions for various conditions of the radial trimmer quickly and reduce the effect of the frequency drift. The preliminary results of the measurement are shown in Fig. 6. The voltage distribution is radially increasing and shows convex shape. The distributions are almost frequency independent, and can be varied with the radial trimmer. These properties of the voltage distribution are ideal for acceleration system of the ring cyclotron.

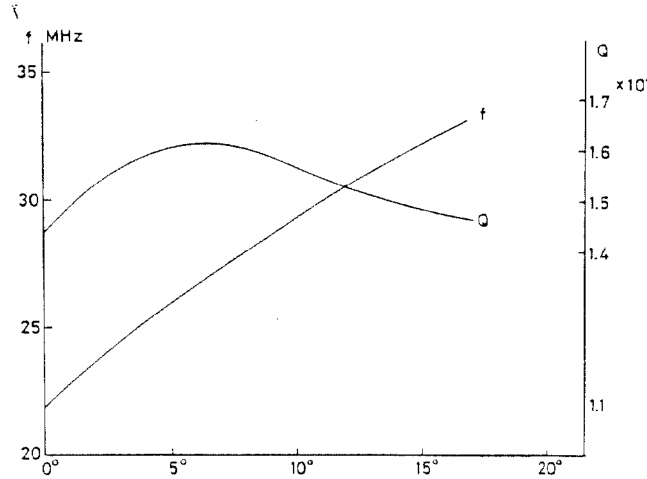

Fig. 5. Measured Q value and resonant frequency of H_{101} mode vs. angular position of the tuning plate.

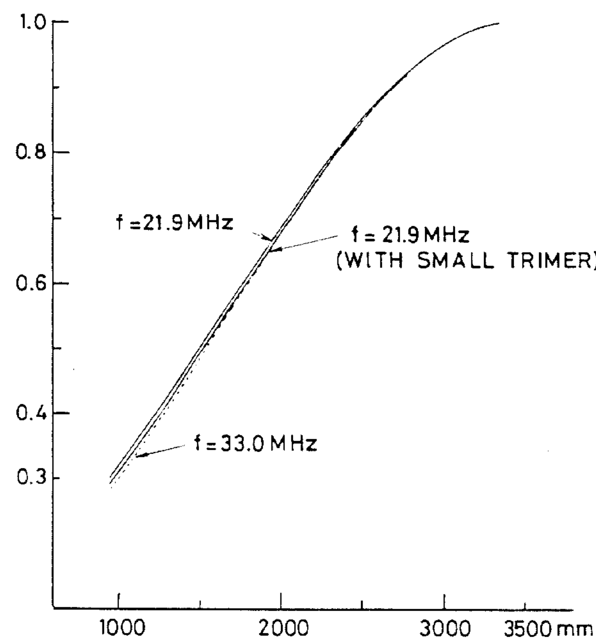

Fig. 6. Voltage distribution of the cavity vs. radius.

Power Test

The cavity was excited up to 270 kV in a preliminary test. On the test, the skin of the tuner plate and the stock were watercooled whereas the aluminium chamber was not cooled. An RF power amplifier inductively coupled with the cavity has been developed.[4] The block diagram of the circuit for the power test is shown in Fig. 7.

The cavity was excited with pulse mode operation since multipactoring can be overcome easily and the RF power loss on the cavity wall or anode dissipation of the power tube during multipactoring phenomena can be effectively reduced to acceptable level. The repetitional frequency and duty factor of the pulse were 10 Hz ~ 10 kHz and 1/2 ~ 1/20, respectively. After 50 hours conditioning, multipactoring was overcome.

The test was performed at several frequencies. The RF voltage is monitored with a pick up loop shown in Fig. 7. The sensitivities of the loop were calibrated at gap voltage of 18.5 kV with a capacitive voltage divider.

Wave forms of the pulse modulated RF voltage are shown in Figs. 8 and 9. Typical multipactoring discharges were observed at several levels of gap voltage from 300 V to 200 kV in the test. The power test of the cavity is in progress.

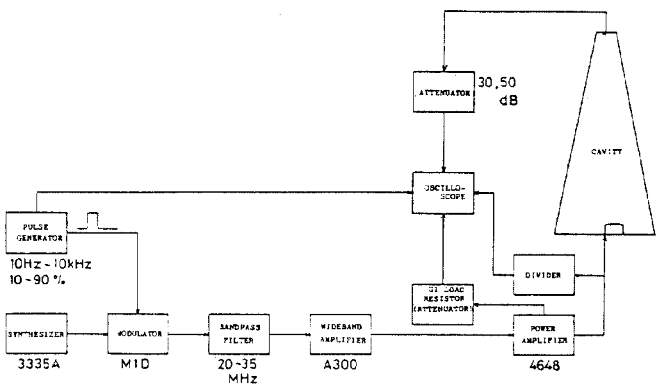

Fig. 7. Block diagram of the power test system.

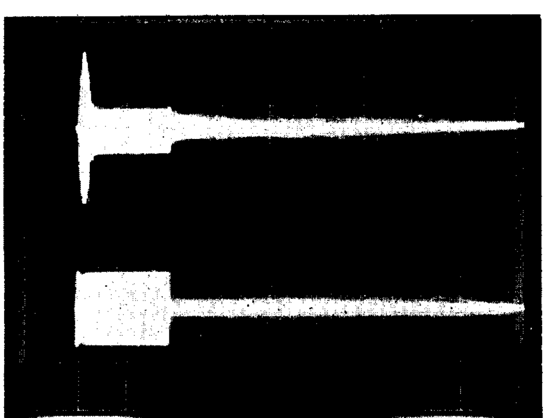

Fig. 8. Typical wave form of the cavity voltage during multipactoring.
Upper: Cavity voltage 2.65kV/div
Lower: Control grid voltage
Horizontal: 50μS/div
f = 33 MHz

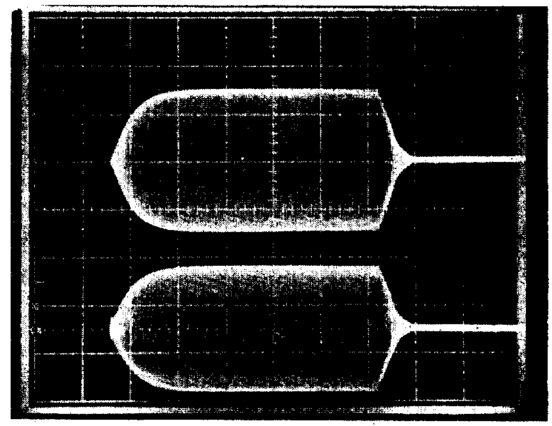

Fig. 9. Typical wave form of the cavity voltage above multipactoring.
Upper: Cavity voltage 170 kV/div
Lower: Anode voltage
Horizontal: 200 μS/div
f = 33 MHz

References

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[3] S.W. Kitchen et al., "Resonant-Cavity Field Measurements," in J. Appl. Phys., 26 pp.618-621.

[4] T. Saito et al., "Aluminium RF Cavity for the RCNP Ring Cyclotron," in Proc. 10th Int. Conf. on Cyclotrons and Their Applications, East Lansing (1984) pp.381-384.