CONSTRUCTION OF THE RF-RESONATOR FOR THE RIKEN INTERMEDIATE-STAGE RING CYCLOTRON (IRC)

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Abstract

A frequency tunable resonator for the RIKEN-IRC(intermediate stage ring cyclotron) [1] has been constructed and its rf characteristics were measured. The dimension of the resonator was optimized by using a three-dimensional rf calculation code, MAFIA. The measured frequency range covers the required range of 18∼40.5 MHz as expected and Q-values are as large as 74–79% of the calculated values.

1 INTRODUCTION

The IRC, four-sector ring cyclotron, has two accelerating resonators and one flattop resonator. The design parameters of the resonators are listed in Table 1. While the flattop resonator is a traditional single-gap-type with shorting-plates, the accelerating resonator has a new structure of a RCNP-ring-cyclotron type [2] whose frequency is tuned by adjusting two flapping-panels which are placed symmetrically to the median plane. In the case of 38.2 MHz operation, the highest operational frequency of the existing heavy-ion-injector RILAC (riken linear accelerator), acceleration voltage of 600 kV_p/gap is required to be generated with an existing 150 kW rf-power amplifier.

Table 1: Key parameters of the acceleration and the flattop resonator for the IRC

resonators	accel.	flattop
No. of units	2	1
Frequency[MHz]	$18 \sim 40.5$	$72 \sim 121.5$
Acc. gap	single gap	
[mm]	260	120
Coarse tuner	flapping-panel	shorting-plate
Tuner stroke	$0° \sim 90°$	420∼1000 mm
Trimmer	block tuner	
Feeder	inductive loop	
Max.V_p* [kV/gap]	600	14
Voltage stability	10^{-4}	10^{-3}
Phase stability	$< \pm 0.1°$	$< \pm 0.3°$
$P^{\rm out}_{\rm final\ amp.}$ [kw]	150	30
Q-values*	37500	29300

*Theoretical values at the highest frequency.

2 DESIGN OF THE RESONATOR

The shapes of the resonators are optimized using the computer code MAFIA [3] and modified based on the test using a 1/5 scale copper model. A photograph of the model is shown in Fig. 1. It is known from the model test that the resonant frequency of the real cavity tends to be higher by several hundreds kHz than the MAFIA predictions. A gap size between the flapping-panel and the dee surface at the panel angle of 0° was reduced by 5 mm from the original design.

A schematic drawing of the IRC acceleration resonator is shown Fig. 2. The resonant frequency is coarsely varied from 18 MHz to 40.5 MHz by adjusting the flapping-panels from 0° to 90° and is finely tuned with a ratio of more than 0.5% inserting the block tuners.

The estimated current density on the sliding contact which is adopted to the connection between flapping-panels and the cavity wall is less than 60 A/cm. The rf power is fed by an inductive loop whose coupling strength can be varied changing the cross section of the loop to obtain an impedance matching to 50 Ω. The size of the loop is also determined by a 1/5 scale model test.

The resonator wall consists of an oxygen-free copper board with a thickness of 4 mm, 25 mm space gap, and a stainless-steel board with a thickness of 45 mm (see Fig. 2). In order to reduce the out-gas into the inside of the resonator, the space between the walls is differentially pumped using turbo-molecular pumps. The thickness of the stainless-steel wall is decided so as to make the deformation due to the pressure of the atmosphere less than 1.5 mm. The water channels attached to the copper wall utilizing 25 mm space gap are arranged based on the heat calculation. The heat density distribution is obtained using MAFIA.

The fabrication of one of the resonators has been com-

Figure 1: Photograph of the model resonator(1/5). Flapping-panels are set to the position of the lowest frequency, 0°. The side flange on which the dee electrode is attached is removed.

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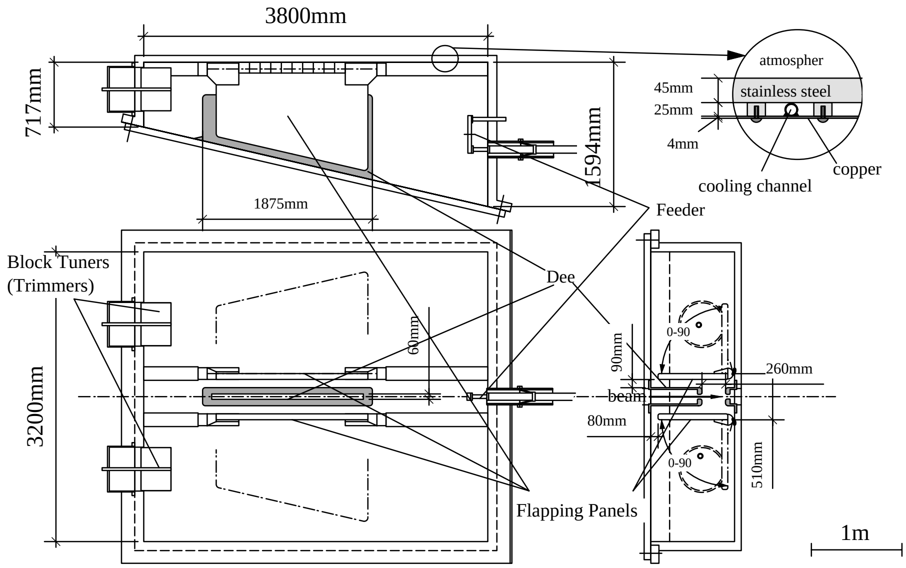

Figure 2: Schematic drawing of the IRC acceleration resonator.

pleted. The photograph of the resonator is shown in Fig. 3.

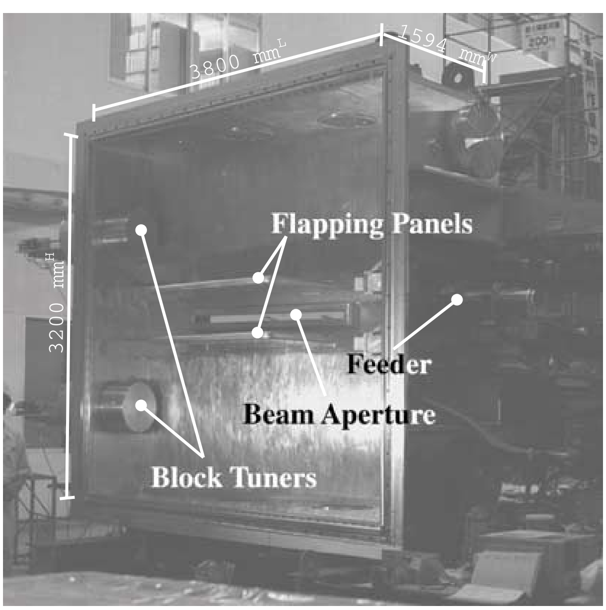

Figure 3: The IRC accelerating rf-resonator. The side flange on which the dee electrode is attached is removed. The flapping-panels whose position can be set independently are set to 0°. The block tuners are fully inserted.

3 LOW POWER TESTS

3.1 Measurement of RF Characteristics

The resonant frequency and Q-values of the actual cavity were measured and plotted in Fig. 4. The results are compared with the prediction values using MAFIA in Table. 2. The measured frequencies were in good agreement with the prediction. The unloaded Q-values were obtained from measured loaded Q and SWR. The Q-values were as large as 74∼79 % of the calculated values. The block tuners changed the resonant frequency more than 0.7 % over the entire frequency range.

Using the ratio of measured Q-values to the calculated one, we can guess the parallel shunt impedance of the resonator. The estimated maximum wall loss with a 600 kV$_p$ voltage at 38.2 MHz is about 80 kW.

The higher modes appear at $f > 70$ MHz as shown in Fig. 5. These are well reproduced by a MAFIA calculation.

Table 2: Measured (Estimated) resonant frequencies and Q-values at the panel angles of 0° and 90°

Flapping-Panel	0°	90°
Frequency(MHz)	17.83	41.34
	(17.58)	(40.74)
Trimmer $\Delta f/f$(%)	0.83	0.74
	(0.94)	(0.83)
Q $_{unloaded}$	21600	29500
	(29300)	(37500)

() Values estimated using MAFIA.

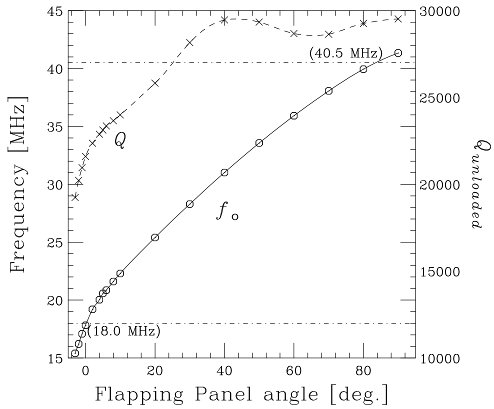

Figure 4: Measured resonant frequency and unloaded Q-values.

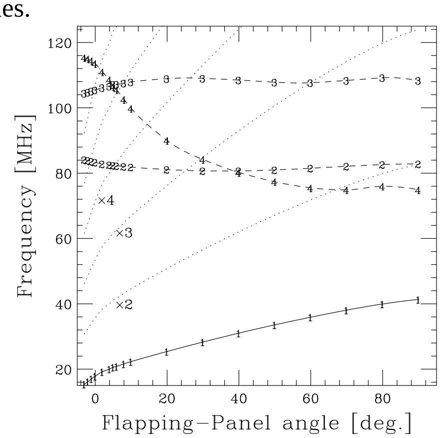

Figure 5: Frequencies of the higher modes.

3.2 Detection of Leakage Field

The problem of the rf field leakage through the beam aperture is one of the most important issues for this kind of resonator. Misalignment of the flapping-panels and dee causes a vertical electric field at the median plane and the leakage of the rf field power into the vacuum chamber (see Fig. 6). In the worst case, elements such as the phase probe are damaged by the leaked rf power. To detect the vertical component of the electric field at the median plane, a balance-monitor (capacitive pickup) is installed in the beam chamber outside the resonator. Using this monitor, the leakage can be minimized by offsetting one flapping-panel to the other. The principle of the leakage field detection is illustrated in Fig. 6. An example at 18 MHz shown in Fig. 7 indicates that an offset angle of 0.2 degrees is needed to cancel the vertical field.

4 OUTLOOK

Measurement of the electric field distribution using a perturbation method is planned after this conference. The fabrication of the No. 2 resonator and flattop resonator are now in progress. Commissioning is scheduled in the middle of 2003. The construction of SRC resonators which have the

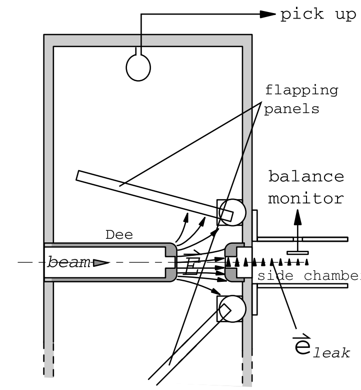

Figure 6: Conceptual illustration of the leakage field detection.

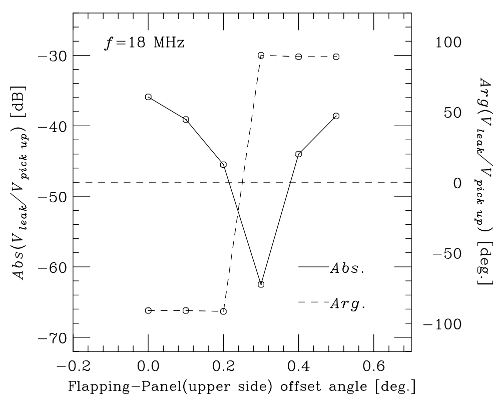

Figure 7: Leakage field due to a misalignment of the flapping-panels.

same structure of the IRC one is started from this year.

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6 REFERENCES

[1] T. Mitsumoto et al., in this report, “Construction of the RIKEN IRC ”.

[2] T. Saito et al., Proc. 12th Int. Conf. on Cyclotrons and Their Applications (Berlin 1989), p. 201.

[3] The MAFIA collaboration, User’s Guide MAFIA Version 4.0, CST GmbH, Lauteschägerstraße 38, D-64289, Darmstadt, Germany