FABRICATION STATUS OF ACS ACCELERATING MODULES OF J-PARC LINAC

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Abstract

We have been fabricated the several ACS modules step by step: the first buncher, the second buncher, the low-β accelerating module, and so on. This paper reports the improvement of the frequency and summarizes these RF measurement results. The data of the frequency fluctuation from brazing or stacking have been accumulated, and then the second buncher could be tuned correctly, although the frequency of the first buncher was lower than the target design. In the present fabrication process, about 0.1 to 0.2 MHz fluctuation should be corrected at each measurement step. As the result, the frequency could be tuned to the range of the movable tuner.

INTRODUCTION

The J-PARC LINAC accelerates H- ions with 50 mA peak current, the pulse length of 500 μs and 50 Hz repetition[1]. It is necessary to suppress the beam loss to avoid the activation of the accelerator components. For the quality of the beam, it is quite preferable to keep the axial symmetry of the accelerating electric field. The ACS (Annular Coupled Structure) was adopted as the most suitable structure in the balance of the axial field symmetry and the shunt impedance.

The ACS module is composed of two accelerating tanks and one bridge tank. Fig. 1 shows the schematic drawing of the ACS. (Refer to the paper[2] for details.)

The 21 ACS modules accelerates the H- beam from 200 MeV up to 400 MeV. We plan to fabricate these modules for four years from FY2008.

We have fabricated the several ACS modules step by step: the first buncher, the second buncher, the low-β accelerating module, and so on. This paper reports the improvement of the frequency tuning on the basis of the first module mainly. These RF measurement results are also summarized.

CAVITY PROPERTIES

Coupling Mode Frequency

The accelerating mode frequency is tuned to the operating frequency of 972 MHz by a movable tuner. Figure 2 shows the dispersion curve after the accelerating mode is adjusted to the operating frequency of 972 MHz. The coupling mode frequency is evaluated from the average value

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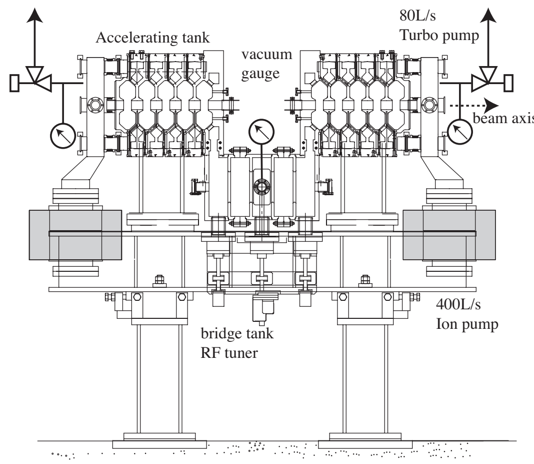

Figure 1: Schematic drawings of ACS buncher module.

of the next higher and the next lower mode frequencies from the accelerating mode.

From now on, we will discuss the coupling mode. It is preferable to tune the coupling mode at higher than the accelerating mode. This is because the wall loss makes the coupling mode lower when the coupling cell is excited.

For the first buncher module, the coupling mode is at 971.55 MHz, because the frequency shift by brazing was smaller than an expectation. This is described in the following section in detail. After that, the data of the frequency fluctuation from brazing or stacking have been accumulated, and then the second buncher could be tuned

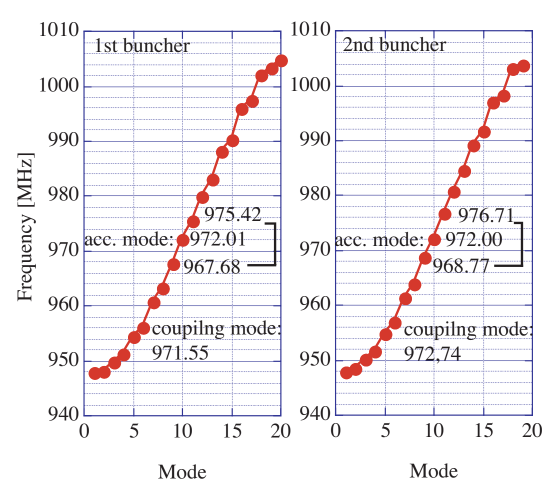

Figure 2: Plots of the dispersion curve.

correctly: the coupling mode is at 972.55 MHz.

Field Distribution

Figure 3 shows the electric field distribution. The field flatness between the cells except the end cell is 1.4% for the first buncher and 2.0 % for the second buncher.

The end cell shows the small peak value of the electric field. After the first module measurement, the reason and the improvement had been studied with a 3D electromagnetic analysis. In our understanding, this is because that the coupling factor between an end cell and the next cell is larger than one of the other periodic structure parts.

It is improved by tuning the coupling factor to one of the other cells. For example, this is one way preparing the dummy coupling slot as the periodical part in the end cell. In this case, the outer diameters of the end cell parts become the same as those of the periodic cells. It is necessary to avoid the interference with the vacuum manifold. The improvement in the future acceleration module needs more consideration.

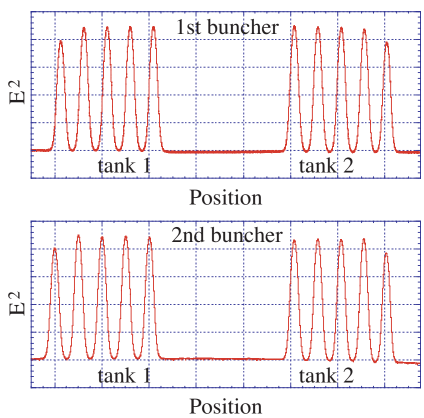

Figure 3: Electric field distribution.

Shunt Impedance

The cavity design used the MAFIA and the SUPERFISH. The shunt impedance is $Z = 51.3$ MΩ/m calculated by the SUPERFISH. The transit time factor is $T = 0.82706$ ($ZT^2 = 35.1$ MΩ/m). The additional loss factor is considered in the following each item: i) coupling slot 20%, ii) surface finish 5%, iii) temperature (the design is 20 ℃. The measurement is 20 to 22 ℃, so that we can neglect it.) 0 %, iv) bridge tank (3 cell / 5 cell $\times 4 \times 2$ tanks =) 7.5 %. In total, the wall loss increases by 1.422 times. Consequently the design value of the shunt impedance Z is

$$Z = 51.3 \div 1.422 = 36.06 \text{ M}\Omega\text{/m}. \quad (1)$$

From the measurement result, the shunt impedances of the first buncher and the second buncher are $Z = 33$ .MΩ/m and $Z = 35$ MΩ/m, respectively. These results obtain more than 90% of the design value, so that we consider they are reasonable.

RF MEASUREMENT IN THE FABRICATION PROCESS

In the ACS structure, the coupling cell is surrounding the accelerating cell. Thus it is difficult to access the accelerating cell directly from the outside. The frequency tuning of the ACS have to be finished before the brazing process.

We have been fabricated several ACS modules step by step: the first buncher, the second buncher, the low-β accelerating module, and so on. This section summarizes the data of the frequency fluctuation from brazing or stacking.

Cell vs. Whole Tank Frequency

The frequencies of cells are measured with the shortest periodical unit with the short plate (half accelerating cell + coupling cell + half accelerating cell)[3]. The frequency shift of the short plate is calibrated by the end cell measurement.

The frequency of the whole accelerating tank is measured under the temporal stack. Theoretically the average of half-cell measurement frequencies is equal to the whole accelerating tank frequency. The frequency differences between the average and the whole accelerating tank frequency are as follows:

1st buncher,
Acc. tank 1: +0.079 MHz, Acc. tank 2: -0.095 MHz,
2nd buncher
Acc. tank 1: -0.095 MHz, Acc. tank 2: -0.128 MHz.

From the viewpoint of the average, the first buncher is almost zero and the second buncher is -0.11 MHz. Consequently the accelerating tank frequencies of the second buncher are lower than the target frequency.

Frequency Shift by Brazing

The frequency shifts by brazing are described below:

test cell,
acc.mode: +0.1 MHz, coupling mode: +0.7 MHz,
1st buncher,
acc. mode: +0.17 MHz, coupling mode: +0.1 MHz,
2nd buncher,
acc.mode: +0.03 MHz, coupling mode: +0.21 MHz.

These frequency shifts by brazing were not constant.

For each accelerating tank, table 1 summarizes the accelerating and coupling mode frequencies after the brazing.

The target of the frequency tuning was fixed on the basis of the result of the previous brazing result. For the first buncher, the coupling mode shift was also expected +0.7 MHz, however, the actual shift was only +0.1 MHz. Consequently the coupling mode became lower than the target design.

We thought this is because that the measurement accuracy of the coupling mode was not enough. The flatness of a half-cell disk should be 0.01 mm or less to measure the coupling cell frequency correctly ,which are on the basis of our experiments. The test cell could not be measured correctly, so that we could not compare the frequencies precisely before and after brazing.

For the second buncher, +0.2 MHz shift of the accelerating mode was expected, and then the actual result was only 0.03 MHz. It was compensated by the bridge tank frequency.

Table 1: Accelerating mode and coupling mode frequencies of the each accelerating tank

module	Acc. mode	Coup. mode
Buncher 1 (acc. tank 1)	972.17 MHz	971.81 MHz
(acc. tank 2)	972.16 MHz	971.73 MHz
Buncher 2 (acc. tank 1)	971.74 MHz	972.14 MHz
(acc. tank 2)	971.75 MHz	972.10 MHz

Estimation of Whole Module Frequency

One ACS module is composed of two accelerating tanks and one bridge tank. It is difficult to assemble the cell parts into the whole module temporarily before the brazing. Hence, the frequency is measured each tank separately. After that, we are required to judge whether the accelerating mode could be tuned to the operating frequency of 972 MHz with movable tuners after the whole assembling.

The electromagnetic analysis corrects the boundary condition (frequency shift) between the assembled tank and the single tank. We have estimated the whole module frequency from the weighted average with the stored energy ratio.

This relation is expressed as:

$$f = \frac{1}{10\alpha+3}((5f_{acc1})\alpha + (f_{acc_1} + \Delta f_1 + C_1 + C_2) \\ +(5f_{acc2})\alpha + (f_{acc_2} + \Delta f_2 + C_1 + C_2) \\ +(f_{bri} + \Delta f_{bri})), \quad (2)$$

where f_{acc1},f_{acc_2} are accelerating tank frequencies (detuned measurement), f_{bri} is the bridge tank frequency, $\Delta f_1, \Delta f_2$ are frequency shifts of the bridge end-cell by a tuner, Δf_{bri} is the frequency shift of the bridge cell by the tuner, α is the stored energy ratio between the accelerating tank and the bridge tank, C_1 is the bridge end-cell boundary correction by the MAFIA analysis and C_2 is the fitting parameter for measurement result.

The stored energy ratio α was defined from the ratio of the frequency tuning range (ratio of the bridge end-cell only and the whole accelerating tank) with the movable tuner.

Figure 4 compares the estimation by Eq.(2) and measured frequencies. For the first buncher, the measured frequencies are about 0.2 MHz lower than estimated values. This result means that the magnetic boundary condition at the joint part of the bridge and the accelerating tank became not strict, as a result, the frequency moved to a lower side.

For the second buncher, the parameter C_2 was defined to -2.6 MHz to fit the measured frequency at the 0 mm tuner position of the first buncher. This result shows a -0.1 MHz error at the 0 mm tuner position. The tuning range is almost equal to the measurement result.

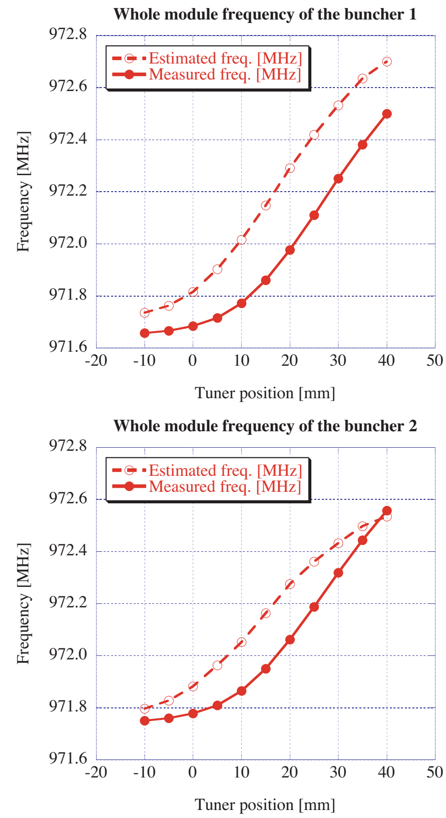

Figure 4: Estimated whole module frequency vs. measured frequency.

SUMMARY

This paper reports the improvement of the frequency and summarizes these RF measurement results. These results show that the cavity properties are in reasonable agreement with the designed ones. In the present fabrication process, an error of about 0.1 to 0.2 MHz should be corrected at each measurement step. As the result, the frequency could be tuned to the range of the movable tuners for the two buncher modules. In this study, we have established the basic fabrication and measurement procedures of the J-PARC ACS.

REFERENCES

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