ADJUSTMENT OF THE COUPLING FACTOR OF THE INPUT COUPLER OF THE ACS LINAC BY A CAPACITIVE IRIS IN J-PARC

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Abstract

Annular-ring Coupled Structure (ACS) cavities have been installed to increase the beam energy of the Japan Proton Accelerator Research Complex (J-PARC) linac from 181 to 400 MeV in the maintenance period of 2013. Some of the pillbox type input couplers with a ceramic window to the ACS cavity have a larger coupling factor than the target value by an avoidable manufacturing error. To adjust the coupling factor, a capacitive iris was introduced in the rectangular waveguide near the coupler. As a result, it has been confirmed that the iris decreases the coupling factor to a target value without any significant increase in temperature and in a discharge rate during high-power operation.

INTRODUCTION

To increase the beam energy of the Japan Proton Accelerator Research Complex (J-PARC) linac from 181 to 400 MeV, twenty-one Annular-ring Coupled Structure (ACS) accelerating cavities, two ACS buncher cavities, and two ACS debuncher cavities have been installed in the beam transport at the downstream of the separated-type drift tube linac in the maintenance period of 2013. After the installation, RF power has been fed into the cavities. And then, the negative ion beam has been successfully accelerated to the beam energy of 400 MeV in January 2014. Figure 1 shows the diagram of the J-PARC linac accelerating structure in the 400-MeV beam operation.

The ACS cavities consist of two accelerating tanks and one bridge tank. In ACS accelerating cavities, shown in Fig. 2, one accelerating tank consists of 17 accelerating cells and 16 annular-ring type coupling cells, while one

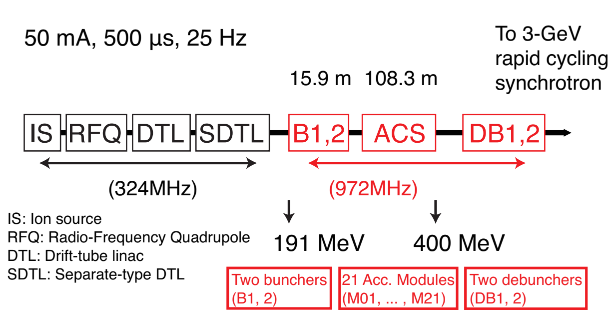

Figure 1: Diagram of the J-PARC linac accelerating structure in the 400-MeV beam operation.

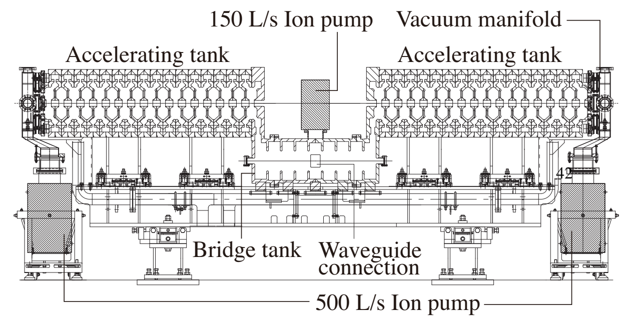

Figure 2: Accelerating cavity in the J-PARC ACS.

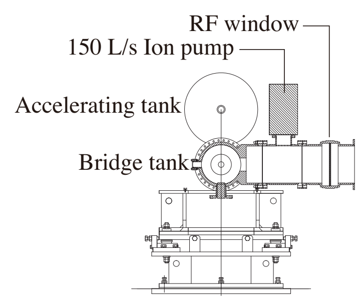

Figure 3: Bridge coupler of the J-PARC ACS.

bridge tank consists of 5 accelerating cells (excited in $\pi/2$-mode) and 4 coupling cells (unexcited in $\pi/2$-mode). The accelerating mode ($\pi/2$-mode) frequency of the cavity is tuned by the plunger tuners installed in the accelerating cells of the bridge tank. As shown in Fig. 3, an RF power from a klystron is fed into the cavity through the iris in the side of the center cell of the bridge tank [1].

Some of the pillbox type input couplers to the manufactured ACS cavity have a larger coupling factor than the target value by an avoidable manufacturing error [2]. The matching of the ACS cavity and the waveguide is decided by the configuration of the iris in the side of the center cell of the bridge tank. However, this part is difficult to be machined for tuning the coupling after the cavity fabrication is completed [3]. So we decided to correct the coupling factor by introducing a capacitive iris, shown by the purple color in Fig. 4, in the rectangular waveguide between the cavity and the RF window[1]. We aimed to adjust the VSWR of

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[1] The reflection from the total load (the cavity and the RF window) is decided by the VSWR of the cavity adjusted by the capacitive iris and of the RF window [4]

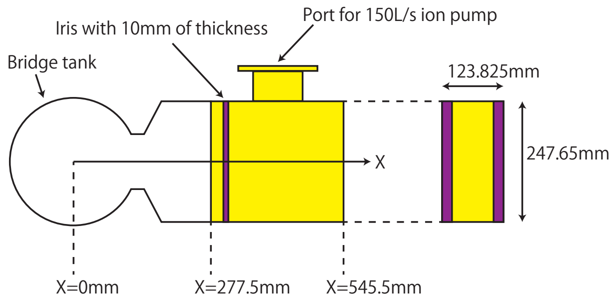

Figure 4: Rectangular waveguide with a port for 150 L/s ion pump.

one of the accelerating cavities, which is the 11th accelerating cavity in order of the particle velocity β among the 21 accelerating cavities, from 1.85 to 1.45. This can put flexibility into the output power of the klystron in the phase of the beam power upgrade.

VSWR ADJUSTMENT BY REFLECTOR

We adjust the VSWR of the 11th accelerating cavity by introducing a capacitive iris in the rectangular waveguide. The rectangular waveguide, which contains the port for an ion pump evacuation, is shown by yellow color ($277.5\mathrm{mm} < \mathrm{X} < 545.5\mathrm{mm}$) in Fig. 4. The position (X-direction) and the width of the capacitive iris with the thickness of 10 mm is decided by the three-dimensional electromagnetic field analysis software ANSYS HFSS. The adopted analysis model is shown in Fig. 5. In this analysis model, a quarter of the geometry is analyzed using symmetric property. This consists of the WR975 waveguide, the iris-type connected portion, the center cell of the bridge tank (a half cell), the adjacent coupling cell (one cell), and the adjacent accelerating cell (a half cell). In the simulation, the electrical conductivity of the end cell shown by the bluish-violet surface in Fig. 5 is modified, so that the end cell covers the total wall loss of the cavity exclusive of that of the center cell of the bridge tank. And also the radius

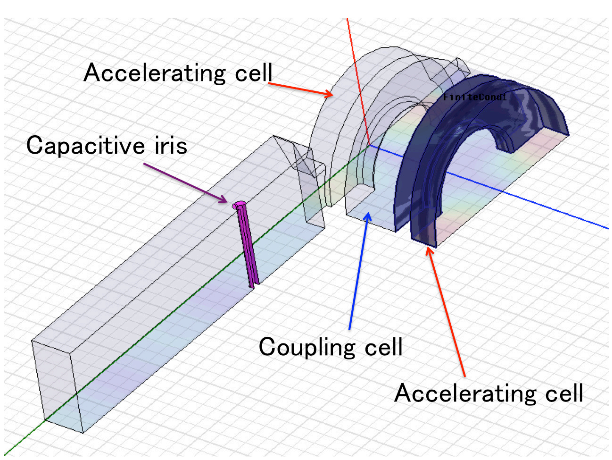

Figure 5: Analysis model for the bridge coupler.

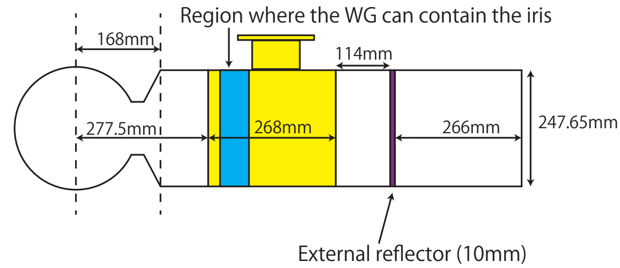

Figure 6: External reflector for LLRF measurement.

of the end cell is adjusted so that the accelerating-mode frequency is set to the operation frequency of 972 MHz.

To confirm the validity of the result obtained using this analysis model, the simulation result has been compared with the result obtained by the LLRF measurement. The measurement has been performed using the external reflectors and the existing waveguide which does not have an iris. Figure 6 shows the setup of the LLRF measurement. The reflectors indicated by purple color in Fig. 6 is located 114 mm far from the waveguide. The thickness of the reflectors are 10 mm. These reflectors narrow same widths of 10 mm, 20mm, and 30 mm from the both sides of the E-plane of the waveguide. The input wave port is located 266 mm upstream from the reflector. In the measurement, the accelerating-mode frequency has been tuned to the operation frequency of 972 MHz by adjusting the position of the plunger tuners.

The simulation results agree well with the result obtained by the measurement. Figure 7 shows the dependence of the VSWR on the width of the capacitive iris, and Fig. 8 shows the comparison of the simulation with the measurement. The VSWR indicated by the blue triangles in Fig. 8 are obtained by multiplying the simulation results by a normalization factor. In the case without the reflector, the factor equalizes the VSWR obtained by simulation with that obtained by measurement. It is shown that the VSWR can be adjusted from 1.85 to 1.0 by using reflectors with widths

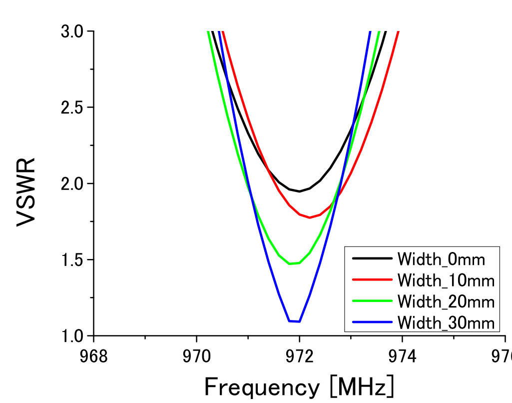

Figure 7: Simulation result of the VSWR depending on the width of the capacitive iris.

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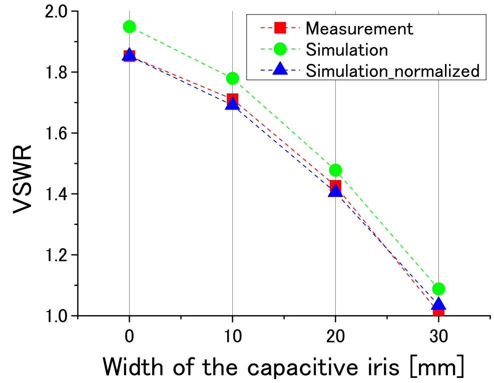

Figure 8: Comparison of the VSWR obtained by measurement and simulation.

from 0 to 30 mm.

WAVEGUIDE WITH CAPACITIVE IRIS

The configuration of the capacitive iris in the rectangular waveguide with a vacuum port has been decided by the analysis model shown in Fig. 5. Figure 9 shows the dependence of the VSWR on the position and the width of the capacitive iris. The position of the iris in Fig. 9 is represented by "Short", "Middle", and "Long". In the region where the waveguide can contain the iris, the iris is located in the nearest position (302.5 mm $<$ X $<$ 312.5 mm) to the cavity in "Short", in the farthest position (353.2 mm $<$ X $<$ 363.2 mm) in "Long", and the middle position in "Middle". The VSWR changes periodically with the position of the iris. In this case, it decreases in "Short" position, and increases in "Long" position. The iris with the width of 20mm located in "Short" position has been adapted to correct the VSWR from 1.85 to 1.45.

It has been confirmed that the iris decreases the VSWR from 1.85 to 1.45 by installing the waveguide which contains the capacitive iris. The manufactured waveguide is shown in Fig. 10. The measured value of the VSWR is 1.4567.

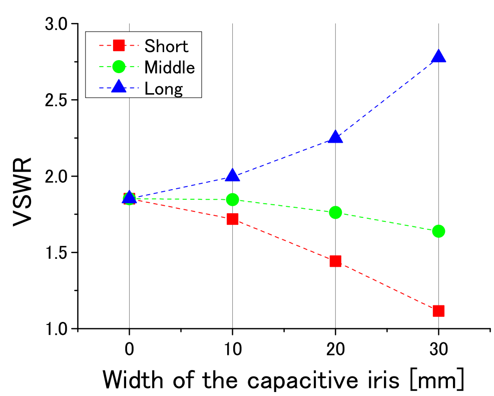

Figure 9: Dependence of the VSWR on the position and the width of the capacitive iris.

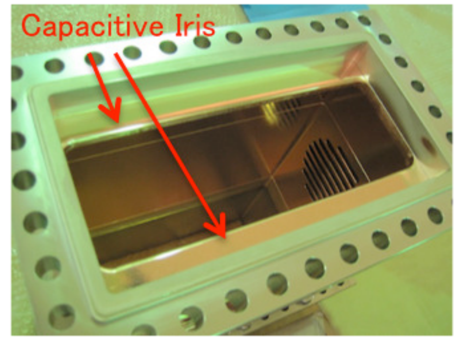

Figure 10: Manufactured waveguide which contains the capacitive iris.

The 11th accelerating cavity with the capacitive iris has been successfully conditioned up to 1.75 MW, which includes a margin of 20% of the designed accelerating field [5]. Throughout the high-power operation, no significant increase of the temperature around the iris was observed. And an apparent increase of discharge rate was not observed, too.

SUMMARY

To correct the coupling factor of the input coupler of the 11th accelerating cavity, the rectangular waveguide with a capacitive iris was manufactured. It has been confirmed that the iris decreases the coupling factor to a target value without any significant increase in temperature and in a discharge rate during high-power operation.

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