INPUT COUPLER OF THE J-PARC DTL

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Abstract

DTL of the J-PARC has two input couplers in one tank. The coupler has a movable coupling loop with an capacitive element which increase the coupling with the tank. The loop position is the outside of the tank, where is in the atmosphere. The tank vacuum is kept by the ceramic window on the wall in the coupler port. The rf properties and the mechanical structure of the coupler were designed to achieve the larger coupling constant. Features of the coupler design for J-PARC DTL is described.

INTRODUCTION

Japan Proton Accelerator Research Complex (J-PARC) is a high-intensity proton accelerator facility constructed in the Tokai campus of Japan Atomic Energy Agency (JAEA) under the collaboration between KEK and JAEA. The accelerator consists of a 181-MeV linac, a 3-GeV rapid cycle synchrotron and a 30-GeV synchrotron main ring. The 181-MeV injection linac comprised of the an H^- ion source, RFQ linac, DTLs, and separated type DTLs (SDTLs). The resonant frequency of whole rf cavities in operation is 324MHz. The beam energy of linac will be increased to 400MeV by adding the annular-ring coupled structure (ACS) linac at the end of 2013[1].

The DTL section is composed of three long tanks. The length of each tank is approximately 9m. Each drift tube in the tank accommodates the compact electric quadrupole magnet. The beam is accelerated to approximately 50-MeV by the three DTL tanks.

The SDTL is a short DTL which has 5 gaps in a tank. Drift tubes in the SDTL do not accommodate the quadrupole magnet but the quadrupole doublet is set between the tanks. J-PARC has 30 SDTL tanks for the beam acceleration and two SDTL tanks as a debuncher.

The input coupler of the DTL has a different design from that of the SDTL. In the following sections the different points are mainly described.

REQUIREMENT ON THE COUPLER

The high-power rf is provided to each DTL tank independently. Each DTL tank has two input couplers so that the rf power which one coupler should transfer is reduced by half compared to the case that one tank has one coupler. However it is not simple to tune the coupling constant for both couplers adequately. In order to simplify the tuning procedure, the coupling constant of the coupler must be changed easily keeping the vacuum in the tank.

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Rf coupling method we usually use is a loop coupling for DTL because it is much easier to adjust the coupling constant than an iris coupling. The coupling constant of the loop coupler is tuned by changing the tilt of the loop to the tank or changing the distance from the cavity.

The input coupler has a ceramic window to keep the vacuum in the tank. If the coupling loop of the coupler is in the vacuum side, the vacuum is usually broken when the loop tilt or the loop position is changed. Of course it is possible in principle to make a certain mechanical structure to move the loop in vacuum. However it is not reliable because the structure is probably too complicated.

For the DTL of J-PARC the coupling loop is set outside of the tank, where is in the atmosphere. The tank vacuum is kept by the ceramic window on the wall in the coupler port. The schematic view of the coupler design is shown in figure 1. The distance between the loop and the window is changeable by sliding the inside cylinder of the coaxial waveguide on which the loop is brazed. The loop is not fixed on the outer cylinder of the coaxial waveguide but the loop is contacted to the outer by the finger type rf contact.

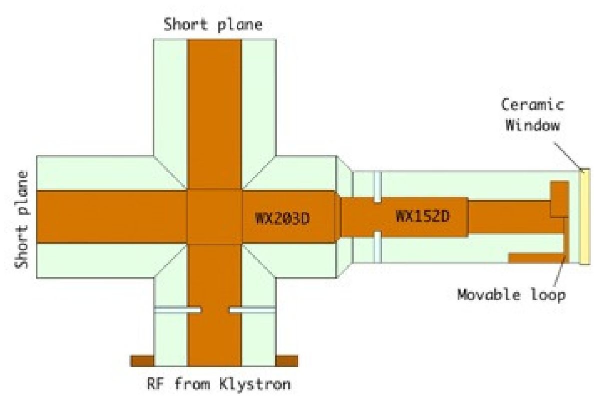

Figure 1: Coupler design.

As the loop is located outside of the tank, it is hard to have the large coupling constant with the tank. As the result, the coupling strength achieved by the loop is not enough for the DTL in spite of the fact that one DTL tank has two couplers as mentioned before.

Consequently the movable loop of the coupler has been put an capacitive element as shown in figure 2, which increase the coupling with the tank. In the figure 2 the rectangle plate on the right of the coaxial waveguide is the coupling loop. The half circle on the left is the capacitive element. Figure 3 shows the loop of the coupler for the SDTL. It is the simple loop. It is described that how we fixed the radius and thickness of the element in the next section.

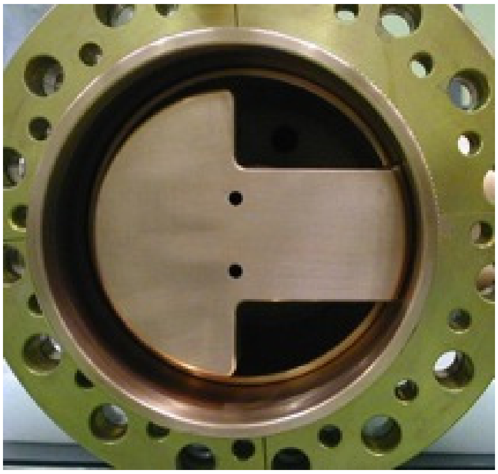

Figure 2: Rf coupling loop of DTL
The left semicircle is the capacitive element.

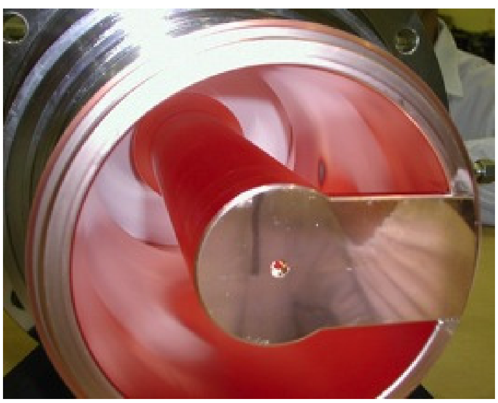

Figure 3: Rf coupling loop of SDTL
The white ceramic window is placed in the coupler.

Design of the coupling loop

The rf simulator HFSS was used for the design of the coupling structure. The example of the input shape of the loop for the simulater is shown in figure 4. It includes the magnetic coupling loop and the capacitive element. The parameters are the radius and thickness of the capacitive element. The loop is connected the cylindrical cavity in the simulator. The resonant frequency is tuned around 324-MHz.

In the simulation, there is no wall loss in the cavity. Thus $\S_{11}$ is always one. To determine the coupling strength of the loop to cavity, the phase shift of $\S_{11}$ was used. Here we defined the width as the measure of the coupling strength by the frequency span in which the phase is changed from -45 degree to +45 degree. The $\frac{1}{Q_{ext}}$ is proportional to the width. The results are shown in figure 5 and figure 6, respectively. The vertical line of both figures shows the width as mentioned just before. The simulation results has fixed the radius and the thickness of the capacitive element at 60mm and 30mm, respectively.

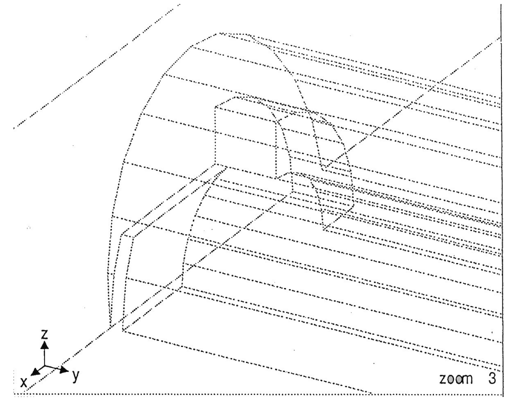

Figure 4: Loop for simulation

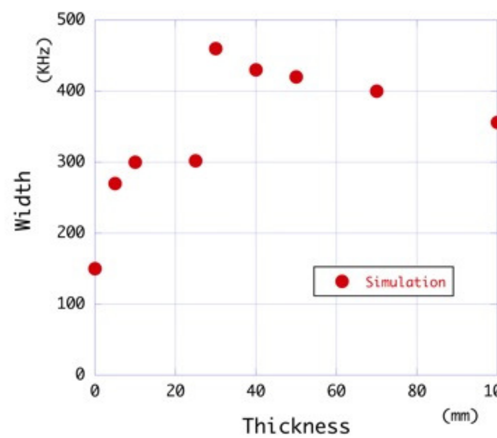

Figure 5: Frequency width vs the thickness of C
Simulation result. The Radius is constant (55mm).

Design of the ceramic window

The ceramic window is made of aluminum oxide of 99.7% purity. The shape of the window is a disk of which the thickness and the diameter are 17mm and 160mm, respectively. The oxide TiN is coated on the surface of the vacuum side in order to reduce the secondary electron emission coefficient.

The vacuum seal for the window is a metal seal. To put the window inside the tank as many as possible, we designed the step shape cross section shown in the upper of figure 7 at first. However the window was broken during the high-power test by the sparking problem happened at the step. Thus we modified the shape as shown in the lower of figure 7. It has no step. It has a simple shape but the window position is more outside compare to the first design.

MEASURED COUPLING CONTSANT FOR DTL-1

The coupling constant was measured by using DTL-1 of J-PARC. Figure 8 shows the measured relation between the loop position and the observed coupling constants (β_1 and

ISBN 978-3-95450-122-9

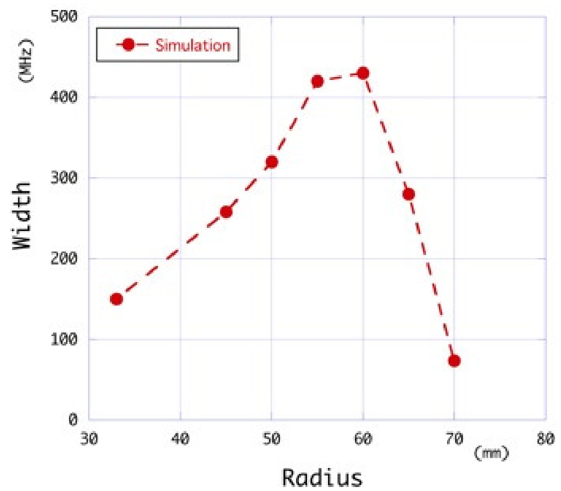

Figure 6: Frequency width vs the radius of C Simulation result. The thickness is constant (50mm).

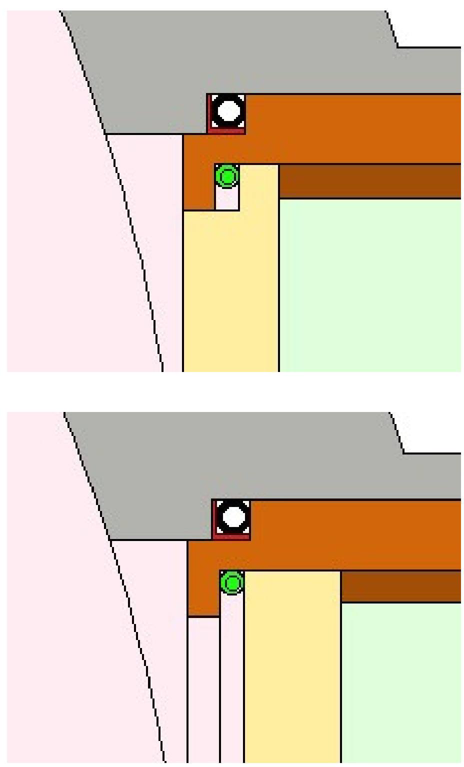

Figure 7: Cross sectional view of the cerarmic window Yellow:window, Brown:outside cylinder of the waveguide Green:vacuum seal, Red:rf contact, Gray:cavity wall

β_2) for two couplers. It also shows the measured unloaded-Q (Q_0) values. Since the unloaded-Q (Q_0) does not depend on the coupling constant, it shows that the moving coupler works well.

The maximum coupling constant we can have by two coupler is approximately 2. It is large enough for us, because the required total coupling is usually less than 1.5. Thus the distance of the loop from the window is around 10mm.

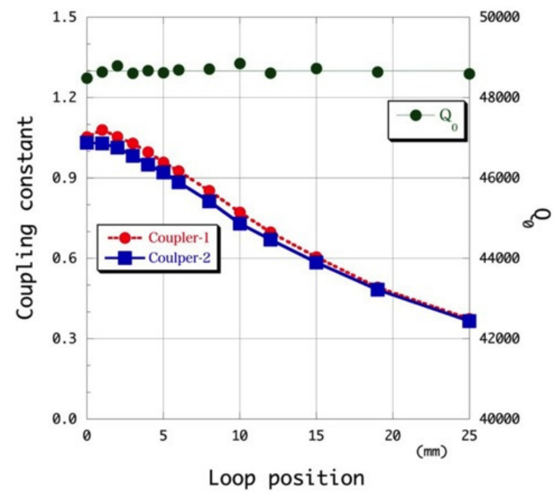

Figure 8: Measured coupling constant for DTL1 [2].

In the two port cavity, the measured coupling constant β_1^* and β_2^* by using a network analyzer do not mean the true coupling constant β_1^* and β_2^*. This we use the following relations to estimate the true values.

$$\beta_1 = \frac{\beta_1^*(1+\beta_2^*)}{1-\beta_1^*\beta_2^*}, \quad \beta_2 = \frac{\beta_2^*(1+\beta_1^*)}{1-\beta_1^*\beta_2^*}$$

CONCLUSION

The high-power rf coupler with a movable coupling loop has been developed for the DTL of J-PARC. The coupling loop has the capacitive element which increases the coupling constant. Its design was fixed by using the rf simulator. The shape of the ceramic window was checked by the high-power test. Finally the performance of the coupler has been confirmed by real DTL cavity. The couplers are working well after the earthquake also.

ACKNOWLEDGMENT

The authors would like to acknowledge Professor emeritus Kato and Professor emeritus Takasaki for their essential suggestions and the continuous encouragement.

REFERENCES

[1] K. Hasegawa, "STATUS OF THE J-PARCT LINAC", Proc. of LAC 2010, Tsukuba, JAPAN, 449 (2010)

[2] F. Naito, et. al, "RESULTS OF THE HIGH-POWER CONDITIONING AND THE FIRST BEAM ACCELERATION OF THE DTL-1 FOR J-PARC" Proc. of LAC 2004, Lubeck, GERMANY, 300 (2004)