MEASURED RF PROPERTIES OF THE DTL FOR THE J-PARC

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Abstract

RF properties of the second DTL tank for the J-PARC have been measured at KEK. The required flatness and stability of the accelerating field of the second tank have been obtained by the tuning of the post-couplers, whose shapes were modified to tune the resonant frequency to 324MHz. Consequently we have confirmed the following: (1) the achieved flatness of the field is 0.5% in maximum deviation, (2) the stabilized field can bear the perturbation of a 25% tilt of the field distribution.

INTRODUCTION

The J-PARC consists of a 181-MeV linac, a 3-GeV rapid cycle synchrotron and a 50-GeV synchrotron. The 181-MeV injection linac is comprised of an H^- ion source, a radio-frequency quadrupole (RFQ) linac, a drift-tube linac (DTL), a separated DTL (SDTL) and several beam transport lines. The linac will be extended to obtain a 400-MeV beam by adding the annular coupled structure (ACS) linac at the downstream of the SDTL in the next phase of the project.

The Alvarez-type DTL accelerates the H^- ion beam from 3 to 50 MeV. It consists of three independent tanks of which the length is about 9 m. Furthermore each tank is comprised of three short unit tanks (about 3 m in length). The inside diameter of the tank is 560 mm. The resonant frequency is 324 MHz. Each drift tube (DT) accommodates a tunable electromagnetic quadrupole magnet.

At this stage the assembling of all DTs for the DTL-2 and the DTL-3 has been completed. Moreover the first tank (DTL-1) already accelerates a 3 MeV beam from the RFQ up to an energy of 20 MeV at KEK [1]. Some RF properties were already described in the reference [2].

For the second DTL tank (DTL-2), which is designed to accelerate the beam from 20 to 37 MeV, some RF properties have been measured. A uniform accelerating field has been achieved by the fine adjustment of the post couplers and the fixed tuners. The field stabilization by the post-couplers against perturbations has been confirmed also. In order to achieve the stabilized-uniform distribution of the average field at the final target frequency of 324MHz, the following techniques have been applied for the post-coupler tuning: (1) non-uniform insertion length of the post-couplers from the tank wall; (2) increment of diameter of all post-couplers of the wall side.

Furthermore measurements of RF properties of the third tank (DTL-3) which will be used for beam acceleration from 37 MeV to 50 MeV, has been started.

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STRUCTURE OF THE DTL-2 AND THE DTL-3

The second DTL tank consists of 42 full-size drift tubes, 42 post-couplers and 10 fixed tuners. Bore diameter of the DT is 22 mm. The third DTL tank consists of 26 full size drift tubes, 26 post-couplers and 8 fixed tuners. Bore diameter of the DT is 26 mm. Both tanks have two movable tuners and two half drift tubes. The layout of the tuners and the input couplers are shown in figure 1. The first and the third unit tanks for the DTL-2 and these for DTL-3 have four and three fixed tuners, respectively. The second unit tank has two fixed tuners and two movable ones. Diameter of the tuner is 90 mm. There are two ports for the input couplers in the tank in order to reduce the RF power per coupler. Each coupler is located at one fourth of the total length from the end plate in order to suppress the excitation of the TM_{011} mode.

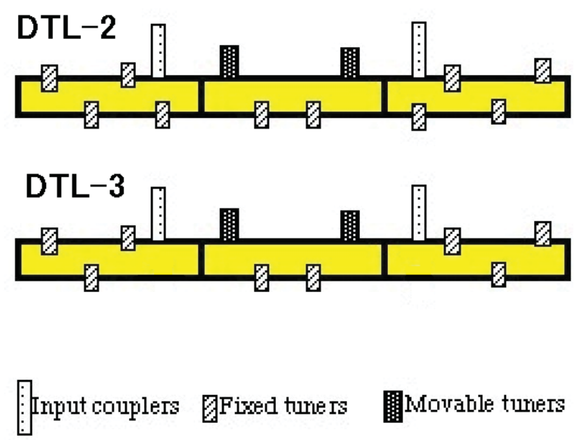

Figure 1: Layout of tuners.

TUNING OF THE DTL-2

Adjustment of the Tuners

The accelerating-field measurement for the DTL-2 has been done by using a bead-pull perturbation technique [3]. Initial field distribution of the TM010 mode without the tuners and the post-couplers is shown by the square marks in figure 2. The ordinate of figure 2 shows the normalized electric field of each gap. The DTL-2 tank has two movable tuners and 10 fixed ones as described above. The length of each fixed tuner was adjusted in order to tune the resonant frequency and to obtain the uniform accelerating field along the beam axis. (During the tuning, the "fixed" tuners are replaced by the "movable" model.)

The target frequency of tuner tuning is 323.650 MHz. The difference in the frequency from the operating point of 324 MHz is compensated by the effects of insertion of post-couplers, dielectric constant of the air, the deformation of the DT by the RF losses on the DT surface and the heat from the magnet in DTs. However, the measured resonant frequency is 323.105 MHz, which requires 80mm insertion in average of all tuners. It means that the effect of tuner is insufficient to tune the accelerating field. The reasons are as follows: (1) the maximum effective length of our tuner is about 100 mm, (2) however it was confirmed by the measurement that the maximum tuner length which is required to obtain the uniform field is approximately 40 mm longer than the average insertion length of the tuners.

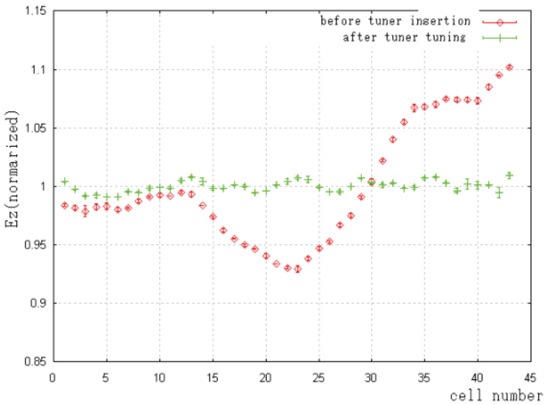

Figure 2: Field distribution (before and after tuning the tuners).

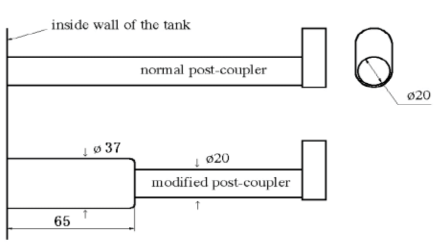

Figure 3: Shape of modified post-coupler.

Therefore, we modified the design of post-couplers in order to increase the resonant frequency. The designs of the post-coupler are shown in figure 3. The effect of the shape of the post-coupler (figure 3) on the resonant frequency was already confirmed by the tuning of the DTL-1. In the DTL-1 one third of the post-couplers were modified. However, all post-couplers had to be modified in the DTL-2, since the observed frequency difference for the DTL-2 was much larger than that for the DTL-1.

As a result, the resonant frequency became 323.653 MHz after tuning the tuners. The insertion length of the tuner is shown A in table 1. The accelerating field in this case is represented by the crosses (+) in figure 2.

After tuning the tuners, the measured unloaded Q (Q_0) value is 47000, which is about 84% of the calculated value. The Q_0 value is sufficiently high for the accelerating cavities.

Adjustment of the Post-Couplers

The length of the post-couplers has been adjusted by the measurement of the distribution of the average electric field for each gap along the beam axis with tuner perturbation. Two kinds of the tuner perturbation were applied. Both of tuner perturbations make a 25 % tilt of the field distribution without post-couplers. The perturbed field distributions without post-couplers are shown in figure 4.

The initial adjustment of the post-couplers has been done by keeping up the length of all post-couplers constant. The results are shown in figure 5 A). The ordinate of figure 5 is stability parameter which is defined as an RMS of difference between perturbed and non-perturbed electric fields of each cell.

$$\text{stability parameter} = \sqrt{\frac{\Sigma \Delta E z_n}{N}}$$

$\Delta E z_n$ means difference of accelerating field between perturbed and non-perturbed at the n-th cell.

In order to obtain the best stabilization against the perturbations, the fine tuning of post-coupler length has been tried. The length of post-couplers was varied for each unit tank. Figure 5 B) shows the results of the stability parameter described above for the fine tuning of the post-coupler. A-G at abscissa in figure 5 means insertion patterns as shown in table 2. Thus, the best stabilization against perturbations is achieved by the pattern E.

The field distributions shown in figure 4 are changed to ones shown in figure 6 by the post-couplers with pattern E. In figure 6 the effect of perturbations shown in figure 4 has been suppressed.

Table 1: Insertion length of tuner

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	A1	A2
A	60	48	83	75	14	43	65	86	75	85	46	39
B	65	53	88	80	14	43	60	81	70	80	46	39
C	55	43	78	70	14	43	75	95	85	94	46	39

A: uniform distribution [mm]
B: upward perturbation Fx: x-th fixed tuner
C: downward perturbation Ax: x-th movable tuner

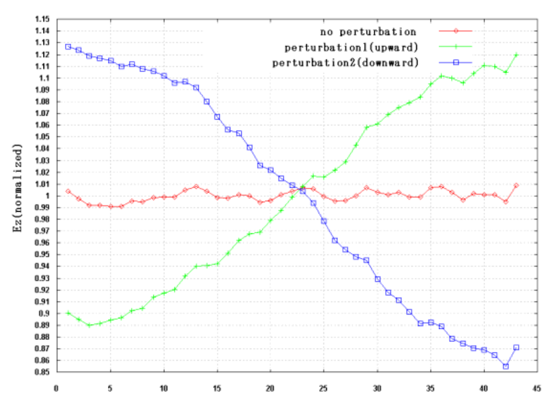

Figure 4: Field distribution without post-couplers.

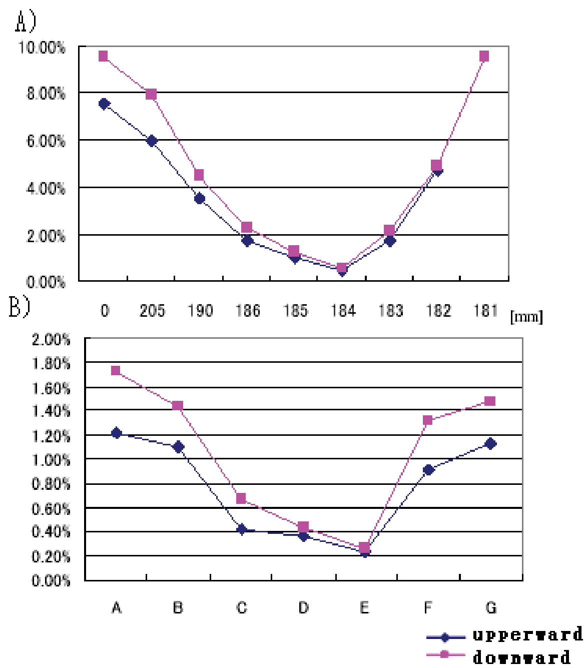

Figure 5: Stability parameter for each insertion pattern of post-couplers.

Table 2: Insertion patterns of post-couplers

	Insertion length of post-couplers(mm)		
	Unit tank 1 (1-16)	Unit tank2 (17-29)	Unit tank 3 (30-42)
A	186	185	184
B	186	185	183
C	186	184	183
D	185	184	183
E	185	184	182
F	185	183	182
G	184	183	182

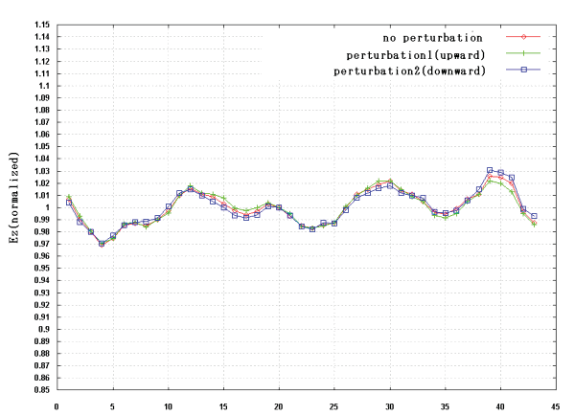

Figure 6: Field distribution with post-couplers.

After adjusting the post-coupler's length finely, the tabs of a part of post-couplers were tilted in order to improve the uniformity of the field distribution. Finally distribution of accelerating field without perturbation is achieved (figure 7). The maximum deviation and the standard deviation of the distribution are approximately 0.5% and 0.16%, respectively. The effect of perturbation on the field distribution is as small as (figure 6).

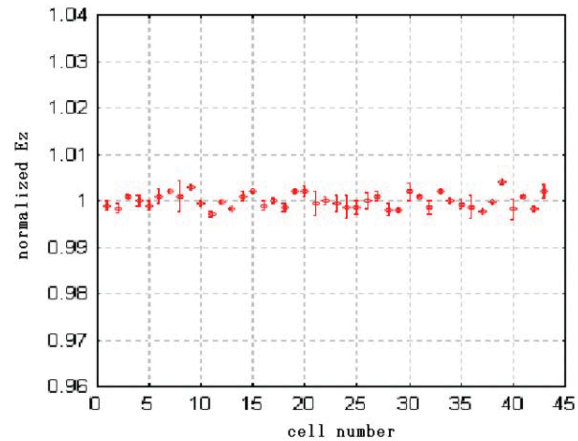

Figure 7: Field distribution after fine tuning (Error bar: 1 sigma).

CONCLUSION

The RF properties have been measured for DTL-2 of the J-PARC linac. As a result, sufficiently high Q_0 value of about 47000 has been confirmed. The value is more than 80% of the calculated one. The stabilized and uniform accelerating field has been achieved by the fine adjustment of post-coupler's length and rotation of tabs. The standard deviation of the field distribution is 0.16%.

The measurement of the RF properties for DTL-3 is in progress.

REFERENCES

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