TUNING OF THE RF FIELD OF THE DTL FOR THE J-PARC

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Abstract

Tuning of the accelerating field of the DTL first tank for the Japan Proton Accelerator Research Complex (J-PARC) has been done. The first DTL tank consists of 75 full drift tubes, 37 post-couplers and 10 fixed tuners. The resonant frequency of the tank is 324 MHz. An 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 for each accelerating gap, the following techniques have been applied for the post-coupler tuning: (1) non-uniform insertion length of the post-coupler from the tank wall; (2) increment of the diameter of several post-couplers. The recipe of the fine post-coupler tuning is described.

INTRODUCTION

The construction of Japan Proton Accelerator Research Complex (J-PARC) has been started[1]. 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 a 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 the 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 the three independent tanks of which the length is about 9 m. Furthermore each tank is comprised of three short unit tanks ($\sim$3 m in length). The inside diameter of the tank is 560 mm. The resonant frequency is 324 MHz. Each drift tube (DT) accommodates the tunable electromagnetic quadrupole.

For the first tank (DTL-1), which accelerates the beam from 3 MeV to 20 MeV, the assembling of the tube and the tuning of the post-coupler have been completed.

The tuning of the post-couplers were not so simple. In the following section we describe the situation of our DTL-1 rf properties and the tuning procedure of the post-couplers in detail.

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STRUCTURE OF DTL-1

The DTL-1 has 75 full-size DTs and two half-size DTs. The drift tube is 140 mm in diameter. Bore diameter of the DT is 13 mm till the lower energy side of the 57th DT, and it changes to 18 mm from the higher energy side of the DT to the last DT in DTL-1.

The layout of the tuners and the input couplers are shown in figure 1. The first and third unit tanks have four fixed tuners. The second unit tank has two fixed tuners and also has two movable tuners. Diameter of the tuner is 80 mm. There are two power input ports 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.

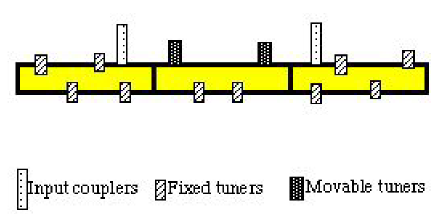

Figure 1: Layout of the tuners and the input couplers.

ADJUSTMENT OF THE TUNERS

The accelerating field measurement has been done by using a bead-pull perturbation technique[2]. Initial field distribution of the TM_{010} mode without the tuner and the post-coupler is shown in figure 2 and the bullets (•) in figure 3. The former is the raw data and the latter is the calculated average field for each cell. The ordinate of figure 2 shows the frequency shift at each point on the beam axis. (The left side of the abscissa is the beam injection side.) The results show the non-uniform distribution of the field. One of the reason for the non-uniformity is the systematic increment of the inside diameter of the unit tank. However more precise investigation is required to explain the field distribution.

The DTL tank has two movable tuners and 10 fixed tuners as described above. The length of each fixed tuners was adjusted in order to obtain the uniform accelerating field along the beam axis. (During the tuning, the ”fixed” tuners are replaced by the ”movable” model tuners.) The circles (○) in figure 3 show the accelerating field for each gap along the beam axis after the adjustment of the tuners. Here, no post-couplers are used. The resonant frequency is 323.72 MHz which is approximately 100 kHz lower than the desired value. The length of each fixed tuner is shown by bullets (•) in figure 4. As shown in figure 5, which plots the frequency shift of the tank by a tuner, the length of the last four tuners are almost maximum. Because the last four tuners can not be inserted more, other 7 tuners have to be inserted more in order to increase the tank frequency. Consequently the accelerating field distribution tilts by the unbalanced tuner effect along the tank.

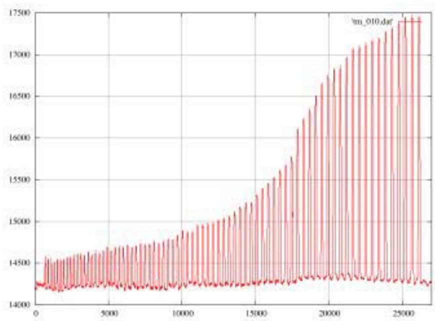

Figure 2: Measured frequency shift along the beam axis. (TM_{010} mode. No post-couplers and tuners)

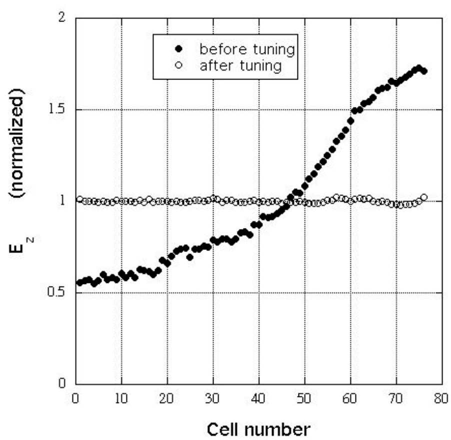

Figure 3: Accelerating field for each cell.
•: without tuners, calculated from data of figure 2.
○: after tuner tuning.

There are three methods to decrease the length of the last four tuners: (1) decrease the diameter of the third unit tank; (2) increase the diameter of the tuners; (3) increase the diameter of the post-couplers. Although the first and the second methods are standard techniques, it was very hard to apply to our cavity since the tank has been assembled. Thus the last 13 post-couplers have been rebuilt with a modified design shown in figure 6. Finally the distribution of the tuner length has been improved as shown by circles (○) in figure 4. In this case, the resonant frequency is 323.81 MHz with the correction of the volume increment of the post-coupler[3].

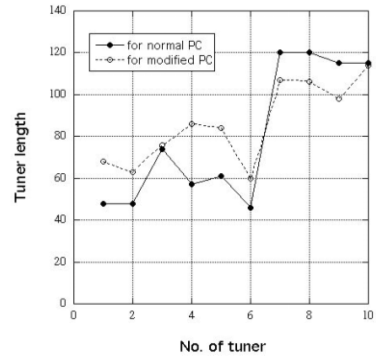

Figure 4: Length of the tuners.
•: for normal post-couplers.
○: for modified post-couplers.

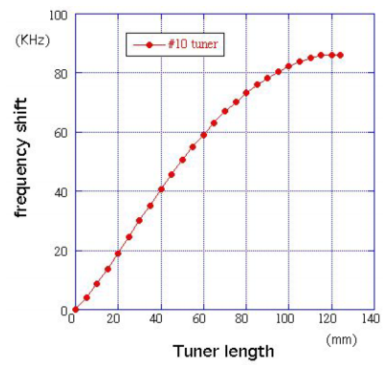

Figure 5: Frequency shift by a tuner.

TUNING OF THE POST-COUPLERS

The length of the post-couplers, which include the modified-shape ones, has been adjusted by the measurement of the distribution of the average electric field for each gap along the beam axis. The initial adjustment of the post-couplers has been done by keeping up the length of all post-couplers constant.

For the field stabilization of the TM_{010}, the field distributions on the beam axis of the nearest neighbor modes, which are TM_{011} and the mode of the highest resonant fre-

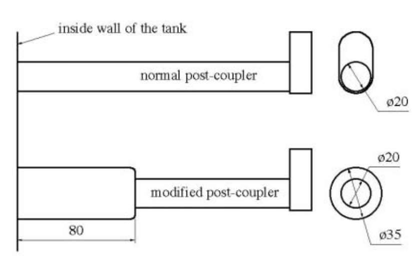

Figure 6: Design of the post-coupler.
(upper) normal post-coupler.
(lower) modified post-coupler.

quency in the post-coupler modes (it is called PC_1" mode in this report), should be almost same as each other. However, both modes have different field distributions on the axis as shown in figure 7 after the adjustment by the post-couplers with the uniform length. As a result, it has been confirmed by the measurement that the field stabilization of the TM_{010} is not so strong against perturbation in this case.

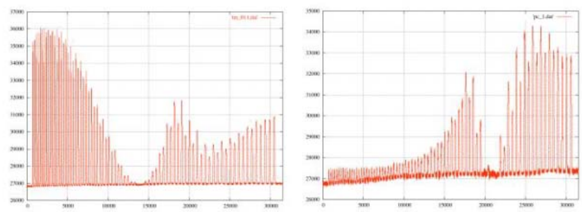

Figure 7: Measured frequency shift along the beam axis with the post-couplers of the uniform length. (left): TM_{011} (right): PC_1

Consequently it was known that the tuning of the post-coupler has to achieve the following two subjects simultaneously: (1) close the stop band between the dispersion curve of the post-mode and that of the TM-mode[4]; (2) increase the similarity between the field distribution of the TM_{011} and that of PC_1 mode along the beam axis.

As the tuning of the post-couplers with uniform length did not succeed, the length of the post-coupler was varied along the beam axis. During the tuning, the resonant frequency of the localized post-coupler mode in each cell calculated by MAFIA was very useful as the initial values of the setting. The adjusted length of the post-couplers is summarized in figure 8. The distribution of the TM_{011} and PC_1 modes was improved as shown in figure 9.

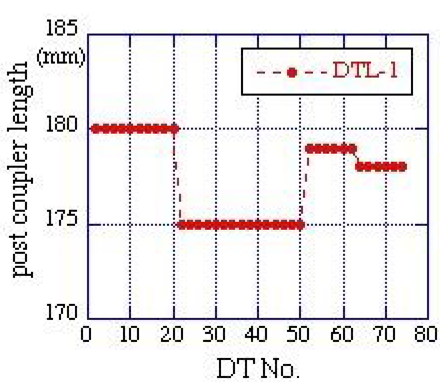

Figure 8: Final insertion length of the post-couplers.

After the fine adjustment of the post-couplers length, the tub of several post-couplers was tilted in order to improve the uniformity of the field distribution. The final result of the field distribution is shown in figure 10. The maximum deviation and the standard deviation of the distribution are approximately 2% and 0.6%, respectively. The distribution is not changed even if the tuner perturbation is applied.

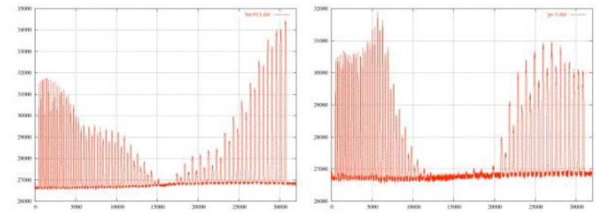

Figure 9: Measured frequency shift along the beam axis with non-uniform insertion of the post-couplers. (left): TM_{011} (right): PC_1

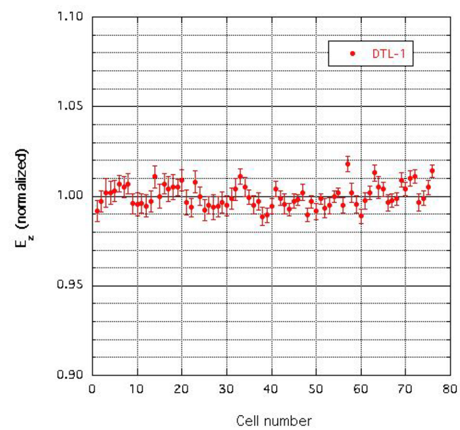

Figure 10: Accelerating field for each cell. (Error bar: 1 σ)

CONCLUSION

The post-coupler tuning has been done for the DTL-1 of the J-PARC project. The tuning required the fine adjustment of post-couplers. The good measure of the tuning is the similarity between the shape of the field distribution of the TM_{011} and that of PC_1 along the beam axis. The tank has been installed in the tunnel of the test facility in KEK for the high-power test and the beam experiment.

REFERENCES

[1] F. Naito, et al, "The KEK/JAERI joint project; Status of design and development", Proc. of LAC2002, Gyeongju, Korea, to be published.

[2] S. Okumura and A. Swenson, "Bead perturbation measurement for the KEK linac cavity", KEK-report, KEK-74-15 (1975).

[3] F. Naito, et al, "Mechanical and rf properties of the DTL for the JAERI/KEK joint project", Proc. of LAC2002, Gyeongju, Korea, to be published.

[4] J. Ungrin, S. O. Schriber and R. A. Vokes, "Post-coupler and stem current measurements for high current cw drift-tube linac", IEEE Trans. Nucl. Sci. NS-30, 3013 (1983).