THE DTL/SDTL ALIGNMENT OF THE J-PARC LINAC

T. Morishita#, H. Asano, T. Ito, A. Ueno, and K. Hasegawa, JAEA, Tokai, Ibaraki 319-1195, Japan
F. Naito, E. Takasaki, H. Tanaka, K. Yoshino, and M. Ikegami, KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

The required alignment accuracy in the J-PARC linac is 0.1mm in transverse direction. In the DTL/SDTL section, the fine alignment was carried out by using an optical alignment telescope along with the cavity installation. The displacement of the DTL by the unit tank connection was monitored by a laser tracker to obtain the tolerable displacement between unit tanks. The heights of cavities and magnets were compensated form the local settlement of the linac tunnel.

INTRODUCTION

J-PARC linear accelerator components have been installed and the beam commissioning has been started in Nov. 2006. The length of the straight section is about 300 m which consists of the ion source (IS), the radio frequency quadruple linac (RFQ), the drift tube linac (DTL), separated type DTL (SDTL), and the beam transport line [1]. Precise alignment of the accelerator components is essential for high quality beam acceleration. The outline of the alignment scheme for J-PARC linac was presented in the previous paper [2]. Following the planned scheme, metrological survey and floor making of the linac building has been performed for the primary alignment on the installation phase [3]. The local settlement of the accelerator tunnel has been worried because the J-PARC site stands on the sandy ground with abundant ground water. Since the beginning of the installation, the height elevation of the tunnel floor has been carefully watched.

In this paper, the alignment procedure for the DTL/SDTL section and the final results of cavities and magnets are described.

DTL / SDTL ALIGNMENT AT THE INSTALLATION

The tolerances of the DTL and the quadruple magnet are 0.1 mm for both of transverse and longitudinal direction. The transverse tolerance of the SDTL cavity is 0.3 mm. Even in the installation phase, good linearity is required especially for DTL, because the clearance for the final alignment is very small due to heavy wiring for DTQ's.

The floor markers, which act as the horizontal reference, have been set on at the entrance of the DTL and at the exit of the SDTL [3]. The DTL cavities, the SDTL cavities, and the quadruple magnets have been aligned along the line of these two floor markers. For the installation of the DTL and the SDTL tanks, an alignment telescope (Farrand Optical 95360) was used to secure linearity between neighbouring tanks. However it is necessary to arrange the alignment reference closely due to the limitation of visibility of the telescope. The relay points for the alignment are fixed along the line by long-base measurement with a total station (TDA5005 Leica Geosystems AG). The telescope axis is aligned along the reference targets, which are held above the relay points at the beam height.

DTL ALIGNMENT

The DTL section is about 30 m long in which three DTL cavities are aligned. The installation of the DTL and SDTL started form the lowest energy part. The DTL cavity consists of three unit tanks. The alignment of DTL has been performed with the following steps.

Step 0: The DTQ's in a unit tank is aligned using a template. This step is performed off line.

Step 1: The optical alignment telescope is aligned on the reference line that is set up from the floor marker. The reference line is set up with a long base-line measurement using a high-precision total station to keep the reference line from gradually sheering away from the ideal line.

Step 2: The unit tank is aligned on the reference line with an optical target on the same template with Step 0, which ensures that the DTQ's in the unit tank are also aligned on the same line. In this stage, the unit tanks are placed with gaps from the neighboring unit tanks to accommodate the template.

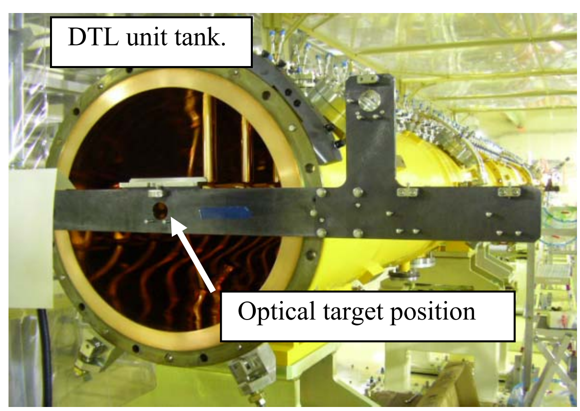

Figure 1: DTL unit tank and template for the alignment target holder.

Step 3: The template is removed and the gap is closed to connect unit tanks. In the connection, the unit tank is slid on a linear rail placed on the girder. The linear rail is aligned to be parallel with the reference line in advance, so that the unit tank does not go off to the side during the sliding.

takatoshi.morishita@j-parc.jp

The amount of the transverse shift during the connection is monitored with a laser tracker (LT600 Leica Geosystems AG). The target for the laser tracker is placed on the reference base, which are installed on the outside of the cavity, on the unit tank shown in Fig. 2.

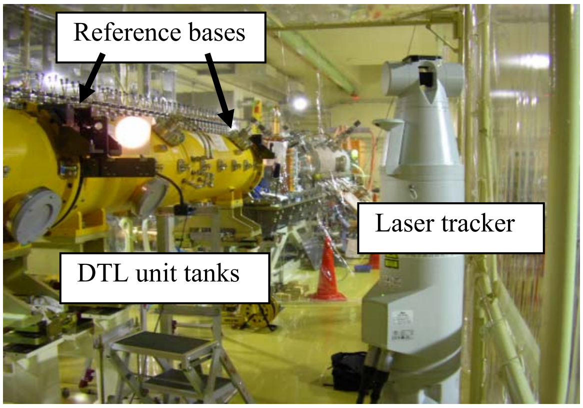

Figure 2: Laser tracker and reference bases on unit tanks.

By comparing the transverse position of the tank before docking with that after the docking, the unit tank displacement has been evaluated. Figure 3 shows the relative displacement at the unit tank connection after the docking of DTL 1, 2, and 3. In the vertical axis, x and y shows the directions of horizontal and vertical, respectively.

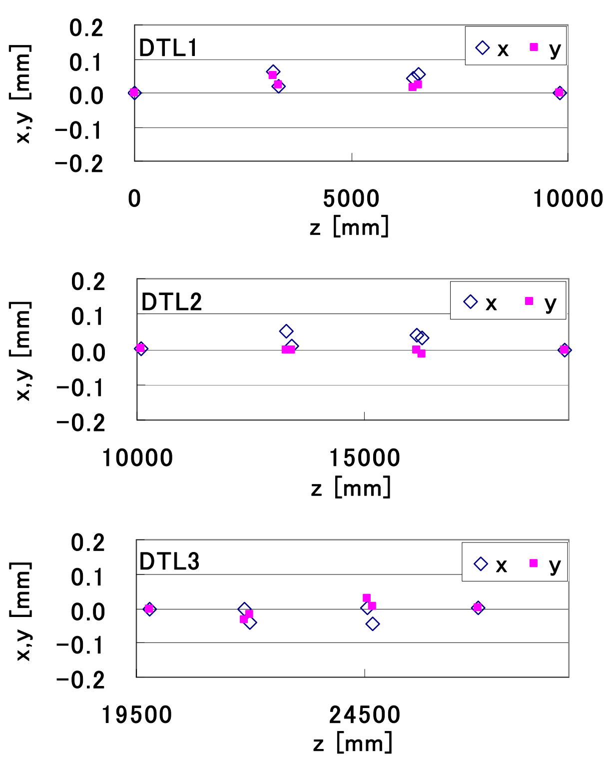

Figure 3: Displacement of unit tanks by docking for DTL 1, 2, and 3.

By the docking, at first, the displacement of approximately 0.1 mm was detected at some joints of the unit tanks. Then, the docking has been retried a few times to finally obtain the displacement of less than 0.06 mm as shown in Fig.3. Assuming the measurement errors of the telescope and the laser tracker are 0.03 mm, the maximum error of this series of DTL alignment becomes $0.06+\sqrt{0.03^2+0.03^2}=0.1$ mm, which is tolerable for the transverse accuracy as noted before.

SDTL ALIGNMENT

The SDTL cavities and quadruple magnet are aligned with the same procedure with the DTL. The length of SDTL section is about 90 m. The ground motion and the tunnel deformation of the new building have been anticipated. Then, the settlement of the tunnel floor has been measured during the DTL/SDTL installation. The vertical markers are placed with the intervals of 10 m on the base plate, on which the platforms of DTL/SDTL cavities are mounted. The heights of these markers have been measured with a digital level (DNA03, Leica Geosystems AG) with the intervals of two weeks. Figure 4 shows the elevation of these markers from Oct. 2005 to Jul. 2006. The uppermost marker (at RFQ) was taken as the reference point.

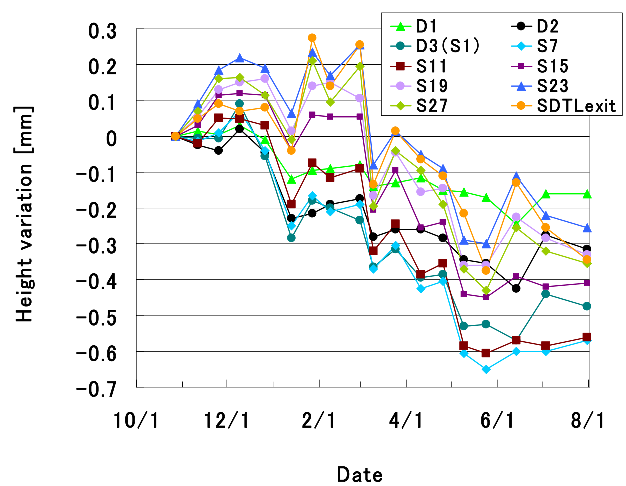

Figure 4: Elevation of vertical markers measured since Oct. 2005. Horizontal axis is the measured date and vertical axis is the height change from Oct. 2005.

The period of the SDTL installation is from Nov. 2005 to Mar. 2006. During this period, the local settlement was observed as shown in Fig. 4 and the height difference between highest and lowest marker was about 0.5 mm. Since the early stage of the SDTL alignment, we have recognized this local settlement, and then the height of the reference for SDTL alignment was adjusted to compensate it. Additionally, we have compensated the earth curvature. The total length of the straight section of the J-PARC linac is more than 300 m, the earth curvature compensation is about 2 mm / 150 m.

In the whole SDTL section, 60 quadruple magnets have been installed in total. Figure 5 shows the relative height of all magnets in the SDTL section measured just after the SDTL installation. The horizontal axis is the numbers of magnets and the solid curve is the ideal height including the earth curvature. As a result, all magnets are aligned smoothly along the ideal height.

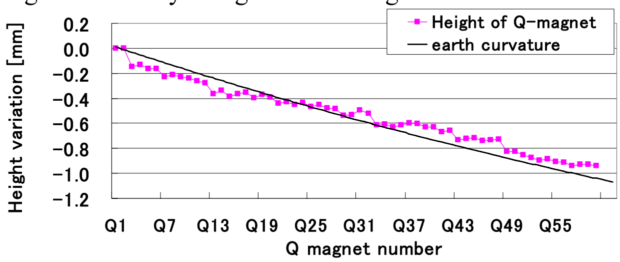

Figure 5: Relative heights of all magnets in the SDTL section. Dots are measured height and solid curve is the earth curvature.

At the upstream side of SDTL section, the heights of Q-magnets are slightly lower than the down stream side. This disagreement have caused by the local settlement during the installation. Figure 6 shows the height elevation of the vertical marker as a function of the position, where the SDTL section locates from 30 m to 120 m. These plots represent the height change form the start of elevation watching. From 26th Dec. 2005 to 24th Mar. 2006, we have observed the settlement on the upstream side of the SDTL section.

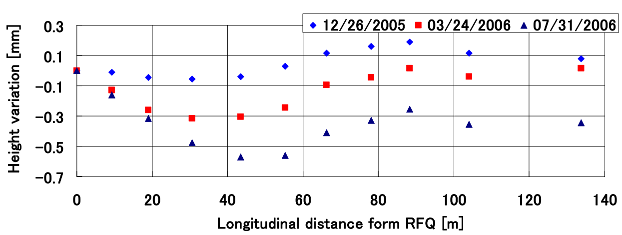

Figure 6: Height elevation of the vertical marker. Horizontal axis is the longitudinal position of the marker.

Before the beam commissioning, the precise survey and re-alignment have been performed from Jul. 2006 to Sept. 2006, where the additional reference points have been placed on the tunnel wall to build a horizontal survey network. Based on the precise survey, re-alignment of unacceptably displaced magnets and cavities has been performed as described in [4]. After this re-alignment, the height of the DTL cavities and Q-magnets in the straight section are shown in Fig. 7. The solid curve shows the earth curvature. On the upstream end, the disagreement of 0.7 mm from the ideal curve is seen. The value of this displacement is consistent from the vertical marker measurement at 31st Jul. 2006 as shown in Fig. 6. The magnitude of this monotonous deflection is sufficiently in the tolerable range. We have emphasised on attaining the smoothness between adjacent magnets without correcting above disagreement. For the same reason, about 0.5 mm displacement at the downstream side was not corrected.

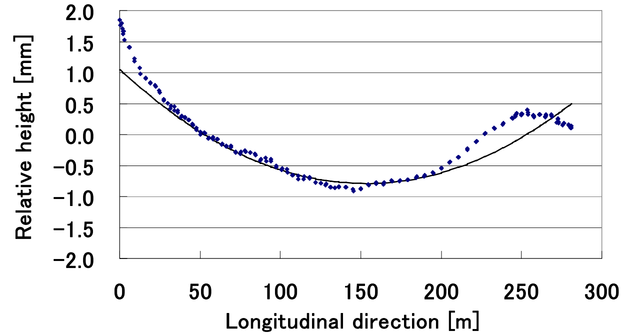

Figure 7: Relative heights of the DTL cavities and the quadruple magnets in the linac straight section.

SUMMARY

The alignment procedure of the DTL and the SDTL is described, where the cavities and magnets were aligned by utilizing the telescope. The DTL unit tanks have successfully connected, which has been confirmed by monitoring the transverse positions of the reference bases with a laser tracker. For the vertical alignment, the height of the optical targets, which produces the axis of the telescope, has been aligned with compensating the local settlement of the accelerator tunnel. Finally, all the cavities and magnets are aligned within the tolerable alignment error. Excellent beam transmision has been obtained in the early stages of the beam commissioning [5].

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REFERENCES

[1] Y. Yamazaki (eds), “Accelerator Technical Design Report for J-PARC”JAERI-Tech 2003-044; KEK-Report 2002-13.

[2] M. Ikegami *et al.*, Proc. of LINAC2004., August 2004, p474, (2004).

[3] T. Morishita *et al.*, Procs. of 2005 Particle Accelerator Conference, Knoxville, Tennessee, USA, p. 2851, (2005).

[4] T. Morishita *et al.*, ‘THE PRECISE SURVEY AND THE ALIGNMENT RESULTS OF THE J-PARC LINAC’ , in these proceedings.

[5] K. Hasegawa, ‘COMMISSIONING OF THE J-PARC LINAC’, in these proceedings.

