J-PARC LINAC ALIGNMENT

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Abstract

J-PARC lianc has the total length of more than 400 m including the beam transport line to the succeeding synchrotron. In this paper, planned schemes for the linac alignment is presented together with instrumentation for the long-term ground-motion watching.

INTRODUCTION

J-PARC linac has the total length of more than 400 m including the beam transport line to the succeeding RCS (Rapid Cycling Synchrotron) [1, 2]. In high-current proton accelerators, precise alignment of accelerator components is indispensable to reduce uncontrolled beam loss and beam-quality deterioration. It is of essential importance to achieve precise alignment and to maintain its long-term accuracy for realization of the high-power proton beams.

Although we originally planned to develop a laser-based alignment system for J-PARC linac [3], we totally revised the alignment scheme to reduce construction cost and R&D burden. Main difficulty in the original system was the avoidance of the effect of air-turbulence on the measurement. It was also anticipated to be difficult to use the system for continuous observation of the alignment, because its silicon-photo-diode sensors are supposed to be vulnerable to radiation damage. In the revised system, the emphasis is put on the continuous watching of the ground motion as well as the accuracy of the initial alignment. In this paper, the revised alignment scheme for J-PARC linac is described.

ALIGNMENT GOALS

Tolerances for the transverse displacement from the design axis, Δx and Δy, the longitudinal displacement from the adjacent elements Δz, and the roll error, θz, are listed in Table 1. These tolerances are not margins for the alignment procedure, but include various errors in the machining and assembling procedures of a component. The requirement for the transverse displacement of quadrupole magnets, including DTQ (Drift Tube Quadrupole), is especially severe to avoid orbit distortion and resulting emittance growth. However, it has been confirmed that a gradual deflection of the alignment axis is tolerable, and the tolerance for the monotonous deflection is around 0.05 mm/10 m.

INITIAL ALIGNMENT

Link to the Global Survey

Before the commencement of the accelerator alignment, we need to know the relative position of the linac building with the other J-PARC buildings. To this end, we set up a metrological network on the ground which covers the whole J-PARC facility. It also has a few GPS (Global Positioning System) measurement points to link with a global coordinate system. Because the metrological network is set up on the ground level, we need to have access holes to the linac accelerator tunnel (that is located at 13.5 m underground) to introduce the coordinate. We have three access-holes to the linac accelerator tunnel from the ground level (klystron gallery). Just below the access-holes, we have three "primary reference points" for the linac tunnel, which will be the starting points of the linac tunnel survey. Through the access-holes, the height reference of the whole J-PARC facilities is also introduced into the linac tunnel.

Alignment Reference on the Components

The horizontal and longitudinal alignment are planned to be performed with a laser-tracker. Although a laser-tracker can be used for the vertical measurement, we plan to use a digital level (Leica DNA03) for the vertical alignment to improve the accuracy [4, 5]. As a back-up scheme for the horizontal alignment of straight sections, we are preparing a stretched-wire method with capacitive wire-position sensors (Fogale nanotech WPS2D). In addition, we will use an alignment-telescope (Taylor-Hobson 112/2582) in pre-alignment of the accelerator elements. The rotation about the beam axis will be avoided with a digital inclinometer (Wyler Minilevel NT). To enable these alignments, each accelerator element has "alignment reference bases" which are standardized for J-PARC accelerators. The alignment base is a stainless steel plate which has a standardized reference hole at the center of its top surface. The position of the reference hole is adjusted to a certain position with respect to the beam axis before the installation of the component. Various targets, including a CCR (Corner Cube Reflector) for a laser-tracker, an optical target for an alignment telescope, a leveling staff for a digital level, and a capacitive wire-position sensor, can be mounted on the reference base via dedicated attachments with precise position reproducibility. Figure 1 shows an example of these attachments, in which a drawing of a wire-position-sensor holder for DTL and SDTL tanks is shown. To attain the precise position reproducibility, we use a preside attach/detach sys-

Table 1: Tolerances for alignment

	Δx, Δy	Δz	θ_z
DTQ, quadrupole magnets	±0.1 mm	±0.1 mm	±5 mrad
SDTL tanks, other RF cavities	±0.3 mm	±0.1 mm	

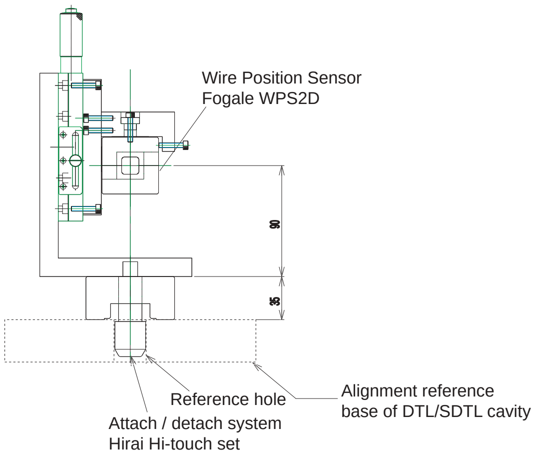

Figure 1: A wire-position-sensor holder for DTL and SDTL tanks.

tem (Hirai High-touch set) for these attachments.

Horizontal and Longitudinal Alignment

The concept of alignment with a laser-tracker is shown in Fig. 2. The procedure is conventional, in which a laser-tracker is placed at a position (red circle in Fig. 2), and measure the positions of reference bases and wall monuments, and then it is moved to the next position (blue circle). Some of the measurement points for the new tracker-position are overlapped with the previous ones in order to find out the movement of the laser-tracker itself. Repeating this procedure, the whole linac and the beam transport line will be covered. Each element, i.e., RF cavities, quadrupole doublets, has two or more reference bases for a CCR.

The main concern in using a laser-tracker for linac alignment is the possible gradual deflection of the alignment axis, which might be resulted from the insufficient accuracy of angular measurement [4]. The narrow tunnel width is also an obstacle to setup a secure metrological network sustainable for the measurement errors. Our strategy is to setup a fine metrological network which minimizes the statistical errors of the coordinate measurements with geometrical considerations [6]. If we find an unacceptably large deflection of the alignment axis (which is supposed to be detected with an alignment-telescope), we plan to use a WPS (Wire Positioning System) for the horizontal alignment of the straight section (in which case, the longitudinal alignment can be performed with a tubular inside-micrometer). Figure 3 shows a conceptual view of alignment with WPS. A stretched wire is located above the ref-

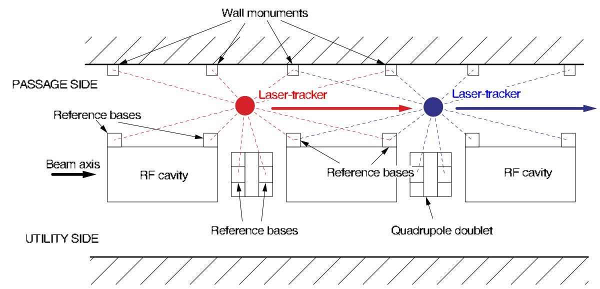

Figure 2: Conceptual view of alignment with a laser-tracker.

erence bases for DTL and SDTL tanks. A WPS sensor is placed on the reference base with a removable attachment. The attachments for the quadrupole magnets have a long arm, because the reference bases for quadrupole magnets are located above the beam axis which is 460 mm horizontally from the wire axis. We prepare several sets of WPS attachments, and we measure the horizontal position of each element utilizing them. The maximum length of a stretched wire is 120 m, and DTL (27m) and SDTL section (90 m) can be covered with one wire. A stretched wire can cover the ACS section (107 m) also. To avoid the tilt between these two wires, we plan to set up an additional wire which overlaps with these two wires [4]. We also plan to use WPS for the halo scraper section after the first arc of the beam transport line.

Vertical Alignment

In the vertical alignment, we plan to use an HLS (Hydrostatic Leveling System) as the reference in order to avoid accumulating errors of the height measurements. We plan to install 13 HLS sensors (Fogale nanotech HLS) along the linac and the beam transport line between the linac and the succeeding RCS. Figure 4 shows the schematic layout of the HLS sensors. Spacing between HLS sensors is about 50 m, except for the vicinity of expansion joints and a partition wall where sensors are densely populated. The HLS sensors are fixed on steel base plates on which accelerator components are placed, and the base plates are fixed to a structural concrete slab of the tunnel floor. Based on the communicating vessel principle, the height difference among sensor positions can be obtained by measuring the difference of the water levels. The HLS sensor has a high-precision capacitive water-level sensor and a reference sphere nest for connection to the metrological measurement.

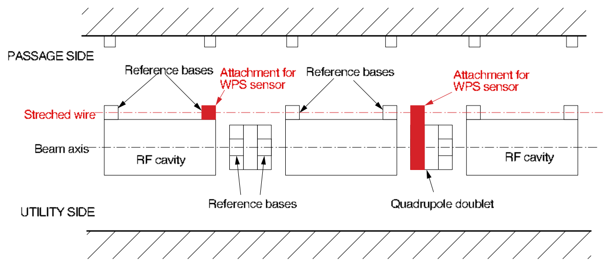

Figure 3: Conceptual view of alignment with WPS.

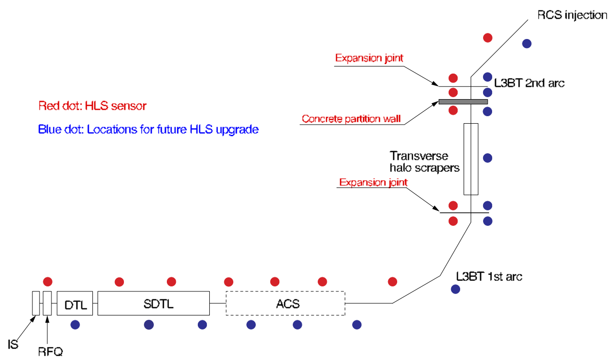

Figure 4: Schematic layout of HLS sensors.

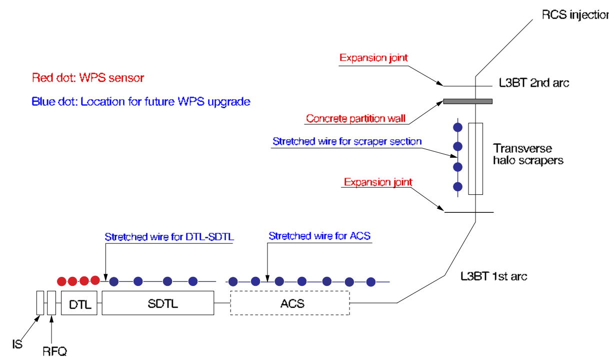

Figure 5: Schematic layout of WPS sensors.

CONTINUOUS WATCHING

We plan to use HLS sensors and WPS sensors for continuous watching of the ground motion. The HLS sensors installed as the reference for vertical alignment will be used for this purpose. The HLS sensors are densely populated in the vicinity of the expansion joints to closely watch the movement bordering the joints. We also plan to place some WPS sensors, which has been prepared as a back-up for horizontal alignment, for the continuous monitoring. Figure 5 shows a schematic layout of the WPS sensors for the continuous watching. Because we don't have enough sensors, we plan to focus on DTL section at the beginning, and then increase the number of sensors and extend the coverage to downstream sections.

The sensor electronics of both HLS and WPS are separated and placed in the sub-tunnel to avoid radiation damage. The cable between a sensor and sensor electronics is extended to 20 m to enable these layout. While the cable extension increases the noise level, the resulting deterioration ofthe sensor resolution is expected to be around $\pm 4\mu$m, which is negligible for our purpose.

To watch more large-scale movement, i.e., relative movement between the linac building and the RCS building, we utilizes the access-holes mentioned above. Using these access-holes we can measure the relative position between the linac tunnel and other J-PARC buildings. Performing metrological measurement using these access-holes occasionally, the large-scale movement of J-PARC facilities can be measured.

The data obtained with the long-term monitoring will be used for realignment scheduling and, possibly, a slow feedback of the beam orbit correction.

SCHEDULE

Metrological measurement of the accelerator tunnel and marking for component installation will be performed in March 2005. The installation of main components will be started in May 2005. The fine alignment will be performed in May-June 2006. Fundamental testing of HLS sensors and WPS sensors has been started.

SUMMARY

We plan to perform J-PARC linac alingment with a laser-tracker (horizontal and longitudinal) and a digital level (vertical), basically. As a reference for the vertical alignment, we prepare HLS sensors along the linac. We prepare WPS sensors as a back-up method for the horizontal alignment. We plan to use the HLS sensors and WPS sensors also for the long-term monitoring of the floor motion.

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