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LINAC ALIGNMENT FOR SUPERKEKB INJECTOR

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Abstract

The KEKB injector linac is now under upgrade for the SuperKEKB, where the required local alignment is 0.1mm in sigma. The straight line as a reference for the alignment was defined by a laser beam over 500m and the girders are set with respect to this reference line. Then the hard wares on the girder are set with respect to the girder reference position by using a laser tracker. This alignment method should give us in principle the misalignment evaluation equivalent to the required level of 0.1mm. In this paper we show the present status of the installation/alignment of newly installed positron production section in addition to the improvement on the existing part. Through it we discuss the measurement method confirmation and strategy toward meeting the alignment requirement. On the other hand, we noticed that the tunnel floor moved in the range of 0.1mm or more over months. We report briefly the test evaluation of the movement and discuss the possible scenario to cope with the movement.

INTRODUCTION

The alignment of the hard wares is one of the key issues for preserving the beam emittance through a long linac. Comparing to the KEKB, the injector linac for the SuperKEKB ring is required to supply several times higher charge with the emittance of an order of magnitude smaller, 10 – 20 micron [1]. To this end, the local alignment is required to be within 0.1mm in sigma over at most 100m, while globally 0.3mm in sigma, over the whole linac extending to several hundred meters [2]. Considering as much as a millimetre level of misalignment left as of KEKB era, we need a quite improvement for the SuperKEKB to meet the above stringent requirement.

The effort toward improving such big misalignments has long been pursued but could not be fully realized and the alignment actually became completely deteriorated after the East-Japan earthquake in March 2011 [3]. To date we have been paying an enormous effort to realign the existing components and install new components with keeping the new requirement in mind.

The straight reference line is defined by a new laser system running over 500m [4]. Firstly the girders, typically 10m long, were aligned to this reference line. Then the hard wares on the girder are aligned with respect to the girder by using a laser tracker. In principle, the local alignment can later be improved by measuring the hard wares directly by a tracker system over a few girders, 10 – 30m region.

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On the other hand, we understand that the tunnel floor moves daily in several tens of microns and we are afraid that it may develop to a fraction of a millimetre or even above a millimetre over months [5]. We briefly report the ongoing evaluation of the movement and discuss the possible development scenario to cope with the existing floor movement.

ALIGNMENT PROCESS

Requirement

The alignment procedure was designed with the nominal required values, local 0.1mm sigma and global 0.3mm sigma, in mind. The transverse wake field leading emittance growth is severe and it puts more weight on the accelerator structure alignment.

We assume the definition of “local” to be the order of the betatron wave length, several tens of meters. Since the size of the girders is about 10m for a unit carrying 4 accelerator structures, the local alignment spans over several units. On the other hand, the “global” means up to 500m. This puts the requirement to the whole linac composed of two linacs, the initial 120m one connecting through 180 degree turn around to the second 500m-long one.

Basic Alignment Procedure

We took basically the same alignment procedure as that of KEKB case. This means that the girders are firstly aligned along the reference laser line and the hard wares are aligned on each girder with respect to the mechanical reference lines and planes on each girder. However in the present case, the hard wares can be measured by the laser tracker so that they can be adjusted independently as needed.

This laser tracker measurement cannot be used for the long distance measurement, but it serves the better misalignment information of the hard wares irrespective of the girder position. Therefore, such measurement over a few accelerator units, extending 20 – 30m, can be used in future to improve the local alignment.

Many of the Q magnets are located between two girders and were not aligned independently. However we started the magnet measurement by installing the reflector base for the tracker measurement in addition to the beam based alignment so that we will adjust then independently as needed.

Reference Line Defined by Laser Beam

The alignment requirement can basically be set with respect to a line which can be along the straight line in a smooth nature. However, we defined our reference line to be straight so that the optical laser can be used to define

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the line. This makes the beginning and the end of the 500m long section to be inclined by 40 micro radians from the horizontal plane. This makes the alignment procedure there a bit complicated but the capability to set a straight line over 500m is more beneficial, especially in the initial installation process. Actually we need for the present upgrade to make the renewal of the whole positron line extending over 100m and the installation procedure became much easier by taking this straight reference.

The Gaussian profile HeNe laser is transmitted through a pipe of 117mm in diameter evacuated down to 3 Pa [4]. Since the free space in this pipe is only 50mm in diameter due to the position sensing mechanism in the pipe, the maximum laser profile is about 30mm at both ends of the 500m line. At each end of girder, four segmented photo diode detects the laser position. This system is called "laser PD" system. The sensors were deteriorated, due to radiation from the KEKB operation for ten years, and those with excessive output loss were replaced this time by new ones. We do not have any quantitative data how long the present sensors survive but they should work properly in the early stage of the commissioning.

This system was set from the beginning of the linac history so that the girders and hard wares were designed to set based on this system. We took this system even for the upgrade toward SuperKEKB, because it is for us more practical than initiating any other system. The only remaining issue is to validate the system and cope with the degradation due to the radiation.

Girder Alignment

We have two straight lines, 120m and 500m. Let us describe the 500m case to discuss the system feasibility. This system starts from the arc exit and runs through 6 sectors ending at the beginning of the beam transport. The measurement error comprises of the systematic error of 0.046mm [4] in addition to the laser beam drifting error. The latter is proportional to the laser passage to the sensor and becomes 0.04mm in sigma at the end where the laser beam position is fed back by tilting the laser pointing angle. Then, we estimated the total measurement error to be at most 0.06mm.

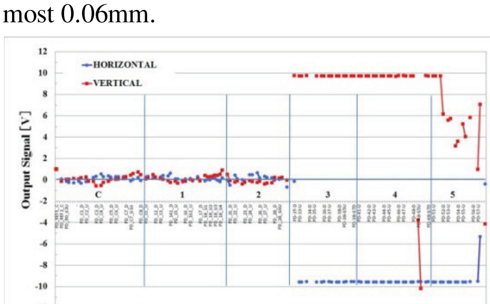

Figure 1: 500m alignment measured with laser PD. Note that the PD sensitivity varies from 1.7 V/mm at the ends to 5 V/mm near the center of the linac.

The recent measured position of the girders along 500m line is shown in Figure 1. We understand that there is a big step between sector 2 and 3, which should be corrected for SuperKEKB. Note that the line from the sectors 3 to 5 were not realigned yet, due to the frequent operation of this part for photon factories. From these examples, we understand that the initial alignment using the laser PD was successful.

Hardware Alignment on a Girder

The next alignment procedure is the setting of the hard wares on the girder. The laser PD position is mechanically moved to the position better for the laser tracker. Referring to this position, the girder upper plane or the sub-planes on the girder is set as the vertical reference, while the straight bars are set on such planes to serve as the horizontal reference position. The hard ware support is made to use with respect to these references plane and lines.

The position of the hard wares thus installed can be measured with respect to the reference position of the girder by using laser tracker. Figure 2 shows the typical measurement of the accelerator structures set in the solenoid magnet followed by Q magnets outside of the solenoid. Because of the difficulty to measure the alignment of the structure set in the solenoid, there is an additional systematic error involved, but the measured example showed probably better than 0.5mm with some exception due to measurement error or actual misalignment, which are to be analysed from now.

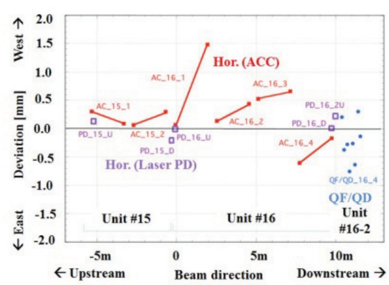

Figure 2: Measured hardware misalignment on a girder.

Issues for Improving Alignment

We believe that the hard ware alignment on a girder can be improved every time the measurement with laser tracker is repeated. In turn, the girder position can be checked by laser PD measurement. However, the deterioration of the PD sensor is not understood quantitatively. Therefore, we will need to measure again by laser tracker in a few tens of meter spans so that the local alignment, or local smoothness, will be confirmed or improved.

GROUND MOTION

Floor Structure

The linac floor base plate is supported on 30 – 40 meter pillars extending deep into the solid base with N value > 50. Such plate extending over 80m long is connected to

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the next one at the expansion joint, where the coupling is more flexible. We suspect the mechanical weakness exists mostly at such joints.

Floor Movement

To date, there are many measurements which indicate the floor movement. The relative motion between an expansion joint is shown in Figure 3. It shows the daily movement of several tens of micro meters and a possible drift of a few tens of micro meters over days. In Figure 4 is shown the difference of two measurements separated by half month using the laser tracker over a 200m distance by connecting the 10m step data. The difference clearly shows the movement at the expansion joints in the order of a fraction of 1mm. The longer-term drift may be more, though no reliable data over months were taken yet. Figure 5 shows the laser PD vertical measurement in a week along 120m line, where the expansion joint exists between sensors V18 and V20. This shows the case of 0.1mm movement in a day and more in several days. An automatic measurement system based on the laser PD is under development to quantify the long-term drift.

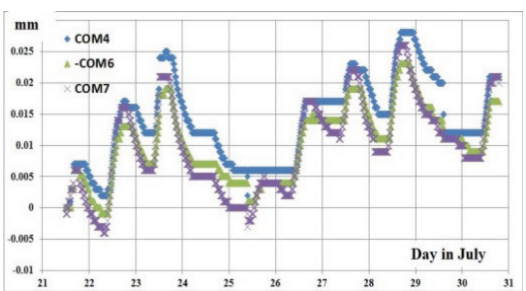

Figure 3: Relative floor motion between expansion joint.

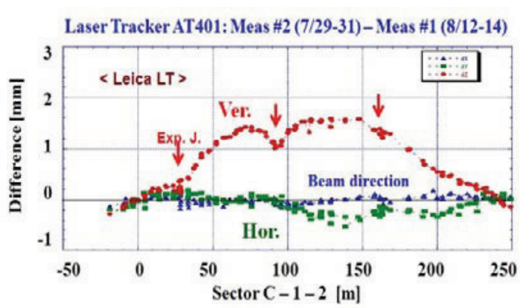

Figure 4: Difference between two tracker measurements.

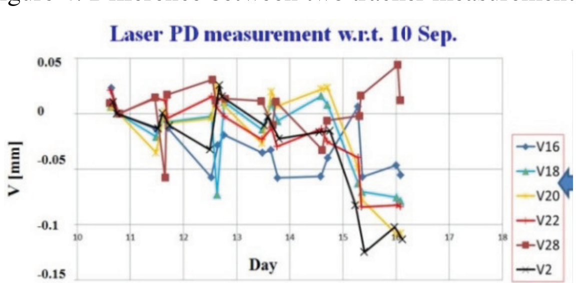

Figure 5: Laser PD measurement along 120m line.

Discussion

We understand that the measurement of the floor movement should be done in a quantitative manner over much longer term for defining the strategy.

If we have any tool to measure the ground motion reliably and continuously, we can design a system with the feedback mechanism to all the girders or hard wares. The vulnerability of the laser PD sensors against radiation is under estimation. However, the measurement technology is not yet promised and the feedback system with movers may be very costly. Therefore, we want to study the cure method with the beam-based measurement, once the better beam is realized in the linac.

SUMMARY AND PERSPECTIVE

The installation of the positron line components for the SuperKEKB has just finished and the better alignment of the hard wares than KEKB case is undergoing including the many of the existing components. The initial alignment was done with the reference laser beam. The alignment improvement may be demanded soon after the low emittance beam commissioning. The local alignment will be improved by the laser tracker measurement. The floor movement is clearly above the negligible level and some cure should be developed. Unless the beam based evaluation of the movement is done, other direct measurement of the ground motion should be utilized to feed back to the alignment.

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