ALIGNMENT OF THE TPS FRONT-END PROTOTYPE

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Abstract

The Taiwan Photon Source (TPS) is a 3-GeV third-generation source of synchrotron radiation with beam current 500 mA stored in the storage ring. A front end allows intense synchrotron light generated in the storage ring to pass through to a beamline. Most heat load of the synchrotron light is removed in the front ends to protect the beamline components. Alignment of front-end components becomes important to prevent damage from the large heat load. Because of the many front ends and the brief period of installation, the alignment work should be easy, quick and reliable. Using a shim method, the adjustable degrees of freedom are decreased from six to two. This adjustment work becomes easier and quicker. The alignment of a front-end prototype is described here.

INTRODUCTION

The TPS is a third-generation synchrotron radiation facility under construction. The electron beam stored in the storage ring, of circumference 518m, has energy 3 GeV and current 500 mA. In phase I there are seven insertion devices (ID), installed in the straight section, emitting much power of synchrotron radiation to the front end. IU22 of ID has maximum power density 46.3 kW/mrad^2 and total power 5.4 kW. EPU48 of ID has maximum total power 10.7 kW and power density 13.6 kW/mrad^2. Parts of the straight sections have two ID, doubling the power. Without suitable components to absorb the heat and to maintain accurate alignment, such great power can induce a large heat load to melt the metal.

Figure 1 shows the front-end layout of the IU22 prototype. Most power produced by the ID becomes absorbed by the absorbing heat components in the front end. The pre-mask, fixed mask, photon absorber and slit are the absorbing heat components to eliminate the useless power from the beam. The lengths of the center of the ID to these absorbing heat components are large, from 10 m to 25 m. All these absorbing heat components are surveyed within 0.25 mm from their theoretical positions.

The Laser Tracker is a powerful instrument for survey and alignment work. If we use this instrument to do the survey and alignment works of all components in the front end, it would take much time. Combining a Laser Tracker with the survey networks, the final alignment will attain 0.25-mm value. If the component has six degrees of freedom, three are axes *x*-*y*-*z* and three are angles pitch-roll-yaw; adjusting these components becomes complicated. Many methods exist for the alignment [1~4]. To decrease the degrees of freedom and to establish a local reference plane of alignment will be more efficient for the installation of the front end.

DESIGN CONCEPT

To align a component to a position, six degrees of freedom require to be confirmed. If there is a coupling effect between these degrees of freedom, the alignment work becomes more complicated. The design concept of the support in the front end involves decreasing the degrees of freedom, verifying the relative positions to a reference plane without a Laser Tracker, having fiducial holes in the components, and controlling the deviation of the height of the support and its deflection.

Decreasing the degrees of freedom

As in the direction of the beam this task is less important, we can neglect the *z*-direction. If we need to adjust the *z*-direction, the rails have period 50 mm of M10 screw hole. In the *y*-direction we use shims to compensate the height. Before installation we measure the height of all components; the thickness of the shim can thus be decided and manufactured. By using shims to compensate the height, we need not adjust the *y*-direction, roll and pitch angles. The two degrees of freedom left are the *x*-direction and the yaw angle. Figure 2 shows the design of the support.

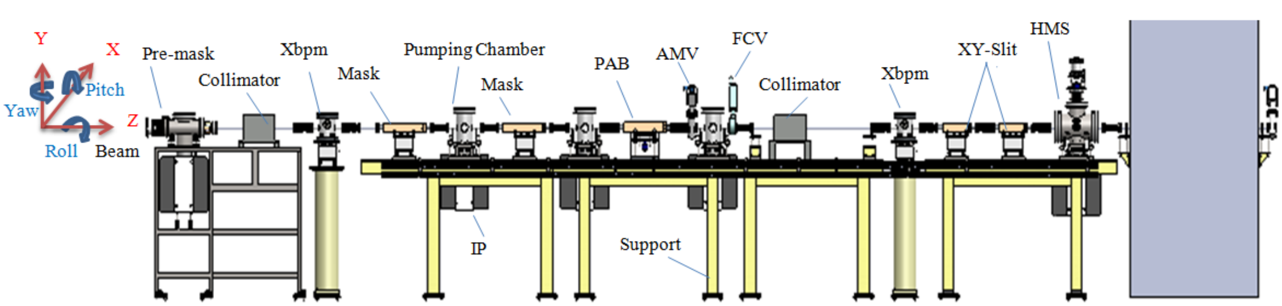

Figure 1: Front-end layout of the IU22 prototype.

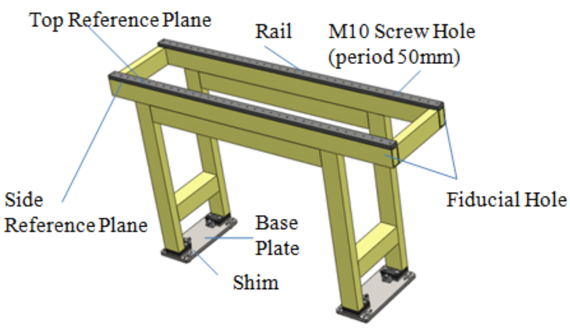

Figure 2: Support of the front end.

Reference plane on the support

The rails of the support are machined to serve as reference planes for alignment, top plane and side plane, as shown in Fig. 2. All components installed on the support are pre-aligned from the reference planes. The alignment tools are a portable measuring arm and dial gauges with a fixture. The portable measuring arm is a portable 3D coordinate measuring machine. The portable measuring arm and dial gauge are convenient and more efficient than a Laser Tracker to measure these components.

Fiducial holes

The support has four fiducial holes on the corners for the final alignment as shown in Fig. 2. All components also have at least two fiducial holes for the final alignment. The diameter of the fiducial hole is 6.35 +0.02/+0.01 mm.

Deviation of the height of the support

If the support is made of iron, the surface of the iron would have a layer of paint; this deviation of height of the support depends on the thickness of the paint. To decrease the deviation of the height, the top rail and bottom plate are made of stainless steel. The support should be strong enough to withstand the deflection and vibration. The support is designed to have maximum 0.1-mm deflection for a 100-kg loading on the support as shown in Fig. 3.

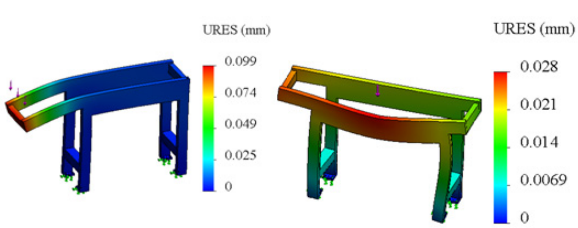

Figure 3: Deflection analysis of the support.

ALIGNMENT PROCEDURES

The alignment procedures for the front end follow. (1) Draw the center line of the beam on the ground and mark the distance value. (2) Adjust the base plate of the support to the level. (3) Measure the differences between the height from the rail plane to the base plate and to the bottom of the support before installation. (4) Use the difference value in item 3 to machine the thickness of the shims. (5) Place the shims on the base plate. (6) Put the support on the shims, (7) Survey all fiducial holes with a Laser Tracker. (8) Adjust the *x*-direction and yaw angle of the support. (9) Adjust the *x*-direction and yaw angle of all the absorbing heat components with a XY-stage.

The deviations of dimensions are surveyed from the theoretical positions. All absorbing heat components are surveyed within 0.25 mm. All chamber, pipe and bellows are surveyed within 0.5 mm. The support is shimmed within 0.1 mm. The components with the motorized XY stage can be adjusted within 0.01 mm with the stage, e.g. Slit. Figure 4 shows the XY Slit and XY stage assembly.

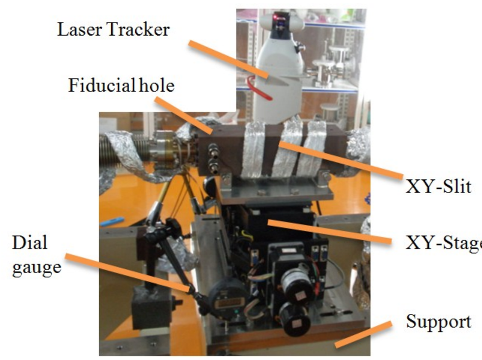

Figure 4: XY Slit and XY stage assembly.

The level of the base plate is measured with two tubular bubble levels with specification 0.1 mm/m. If we use the traditional method of three adjusting set screws and three locking hex screws, the base plate can reach a level within 0.1 mm/m under a torque of the hex screw less than 100 kg-cm. The larger is the torque on the hex screw, the greater is the deformation on the base plate. With a torque of the hex screw attaining 420 kg-cm, the level of the base plate is more than 0.5 mm/m. Using this method, the base plate is unstable and not strong enough.

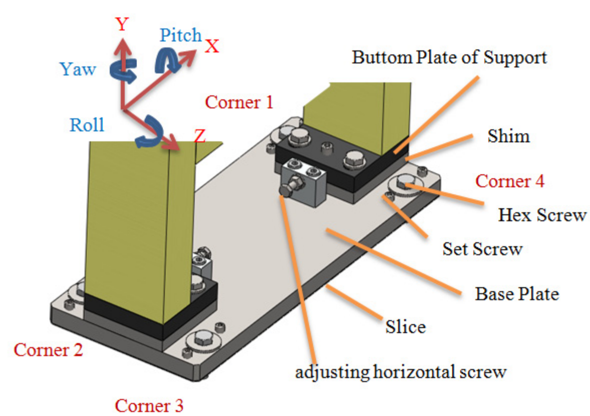

Figure 5: Design of the base plate.

Figure 5 shows the base plate of the support adjusted with eight set screws and locked with four hex screws. Numbering the four corners of the base plate from 1 to 4, the alignment procedures for the base plate follow. (1) If corner 1 is at the highest place, lock the hex screw at the corner 1 first with the torque 100 kg-cm. (2) Adjust the roll angle with the set screws and lock with the hex screw with torque 100 kg-cm at corner 2. (3) Adjust the pitch angle with the set screws and lock with the hex screw with torque 100 kg-cm at corners 3 and 4. (4) Following the sequence from corner 1 to 4, increase the torque on the hex screws, every cycle of 100 kg-cm, to torque 420 kg-cm.

The positions of each compnonet relative to the reference planes of the support are measured with a portable measuring arm and dial gauge. This combined tool is more efficient than a Laser Tracker. Figure 6 shows the portable measuring arm is measuring the flatness and height of the support on a granite surface plate.

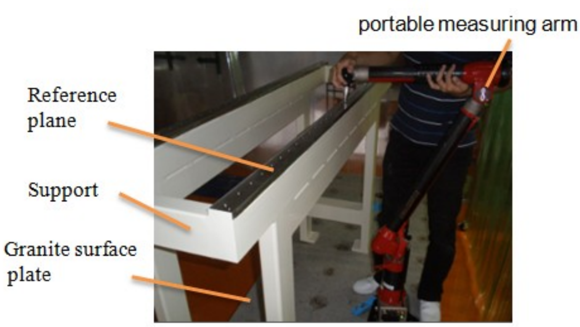

Figure 6: The portable measuring arm is measuring the dimension of the support.

RESULTS OF ALIGNMENTS

Following the alignment procedures for the base plate, the level of the base plate can be adjusted to less than 0.5 mm/m in just one cycle. Each component can be adjusted to within 0.1 mm relative to the reference planes of the support with the tool of the portable measuring arm and dial gauge. The positions of the support are measured at six positions, two horizontal and four vertical points. Although the support can be adjusted to within 0.1 mm as seen in fig. 7, the adjusting cycles need at least two to three adjusting cycles, because of the use of multiple layers of shim intead of one shim; the total thickness of the shim is inaccurate.

Figure 7: Displacement error of the reference plane on the support after alignment.

The XY stage is designed to have resolution 1 μm. We adjust the XY slit and mask to 0.01 mm easily at the beam exit port.

CONCLUSION

We have tested the method of installation of the TPS front end. The adjustment method of the base plate of the support is standardized to save installation time. Using the shim method, the adjustable degrees of freedom are decreased to two, only the x-direction and the yaw angle, for most components in the front end.

The reference planes on the rails are efficient to verify and to install the relative positions of the components. Using one accurately machined shim is better than using multiple layers of shim.

The final alignment data will be surveyed using a Laser Tracker with fiducial holes on the components. We use these data to adjust the components with the dial-gauge tool and then to survey the components again with a Laser Tracker. The results of the dial gauge and the Laser Tracker are matched because we have decreased the coupling effect of most degrees of freedom.

ACKNOWLEDGEMENT

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REFERENCES

[1] H. Aoyagi, T. Mochizuki, M. Oura, Y. Sakurai, M. Sano, S. Takahashi, And H. Kitamura, “Alignment of Photon Beamline Components of the Spring-8 Front End”, Proceedings of the 7th International Workshop on Accelerator, 2002.

[2] F.Q. Wei et. al, “Status of the SLS Alignment System”, Proceedings of the 7th International Workshop on Accelerator, 2002.

[3] J. Strachan et. al, “Front Ends at Diamond”, Proceedings of EPAC 2006, Edinburgh, Scotland 2006.

[4] Ming Ke et. al, “Alignment of the First 7 Front-Ends at SSRF”, The 10th International Workshop on Accelerator Alignment, KEK, Tsukuba, 11-15 February 2008.