ALIGNMENT OF PHOTON BEAMLINE COMPONENTS OF THE SPRING-8 FRONT END

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1. INTRODUCTION

The SPring-8 is a third generation synchrotron radiation facility, and has been opened for users' experiments since 1997. The electron beam with an energy of 8 GeV and a current of 100 mA is stored in the storage ring, which has a circumference of 1436m. Standard in-vacuum X-ray undulators produce powerful synchrotron radiations with the maximum power density of about 500kW/mrad^2 and the maximum total power of about 13 kW, typically. Stable handling of such a large emitted power and accurate position monitoring of very narrow synchrotron radiation beam are major challenges in the field of front-end engineering.

The typical SPring-8 front-end is defined as the part of photon beamline between a back end of a photon beam port of the storage ring and a beryllium (Be) window assembly installed just after the shielding wall. The photon beam from the insertion devices and the bending magnets are guided to the optics hatches by the front-end components. Figure 1 shows the layout of the front-end components for the in-vacuum X-ray undulator, which is the leading photon source of SPring-8. In the front-end there are various components, whose roles are (1) handling of the high heat load, (2) monitoring of the photon beam position, (3) protection of the ultra high vacuum of the storage ring, and (4) shielding the radiation for human safety.

As for (1) handling of the high power of the synchrotron radiation, a pre-mask and a fixed mask and a pre-slit eliminate the useless power off the beam axis. The XY-slit passes the beam with an arbitrary size without a serious lost of 1st harmonic flux density used for experiments. An axis adjustment filter (AFLT) and a graphite filter (GFLT) are for eliminating the low energy part of the radiation. An absorber operates as a shutter. As for (2) monitoring of the photon beam position, an X-ray beam position monitor (XBPM) diagnoses the beam position accurately and continuously, and four screen monitors (SCMs) and a photoelectron monitor are utilized during a commissioning. As for (3) protection of the ultra high vacuum of the storage ring, there are five vacuum pumping chambers and four gate valves (GVs). A fast closing shutter (FCS) is mounted on the upstream of the front-end and triggered with cold cathode gauges and ionization gauges. A pair of Be windows is installed at the down stream of the front end for a partition between ultra high vacuum and high vacuum. Finally as for (4) shielding the radiation for human safety, there are two lead collimators and a beam shutter. The combination of the absorber and the beam shutter is called a main beam shutter (MBS), and beamline users are able to open and shut it. A beamline interlock system covers most of front-end components

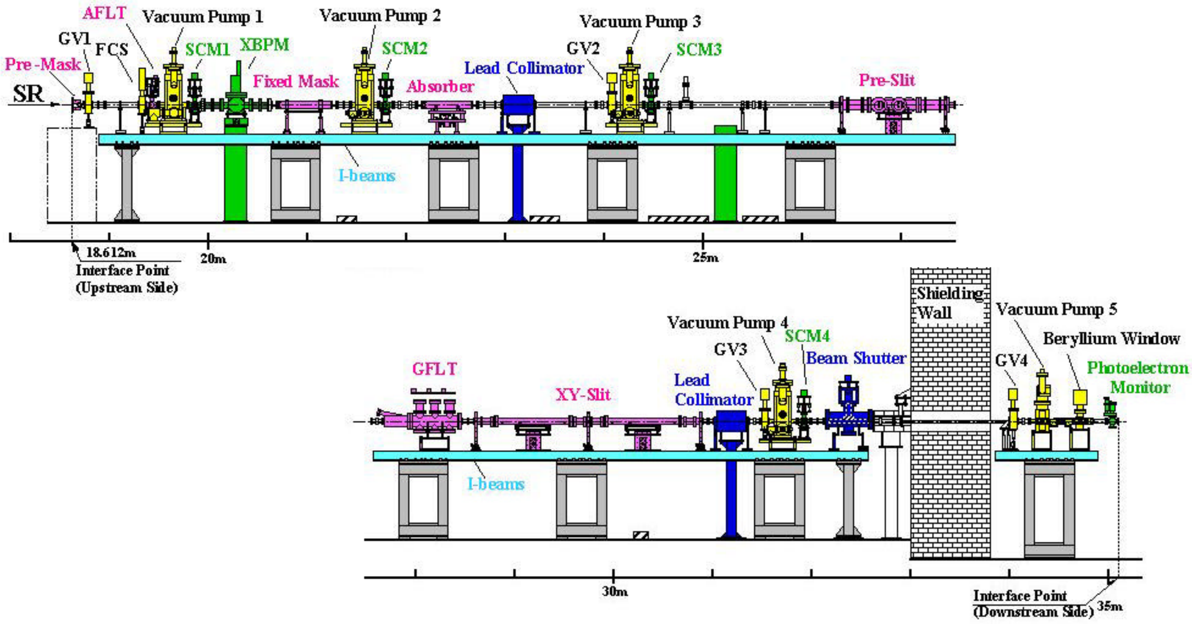

Figure 1. Schematic view of front-end components of the standard in-vacuum X-ray undulator.

2. DESIGN CONCEPT OF FRONT ENDS

The design concepts of the front end are: (1) common bases (a pair of parallel I-beams), (2) standardizing approach, and (3) separated pumping units [1, 2].

(1) All the components except X-ray beam position monitors are mounted on the common base, which consist of a pair of parallel I-beams. One side (storage ring side) of I-beams has a datum plane in both the horizontal direction and the vertical direction. The other has a datum plane only in the vertical direction. The I-beams are aligned beforehand. Then the front-end components are fitted to the datum planes of I-beams, which are clamped on strong bases.

(2) To construct and maintain 62 beamlines smoothly and efficiently, standardizing approach to components and arrangements is indispensable. By directivities of radiations, there are three kinds of front ends, which are for undulator, wiggler, and bending magnet beamlines. In the undulator type, front ends for soft X-ray are slightly different from those for hard X-ray. Still each front-end component is standardized as much as possible.

(3) Each front end has five vacuum pumping chambers for an insertion device beamline, and four for a bending magnet beamline. All pumping chambers are separated from other front-end components. Therefore, replacements of them can be done easily and quickly, even if one of the components needs to be repaired.

3. ALIGNMENT PROCEDURES

3-1 Inspecting of datum points

First of all we check existing datum points. There are two target seals (Fig. 2), which are affixed on a floor. These points are adjusted to the target poles (Fig. 3), which are put on the Quadrupole magnets (Q-magnets) at the up/down steam of an insertion device. We collimate the target poles after rough alignment of a pair of I-beams with a theodolite (Fig. 4). Plummets are set right above datum points (Fig. 5). The tolerance of datum points is 0.1mm. Figure 6 shows the schematic view of the setting of checking standard points. This procedure is carried out before every construction of front ends.

Figure 2. Datum points affixed to the floor. The upper one was affixed by the magnet group during the construction of the SPring-8 storage ring. The lower one was affixed by the front end group just after the construction of the ring in 1996. We check them and mark correct points with a needle just before every construction of a front-end.

Figure 3. Target pole put on the Q-magnet. It is supplied by the SPring-8 magnet group.

Figure 4. Collimating target poles with a theodolite (Leica TM5100). The accuracy of an angle measurement is 0.5”.

Figure 5. Plummets (Leica NL). They are set right above the datum points affixed to the floor.

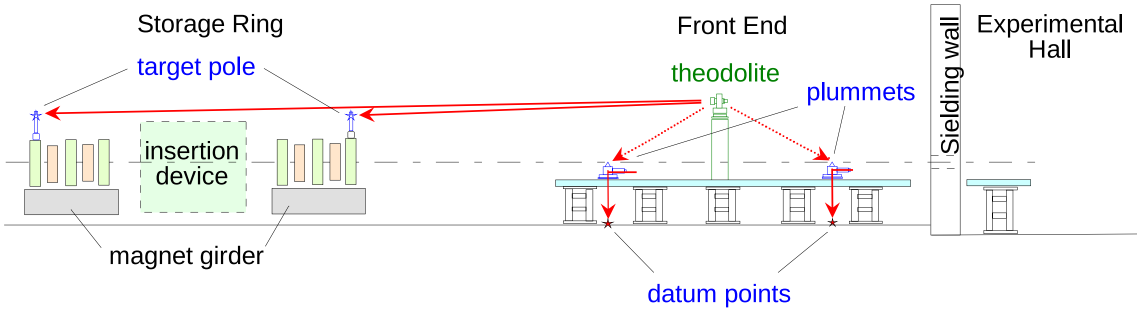

Figure 6. Schematic view of inspecting datum points affixed to a floor. Target poles are collimated to set a theodolite on the ideal beam axis. Plummets are adjusted with the theodolite and transfer the ideal axis to the standard points.

3-2 Installing of I-beams

Using two datum points affixed to the floor, a pair of I-beams is aligned accurately with a displacement error of less than 0.2mm in the horizontal direction. The theodolite is set on the center of I-beams and displacement errors are measured with the standard ruler (Fig. 7). An auto leveling instrument is used to measure the height of both sides of I-beams (Fig. 8). The datum point in the vertical direction is a center of the nearest Q-magnet.

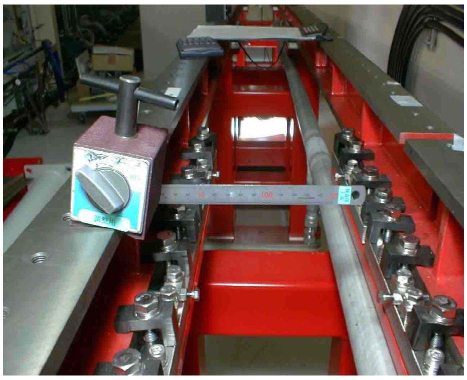

Figure 7. Standard ruler is placed horizontally on the I-beam with a magnet chuck.

Figure 8. An auto leveling instrument (Nikon AS-2). It is based on the center of superposition of the green Q-magnet in the upper left of a photograph. Standard ruler is placed vertically on the I-beam.

3-3 Installing of front end components

About installing of front-end components, it is important to take it into consideration that the difference of the displacements between outside datum of components and irradiated parts (including a monitor head) would have arisen by the vacuum pumping procedure and by the baking procedure with a temperature of 150 ~ 200 ºC, typically. The outside datum is, for example, an edge outside the flange of the upstream and the downstream (Fig. 9). Considering the structure and the role of each component, we took measures against each situation. Basically, the accuracy of an important portion (position of irradiated parts) is checked with the combination of following (a) ~ (d). About position and displacement, here, both directions of horizontal and vertical are considered, and the beam axis direction is omissible.

- Check work at a factory or a laboratory

    (a) The difference of the displacements between the outside datum of components and the irradiated parts cased by the vacuum pumping procedure are measured.

    (b) The positions of irradiated parts from the outside datum of components under a vacuum are inspected.

- Check work at a front-end (in the tunnel of the storage ring)

    (c) The positions of the outside datum of the components from the datum planes of an I-beam in the atmospheric pressure are inspected.

    (d) The displacements between the outside datum of components and the standard sides of an I-beam caused by the vacuum pumping procedure and by the baking procedure are measured.

For some components, an acrylic target (Fig. 10) is used in order to detect center positions of flanges, instead of the outside datum of components using a dial gauge. In the case of the actual survey using the acrylics target, a theodolite and an auto leveling instrument are installed on the beam axis.

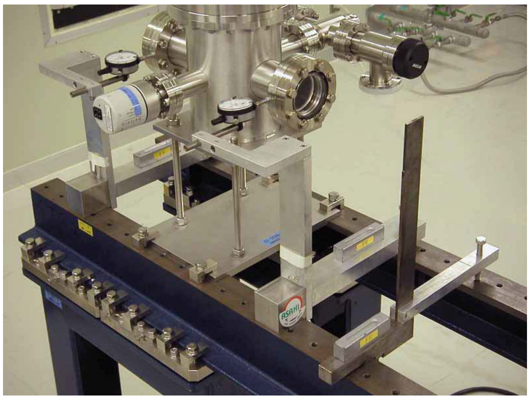

Figure 9. The dial gauge is used for installing. The datum plane of a converted square has an offset by the flange radius.

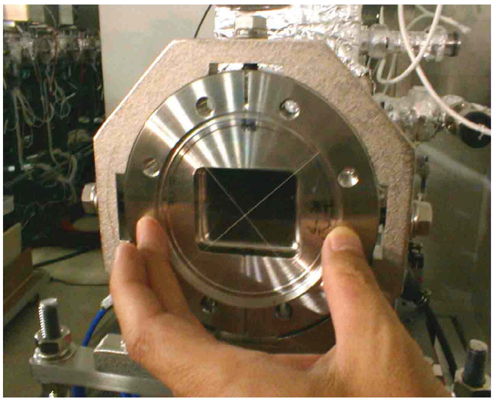

Figure 10. The acrylic target is used for inspecting. The crossing lines are drawn on the transparent plate.

4. RESULTS OF ALIGNMENTS

We have constructed 43 front-ends routinely and successfully until now. There are 26 insertion devise beamlines and 17 bending magnet beamlines. Here, typical results measured at BL12XU, which has a front-end for the standard in-vacuum undulator, are discussed. This front-end was constructed in summer of 2000.

Figure 11 shows the results of the alignments of a pair of I-beams. The I-beams are divided into nine segments, which have the maximum length of 2000 mm. Each segment was measured at an upstream and a downstream point that were about 20 cm away from each edge. Both sides of I-beams were measured in the vertical direction by the auto leveling instrument. The storage ring side of I-beams was measured in the horizontal direction by the theodolite, and the distance between both were measured with vernier calipers, instead of measuring the other side by the theodolite. Tolerances were set at ±0.2 mm. All data were within this number. Standard deviation of each set of measurements was about 50µm.

Figure12 shows the results of alignments of front-end components, which were measured before vacuum pumping. Almost all components were aligned within ±0.2 mm. Some components were slightly out of the tolerance, but they were measured precisely. Therefore, an intrinsic problem was avoided.

Figure 13 shows the relative displacements of components during the vacuum pumping procedure, the baking procedure, and the lowering to the room temperature. It was checked whether relative displacement would have arisen or not. Important components were extracted in order to simplify measurements. Although displacements arise in baking temperature, they return to an original position typically, when temperature is lowered to the room temperature.

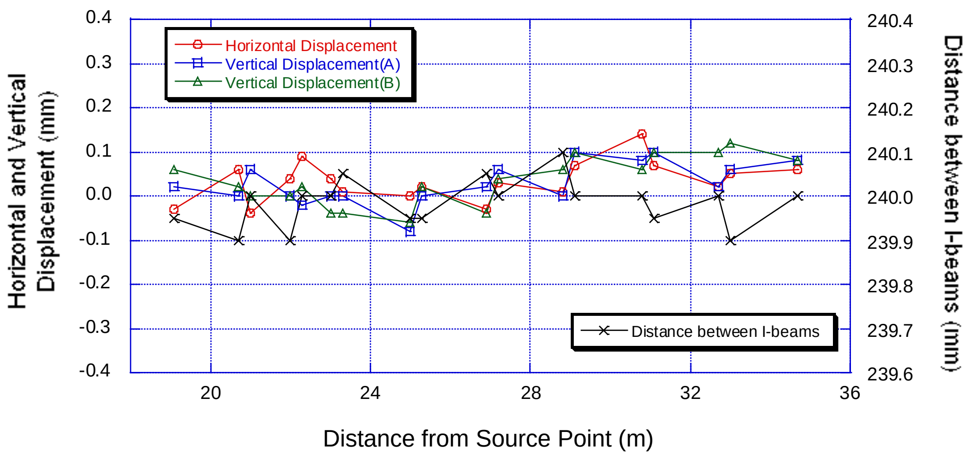

Figure 11. Alignment errors of a pair of I-beams. Horizontal axis denotes a distance from the center of insertion device. Left of vertical axis denotes horizontal displacements and vertical displacements of beam-A and beam-B from an ideal plane. Beam-A and -B indicate I-beams of the ring side and the other side, respectively. Right of vertical axis denotes distances between I-beams, which are measure by vernier calipers.

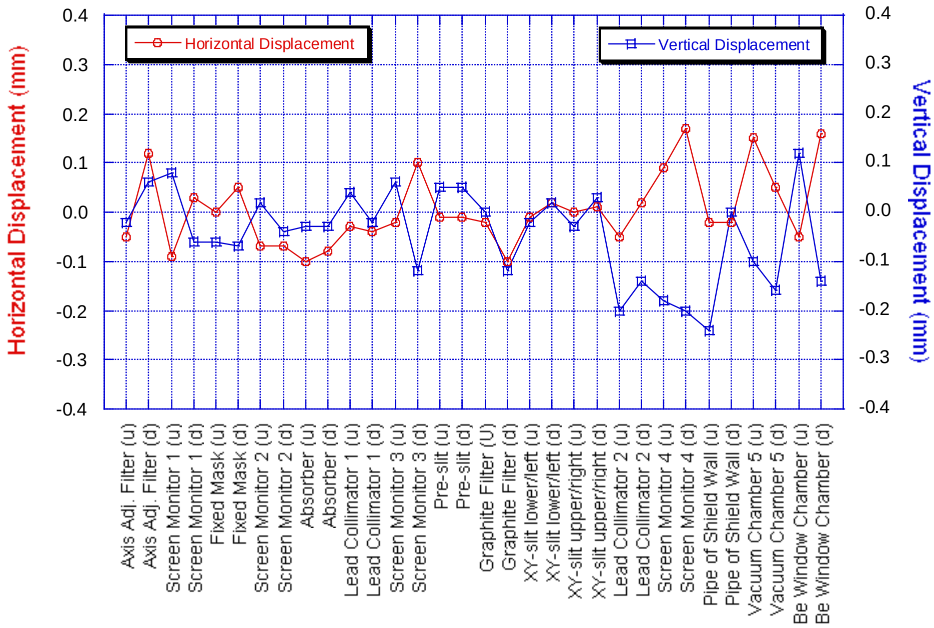

Figure 12. Alignment errors of front-end components. (u) and (d) denote the up steam and down steam of each component, respectively.

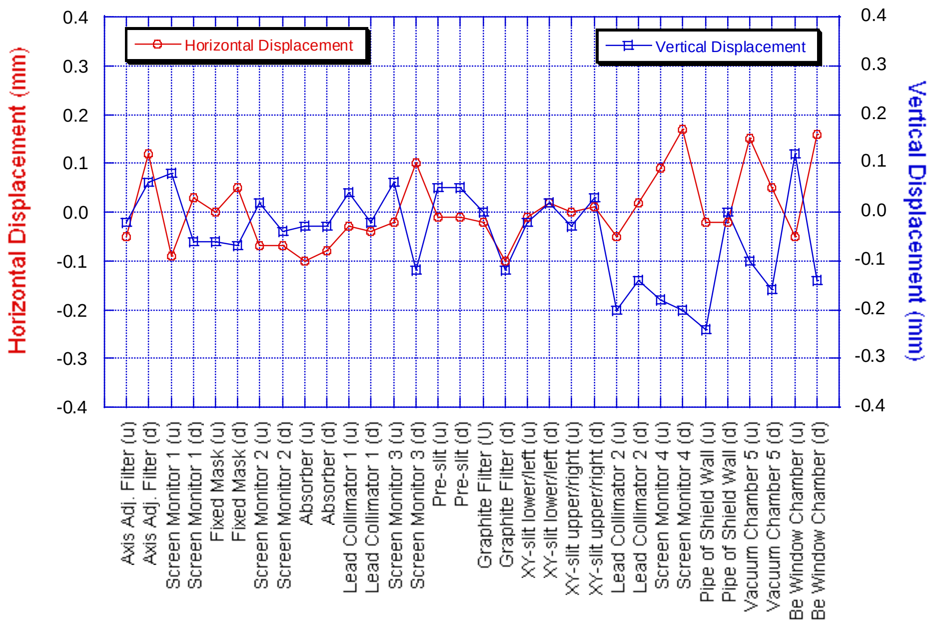

Figure 13. Relative displacements of components. Measurements are carried out under vacuum influence (+), during baking temperature (×), and after lowering to room temperature (●) as the basis of atmospheric pressure and room temperature.

5. CONCLUSION

We have so far built 43 front-ends based on three design concepts, which are (1) common bases (a pair of parallel I-beams), (2) standardizing approach, and (3) separated pumping units. And the alignment works, which follow these concepts, have been performed in the procedure of inspecting of datum points, installation of parallel I-beams, and installation of components. These works have been accomplished regularly with the sufficient results.

For example, the installation error of I-beams is about 50 μm in standard deviation, and we found that components return to their original positions even if some displacements occur during baking procedures. We have had no serious troubles about the alignment works.

The layout of the SPring-8 front-ends can also correspond enough to a rearrangement and an upgrade in the future.

ACKNOWLEDGMENTS

It is thankful to Dr. S. Matsui of accelerator division of SPring-8, who guided about various techniques of alignment work. BL12XU, which is the Taiwan beamline, was described in this report in order to introduce the typical survey result of front-ends. There was an energetic contribution of each person in charge of Kobe Steel, Ltd., ANELVA Corp., and Asahi Group. Although some front-ends are aligned by IHI Co., Ltd. with the method of differing from the usual technique reported here, the details that specialize in the technique were omitted.

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