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REAL-TIME MEASUREMENT OF FLUCTUATIONS OF BUILDING FLOOR AND INSTALLED DEVICES OF LARGE SCIENTIFIC EQUIPMENT*

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Abstract

Several parts that comprise the large scientific equipment should be installed and operated at precise three-dimensional location coordinates X, Y, and Z through survey and alignment to ensure their optimal performance. As time goes by, however, the ground goes through uplift and subsidence, which consequently changes the coordinates of installed components and leads to alignment errors ΔX, ΔY, and ΔZ. As a result, the system parameters change, and the performance of the large scientific equipment deteriorates accordingly. Measuring the change in locations of systems comprising the large scientific equipment in real time would make it possible to predict alignment errors, locate any region with greater changes, realign components in the region fast, and shorten the time of survey and realignment. For this purpose, a WPS's (wire position sensor) are installed in undulator section and a HLS's (hydrostatic leveling sensor) are installed in PAL-XFEL building. This paper is designed to introduce installation status of HLS and WPS, operation status.

INTRODUCTION

All components of PAL-XFEL were completely installed in December 2015, and Hard X-ray 0.1nm lasing achieved through its beam commissioning test and machine study on March 16, 2017. The beam line users are use the hard x-ray since March 22, 2017 [1, 2].

The HLS and WPS system has been installed since September 2016 to measure and record changes of the building floor and devices in real time (see Fig. 1) [3, 4].

THE NECESSITY OF THE SURVEY EQUIPMENT

If the position of the parts for the installed optical mechanism is changed or altered due to vibration, all of the properties of the optical mechanism may be debilitated. So, the optical mechanism should be installed in the isolation optical table. Since the surface flatness of the table hardly changes, the position of the parts for the installed optical mechanism won't change as well. The smart table has the maintenance function of automatically keeping the table surface horizontal when the height of the building floor is altered. The isolation function prevents the vibration of the building floor from being transmitted to the optical mechanism installed on top of the table to prevent errors that arise due to the shaking of the optical mechanism. The optical mechanism installed on the optical table may be tested for a long time while stably maintaining the characteristics of the optical mechanism.

The scale of large scientific equipment is as large as several hundred meters to several kilometers and the degree of precision and stability of the specification is high. Various feedback functions are applied to meet the specifications of large scientific equipment. However, there is a limit to overcoming the degradations of large scientific equipment that caused by devices position moving with only the feedback function. Therefore, a lot of time and money have to be make a payment in order to perform the realignment task after surveying the position of all installed components after periodically stopping the operation of large scientific equipment [5].

While the accelerator operating that generates the radiation that is harmful to the human body, people cannot conduct surveying work in the tunnel. If there were a survey system that can monitor the position of the building floor and the components during the operation of the scientific equipment, it would be much easier to sort out areas that have many changed and that also save time and money for the realignment working. To do so, survey systems such as the HLS and WPS are installed on the PAL-XFEL.

There is workshop that discuss about the techniques and experiences necessary for tasks such as surveys and alignments of large scientific equipment. Also, workshop for improving changes and vibration problems of the building floor through building construction works are being held as well [6, 7].

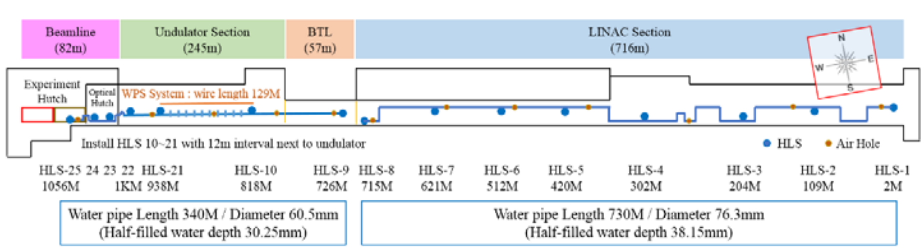

Figure 1: The position of HLS and WPS and specification of HLS water pipe in PAL-XFEL (Top view).

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HLS SYSTEM

The construction process and inspection method of the HLS system for PAL-XFEL is as shown in Table 1. In order to design the HLS and the waterpipe, it is necessary to understand various physical phenomena that occur within the waterpipe (see Fig. 2).

Table 1: Construction and Inspection of HLS

(1)	Selection of HLS: self-calibration.
(2)	Calculation of pipe diameter suitable for the length of the waterpipe.
(3)	Installation of air hole: improvement of differences in atmospheric pressure and air flow within the waterpipe.
(4)	Periodic inspection of HLS system.
(5)	Inspection of water height variation that is caused by the tide.

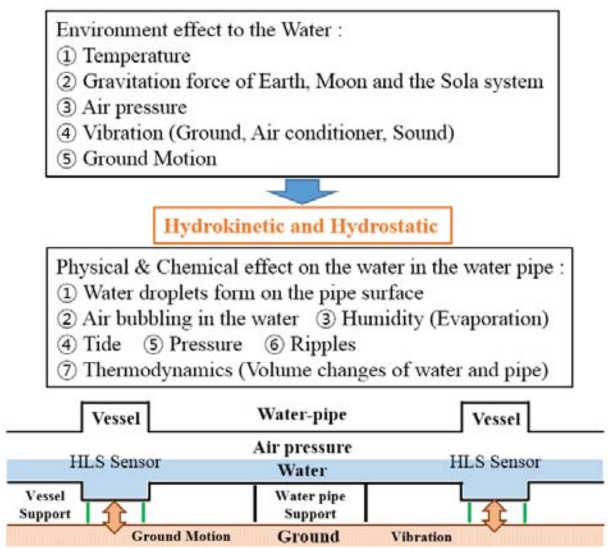

Figure 2: The surrounding environment influencing HLS.

(1) The physical and electrical characteristics of the components constituting the sensor change over time. This produces sensor measurements incorrect. In order to reduce measurement errors, the sensor has to be periodically inspected. Since the HLS that is produced by the budker institute of nuclear physics (BINP) in Russia has the self-calibration function, it can obtain reliable measurements through self-calibration even when the characteristics and the surrounding environments (temperature, atmospheric pressure) of the electronic components have changed over time. Self-calibration is an advanced design technique.

(2) The most important part of the HLS system is the waterpipe that provides measurement reference. One thing that should be taken in to consideration in the process of designing the waterpipe is the water flow. A pipe of an appropriate diameter for the waterpipe has to be selected so that the water will smoothly flow within the waterpipe and maintain the right level. The water inside the waterpipe changes in height twice a day due to the tidal-force. If the water does not flow smoothly in accordance with the revolution period of the moon, a bottleneck phenomenon will occur within the waterpipe and the water won't be able to maintain the reference level anymore.

(3) As water only maintains equilibrium with the force of gravity, the water flow rate slows down if there is a pressure difference inside the waterpipe or if the airflow is not fast enough. Air holes were installed at intervals of 100 meters in order to eliminate atmospheric pressure differences within the waterpipe and to smooth out the air flow. As a result, the water flow was improved and the time required for the water to maintain balance was reduced.

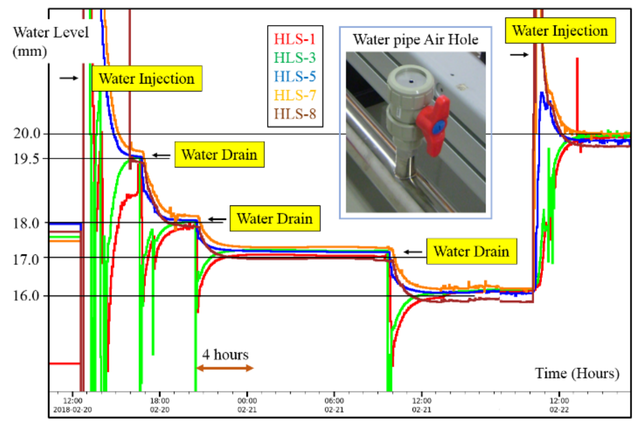

Figure 3: Test for flow of water in the water pipe.

(4) The height of the waterpipe must be constant. If the height of the waterpipe is not constant, changes in the HLS measurement will be inconsistent during the inspection process of the water injection or the water will take a long time to achieve balance. This simple inspection method enables you to check the conditions of the HLS and waterpipe that constitute the HLS system (see Fig. 3).

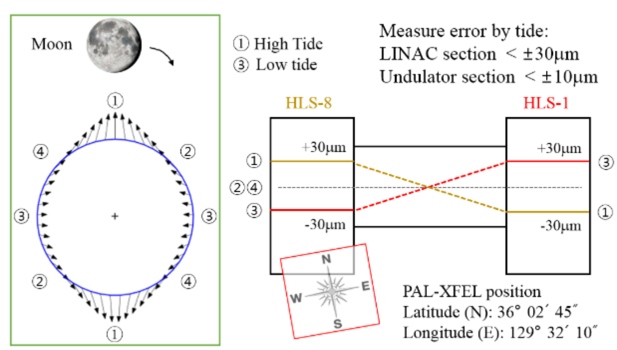

Figure 4: HLS's measurement error by tides.

(5) The height of the water within the waterpipe always changes due to the flowing phenomenon of the water that is caused by the tidal force. This may be the factor that produces error in the HLS measurement, but the HLS measurement can be revised after measuring the water height change caused by the tide. When designing the HLS system, it is important to take into consideration that the longer the waterpipe is, the longer it takes for the water to balance and the variation of the water height caused by the tide gets greater (see Fig. 4).

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WPS SYSTEM

The construction process of the WPS system and the correction method of the measurement for PAL-XFEL are as shown in Table 2.

Table 2: Construction and Correction of WPS

(1)	Selection of WPS and wire.
(2)	Sag calculation according to the length of the wire and WPS support design.
(3)	Position change correction of the wire stretched post.

(1) The most important thing in selecting the WPS system is the wire material that provides the reference. Carbon wire is a light and conductive material that does not change in length even when the temperature and humidity of the surrounding environment changes or even when tension is applied for a long time.

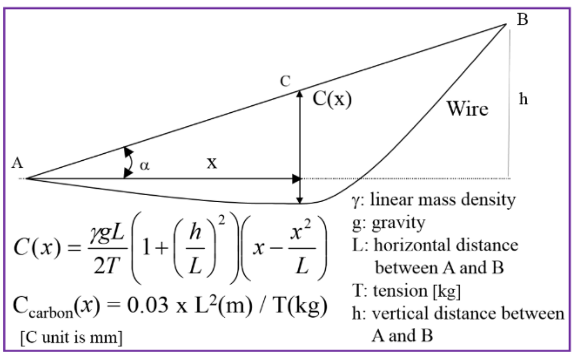

Figure 5: Wire sag calculation.

(2) The wire sag is determined by the length of the wire as well as the pulling tension of the wire. Due to the nature of the carbon, there is no change in the sag of the wire once it has been installed. The height of the WPS support should be adjustable so that WPS can be installed in accordance with the sag condition of the wire. A wire protecting duct should be installed so that the wire does not shake due to the wind that is generated by the air conditioning equipment (see Fig. 5).

(3) The wire stretched post is installed on the building floor. If the wire stretched post is moved due to the deformation of the building floor, the position of the wire which provides the reference also changes. After measuring the change of the wire stretched post by using the HLS (Y axis height) and the tilt meters (roll and pitch), the measurement value of the HLS measurement may be corrected after calculating the position change of the wire (see Fig. 6).

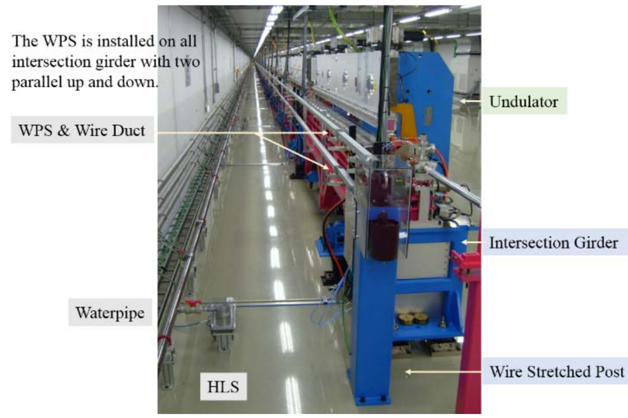

Figure 6: Installed HLS and WPS in Undulator section.

SUMMARY

For an efficient alignment of large scientific equipment, it is required to the survey system to observe and record the position changes of components and building floor. The PAL-XFEL uses the HLS system to survey the deformation of the building floor, and WPS system to survey the 2D (X/Y axis) position change of the devices. By using the survey system, it is possible to easily find out the area where the position change is severe and perform the realignment work (see Fig. 7).

Installing the waterpipe for HLS use in sections of 500 meters is considered to be a method of reducing HLS measurements errors caused by tide rather than installing them at long length of several kilometres.

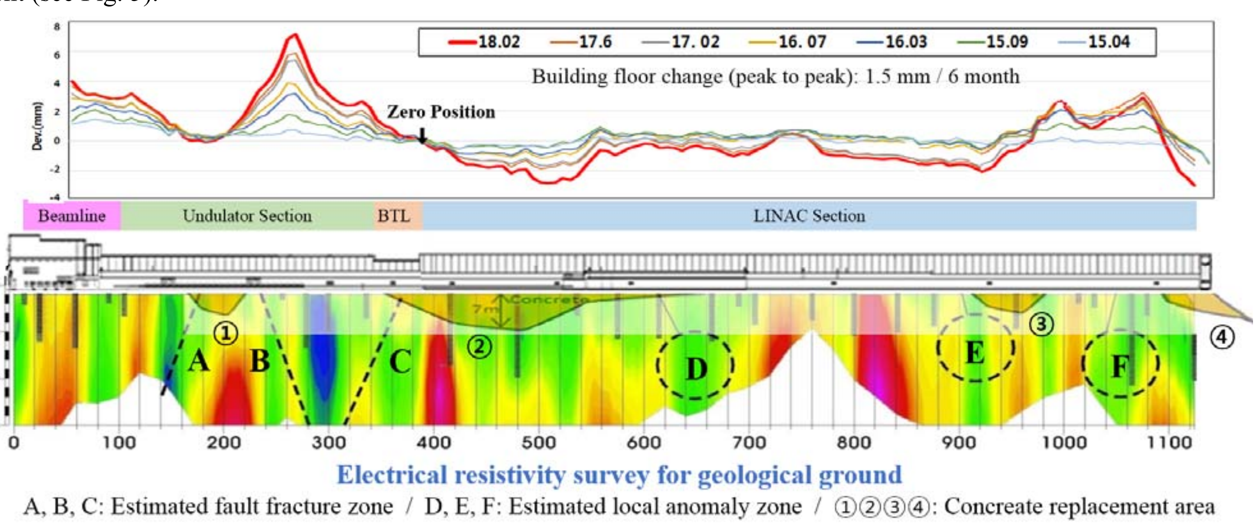

Figure 7: Ground structure and motion of building floor of PAL-XFEL. (Side view).

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