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HLS TO MEASURE CHANGES IN REAL TIME IN THE GROUND AND BUILDING FLOOR OF PAL-XFEL, LARGE-SCALE SCIENTIFIC EQUIPMENT*

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Abstract

A variety of parts that comprise large-scale scientific equipment should be installed and operated at accurate three-dimensional location coordinates X, Y, and Z through survey and alignment in order to ensure optimal performance. However, uplift or subsidence of the ground occurs over time and consequently this causes the deformation of building floors. The deformation of the ground and buildings cause changes in the location of installed parts, and eventually that leads to alignment errors (ΔX, ΔY, and ΔZ) of components. As a result, the parameters of the system change and the performance of large-scale scientific equipment is degraded.

Alignment errors that result from changes in building floor height can be predicted by real-time measurement of changes in building floors. This produces the advantage of reducing survey and alignment time by selecting the region where great changes in building floor height are shown and re-aligning components in the region in a short time. To do so, HLS (hydrostatic levelling sensor) with a resolution of 0.2 µm and a waterpipe of 1000 meters are installed and operated at the PAL-XFEL building. WPS (wire position sensor) with a resolution of 0.1 µm is installed at undulator section where the changes in the location of equipment should be measured with two-dimensional coordinates (vertical Y and horizontal X). This paper introduces the installation and operation status of HLS.

INTRODUCTION

As shown in Figure 1, if the ground and the floor of a building changes, the location of equipment changes accordingly and the performance of the PAL-XFEL is degraded [1]. To measure the displacement of building floors in a real time, an ultrasonic-type HLS, which was manufactured by Budker Institute of Nuclear Physics (BINP) of Russia, was installed as shown in Figure 2 [2-3].

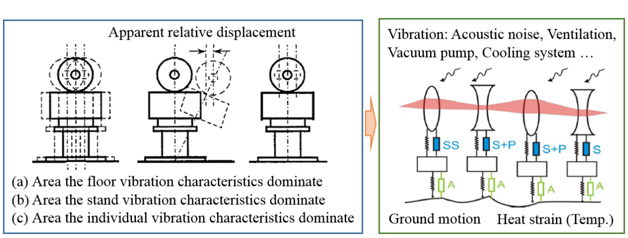

Figure 1: Three vibration patterns which generate relative displacement [1].

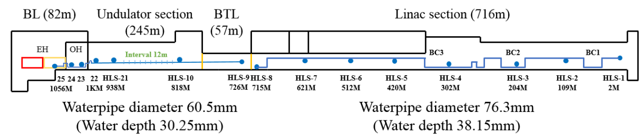

Figure 2: Locations where HLS of PAL-XFEL is installed.

SOURCES OF GROUND VIBRATION

In the section 'Between model and reality, Part I' (pp. 237-244) of the Beam Diagnostic textbook published by CERN Accelerator School [4], beam-orbit instability-inducing elements were classified in categories depending on the time scale as shown in Table 1. In addition to geological changes, various vibrations generating inside and outside the buildings affect the equipment and cause beam orbit instability. The CAS textbook describes the elements and countermeasure of beam orbit instability in detail [4].

Table 1: Instability Classified by Time Scale

Instability	Time Scale
Long term	Weeks to years - sun and moon motion - ground settlement - seasonal ground motion
Medium term	Minutes to days - weather (rain, hot, dry, cold, etc.) - diurnal temperature - thermal drift
Short term	Milliseconds to seconds - ground vibration - cooling water flow vibration - machinery vibration (chillers, air conditioners, vacuum pumps, etc.)
Very short term	Higher frequency or shorter periods

Some instability elements described in the CAS textbook are observed on HLS data as shown in Figure 3. Temperature variation is included in the instability elements. The temperature on the HLS was measured to correct the thermal deformation of instruments according to temperature variation.

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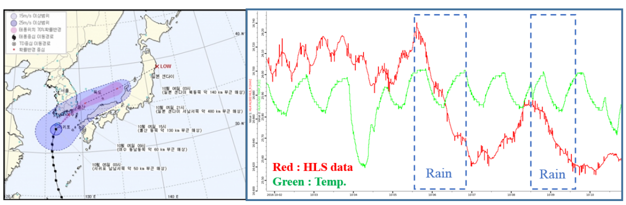
HLS SAMPLING RATE

According to the Nyquist sampling theory, the sampling frequency should be at least twice the highest frequency contained in the signal. The sampling rate of HLS should be increased to measure various external vibrations. As HLS was designed to the water level of waterpipes, it may be short-lived or broken down owing to the principle of measurement and electronic structures if the sample rates increase too high. If the water level oscillates by the influence of vibration, some errors occur in HLS measurements that are recorded as randomized vibration on HLS data.

PAL-XFEL records measurements from the HLS every two minutes. If it is intended to measure vibration, installing triaxial vibration sensors will be helpful to measuring accurate high frequency and monitoring vibration from all directions (X, Y, and Z).



Observation of ground motion due to typhoon storm @ 5 Oct. 2016

Figure 3: HLS data (tide wave, rain, and vibration)


Figure 4: Condition of installed waterpipes and HLSs (Linac on the left and Undulator on the right).

PRESENT CONDITION OF HLS INSTALLATION

As the floor height of undulator building is 1 meter lower than that of the Linac building, waterpipes were installed in the Linac section and Undulator section respectively as shown Figure 2. As shown in Figure 4, as it was impossible to install waterpipes on the floor of the Linac section due to the circumstances, they were installed to the acceleration tube girder. In case of undulator section, waterpipes and HLS were installed on the floor of the building.

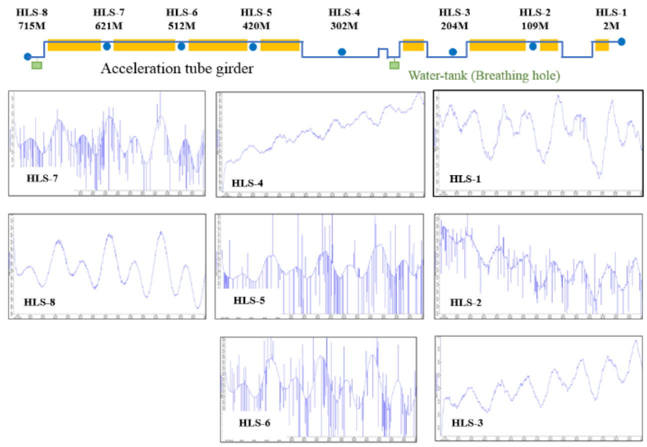


Figure 5: HLS measurements in the Linac section.

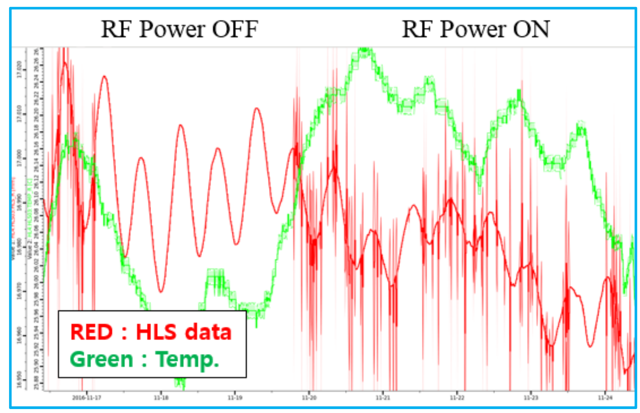


Figure 6. HLS data when RF Power ON and OFF.

In the Linac section, vibration was generated in waterpipes owing to a 80-MW pulse klystron RF power transmitted to the acceleration tube and 1 to 12-µm of randomized vibration was detected by the four HLSs (HLS-2, 5, 6, and 7) installed on the girder as shown in Figure 5. It means that some shock wave energy vibrates water in the waterpipes randomly through the girder after pulse RF energy was transmitted to the acceleration tube but doesn't mean that it vibrates firmly-fixed acceleration tube and girder. As shown in Figure 6, when the RF output of Klystron was switched off, no randomized vibration was observed. Some vibration-proof pads are planned to be installed on the waterpipe mounts in order to reduce vibration. No vibration was observed on the three HLS attached to the wall side of modulator gallery (HLS-3, 4, 8) and on HLS-1, 7 meters away from the girder. Vibration from LCW (low-conductivity water), which keeps flowing to cool the acceleration tube, was not observed on the HLS measurement.

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Table 2: Waterpipe Improvements

Date	Work Content
19 Sep. 2016	Start HLS measurement - no water-tank (no breathing hole): waterpipe is in enclosed state - no tide wave observed in HLS-1 - Tide wave is not visible exactly in HLS-2, 3, 4, 5 - vibration observed in HLS that waterpipe installed at the Linac girder
6 Jan. 2017	Confirm that HLS-1 measurement value is atmospheric pressure change (cause unknown)
15 Jan. 2017	The pressure inside the sealed waterpipe rises and water leaks (waterpipe needs a breathing hole to solve internal pressure problem)
Feb. 2017	Install two water-tanks (breath hole) - HLS connection transparent hose improvement - waterpipe height alignment - no atmospheric pressure observed in HLS-1, but tide wave is not visible exactly
July 2017	Check the water flow of waterpipe - Linac section water flow delayed (Need a breathing hole near to HLS-1)

HLS REFERENCE: WATERPIPE

The flow of waterpipes which provides reference is very important in HLS measurement. A waterpipe the diameter of which was determined in consideration of its length was installed, as shown in Figure 2, so that water flow may be complete within one hour in PAL-XFEL [2]. Table 2 shows the features and improvements resulting from operation of HLS after waterpipes were installed.

The flow of waterpipe was obtained by measuring through HLS the time taken until the water height of waterpipe becomes level after water was injected or drained. As the flow is very fast in the waterpipe of undulator section, the water height becomes level within one hour. As shown in Figure 7, it took more than 2 hours for the water height to become level in the Linac section. In case of HLS-1, it took more than 12 hours for the water height to become level. As the Linac section has eighteen 90 degree curves, it is believed that they interrupt the flow of air and fluids. As HLS-1 is installed at the end of waterpipe, 240 meters away from the breathing hole, it is difficult for air and fluids to flow in an opposite direction at the same time. Therefore, it takes long time for them to flow within the waterpipe. To reduce the water leveling time of HLS-1, some more breathing holes are planned to be installed near to HLS-1.

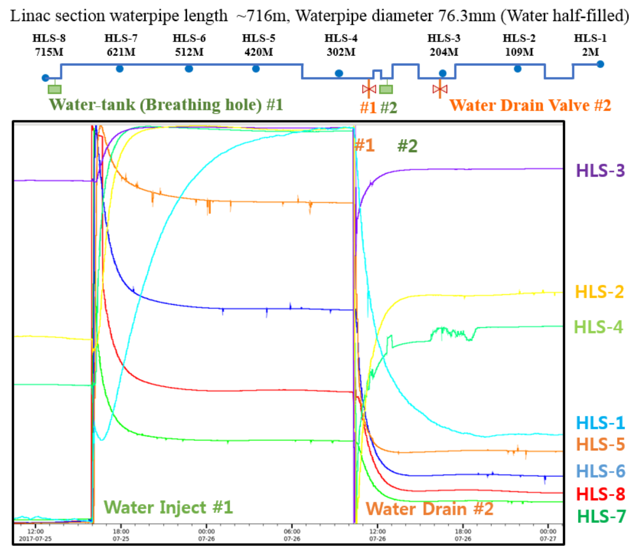

Figure 7: Flow measurements in the Linac section (HLS value axis scales are not same).

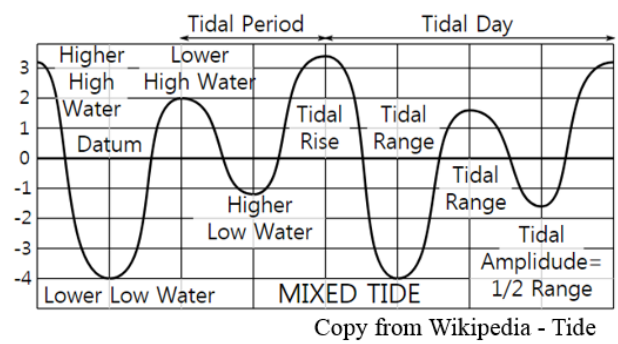

Figure 8: Distribution of tidal phase.

The flow of waterpipe should be fast to monitor HLS in a real time and the tide wave of HLS data be observed at the time-synchronized form. If HLS data are not time-synchronized, the average on tidal periods should be taken as shown in Figure 8.

PRESENT CONDITION OF HLS OPERATION

HLS program was built on the NI-PXI system by using NI LabVIEW [5]. Real-time HLS data can be checked on the operator interface (OPI) screen in the PAL-XFEL operation room. Figure 9 shows the ground variations measured by using HLS data on a weekly basis.

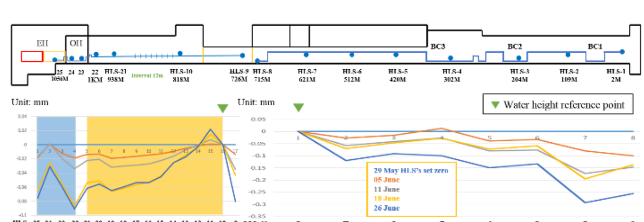

Figure 9: Observation of ground variations by HLS.

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CONCLUSION

The waterpipe design providing reference for HLS measurement is very important and should meet the Table 3 conditions for real-time measurement.

Table 3: Conditions for Real-Time HLS Measurement

□ The flow of waterpipe should be fast so that it may become level within one hour.
□ The tide wave of all HLS should be time-synchronized.
□ All tidal amplitudes should be identical or similar.
□ HLS data should have no vibration elements or a small amount of them.

REFERENCES

[1] Kazuyoshi Katayama *et al.*, "The investigation of vibration of LINAC at KEK", IWAA'90, pp. 333-342.

[2] Hyojin Choi *et al.*, "Introduction to BINP HLS to measure vertical changes on PAL-XFEL buildings and ground", *IPAC'15*, paper MOPTY028.

[3] Hyojin Choi *et al.*, "The BINP HLS to measurement vertical changes on PAL-XFEL buildings and ground", FEL'15, paper MOP047.

[4] *Beam Diagnostics*. CERN-2009-005, Geneva, 2009.

[5] Hyojin Choi *et al.*, "LabVIEW EPICS program for measuring BINP HLS of PAL-XFEL", ICAL-EPCS'15, paper WEPGF115.