ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-WEPH18

OPERATION STATUS OF HLS SYSTEM INSTALLED TO MEASURE GROUND CHANGE OF LARGE SCIENTIFIC EQUIPMENT IN REAL TIME*

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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 performance enhancements to reduce observed phenomena and measurement errors in the HLS system operation process.

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 [3, 4].

HISTORY OF HLS USED ON THE ACCELERATOR

HLS was developed by the Alignment and Geodesy group at the European Synchrotron Radiation Facility (ESRF) for long term monitoring and control of rapid realignment of the storage ring machine at 1990. The concept of the non-contact capacitive sensor developed at the ESRF has been considerably improved upon by the company FOGALE-Nanotech. Various types of HLS Sensors, including Capacitive and Ultrasonic, are developed and used in recent. European Council for Nuclear Research (CERN) announced the results of the comprehensive testing of HLS and WPS in many forms [5].

SELF-CALIBRATION FUNCTION

Deutsches Elektronen Synchrotron (DESY) conducted In-situ experiments to develop the Ultrasound sensor for HLS in 2001 and the basic design concept of Ultrasound sensor for HLS was built based on the result of the experiments [6]. The structure of Ultrasonic pulse hydrostatic level sensor developed by Budker Institute of Nuclear Physics (BINP) in Russia is described in Fig. 1. The sound reflector made of invar metal that has a low thermal deformation acts as an absolute ruler at an interval of 7.5mm and self-calibrates the differences of water density due to the changes in temperature (sound speed) and electrical properties of the transducer. The composition and operating principle of ULS Electronics developed by BINP and its results of field tests are described in more detail in related papers [7, 8].

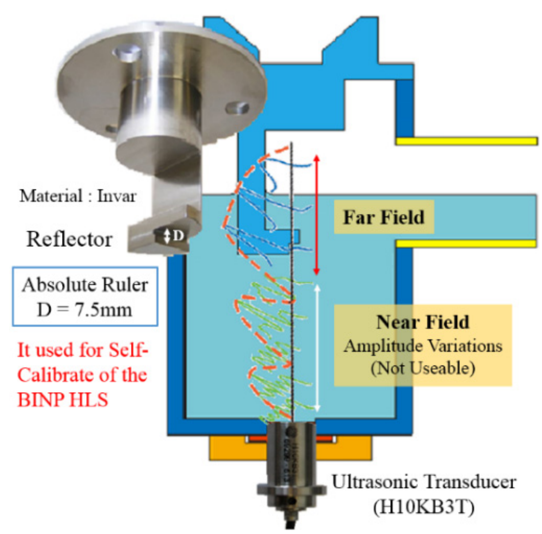

Figure 1: The HLS measurement concept using an Ultrasonic transducer and self-calibration.

INSTALLATION OF HLS AND WATERPIPE

Although it is best to survey the changing progress conditions of the building floor with a view to installing the HLS system, it is desirable to install it low and in close contact to the floor. However, since the concrete anchor, height controlling equipment, etc. is reflected in the support design, the HLS support of the Undulator section was designed to be 15cm in height and the waterpipe support to be 25cm in height. In order for the waterpipe to pass

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ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-WEPH18

through the walls of the building in accordance with the radiation safety regulations, the process of radiation shield with a lead block must be carried out after bending the pipe. To do so, ten 90° elbow pipes were used. Waterpipes of all sections apart from sections close to the building walls were installed in a straight line (see Fig. 2).

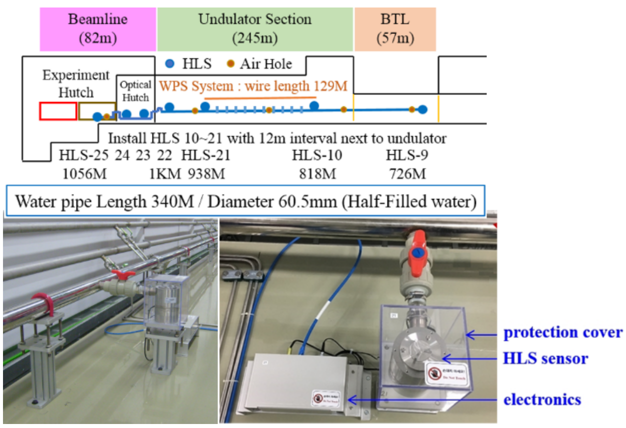

Figure 2: HLS and waterpipe of the Undulator section.

In the case of the linear accelerator (LINAC) section, with regard to maintenance work of the waveguide and the cable installed across from the accelerator tube girder, a person must pass through under the girder. This is the reason for why the waterpipe is installed beside the accelerator tube girder. The pipes in the Bunch Compressor (BC) area that moves from side to side due to the actuator had to be installed on the surface of the wall and the pipes installed in area where the Screen Monitor as well as the Beam Collimator had to be installed beside the equipment. As a result, eighteen 90° elbow pipes, twelve 45° elbow pipes and fifty-six 25° elbow pipes were used (see Fig. 3). When elbow pipes are used, the flow of the water slows down.

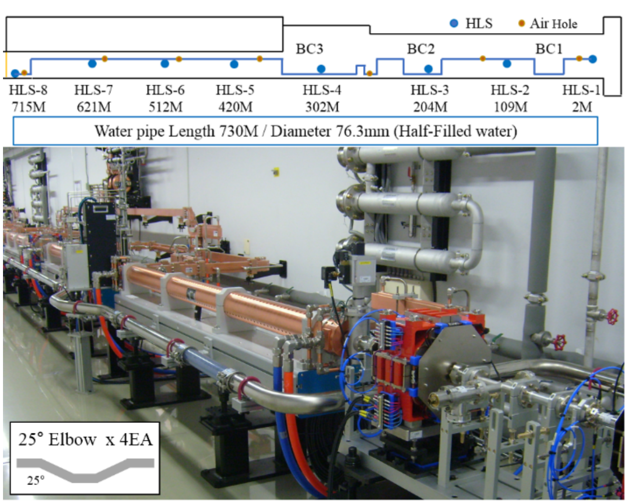

Figure 3: 25° and 90° elbow pipe of the LINAC section.

IMPROVEMENT OF PROBLEM THAT AROSE AFTER INSTALLING THE HLS SYSTEM

Utilizing the Half-Filled method to improve the water flow within the waterpipe, the height of the pipe must be installed in a uniform manner so that the water can flow in a stable and smooth fashion.

Observation of Atmospheric Pressure

Ever since the beginning of data acquisition in September 2016, after having completed the installation of the HLS system, the measurement values of HLS-1 could not be understood. We searched through many literatures and reference materials because we had to know what the measurements meant in order to find the cause of the problem and to solve it. In the process of reviewing the Meteorological Administration data of January 2017, we were able to confirm that the atmospheric pressure changes and the HLS-1 measurements coincided (see Fig. 4).

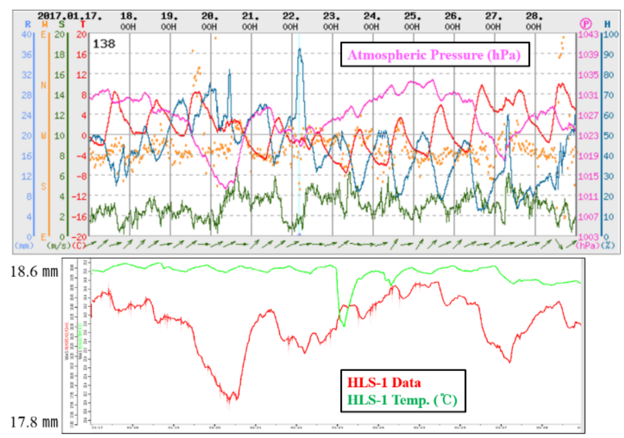

Figure 4: Reference materials of the Meteorological Administration about atmospheric pressure (above), HLS-1 data (below).

The reason why the atmospheric pressure changes were clearly observed in HLS-1 was thought to be the same as the principle of measuring the pressure of Torricelli, which we learned about during physics class in middle school. Therefore, we measured the height of the pipes around HLS-1 and were able to confirm that the pipes installed on the surface of the BC1 wall were 3~4cm and the pipes installed on the surface of wall BC2 and BC3 were installed 1~2cm lower. This was a situation that was identical to the Manometer, which measures the atmospheric pressure changes (see Fig. 5).

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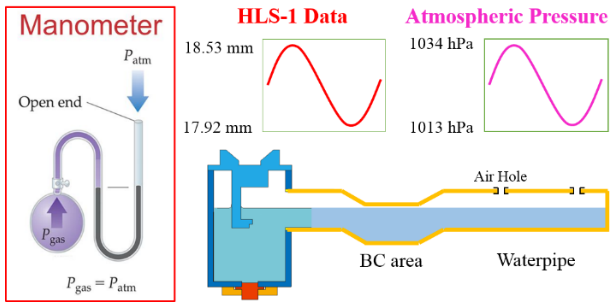

Figure 5: Manometer for measuring atmospheric pressure.

Since the support installed on the surface of the wall was not designed to control the height of the pipes, new support was designed (see Fig. 6). After the pipes near the BC were rearranged at a constant height, the phenomenon of atmospheric pressure being measured in HLS-1 disappeared.

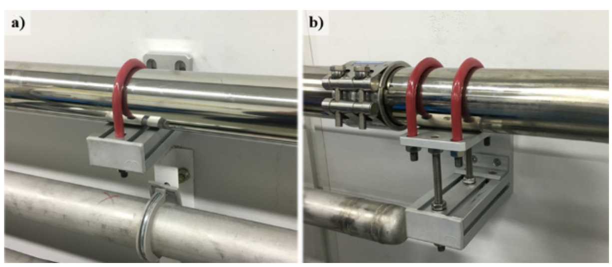

Figure 6: Surface of the BC wall (a) Preexisting support (b) Height controlling support.

Tidal-force and Air Hole

The water within the pipe is affected by the tidal-force and changes in height twice a day (see Fig. 7). In order to measure the changes of the building floor in real-time, the water within the pipe has to flow quickly and maintain balance in accordance with the influence of the tidal-force. As the water flows only by the force of the gravity, if there is a pressure difference within the pipe or if the air flow is abnormal, the flow rate of the water slows or stops. Air holes in intervals of 100 meters were installed in order to remove pressure difference within the pipe and to improve the air flow. As a result, the water flow was improved as shown in Table 1, and the time required for maintaining the balance of water was shortened.

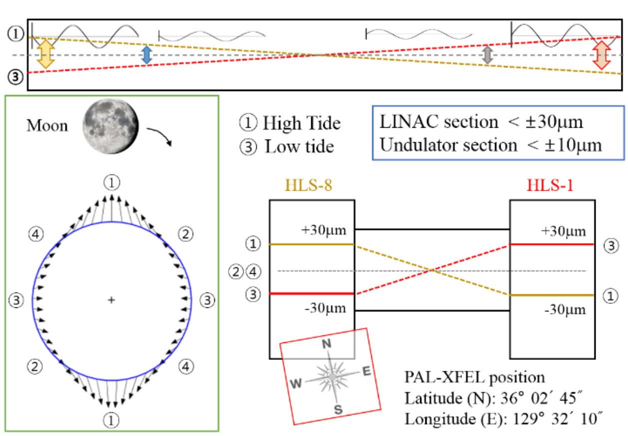

Figure 7: Change in the height of water due to tidal-force.

Table 1: Time Required to Attain Equilibrium of Water After Adding Air Holes

Section	Before adding	After adding
LINAC	14 hours (air hole 2ea)	4 hours (air hole 7ea)
Undulator	2.5 hours (air hole 2ea)	1.5 hours (air hole 4ea)

A simple way of checking the measured conditions of the HLS and the installed conditions of the waterpipe is to inject or drain water to determine the measurement range of HLS (17.5±2.5mm). The water flow rate within the pipe can be confirmed through the balanced run-time of water while injecting or draining water and see whether the pipes have been installed at a constant height up to the measurement range of HLS (see Fig. 8).

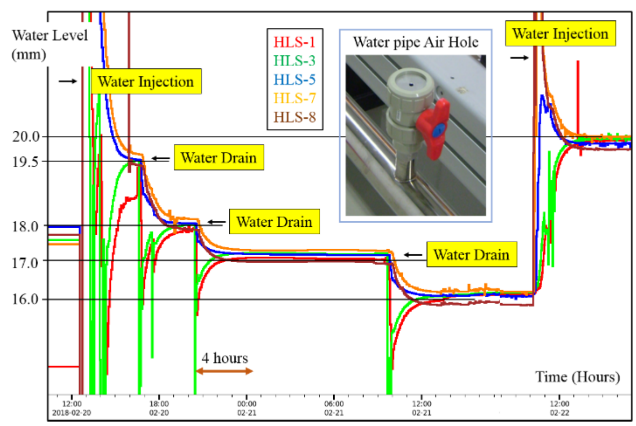

Figure 8: Confirmation of waterpipe installation condition.

The time required for the water to maintain balance within the waterpipe is determined by the length (L) and diameter (Ø) of the pipe. The pipe diameter was calculated so that the pipe could be installed in a straight line and so that the time required to balance the water would take about an hour [9]. However, if a lot of elbow pipes are used in the process of installing the pipes, the water flow slows down as like Table 1.

Vibration

Vibration was observed in the measurement of HLS, which was installed in the LINAC section (see Fig. 9). As a result of using the vibration sensor, it was confirmed that the 449nm vibration of the LINAC tunnel floor was amplified in HLS support and vibrated at 2.11µm in HLS (see Fig. 10). If the vibration is severe, the water within HLS sloshes. It seems that the vibration problem will be solved if the vibration-proof support is designed.

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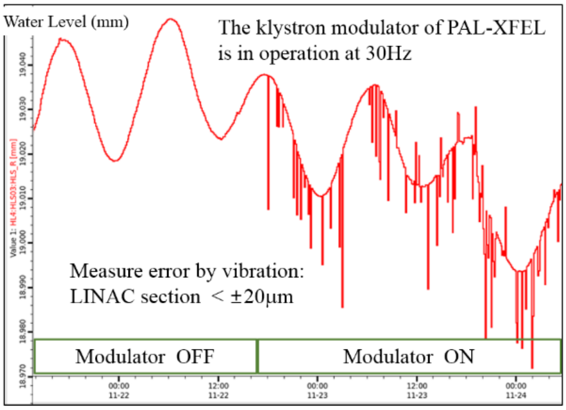
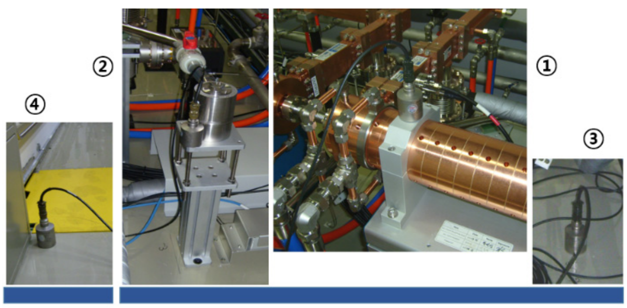


Figure 9: HLS measurement error due to vibration.



Vibration Sensor Position	Modulator OFF		Modulator ON	
	RMS	PkPk	RMS	PkPk
① Accelerator Support	96.6 nm	273 nm	134 nm	380 nm
② HLS Support	39.5 nm	112 nm	746 nm	2.11 µm
③ LINAC Tunnel Floor	60.1 nm	170 nm	159 nm	449 nm
④ Modulator Gallery Floor	25.2 nm	71.4 nm	41.3 nm	117 nm

Figure 10: Vibration measurement within the LINAC section.

SUMMARY

In order to efficiently realign the large scientific equipment, a survey system that can observe and record the changing progress of the building floor in real-time is needed. PAL-XFEL uses a 1km-long waterpipe as well as 24 HLS to survey the changing progress of the building floor in real-time. In the event of heavy rain, earthquakes, etc. the PAL-XFEL continues to maintain its performance by rapidly realigning components by detecting areas with severe floor changes through the HLS system.

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