Stanford Linear Accelerator Center

Stanford Synchrotron Radiation Laboratory

LCLS Engineering Specifications Document # 1.4-105	Undulator	Revision 0

HYDROSTATIC LEVELING SYSTEM SPECIFICATIONS

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Brief Summary: This document describes the Hydrostatic Leveling System, the intended types of sensors and the expected results.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000		All	Initial Version

1 Requirements Summary

Table 1: Summary of requirements listed throughout this document. A reference to the section that defines the parameter is given in column 4.

Parameter	**Value**	**Unit**	**Ref.**
Number of capacitive sensors per girder	3		4.1
Number of ultrasonic sensors per girder	1		4.1
Number of drain / refill stations	1		4.5
Maximum cable length	100	m	4.4
Number of TCP/IP switch stations	2		4.4
Cable type	CAT5e		4.4
Connection pipe diameter	2	inch	4.3
Installation accuracy requirements of pipes	2	mm	4.3
Material of connection pipes	Stainless steel		4.3
Relative height accuracy (capacitive sensor)	1 μm + 1 μm / 1 mm		3
Relative height accuracy (ultrasonic sensor)	0.1 μm + 1 μm / 1 mm		3

2 Introduction

The tolerances for the positioning of the electron beam to the LCLS undulator system axis are very tight, see PRD 1.4-001. To monitor the movements of the girders, and therefore the undulator segment and the quadrupoles, a Hydrostatic Leveling System (HLS) and a Wire Positioning System (WPS) will be installed. The systems provide information about the geometrical stability during the tuning and operation of the undulator. The HLS sensors also provide information about the pitch and roll of the undulator before beam based alignment.

The Hydrostatic Leveling System determines height differences between points. As reference a water surface is used which follows an equipotential surface. The sensors are located on the girder and therefore monitor the height, roll and pitch of the girder. The height accuracy achieved is in the order of 1 μm.

3 Types of sensors

The system consists of two types of HLS sensors, which complement each other. One sensor type is based on capacitive measurements which has the advantage of being well tested and having a lower purchase cost. The resolution of the sensor is 1 μm with an accuracy of 5 μm over 5 mm measurement range. The disadvantage of this sensor type is that capacitive sensors drift by about 1 - 2 μm per month due to the aging of electronic components. The second type of sensor is based on ultrasonic runtime measurements. The measurements are self calibrating and therefore no drifts are expected. The repeatability of the sensor is 0.1 μm with an accuracy of 5 μm over the 5 mm measurement range. A technical note describing the system details, its dynamic behavior and the description of the sensors is in preparation.

4 Installation

4.1 It is planned to install four sensors on each girder, combined on common plates with the WPS, allowing determination of height, yaw, roll and pitch changes of the girders and the stiffness of the girder itself. One plate is situated at the position of the quadrupole, the other at the position of the BFW or physically close to it. As of now it is planned to install one ultrasonic sensor for its high accuracy and lack of drift and three capacitive sensors for their proven reliability. The change of the sensor type requires no change in design and will be decided later.

4.2 An advantage of installing ultrasonic sensors is that the capacitive sensors can be calibrated in-situ. By raising and dropping the water level in the pipes the scale factor of the capacitive sensors can be determined by comparison with the ultrasonic sensors. Theoretically a major part of the drift of the capacitive sensors can be determined.

4.3 The sensors are connected with 2 inch stainless steel pipes. To decouple the motion of the pipes from the sensors, bellows have to be installed at the connection of the pipe with the sensor. The pipes are half filled with water and have to be installed horizontally within ±2 mm. To prevent algae growth a chloride based anti algae is added to the water. The pipes themselves will be mounted to the girder with brackets.

4.4 For the power supply of the sensors and the data transfer each sensor is connected with a CAT5e cable. The cables are connected to TCP/IP switches (supporting 802.3af standard) which also provide power to the sensors (e. g. Netgear Model FSM-7326P). The TCP/IP switches have to be located at each end of the tunnel since the maximum cable length supported is 100 m.

4.5 To calibrate the capacitive sensors in-situ the water level in the pipe must be adjustable, therefore the installation of a refill station is required. To avoid an error source in the tunnel the refill station has to be accessible during operation and should be installed outside the tunnel.

5 Calibration for absolute measurements

The ultrasonic sensors directly provide the height above the water surface in relation to a fiducial on top of the sensor. At the MMF these fiducials can be related to fiducials on the girder and the quadrupole. To allow the same for the capacitive sensors, they have to be calibrated in-situ. This can be achieved by measuring either the position of the tilt and pitch of the girder after turning on the sensors or by directly measuring the fiducials on top of the capacitive sensors in relation to fiducials on top of the ultrasonic sensors. In both cases the measurements can be performed with a portable HLS.

6 Software

For communication with the sensor a command is sent via TCP/IP and the response is either the capacitance measured or the runtime of the ultrasonic pulse. To determine the height of the sensor over the water surface the raw data have to be transformed with previously determined calibration parameters. To transform this data into useable information about the movement of the girder the data have to be corrected for the earth tides, ocean tide loading and the earth radius. After that initially a single HLS sensor is selected to be used as the reference and assumed to be stable. If necessary more sophisticated approaches making assumptions about the behavior of the girder movements can be implemented. Possible approaches are assumptions that the overall movement is minimal or the sum of the absolute movements is a minimum.

7 Conclusion

The HLS described here provides height information in the order of 1 μm for small movements. Over the whole measurement range of 5 mm an accuracy of 5 μm can be achieved. The absolute relation between the measurement and geometrical properties on the girder are mainly limited by the in situ measurements to about 10 μm relative to each other.

By installing four sensors on each girder we can determine not only the height but also roll and pitch and the stiffness of the girder.