

CONTROL SYSTEM FOR THE LCLS II UNDULATOR PROTOTYPE*

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Abstract

The Linac Coherent Light Source (LCLS) has been successfully operated for more than 6 years. In order to expand the capability and capacity of the LCLS, LCLS-II has been planned and funded by the Department of Energy. Advanced Photon Source (APS) at the Argonne National Lab is tasked with building the prototype of the LCLS-II undulator based on the concept of magnetic force dynamic compensation. The control system for the prototype is responsible for four motion and feedback channels with sub-micron level accuracy, eight load cells that monitor how the forces act on the system in real time, and multiple temperature sensors. A detailed description of the control system and its operation is reported.

INTRODUCTION

As the world's first x-ray free electron laser in operation, the LCLS facility at the Stanford Linear Accelerator Center (SLAC) has plans to be expanded in both capability and capacity to meet the needs of the scientific community. Different from the original fixed gap undulators, the LCLS-II will be equipped with adjustable gap undulators.

APS is to build a prototype of the LCLS-II undulator. The device is a 3-meter long adjustable gap undulator with a minimum gap of 7.0 mm and better than 10 micron tolerance [1]. Due to the magnetic force change in the scale of several thousands of kilograms in different gaps during operation, the magnetic force dynamic compensation scheme has been adopted [2].

The control system for the prototype is a windows based PXI system from National Instruments. It is capable of handling four motion axes, four absolute position feedbacks, eight load cell force sensors, and eight temperature sensors. Application software is LabVIEW based with field programmable gate array (FPGA) technology in monitoring the positions and the forces in real-time.

SYSTEM DESCRIPTION

The control system for the LCLS-II undulator prototype consists of a PXI crate with a windows based control card, an FPGA card, and a Digital Multimeter (DMM) card, all from National Instruments.

The peripherals of the system comprise the positioning control system and the positioning feedback system. The control system has four motors that drive the positioning

systems. The motors are SmartMotor servomotors from the Animatics Corporation, with the motor control integrated in the back of each motor including an RS-232 serial interface. Each two motors drive one of the two ID strongbacks into the desired position to form the gap as needed. The motors are connected to the control card via an RS-232 serial interface. All four motors are connected in serial.

The position feedback system has four absolute digital linear encoders with Synchronous Serial Interface (SSI) from Fagor Automation. The resolution of the encoders is 0.1 micron. The maximum range of the encoders is 120 mm. The encoders are programmable. They are configured to 32 bits with non-grey code. The encoders are connected to the digital I/O interfaces of the FPGA card.

The forces acting on the actuators are monitored with eight load cells from Omega Engineering Inc. The load cells are bi-directional. They are powered by a voltage power supply that supplies a 10 volts dc excitation source. The voltage excitation power supply is from Agilent Technologies. The voltage is monitored by a DMM card. The analog outputs of the load cells are monitored by 16-bit analog-to-digital channels embedded in the FPGA card. The load cell signals are normalized by the excitation voltage to compensate the fluctuation of the excitation voltage. The precision of the force monitoring is about 0.2 lbs.

The temperatures are monitored with a web-enabled temperature measurement module equipped with eight RTD sensors. The module is from Omega Engineering Inc. It communicates with the control card via http protocol through a TCP/IP network. The precision of the temperature monitoring system is 0.1 degree Celsius. Figure 1 shows the schematic layout of the prototype device control system.

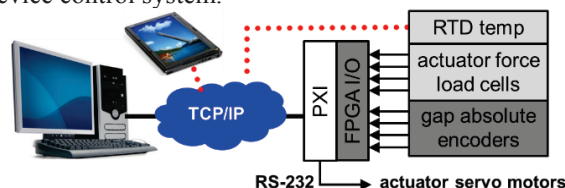


Figure 1: Schematic layout of the prototype device control system.

SOFTWARE

LabVIEW-based system software has been developed to coordinate the motion control and sensor data monitoring. The system can be accessed via the internet from anywhere, anytime through the facility's virtual

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private network. Figure 2 shows the graphic user interface of the control system.

The control system software has two main routines, the motion routine and the monitoring routine. Each routine runs on its own thread. The motion routine is responsible for motion controls. It takes device gap setting inputs from the user input through the graphic user interface, calculates the position of the motors, sends the positions to the motors, and issues commands to move the motors to the positions. Users can also enter specific motor position settings to move the motors.

The monitoring routine monitors the encoder positions and the load cell forces in real-time via the FPGA interface. It also monitors the temperature sensors via http.

Users can also set the dead band for the device gap settings. Once the device gap drifts beyond the band setting, it will automatically trigger the control routine to activate the motors to correct the positions.

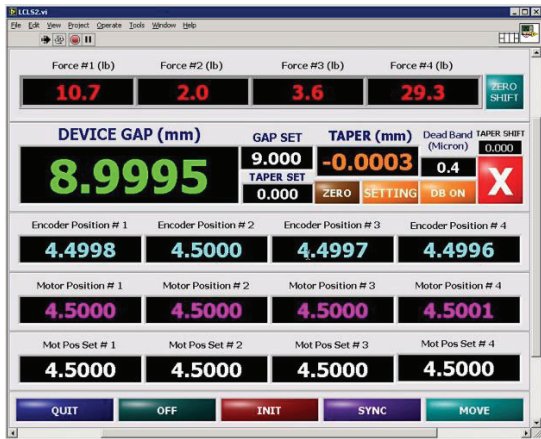


Figure 2: Graphic user interface view of the control system for the LCLS-II undulator prototype.

CONCLUSION

A positioning and control system for the LCLS-II undulator prototype has been developed and constructed. Based on the PXI platform and the FPGA technologies, the system coordinates the device motion and positioning with 0.1 micron precision. It provides real-time device information concerning the forces and temperatures.

REFERENCES

- [1] Physics Requirements Document. LCLSII-3.2-PR-0038-R1.
- [2] N. Strelnikov, E. Trakhtenberg, I. Vasserman, J. Xu, E. Gluskin, “Vertically Polarizing Undulator with the dynamic compensation of magnetic forces for the next generation of light sources”, Rev. Sci. Instrum. 85, 113303 (2014).