ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-WEPHA099

XLEAP-II MOTION CONTROL

M. A. Montironi, H. Bassan, M.A. Carrasco, E.M. Kraft, A. Marinelli
SLAC National Accelerator Laboratory, Menlo Park, USA

Abstract

The XLEAP project was conceived with the main scope of extending the generation of ultrashort pulses at LCLS to the sub-femtosecond (sub-fs) regime. As the project produced the expected results, an upgrade called XLEAP-II is being designed to provide the same functionality to LCLS-II. The XLEAP project utilized one variable gap wiggler to produce sub-fs X-ray pulses. The upgrade will involve four additional wigglers in the form of repurposed LCLS fixed gap undulators mounted on translation stages. This paper describes the design of the hardware and software architecture utilized in the motion control system of the wigglers. First it discusses how the variable gap wiggler was upgraded to be controlled by an Aerotech Ensemble motion controller through an EPICS Soft IOC (Input-Output Controller). Then the motion control strategy for the additional four wigglers, also based around Aerotech controllers driving servomotors, is presented. Lessons learned from operating the wiggler and undulators during LCLS operation are discussed and utilized as a base upon which the upgraded motion control system is designed and built. Novel challenges are also identified and mitigations are discussed.

INTRODUCTION

The X-Ray Laser-Enhanced Attosecond Pulse (XLEAP) Generation project was conceived with the main scope of extending the generation of ultrashort pulses at LCLS to the sub-femtosecond (sub-fs) regime for energies up to 1.25 keV. The technique is based on the concept of shaping the LCLS electron beam with a high-power infrared (IR) laser whose energy is modulated by a variable gap wiggler. The experimental setup developed for the XLEAP project in order to achieve such short pulses is shown in Figure 1 [1, 2].

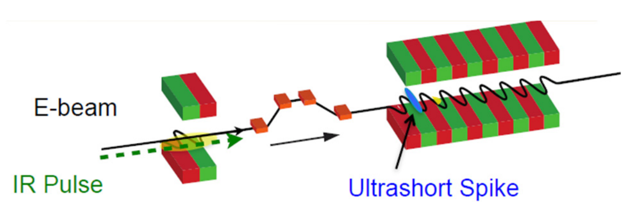

Figure 1: XLEAP experimental setup. The combined effect on the electron beam of the high energy IR pulse, of the magnetic chicane, and of the wiggler produce an ultrashort current spike [2].

As the project produced the expected results [3], an upgrade called XLEAP-II is being designed to provide the same functionality to LCLS-II. Differently than XLEAP though, in this case energy modulation of the electron beam will be induced in four wigglers built by modifying decommissioned LCLS fixed gap undulators. The existing variable gap wiggler utilized for XLEAP will be reused as a space-charge booster after a magnetic chicane. Figure 2, taken from the LCLS Strategic Development Plan [2] is a schematic representation of the XLEAP-II experimental setup.

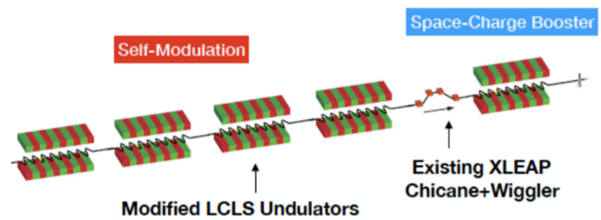

Figure 2: Schematic representation of XLEAP-II experimental setup. The four repurposed LCLS undulator, located upstream of the XLEAP chicane and wiggler provide energy modulation to the electron beam [2].

Motion control is a fundamental component of the experimental setup described in this section. The four repurposed undulators are in fact mounted on translation stages used to control their insertion level into the beamline. Gap control is required for the wiggler in order to modulate beam at different frequencies. The rest of the paper describes the design of the hardware and software architecture utilized in the motion control system of the wiggler and of the repurposed undulators.

MOTION CONTROL SYSTEM

Variable Gap Wiggler

The variable gap wiggler, shown in Figure 3 has a period of 33 cm and a gap adjustable between a minimum of 8 mm and a maximum of 200 mm. Gap actuation is achieved through two Slo-Syn (MH112 series 15-Amps) stepper motors, one located at the upstream end and one at the downstream end. A passive motion transmission system couples the top and bottom jaws. In order to maximize the reliability of the system through redundancy, two independent position feedbacks are implemented for each axis. The primary feedback system is provided by AMOSIN BiSS-C radiation hardened absolute linear encoders measuring the upstream and downstream gap. The secondary feedback system consists of incremental rotary encoders made by Gurley and positioned directly on the motor axis. The motion controller chassis, based on two Aerotech CP20 drives, was developed to control the wiggler during the XLEAP experiment and will be reused. The controller allows to drive the two motors in a coordinated manner thus minimizing the risk of tapering the device. Moreover, it provides dedicated inputs for the primary and secondary

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-WEPHA099

feedback devices, for the ESTOP, and for reading and reacting to the limit switches. Figure 4 is a schematic representation of the architecture of the motion control system for the wiggler. An EPICS Soft Input-Output controller (SIOC) communicates to the controller through an Ethernet connection allowing to interface the device with the accelerator distributed control system and other High-Level Applications (HLA).

Figure 3: Variable gap wiggler.

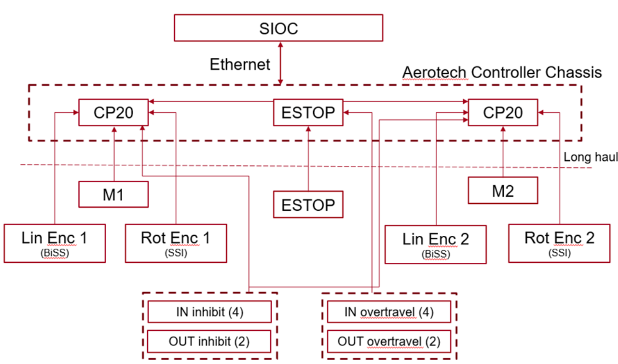

Figure 4: Schematic representation of the wiggler motion control architecture.

Minimal upgrades to the control architecture are required to re-utilize the wiggler for XLEAP-II. In the new project, the device will be relocated downstream with respect to its current position which will require pulling new cables. Also, a new, thicker vacuum chamber will be installed which will require changing the minimum reachable gap from 8 mm to 10 mm. Increasing the minimum gap will require mechanical modifications to the motion safety system such as the hard stops and the mounting of the limit switches. Figure 5 shows the mechanical assembly currently in use to mount the motion inhibit and ESTOP limit switches. The wiggler has four of these assemblies, two upstream and two downstream, one on each side of the vacuum chamber. Both the ESTOP, in blue in the figure, and the motion inhibit, in gray, limit switches do not provide adequate repeatability in their trip point. Moreover, the mounting system for the motion inhibit switch does not allow for precise and repeatable positioning. Such mechanical assembly has caused the limit switches to be activated at a gap bigger than the minimum one multiple times and will thus be upgraded. All the ESTOP and motion inhibit switches will be replaced with high repeatability (Metrol P10DB-A) precision ones. In each assembly, both switches will be mounted on a single axis linear stage, similar to the one used for the ESTOP limit switch in Figure 5, to allow positioning with respect to the vacuum chamber. A threaded support mounted on the linear stage will allow for fine relative positioning of the two switches.

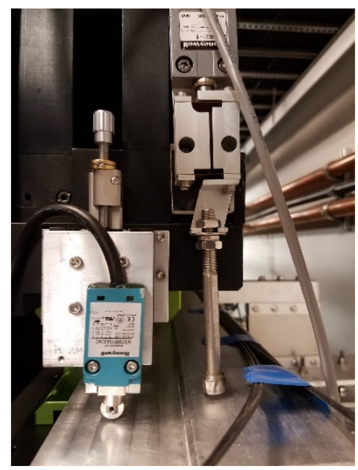

Figure 5: Current mounting system for the wiggler ESTOP (in blue) and motion inhibit limit switches.

Repurposed Undulators

The LCLS undulator line, composed of 33 individual undulator segments each 3.42 m long has been decommissioned in order to install the new LCLS-II undulators [4, 5]. These undulators had a fixed nominal gap of 6 mm and each segment was mounted on two horizontal translation stages to allow relative motion with respect to the electron beam and thus to modify the effective K value of each undulator. Four undulator segments will be converted to 10-period wigglers with a period of 30 mm, a K parameter of ~35, and utilized for XLEAP-II. Figure 6 is a representation of an LCLS undulator segment where the translation stages responsible for rolling the undulator in and out are highlighted as TM1 and TM2. In LCLS, external feedback on the position of each stage was provided by linear potentiometers (LP4-TR and LP8-TR in the figure). Other components highlighted in Figure 6 belong to the cam mover system utilized to reposition each undulator segment in 5 Degrees-Of-Freedom (DOF) and not utilized for XLEAP-II.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-WEPHA099

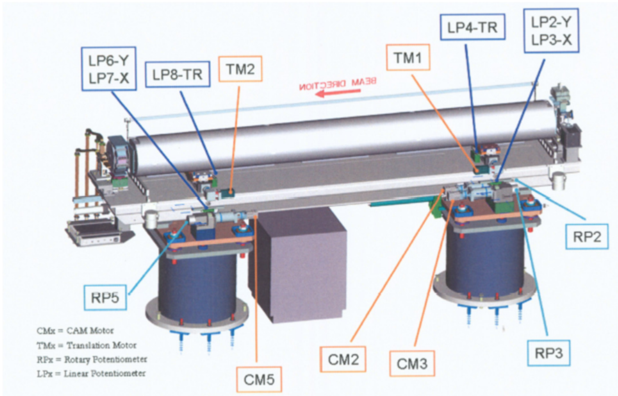

Figure 6: LCLS undulator segment assembly. Translation stages (TM1 and TM2) and linear potentiometers used for feedback (LP4-TR and LP8-TR) are indicated.

The components of an LCLS undulator roll out system can be seen in more detail in Figure 7. A LinTech translation stage (model 206821 – 0.05 µm resolution) was actuated by an Animatics SmartMotor (2000 counts/rev) coupled to a 50:1 gear head. Linear potentiometers provided external feedback on the position of each stage and the information was used by interlocks in the VME-based motion control system to prevent skew and ensure coordinated operation of the two translation stages. In each direction of motion, motion inhibit and ESTOP limit switches are also utilized for additional safety.

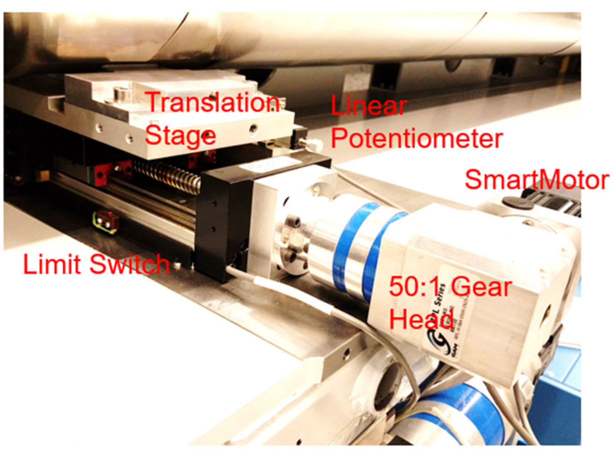

Figure 7: Detail of translation stage for an LCLS undulator segment.

The 80 mm travel range of the translation stages will be maintained in XLEAP-II as well as the number and location of the limit switches and the gear head. The same Aerotech four axes motor controller (CP10) used for LCLS-II Soft X-ray (SXR) undulators [6] will replace the VME-based one used for LCLS. Since each undulator segment requires actuation of two axes, and four segments in total will be reused, one Aerotech controller will be utilized to control two segments. The selected controller will allow to coordinate the motion of all the axes connected thus reducing the risk of skew and eliminating the need for interlocks based on the linear potentiometers. SmartMotors will be replaced with Aerotech-compatible servomotors with the same NEMA 23 form factor and compatible torque and position accuracy characteristics. The motion inhibit limit switches will serve the double purpose of homing each translation stage at power-up and of safety interlocks.

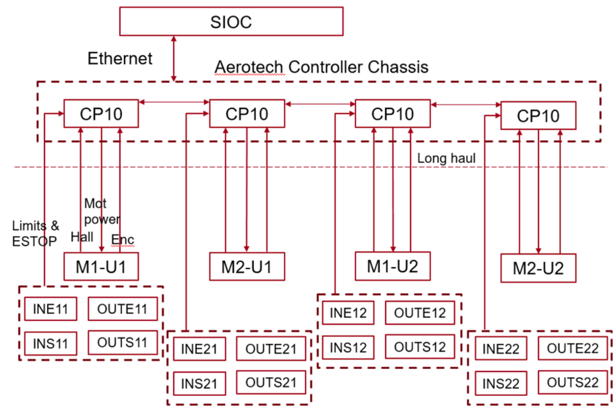

Figure 8: Schematic representation of the control architecture for two repurposed undulators.

Figure 8 is a schematic representation of the software architecture designed to control two undulator segments with one Aerotech controller. Four CP10 Aerotech motor controllers are utilized, one dedicated to each axis and all synchronized through Aerotech AeroNet digital motion bus. Inputs from IN and OUT motion inhibit and ESTOP limit switches are utilized for each axes as well as external ESTOP signals. In order to protect the electronics from radiation damage, the controller will be placed in a separate building and connected to the device through long haul cables. An EPICS SIOC will communicate with the controller through an Ethernet connection and will allow to interface the device with the accelerator distributed control system and other high-level applications.

CONCLUSION

This paper provided an overview of the implementation of the motion control system for the XLEAP-II project. It first discussed the variable gap wiggler and then presented the upgrades to the motion control system for the repurposed LCLS undulator segments. The installation and commissioning of the components of the project are expected to take place as soon as the installation and commissioning of the LCLS-II accelerator is complete.

ACKNOWLEDGMENT

The authors would like to thank all those involved in the past and presently in the XLEAP and in the XLEAP-II project. It has been an undertaking that required many different sets of skills.

This work was supported by Department of Energy contract DE-AC02-76SF00515.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-WEPHA099

REFERENCES

[1] J. P. MacArthur, J. P. Duris, Z. Huang, and A. Marinelli, "High Power Sub-Femtosecond X-Ray Pulse Study for the LCLS", in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 2848-2850. doi:10.18429/JACoW-IPAC2017-WEPAB118

[2] "LCLS Strategic Facility Development Plan", SLAC, Menlo Park, USA, October 2018.

[3] J. Duris *et al.*, "Tunable Isolated Attosecond X-ray Pulses with Gigawatt Peak Power from a Free-Electron laser", 2019, arXiv preprint arXiv:1906.10649

[4] M. Leitner *et al.*, "Hard X-Ray and Soft X-Ray Undulator Segments for the Linear Coherent Light Source Upgrade (LCLS-II) Project", in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 1605-1608. doi:10.18429/JACoW-IPAC2017-TUPAB123

[5] H.D. Nuhn, "LCLS undulator commissioning, alignment, and performance", No. SLAC-PUB-13781, 2009.

[6] K. R. Lauer *et al.*, "LCLS-II Undulator Motion Control", in *Proc. ICALEPCS'17*, Barcelona, Spain, Oct. 2017, pp. 1379-1383. doi:10.18429/JACoW-ICALEPCS2017-THPHA020