Implementation of the Motion Control System for LCLS-II Undulators

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October 9, 2019
LCLS-II Undulator Hall

- LCLS-II undulator hall divided into cells.
- Cells contain one undulator and the downstream interspace assembly.
Overview

• **Overview of LCLS-II undulators**

• Most relevant motion control features:
  - Tracking the motion of the SXR vacuum chamber with the undulator gap
  - Centering of SXR undulator gap on vacuum chamber
  - Calculation of undulator K parameter based on its gap
LCLS-II SXR Undulator Cell

- 21 undulator segments
- 23 interspace assemblies
- 20 phase shifters

Interspace Assembly. 5 DOF through cam movers. Mounting surface for vacuum chamber

Soft X-Ray ( SX R) undulator segment. Gap opens in vertical plane
LCLS-II SXR Undulator Motion Control System

- Multi-Axis Aerotech Controllers

- Servomotors for undulator and phase shifter gap actuation.

- Stepper motors for interspace cam movers actuation.

- Undulator position feedback through half-gap rotary absolute encoders and full-gap linear encoders.

- Phase shifter position feedback through linear absolute encoder.

- Rotary potentiometers for cam position feedback.

LCLS-II HXR Undulator Cell

- 32 undulator segments
- 32 interspace assemblies
- 31 phase shifters


Girder mover. 5 DOF through cam movers. Undulator and interspace.

Phase shifter

Interspace

Beam Direction
LCLS-II HXR Undulator Motion Control System

- RTEMS running on VME. EPICS IOC and interfacing with hardware through Acromag IP modules
- Animatics SmartMotors for undulator gap, phase shifter, and cam movers actuation
- Undulator motion synchronization through CAN network
- Absolute linear encoders for undulator and phase shifter position feedback
- Rotary potentiometers for cam position feedback

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Tracking SXR Vacuum Chamber

- Vacuum Chamber (VC) segments mounted on interspace plate
- Cam mover system to re-position interspaces during beam-based alignment
- Undulator segments to remain centered on VC
- Feedback of VC position through linear potentiometers
- Aerotech “Autofocus” functionality allows to track the motion of the VC while maintaining constant undulator gap

Linear potentiometer

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ICALEPCS 2019 – Brooklyn – 5 – 11 October 2019
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Centering of SXR Undulator Gap on Vacuum Chamber

- Vacuum Chamber (VC) aligned with undulator gap during installation
- Imperfections in undulator drive system. Undulator centerline shifts (~100 μm) during gap adjustment
- Linear potentiometers can be calibrated. Provide feedback on position of vacuum chamber (offset and slope)
- Centering of undulator gap with error < 15 μm RMS. Verified during magnetic tuning
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- Most relevant motion control features:
  - Tracking the motion of the SXR vacuum chamber with the undulator gap
  - Centering of SXR undulator gap on vacuum chamber
  - Calculation of undulator $K$ parameter based on its gap
Undulator K Parameter

- K parameter index of undulator strength and depends on undulator gap
- K-gap relationship determined experimentally during magnetic tuning
- Third order spline approximation
- Spline interpolation EPICS module developed at SLAC for direct and inverse interpolation
- Temperature-dependent
- Basis for HLA controlling the whole undulator line
Installation Status

- All SXR undulators have been magnetically tuned
- HXR undulators are being tuned
- Phase shifters are being tuned
- Installation begun mid-August 2019. All SXR undulators are installed. 20 HXR undulators will be installed by December 2019
- Phase shifters are being installed
- Controls deployment started in mid-September. ~ 4 undulators a week
- Beam-based commissioning will start in January 2020
The Team

- ANL, LBNL, SLAC, Cosylab, Keller Technologies, Motion Solutions, Danfysik
- Mechanical Engineers
- Controls Engineers (HW and SW)
- Scientists (system design, magnetic tuning)
- Metrology
- Riggers
Summary

• LCLS-II will have two undulator lines operating in parallel: SXR and HXR
• New design required implementing new control features:
  - Track motion of SXR vacuum chamber with undulator gap
  - Center SXR undulator gap on vacuum chamber
  - Continuous calculation of undulator K value based on undulator gap and vice versa
• Installation and commissioning to be completed by December 2019
THANK YOU

Questions?