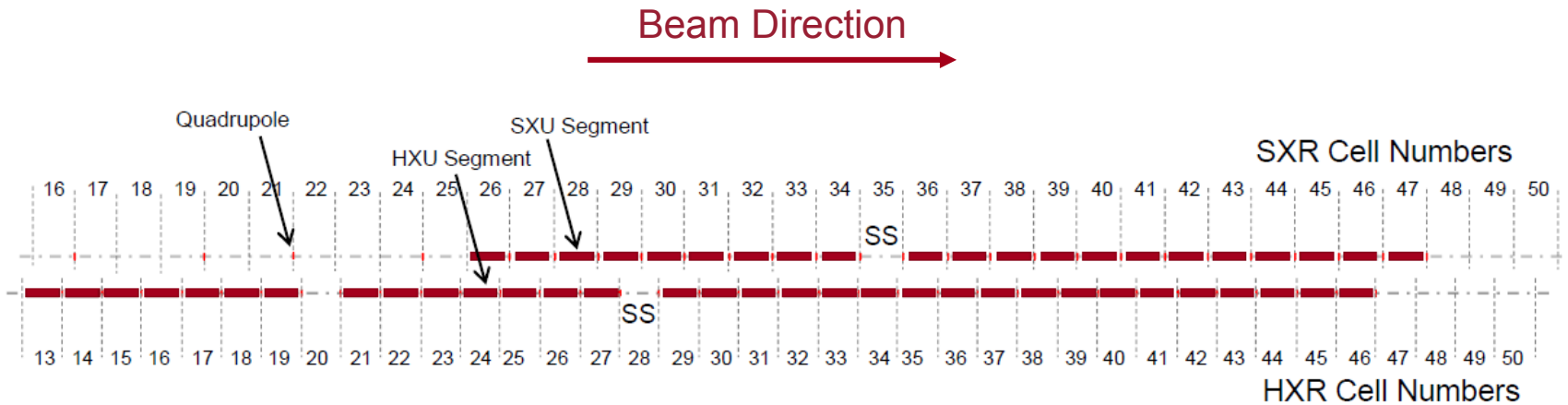# Implementation of the Motion Control System for LCLS-II Undulators

Maria Alessandra Montironi

October 9, 2019

SLAC NATIONAL ACCELERATOR LABORATORY

LCLS-II Undulator Hall

Beam Direction

Quadrupole

HXU Segment

SXU Segment

SXR Cell Numbers

16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

SS

SS

13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

HXR Cell Numbers

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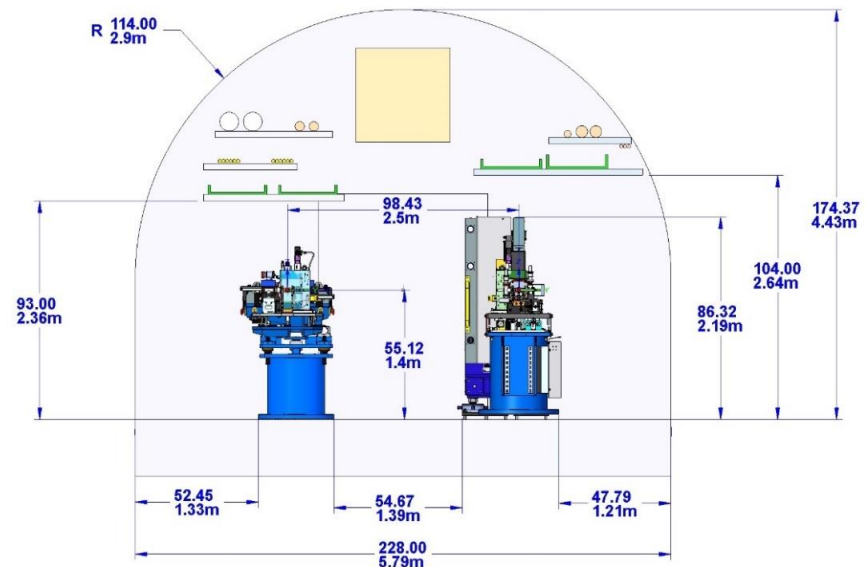
Overview

- **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

Soft X-Ray (SXR) undulator segment. Gap opens in vertical plane

Beam Direction

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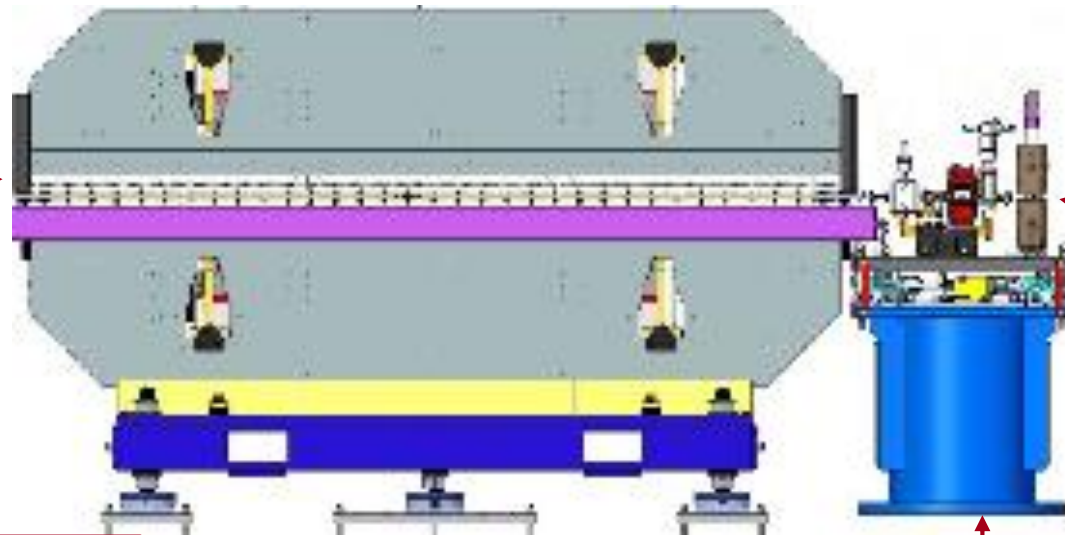
- 21 undulator segments
- 23 interspace assemblies
- 20 phase shifters

Interspace Assembly. 5 DOF through cam movers. Mounting surface for vacuum chamber
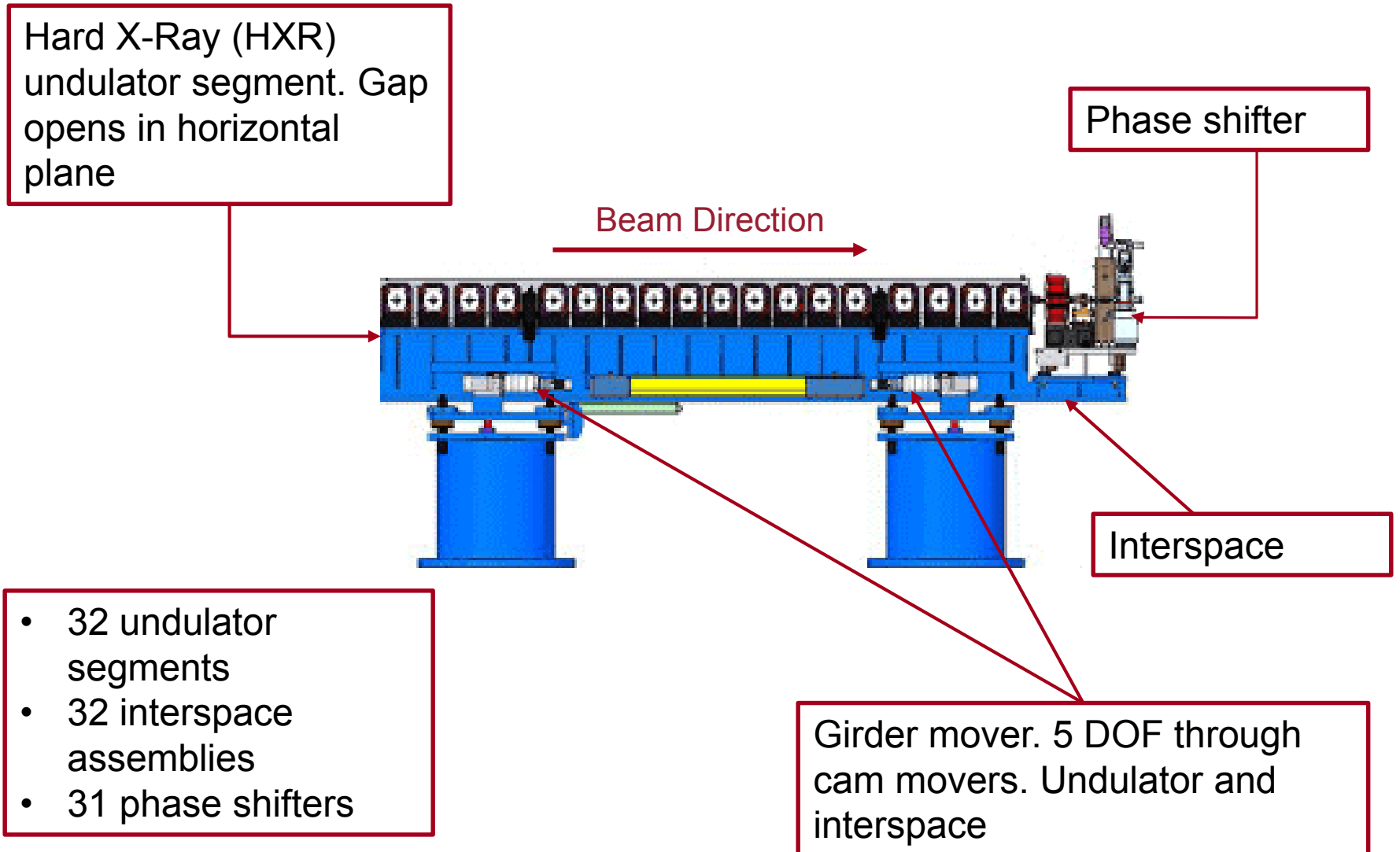
LCLS-II SXR Undulator Motion Control System

- 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.

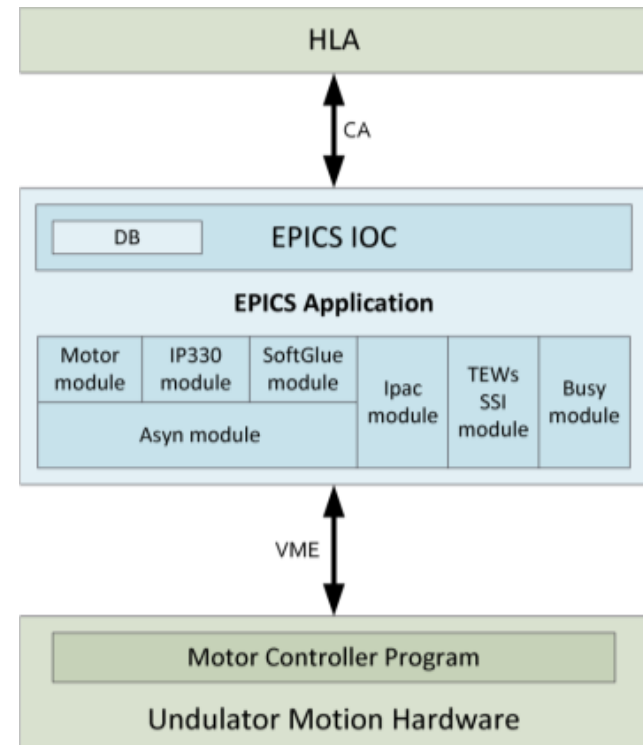- Rotary potentiometers for cam position feedback.
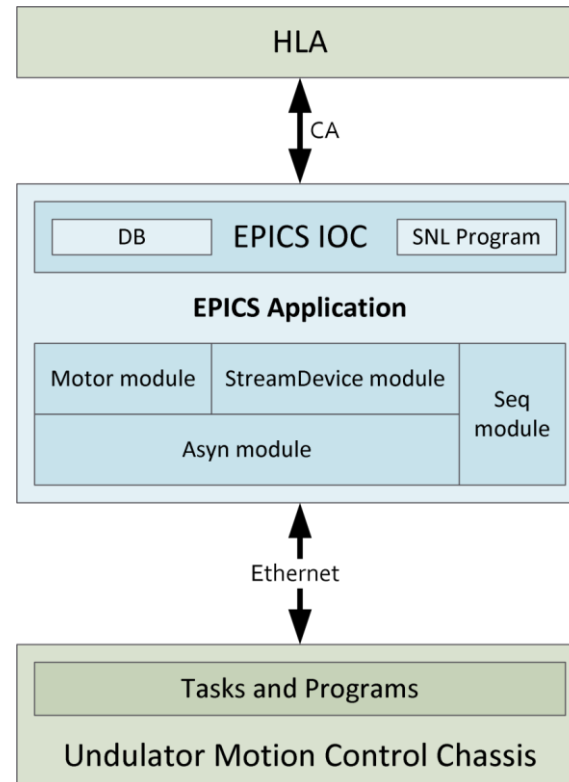
K.R. Lauer et al., "LCLS-II Undulator Motion Control", in Proc. 16th Int. Conf. on Accelerator and Large Experimental Control Systems (ICALEPCS'17), Barcelona, Spain, Oct. 2017,.

LCLS-II HXR Undulator Cell

Hard X-Ray (HXR) undulator segment. Gap opens in horizontal plane

Phase shifter

Beam Direction

Interspace

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

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

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

K.R. Lauer et al., "LCLS-II Undulator Motion Control", in Proc. 16th Int. Conf. on Accelerator and Large Experimental Control Systems (ICALEPCS'17), Barcelona, Spain, Oct. 2017,.
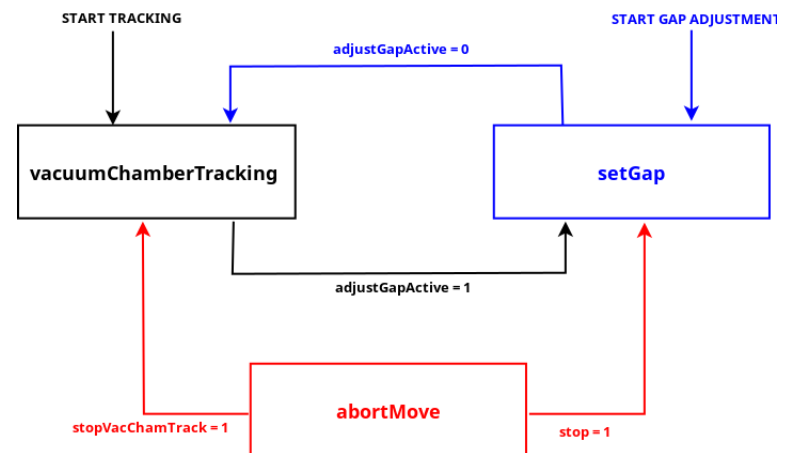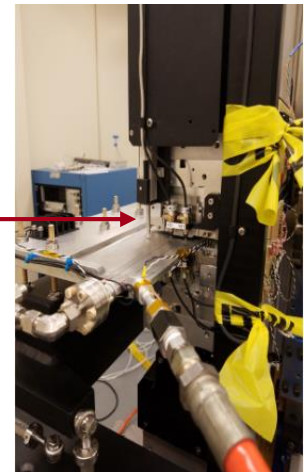
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  - Centering of SXR undulator gap on vacuum chamber
  - Calculation of undulator K parameter based on its gap

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

START TRACKING

START GAP ADJUSTMENT

adjustGapActive = 0

vacuumChamberTracking

setGap

adjustGapActive = 1

abortMove

stopVacChamTrack = 1

stop = 1

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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
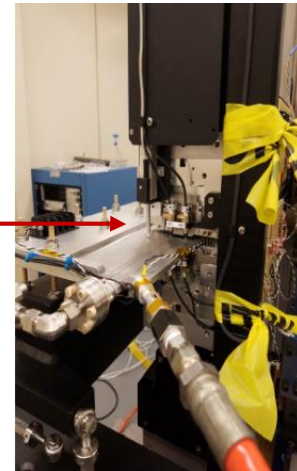
Linear potentiometer

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  - **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

K-GAP EXPERIMENTAL CURVE
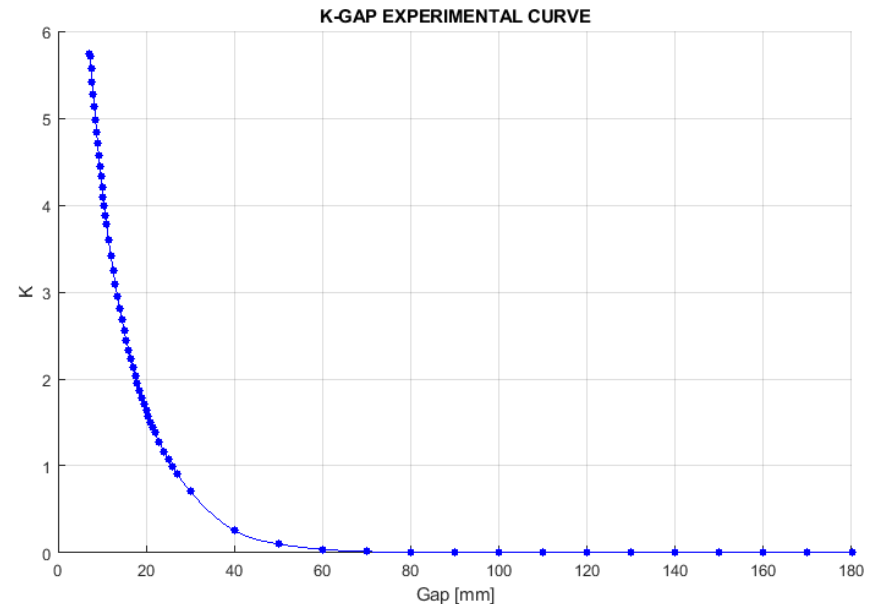
Installation Status

- 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?