Magnetic Measurements of LCLS-II Phase Shifters and Hard X-Ray Undulators

7 October 2019

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SLAC Nobel Prize Laureates

Richard E. Taylor (1929-2018)

1990 Nobel Prize in Physics for
investigations that led to the quark model in particle physics

Burton Richter (1931-2018)

1976 Nobel Prize in Physics for
discovery of the J/psi meson

SLAC Nobel Prize Laureates

Martin Lewis Perl (1927-2014)

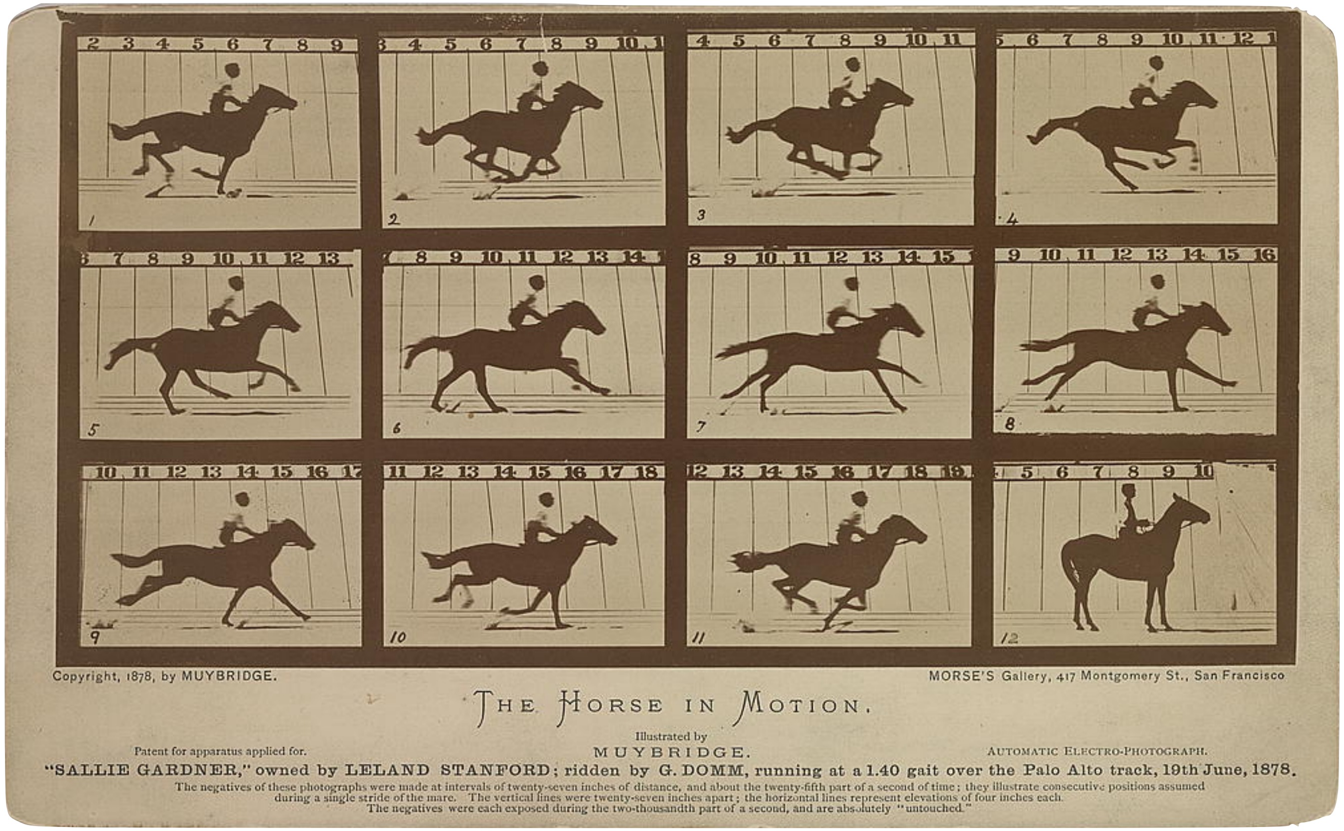
1995 Nobel Prize in Physics for
discovery of the tau lepton

Roger D. Kornberg (1947)

2006 Nobel Prize in Chemistry for
determining how information from DNA is copied to RNA

Beginning of Motion Studies

Leland Stanford
(1824-1893)




LCLS Ground Level
2 miles
STOP


LCLS by SLAC

LCLS-II Upgrade from the Undulator Perspective

Two undulator lines: SXR and HXR

Number of SXR undulators: 22

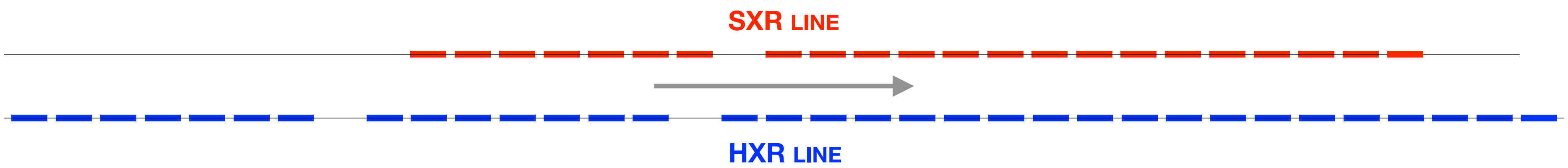
Number of HXR undulators: 33

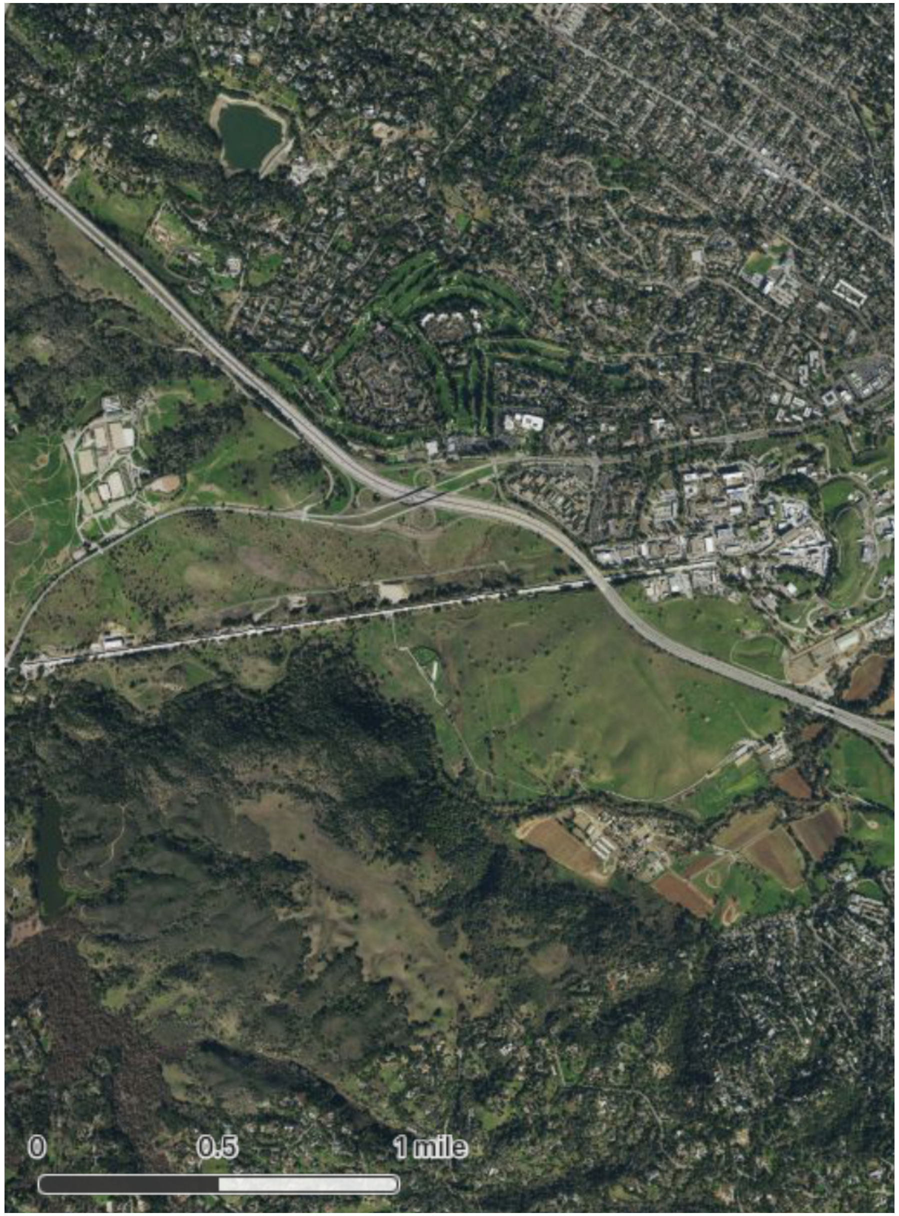
Reusing LCLS pedestals: A, B, and C

Girder cam positioning: 5 DOF

Motion control: EPICS

Measurement end planned by mid 2020

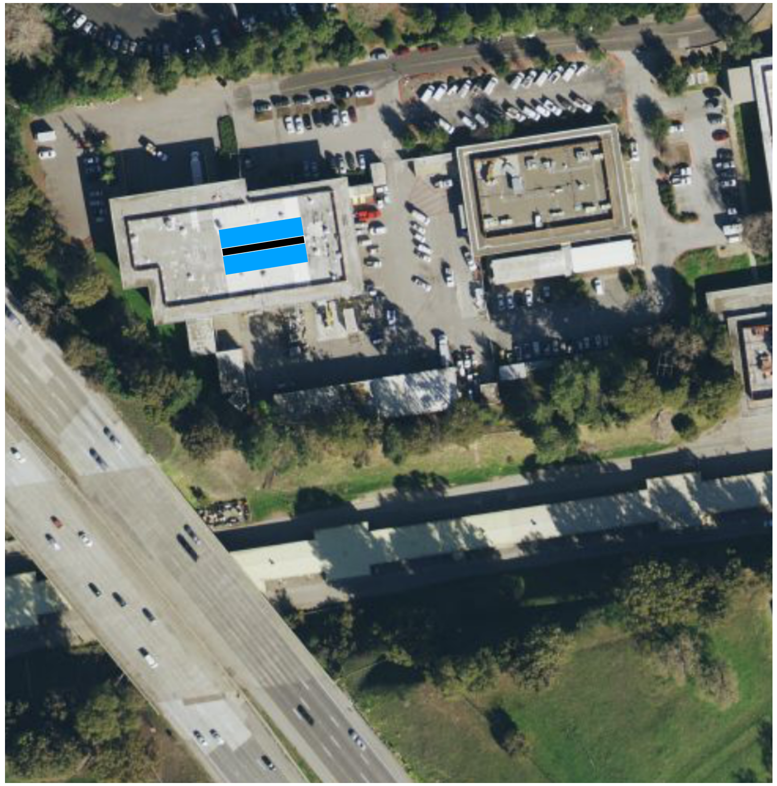




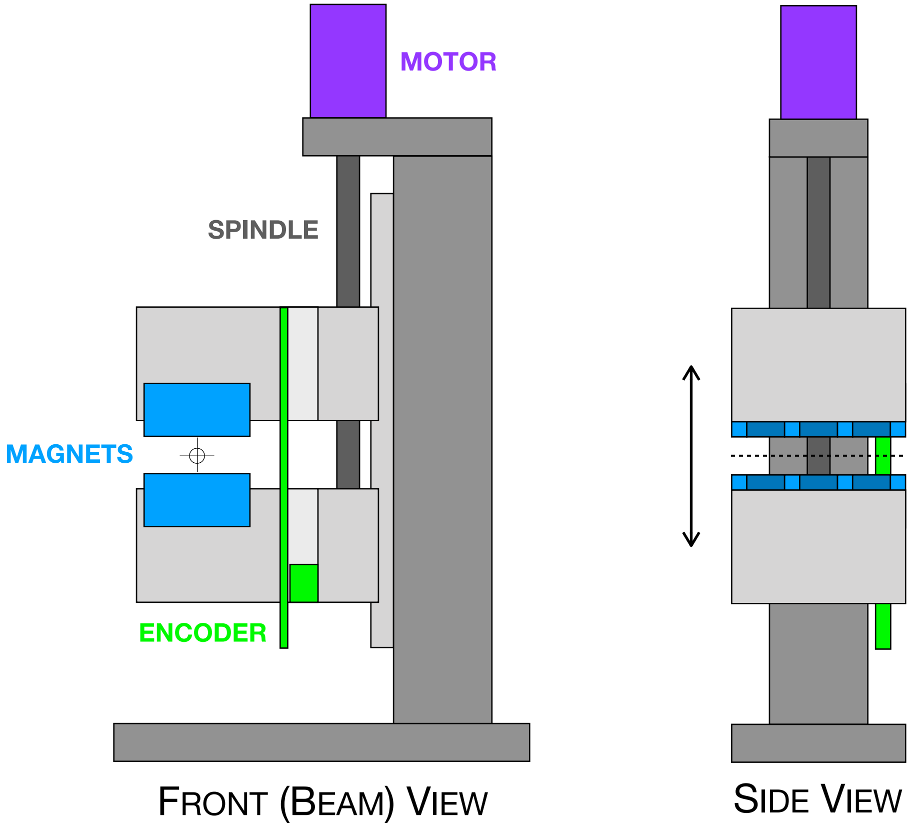
LCLS-II & SLAC MMF

Equal Conditions

Bearings: ~EW (81°)
Temperature: 70 °F (20 °C)



LCLS-II Phase Shifters



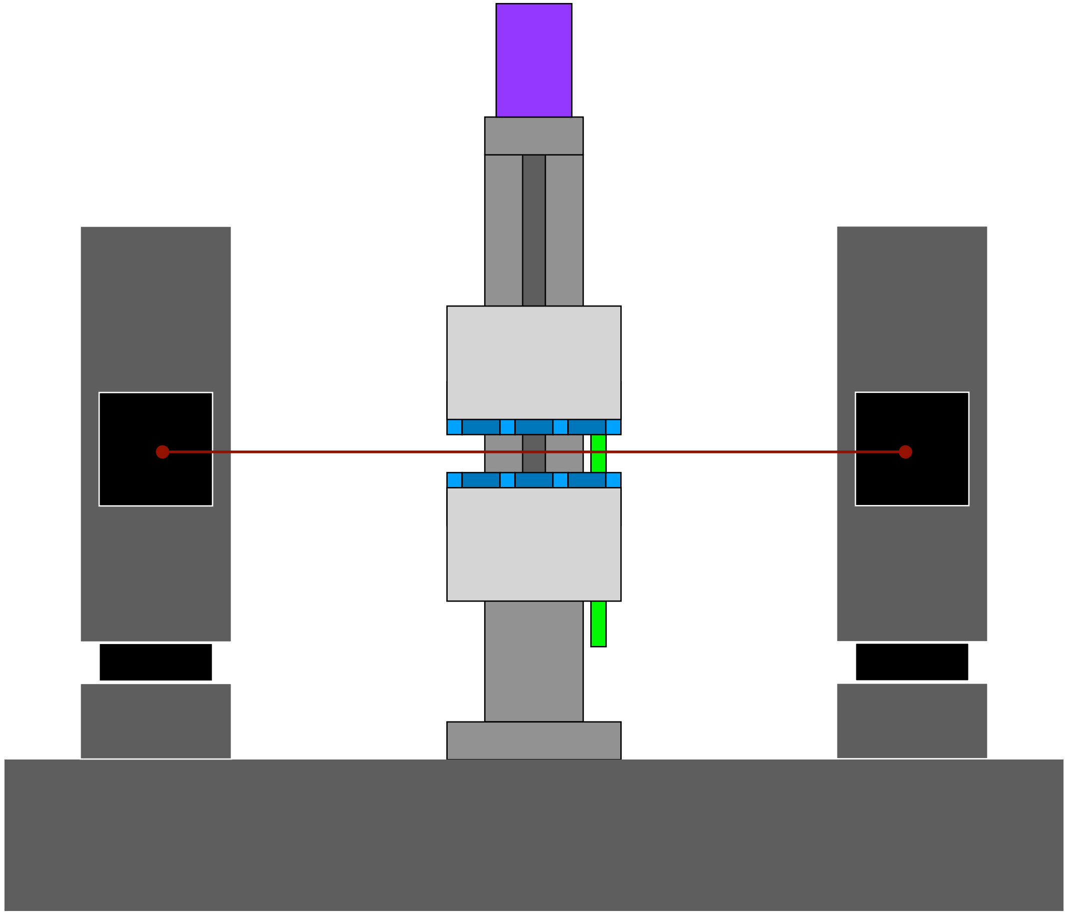
SOFT X-RAY (SXPS)
&
HARD X-RAY (HXPS)
PHASE SHIFTERS

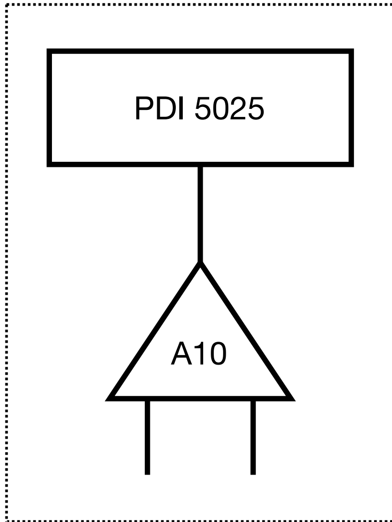
Manufacturer:	Danfysik
Number of periods:	1
Variable gap:	10 – 100 mm
Encoder:	Renishaw (SXPS)
	AMO (HXPS)

MAGNETIC MEASUREMENTS

- Moving stretched wire (MSW)
- Hall probe

MSW-Measurement Setup





Multistrand wire

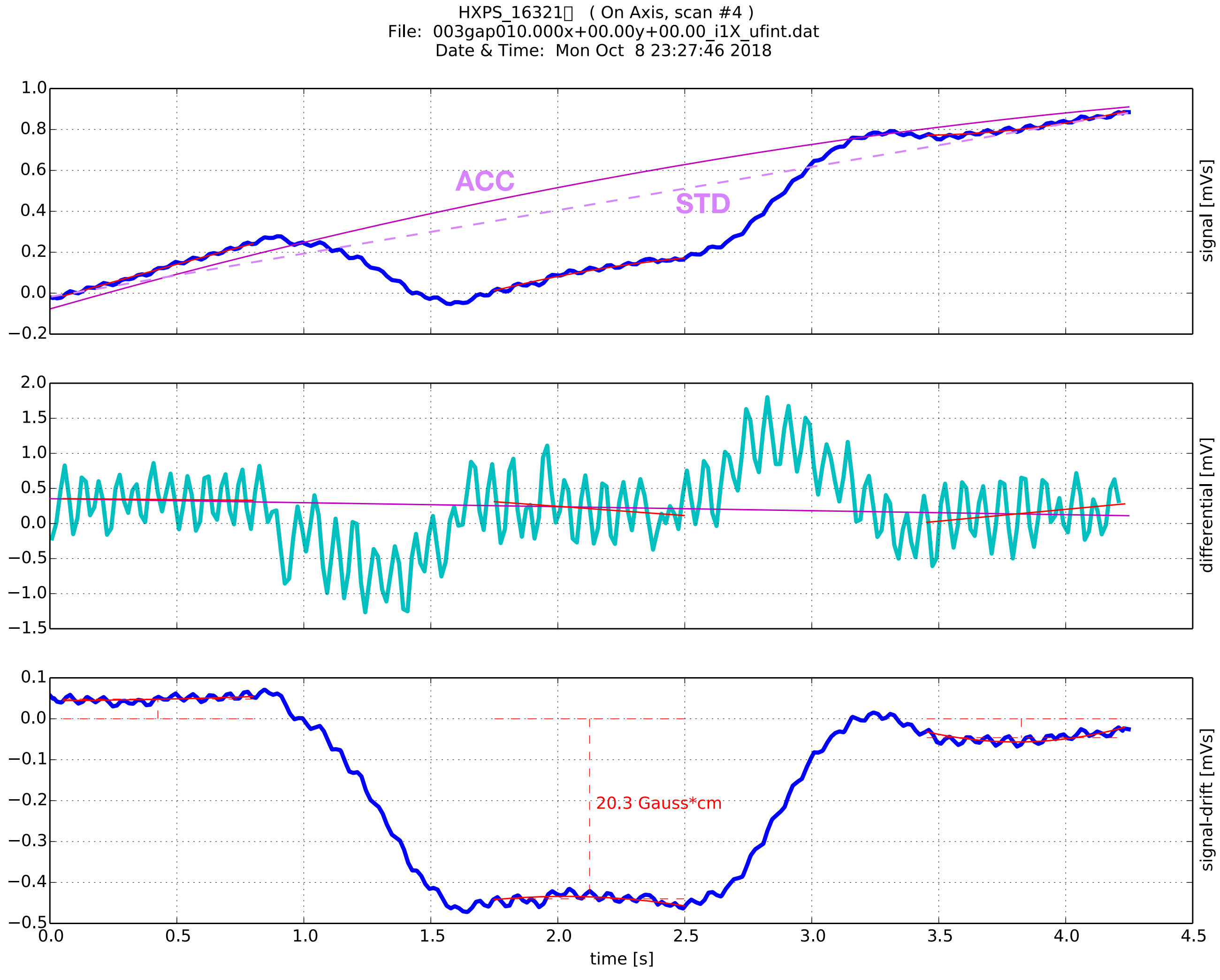
Signal amplification (~2k)

Bench—tunnel =orientation
(HXPS / SXPS 180° rotated)

MSW-Measurements Analysis

SOFTWARE

C
MATLAB
Python
Bash



HXPS & SXPS MSW-Measurements

ONE TIME ONLY

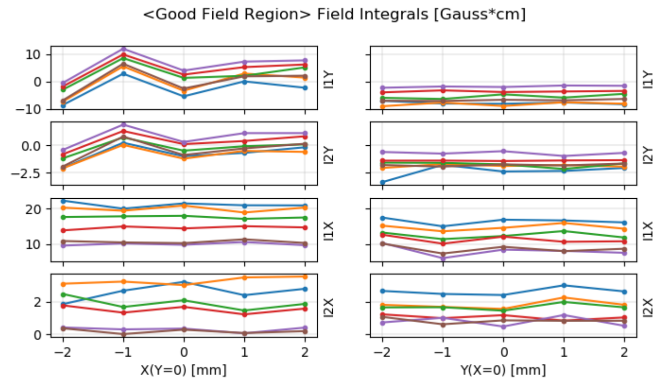
- Background fields
- Calibration

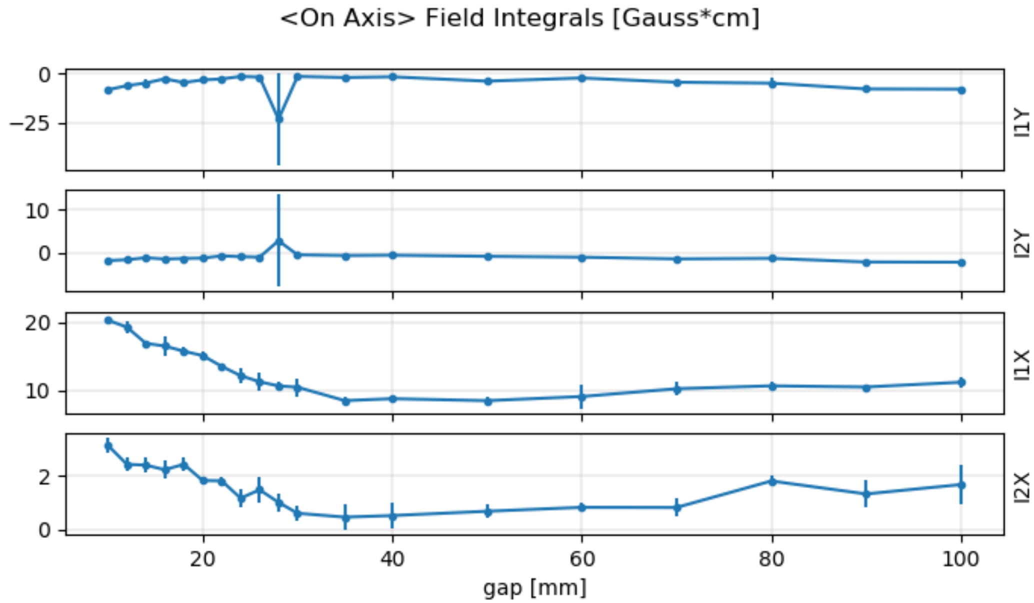
PREPARATION

- From storage
- 1^{+} day T pre-conditioning

MEASUREMENT

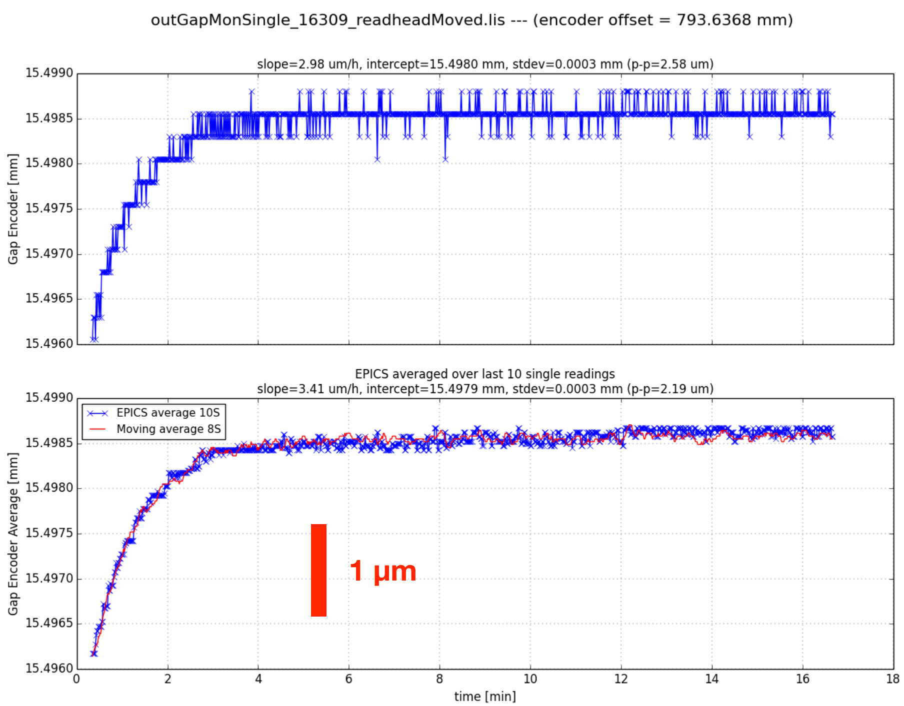
- I_{1Y}, I_{2Y}, I_{1X}, I_{2X}
- 19 gaps (10-100 mm)
- 5 X/Y positions (±2 mm)
- Multiple scans per gap/pos
- >10 h

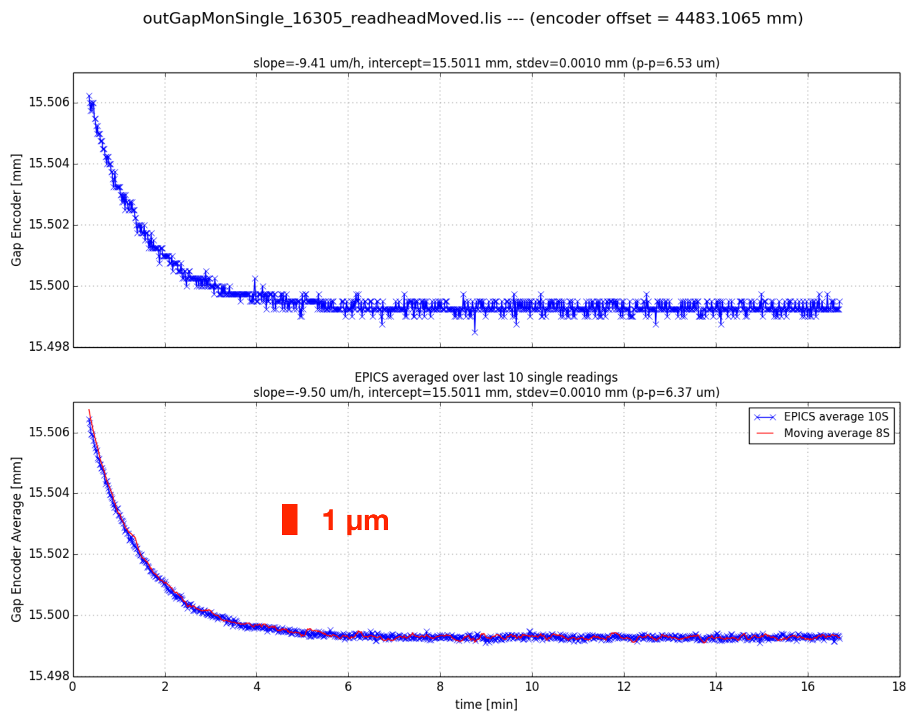




HXPS & SXPS Issues

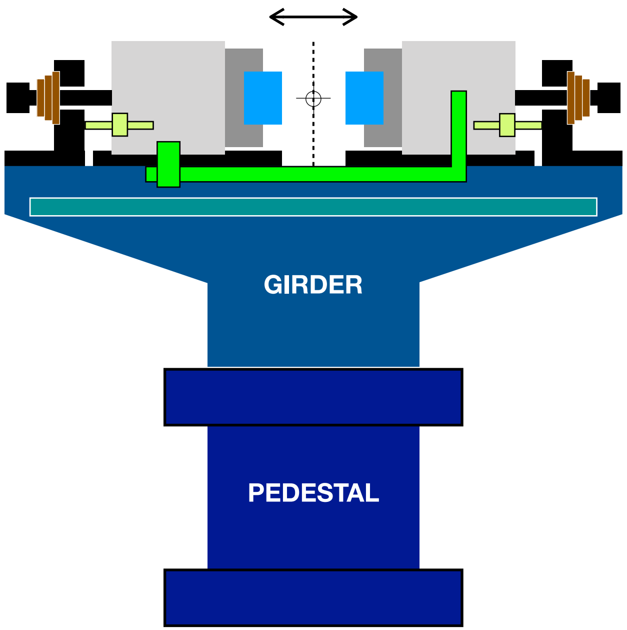
- Gap drifts during measurements ➡ cable pushing onto the encoder scale
- Noisy encoder readings ➡ encoder readhead — scale gap
- Gap changes after control system switches on ➡ encoder readhead — scale angle
- Weakening magnetic field over time ➡ magnetisation | encoder offset | …





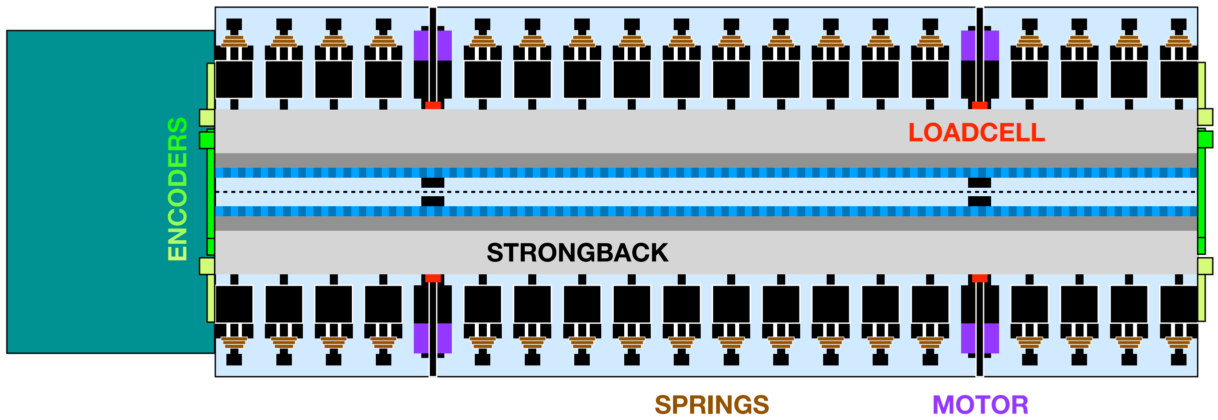
HXR Undulator (HXU)

Horizontal-Gap
Vertically-Polarizing
Out-of-Vacuum Undulator



Front (Beam) View

Top View



Manufacturers:	Keller Technology Motion Solutions
Number of periods:	130
Period:	26 mm
Total length:	3.4 m
Variable gap:	7.2 – 110 mm
Magnet material:	NdFeB
Pole material:	Vanadium

HXU Magnetic Measurements Scheme

PRE-TUNING
- LBNL
- ANL

FINAL TUNING AT SLAC
- HP
- Long coil (LC)

WHEN/IF NEEDED
- Background fields
- HP calibration
- Shim signatures

PERIODICALLY
- Reference undulator

PREPARATION
- From storage
- 1^+ week T pre-conditioning
- Mechanical measurement (CMM)
- Mechanical alignment to HP bench

HP/LC MEASUREMENTS

FIDUCIALIZATION
- Pointed magnets
- Laser tracker
- CMM

HXU HP/LC Magnetic Measurements

HP Measurements
- Magnetic alignment (pitch, yaw)
- Taper in gap correction
- Balancing forces on strongbacks
- Setting half-gap encoder offsets
- Tuning for trajectory correction

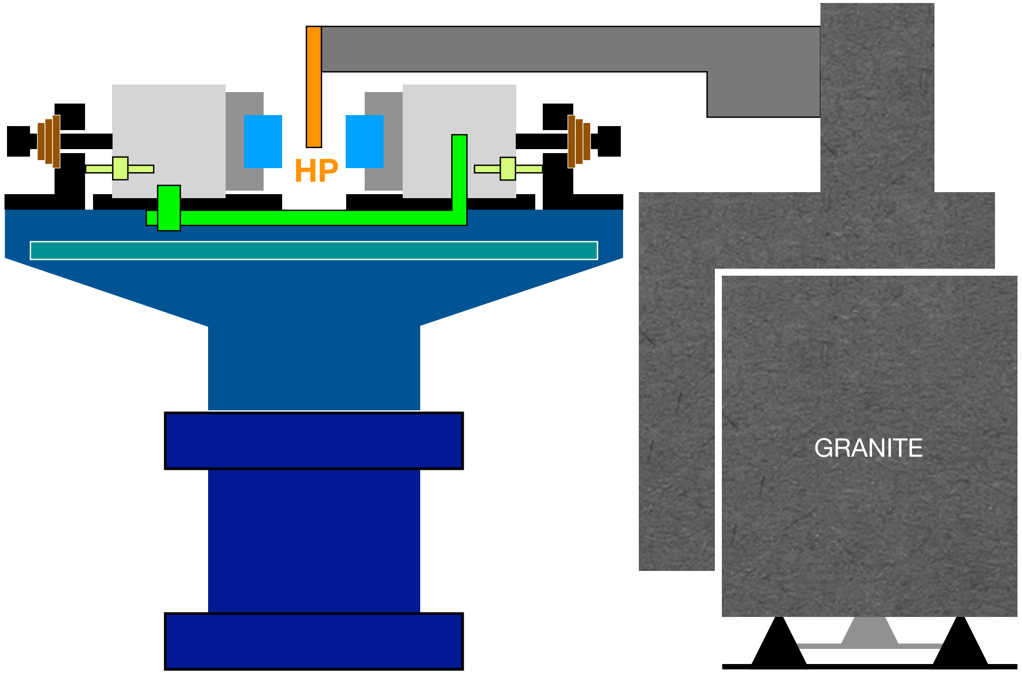
LC Measurements
- Tuning for zero field integrals
- Tuning for phase error correction

HP Measurements
- Checking trajectories [retuning]
- Tuning for phase matching correction

LC Measurements
- Checking field integrals [retuning]
- Final dataset at multiple gaps

HP Measurements
- Finding the commissioning gap (K=2.34)
- Final dataset at multiple gaps

HP / Capacitive Sensors Measurement Setup



Bench—tunnel =orientation

Temperature controlled (<0.1°)

Kugler bench (X.Y.Z)

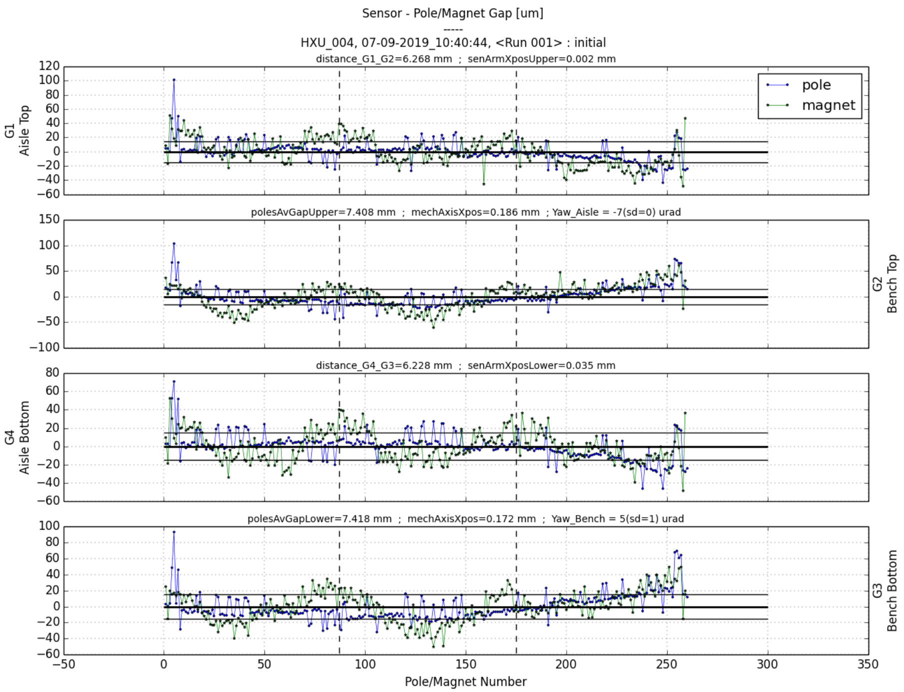
Sentron 2D HP (3 DOF)

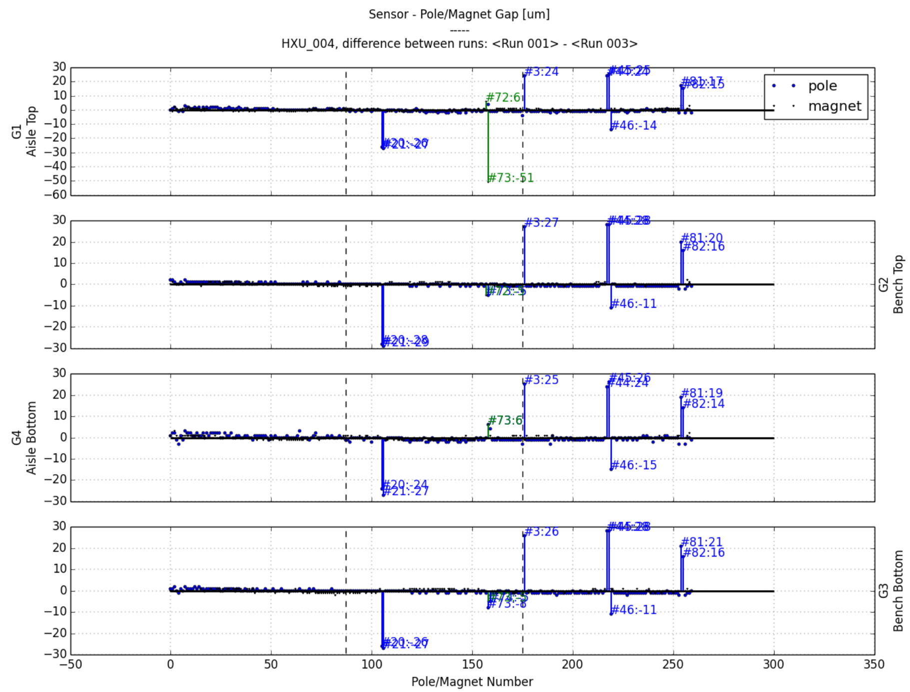
Capacitive sensors (6x)

HP crash protection

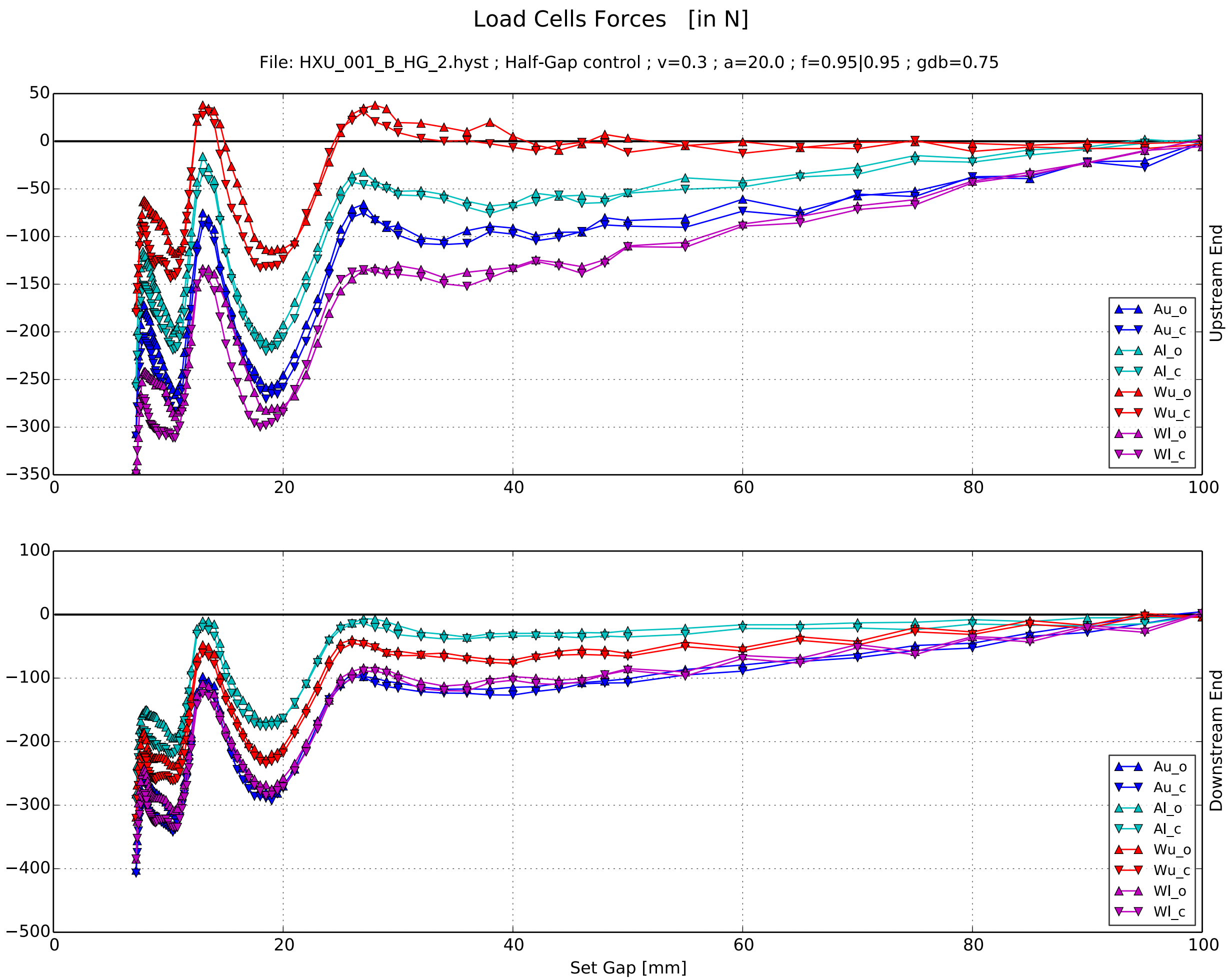
Capacitive Sensors

- Before tuning ➡ yaw and pitch angle; visualize potential problems
- After tuning ➡ control of the applied changes; shows the minimal gap





Load Cells

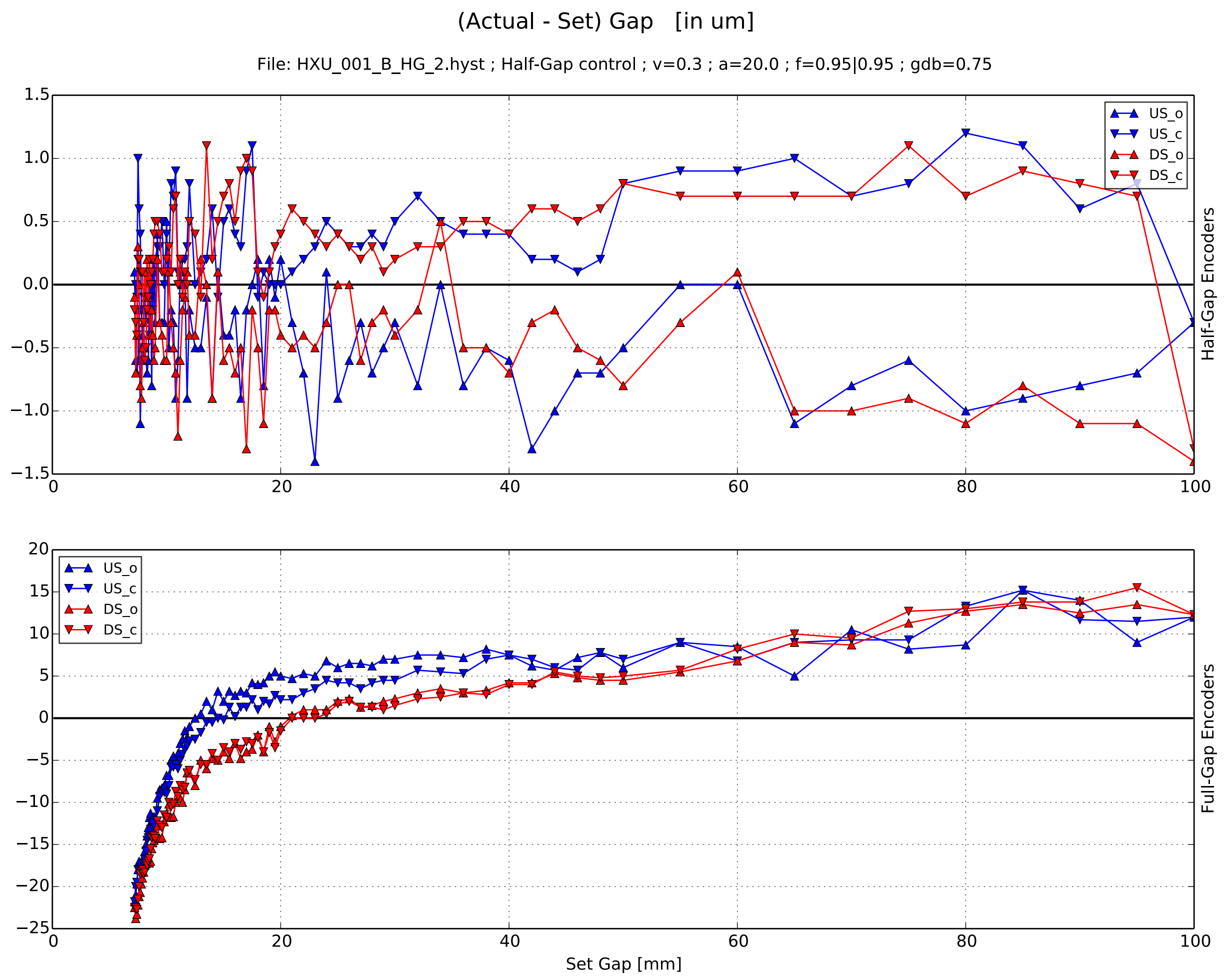


Characteristic force picture

Used for force balancing

Problem with many springs

Half-Gap vs Full-Gap Encoders



Full-gap encoders used

Half-gap not representing the gap change

Hysteresis in opening and closing of the gap

Summary

- Equal conditions during measurement and in operation is indispensable
- Critically, thoroughly and methodically analyse results before starting the measurement series
- Periodic measurement of a reference object reveals problems and is not a waste of time
- Test HP and DMM (multimeter) at the beginning and at the end of the final measurement
- Calibrate HP as soon as it drifts out of tolerance
- Stay in time, follow the measurements with immediate data analysis

AND

*WISHING OUR **SLAC** COLLEAGUES A FULL SUCCESS WITH THE **LCLS-II***