LCLS-II HXU Measurement Results

Serial number from manufacturers label: | HXU-004

Measurement Procedure:
The measurements have been carried out after the undulator segment had been fully tuned according to the “LCLS-II Undulator Test Plan” (LCLS-TN-17-1).

<table>
<thead>
<tr>
<th>General Hall Probe Scan Evaluation Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulator Temperature (should be 20.0)</td>
</tr>
<tr>
<td>First core pole #</td>
</tr>
<tr>
<td>Last core pole #</td>
</tr>
<tr>
<td>Tuning Gap</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation of Hall Probe Scans at Commissioning Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commission Gap Temperature (should be 20.0)</td>
</tr>
<tr>
<td>$r_{ms}$ ($</td>
</tr>
<tr>
<td>$K_{eff}$ at Commission Gap (should be 2.3400)</td>
</tr>
<tr>
<td>Commission Gap</td>
</tr>
<tr>
<td>$I_1 X$ (over 4.012667 m) (should be within ±40)</td>
</tr>
<tr>
<td>$I_2 X$ (over 4.012667 m) (should be within ±150)</td>
</tr>
<tr>
<td>$I_1 Y$ (over 4.012667 m) (should be within ±40)</td>
</tr>
<tr>
<td>$I_2 Y$ (over 4.012667 m) (should be within ±150)</td>
</tr>
<tr>
<td>Phase Shake (rms phase fluctuations over core poles (&lt; 4.0))</td>
</tr>
<tr>
<td>Cell Phase Advance (over 4.012667 m)</td>
</tr>
<tr>
<td>Undulator Entrance Phase$^1$</td>
</tr>
<tr>
<td>Undulator Exit Phase$^2$</td>
</tr>
</tbody>
</table>

$^1$Phase advance from cell start (undulator center −2.006334 m) to center of physical pole 8.

$^2$Phase advance from physical pole 253 to cell end (undulator center +2.006334 m).
### Undulator Encoder Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>USGapEncoderOffset</td>
<td>-663.7807</td>
</tr>
<tr>
<td>DSGapEncoderOffset</td>
<td>-381.1037</td>
</tr>
<tr>
<td>USWLinearEncoder.AOFF</td>
<td>92.9805</td>
</tr>
<tr>
<td>DSWLinearEncoder.AOFF</td>
<td>92.9885</td>
</tr>
<tr>
<td>USALinearEncoder.AOFF</td>
<td>92.2570</td>
</tr>
<tr>
<td>DSALinearEncoder.AOFF</td>
<td>91.2797</td>
</tr>
</tbody>
</table>

### Undulator Load Cell Readings at Tuning Gap

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC.DAL_FORCE</td>
<td>-200.2</td>
</tr>
<tr>
<td>LC.DAU_FORCE</td>
<td>-184.6</td>
</tr>
<tr>
<td>LC.DWL_FORCE</td>
<td>-92.5</td>
</tr>
<tr>
<td>LC.DWU_FORCE</td>
<td>-273.7</td>
</tr>
<tr>
<td>LC.UAL_FORCE</td>
<td>-182.4</td>
</tr>
<tr>
<td>LC.UAU_FORCE</td>
<td>-181.6</td>
</tr>
<tr>
<td>LC.UWL_FORCE</td>
<td>-197.3</td>
</tr>
<tr>
<td>LC.UWU_FORCE</td>
<td>-197.3</td>
</tr>
</tbody>
</table>

### Undulator Load Cell Readings at 100 mm Gap

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC.DAL_FORCE</td>
<td>-2.7</td>
</tr>
<tr>
<td>LC.DAU_FORCE</td>
<td>-2.9</td>
</tr>
<tr>
<td>LC.DWL_FORCE</td>
<td>-2.4</td>
</tr>
<tr>
<td>LC.DWU_FORCE</td>
<td>-1.7</td>
</tr>
<tr>
<td>LC.UAL_FORCE</td>
<td>0.0</td>
</tr>
<tr>
<td>LC.UAL_FORCE</td>
<td>-2.0</td>
</tr>
<tr>
<td>LC.UWL_FORCE</td>
<td>-1.5</td>
</tr>
<tr>
<td>LC.UWU_FORCE</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Evaluation of Hall Probe Scans: $K_{\text{eff}}$ vs. gap

![Graph showing $K_{\text{eff}}$ vs. gap](image_url)
Evaluation of Hall Probe Scans: $K_{\text{eff}}$ Hysteresis

Plotted functions have been calculated from measured values openKeff (opengap) and closeKeff (closegap) using the following Matlab calculations:

- **Blue Stars**: \(1 - \frac{\text{openKeff}}{\text{spline(opengap([1,2,[3:2:end]]),openKeff([1,2,[3:2:end]]),opengap})}
- **Green Stars**: \(1 - \frac{\text{closeKeff}}{\text{spline(opengap([1,2,[3:2:end]]),closeKeff([1,2,[3:2:end]]),closegap})}

Tolerance (+0.00023) and (-0.00023) are indicated on the graph.
Evaluation of Hall Probe Scans: Phase Shake vs gap
Evaluation of Hall Probe Scans: $K_{\text{eff}}$ vs x at Tuning Gap

Tuning Gap = 9.0mm

$K_{\text{eff}}(x) = 0.0592/\text{mm}^2 x^2 - 0.0019/\text{mm} x 2.0071$

$x_{\text{center}} = -0.016 \text{ mm}$
Evaluation of Hall Probe Scans: $K_{\text{eff}}$ vs Y at Tuning Gap

**HXU-004: $K_{\text{eff}}$ vs. y @ Tuning Gap**

Tuning Gap = 9.0mm

$K_{\text{eff}}(y) = -0.000004/\text{mm} \times y + 2.0071$
Long Coil Measurement of the On-Axis First Horizontal Field Integrals

![Graph](image)

**HXU-004: I1x vs. gap**

- First Field Integral x
- Tolerance (+40 μT·m)
- Tolerance (-40 μT·m)

**Axes:**
- Y-axis: First Field Integral x [μT·m]
- X-axis: Full Gap [mm]

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Long Coil Measurement of the On-Axis Second Horizontal Field Integrals

HXU-004: \( I_{2x} \) vs. gap

Second Field Integral x

Tolerance (+150 \( \mu \text{T.m}^2 \))

Tolerance (-150 \( \mu \text{T.m}^2 \))
Long Coil Measurement of the On-Axis First Vertical Field Integrals
Long Coil Measurement of the On-Axis Second Vertical Field Integrals

HXU-004: $I_2y$ vs. gap

- Second Field Integral $y$
- Tolerance (+150 $\mu$T.m$^2$)
- Tolerance (-150 $\mu$T.m$^2$)

Full Gap [mm]
The following plots show the pole and magnet position measurements. The LBNL system has two back-to-back capacitive probes on one probe holder. The x and y stages on the Kugler bench are positioned so that the probe is in the proper location for each of the 9 scan locations. For the data analysis, the average pole position in each scan is used as reference for the plotted pole and magnet positions. Note that for all plots, the first three and last three poles of the device are omitted since the measurement is not accurate due to end effects in the capacitance probe measurement.
G1 Capacitive Sensor Readings

**HXU-004: Distance from Probe (Aisle Top)**

![Graph showing the distance from probe (aisle top) for poles and magnets.](image)

- Distance [mm]
- z [m]

- Distance from Probe (Aisle Top)
- Poles
- Magnets
**G2 Capacitive Sensor Readings**

![Graph: HXU-004: Distance from Probe (Aisle Bottom)]

- Distance [mm]
- z [m]

**Data Points**
- Poles
- Magnets
G3 Capacitive Sensor Readings

![Graph showing HXU-004: Distance from Probe (Wall Top)]
G4 Capacitive Sensor Readings

HXU-004: Distance from Probe (Wall Bottom)

- Distance [mm]
- z [m]

Points represent distances from the probe to the wall bottom for poles and magnets.
Undulator Gap Measurement

HXU-004: Undulator Gap Measurement

Gap = 30.0 mm
Gap = 7.2 mm
Undulator Gap Difference

HXU-004: Gap Shape Change [gap(7.2) minus gap(30)]

- Gap Distortion
- Tolerance: +9.5µm
- Tolerance: -9.5µm
Drive Loads (Gap Opening)

HXU-004 Drive Load Forces

- $F_{\text{Aisle}}^{\text{up}}$, opening
- $F_{\text{Wall}}^{\text{up}}$, opening
- $F_{\text{Aisle}}^{\text{dn}}$, opening
- $F_{\text{Wall}}^{\text{dn}}$, opening

Tolerance (+0 N) vs. Full Gap [mm]

Tolerance (-700 N) vs. Full Gap [mm]
Drive Load Differences (Gap Opening and Closing)

HXU-004 Drive Load Differences: Upstream - Downstream

- Drive Load Force Difference [N]
- Full Gap [mm]
- Tolerance (+130 N)
- Tolerance (-130 N)
Strongback Forces (Gap Opening and Closing)

![Graph showing HXU-004 Strongback Forces]

- HXU-004 Strongback Forces
- Strongback Force [N]
- Full Gap [mm]
- Tolerance (+0 N)
- Tolerance (-1400 N)

Graph legend:
- $F_{\text{Aisle closing}}$
- $F_{\text{Wall closing}}$
- $F_{\text{Aisle opening}}$
- $F_{\text{Wall opening}}$
Strongback Force Differences (Gap Opening and Closing)

![Graph showing Strongback Force Differences: Aisle - Wall](image)

- **HXU-004 Strongback Force Differences: Aisle - Wall**
- **Full Gap [mm]**
- **Strongback Force Difference [N]**

- **Tolerance (+200 N)**
- **Tolerance (-200 N)**

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