**Measurement of LCLS-II SXR undulator K hysteresis.**

One of the features of LCLS-II SXR undulators is a significant hysteresis in setting the desired K value. At a given gap, the undulator K depends on direction from which the gap is set. Whether the source of the hysteresis is mechanical or magnetic or both is not clear now.

The hysteresis is a difference between measured K values at the same gap when the gap was set from two directions; closing, coming from bigger to desired gap, minus opening, coming from smaller to desired gap. Figure 1 shows measured K hysteresis for all SXR undulators.

Figure 1. SXU’s hysteresis measured at calibration.

During the calibration process the undulator K was measured vs. gap with gap changing from the smallest 7.2mm to the maximum 180mm (opening direction) and a file with data for a cubic spline fit was generated. The same direction must be used during the operation to meet the requirement on K, which is set as 1\*10-4. This is one third of total requirement on K accuracy to allow for other errors.

To figure out if this rule should be applied to all possible motions the following test was performed using SXU-021. The undulator K was measured always at 10mm gap with different directions of gap setting. The results are summarized in table 1. The notation 7.2mm->20mm->10mm means that the gap was set to 7.2mm initially, then opened to 20mm, and finally closed to 10mm. The relative change in K value dK/K is given in 10-4 units for easy reading.

The measurements are divided into two sets. The first set was done to determine the amount of “overshot” required to set the K correctly. Initially, the gap was set by opening from 7.2mm to 10mm. The same motion was done before the final K measurement to make sure nothing changed during the test.

The second set of measurements was made to see if small gap changes still required overshoot. The K values are different because the second set of measurements was done after a number of efforts to reduce the hysteresis, like cleaning the encoder surfaces, replacing the encoder springs, re-aligning the read head, lubricating rails and compensation springs. The encoder offsets had to be changed in the process to keep the undulator taper close to zero. As in the first set, an initial measurement was done after 7.2mm to 10mm motion. The same motion done at the end to confirm that nothing changed in the system.

**Table 1**

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| --- | --- | --- |
| **Gap Motion** | **K** | **dK/K \*104** |
| 7.2->10 | 4.229304 | 0.0 |
| 20->8->10 | 4.229149 | -0.4 |
| 20->8.5->10 | 4.228957 | -0.8 |
| 20->9->10 | 4.228722 | -1.4 |
| 20->9.5->10 | 4.228374 | -2.2 |
| 20->9.9->10 | 4.228074 | -2.9 |
| 20->9.95->10 | 4.228041 | -3.0 |
| 20->9.99->10 | 4.227949 | -3.2 |
| 20->10 | 4.228115 | -2.8 |
| 20->7.2->10 | 4.229347 | 0.1 |
|  |  |  |
| 7.2->10 | 4.233436 | 0.0 |
| 7.2->8->10 | 4.233351 | -0.2 |
| 10->9->10 | 4.233457 | 0.0 |
| 10->11->10 | 4.233137 | -0.7 |
| 7.2->11->10 | 4.233037 | -0.9 |
| 10->12->10 | 4.23273 | -1.7 |
| 7.2->12->10 | 4.232751 | -1.6 |
| 15->9->10 | 4.233021 | -1.0 |
| 7.2->10 | 4.233342 | -0.2 |

The “overshot” required in a gap setting from a bigger gap depends on the magnitude of motion. The K would be set to 10-4 if motion is in ±1.5mm range. If a bigger gap closing is required, the “overshot” should be 2mm or the gap should be closed to minimum value of 7.2mm to set the K with 10-4 accuracy.