LCLS-II-HE SXR Undulator Phase Matching Test Results

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Abstract

This note documents a phase matching test of an LCLS-II-HE undulator and phase shifter. Using calibration data from both devices, the undulator gap was set to give a specified K value, and the phase shifter gap was set to give the phase integral calculated to give the phase matching. Measurements were then made and the error in the phase matching was determined.

1 Introduction[1]

A phase matching test using LCLS-II-HE undulator HE-SXU-000 and phase shifter HE-SXPS-000 was performed. A set of undulator K values was chosen for the test. For each K value, the undulator calibration was used to set the gap. The undulator calibration also gave a nominal phase integral to do the phase matching. A calculation was made to add 2π phase jumps to the nominal phase integral so that the calculated phase integral was within the range of the phase shifter. Knowing the phase integral, the phase shifter calibration was used to set the phase shifter gap. Once the undulator and phase shifter gaps were set, a measurement was made to determine the phase matching error.

The undulator and phase shifter were calibrated on different measurement benches. One purpose of the test is to make sure the two benches are cross calibrated. Another purpose of the test is to make sure the software algorithm to set the phase shifter is performing properly with the new high energy upgrade (HE) components.

Phase matching tests were performed previously for the LCLS-II project.[2,3] The documentation for the previous tests explains in detail how the phase matching is done. We do not repeat this explanation here since the basic procedure has not changed. Rather, in this note we document that the test was successfully completed using the new HE components.

[1] Work supported in part by the DOE Contract DE-AC02-76SF00515. This work was performed in support of the LCLS project at SLAC.

[2] Z. Wolf and Y. Levashov, "A Phase Matching Test Of The LCLS-II SXR Undulators", LCLS-TN-19-5, November, 2019.

[3] Z. Wolf, Y. Levashov, and H.-D. Nuhn, "Initial Tests Of Phase Matching An LCLS-II Undulator", LCLS-TN-18-1, February, 2018.

2 Requirements

In order to set a scale for the accuracy of setting the phase shifter, we list the relevant requirement that the HE-SXR undulators and phase shifters must meet.[4]

1. The phase matching error must be less than ± 7 degrees.

3 Measurement Results

3.1 Setup

For this test, phase shifter HE-SXPS-000 was placed at the entrance end of undulator HE-SXU-000 within the 4.4 m cell boundary. The distance between the phase shifter and the undulator is the same as in the tunnel. A picture of the setup is shown in Figure 1.

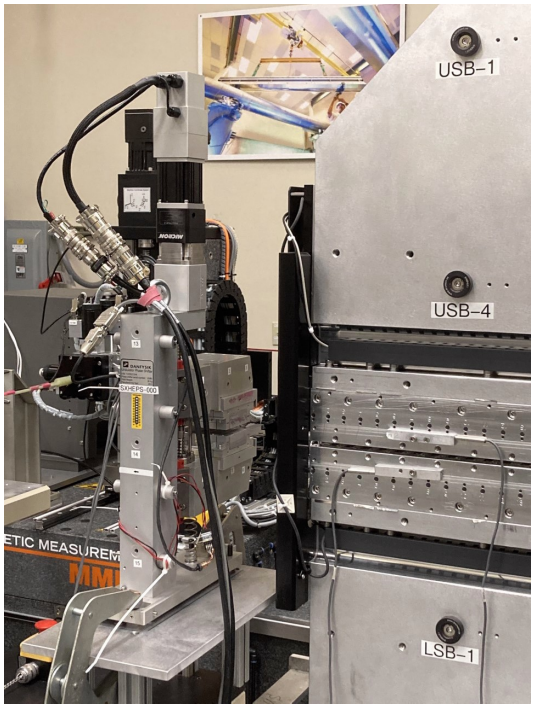

Figure 1: Setup for the phase matching test.

The K value of the undulator was changed in equal steps through its range. For each K value, the undulator calibration was used to set the gap. Also for each K value, the phase integral of the phase shifter required to do the phase matching was calculated. This calculation included phase jumps of multiples of 2π to stay within the phase integral range of the phase shifter. The phase shifter phase integral, including jumps, as a function of

[4] D. Cesar et al., "LCLS-II-HE SXR Undulator System Physics Requirements", LCLSII-HE-1.3-PR-0049-R2, May, 2022.

undulator K value is shown in Figure 2. For each phase integral value, the calibration of the phase shifter was used to determine the gap setting.

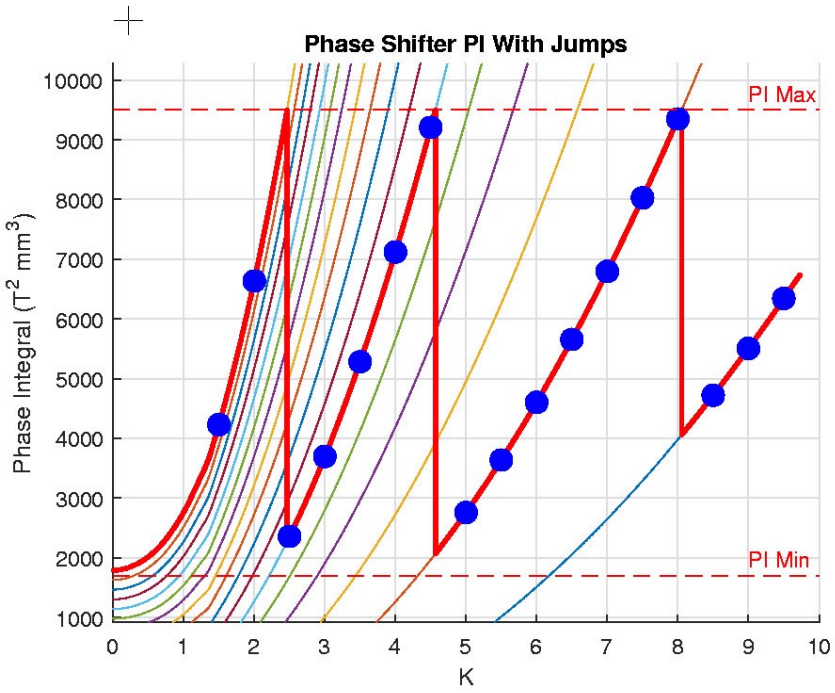

Figure 2: A series of multiples of 2π phase jumps are used to stay within the phase integral range of the phase shifter as it covers the K range of the undulator. The blue circles locate the points where the measurements were taken.

3.2 Results

For each undulator K value used in the test, the undulator and phase shifter gaps were set as described above. A measurement was made using the Hall probe. The phase at each pole was calculated and the phase matching error (PME) was determined. The PME at each K value is shown in Figure 3. The phase matching errors modulo 2π are all well within the tolerance. Typically, they are less than 1 degree.

Phase matching error:

Meas #	Und K	PME (deg)	Mod PME (deg)
1	1.5002	6121.23	1.23
2	2.0000	6119.14	-0.86
3	2.5000	2162.13	2.13
4	2.9998	2160.77	0.77
5	3.4995	2160.48	0.48
6	3.9993	2160.49	0.49
7	4.4991	2161.50	1.50
8	4.9989	720.94	0.94
9	5.4987	720.67	0.67
10	5.9983	720.68	0.68
11	6.4983	720.27	0.27
12	6.9983	720.22	0.22
13	7.4984	720.55	0.55
14	7.9987	720.80	0.80
15	8.4992	360.64	0.64
16	9.0004	360.55	0.55
17	9.5012	360.49	0.49

Figure 3: Measured phase matching error at each undulator K value.

4 Conclusion

Measurements were made on the combination HE-SXPS-000 and HE-SXU-000 to determine the accuracy of phase matching for the HE-SXR line. The phase matching error is well below the tolerance limit.

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