LCLS-II-HE SXR Undulator Transportation Test Results

Zachary Wolf, Yurii Levashov
SLAC National Accelerator Laboratory

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Abstract

LCLS-II-HE SXR undulator HE-SXU-000 was tuned and calibrated. The undulator was then transported to the tunnel and brought back for repeat measurements. The objective was to see if the transportation caused any changes to the calibration. This note details the measurements and compares the measurements after the transportation test to the original measurements used for calibration.

1 Introduction[1]

The LCLS-II-HE SXR undulators are tuned and calibrated in the Magnetic Measurement Facility (MMF). After calibration, the undulators are moved to a storage area and then moved to the tunnel for installation in the beam line. In this note we document the results of a test where an undulator, HE-SXU-000, made a practice move to the tunnel and was then brought back to the MMF and remeasured. The purpose of the test is to see if the transportation causes any changes to the undulator calibration. A future test will study whether temperature excursions during storage cause any changes to the undulator calibrations.

HE-SXU-000 was initially calibrated on October 12, 2022. These measurements are referred to as "Dataset 1" below. It was moved to the tunnel and brought back to the MMF on October 20, 2022. Details of the moves are given in an engineering note.[2] Afterward, the undulator was taken to the temperature conditioning area and then into the lab. The second "Dataset 2" measurements were taken on November 2, 2022. This note documents the Dataset 1 and Dataset 2 measurements taken before and after the transportation test. No significant changes to the calibration were observed.

2 Measurement Requirements

In order to set a scale for the relevance of any changes to the undulator, we list the primary requirements that the HE-SXR undulators must meet[3]. The undulator will be primarily

[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]N. Trac, "LCLS-II-HE Upgraded SXU Transport Test Procedure", LCLSII-HE-1.3-PP-0704-R0, October, 2022.

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

tuned at a gap of 10 mm, but the requirements must be met for all gaps in the operating range of 7.2 to 33 mm.

1. The K value must be known to $\pm 5.5 \times 10^{-4}$ at all gap settings. The K value will be measured at a discrete set of gaps. A fit to the measured K value vs. gap data must allow K values at intermediate points to be known within the tolerance given here.
2. The phase shake in each undulator must be less than 5 degrees rms.
3. The total phase advance in the 4.400000 meter long cell must be known to ± 10 degrees.
4. The phase matching error at both the entrance and the exit of the undulator must be less than ± 7 degrees.
5. The first field integral of B_x and B_y must be within $\pm 50 \times 10^{-6}$ Tm. The second field integral of B_x and B_y must be within $\pm 200 \times 10^{-6}$ Tm^2.

3 Measurement Results

3.1 Shock And Temperature During Transport

Shockloggers were placed on HE-SXU-000 during the transportation test. The shockloggers measured both acceleration and temperature. The maximum acceleration during the test was 0.4 g. The minimum temperature was 17.5 deg C and the maximum temperature was 19.7 deg C.[4] Both the acceleration and the temperature excursions were very modest. It appears that the undulator handling is done very carefully and there is no reason to expect a change in the undulator.

3.2 Measurements At The Tuning Gap

The initial Dataset 1 and the repeat Dataset 2 involved extensive measurements at many gaps, but in this section we compare measurements at the 10 mm tuning gap. The undulator temperature during the Dataset 1 measurements was 20.01 deg C and the undulator temperature during the Dataset 2 measurements was 20.03 deg C. Figure 1 shows a comparison of the B_y peak field measurements through the core of the undulator. The difference in the peak fields is shown in figure 2. The difference is generally below 1 Gauss, which is less than 10^{-4} of the field. The K value in Dataset 1 was 7.327836 and the K value in Dataset 2 was 7.327782, a relative change of -7.4×10^{-6}.

There is a small taper in the field of the second dataset compared to the first dataset. One might expect a small difference in the phase errors. The phase errors at the tuning gap for the two data sets are shown in figure 3. The difference is a fraction of 1 degree and is not significant.

A comparison of the second B_x field integrals is shown in figure 4, and a comparison of the second B_y field integrals is shown in figure 5. The second field integrals are proportional to the beam trajectories. In both cases, the changes in the field integrals are small.

[4] Measurements courtesy of Nick Trac.

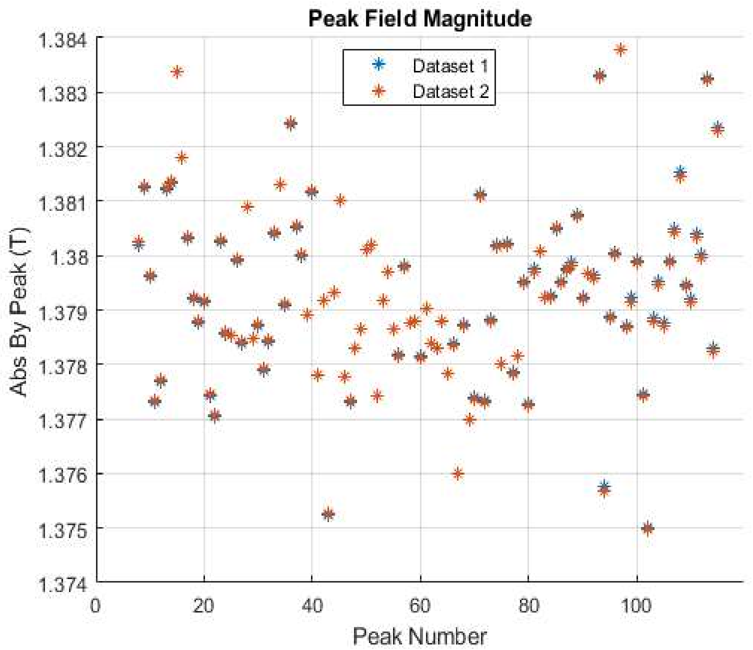

Figure 1: By peak field magnitudes for the two datasets.

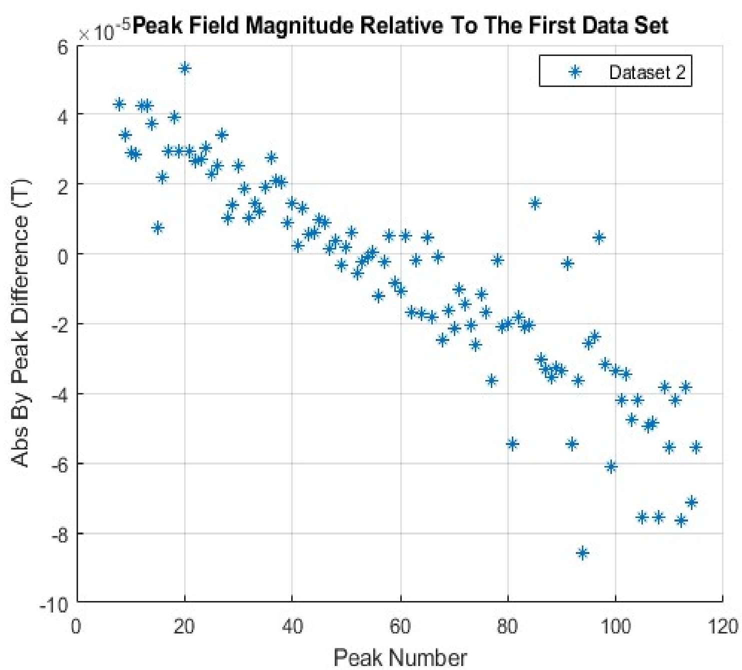

Figure 2: Difference of the peak field magnitudes after the transportation test compared to before the test.

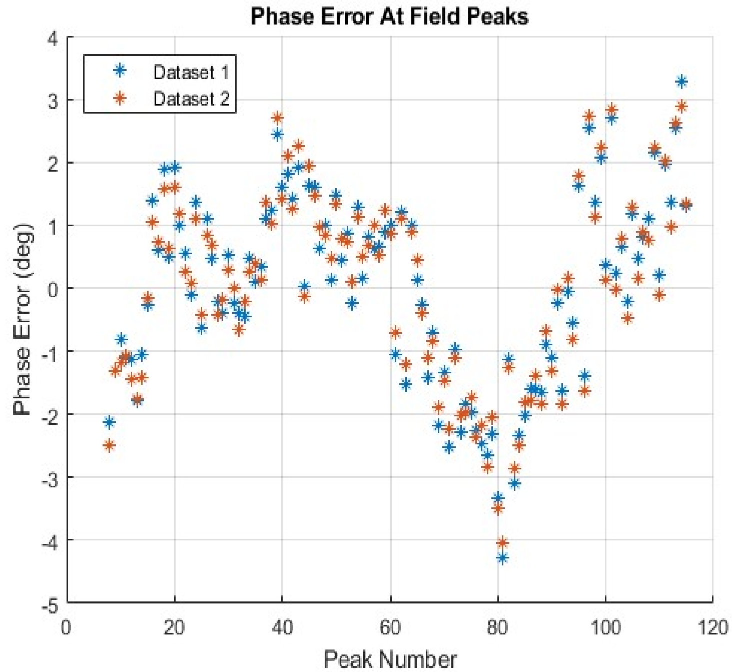

Figure 3: Comparison of the phase errors in the two data sets.

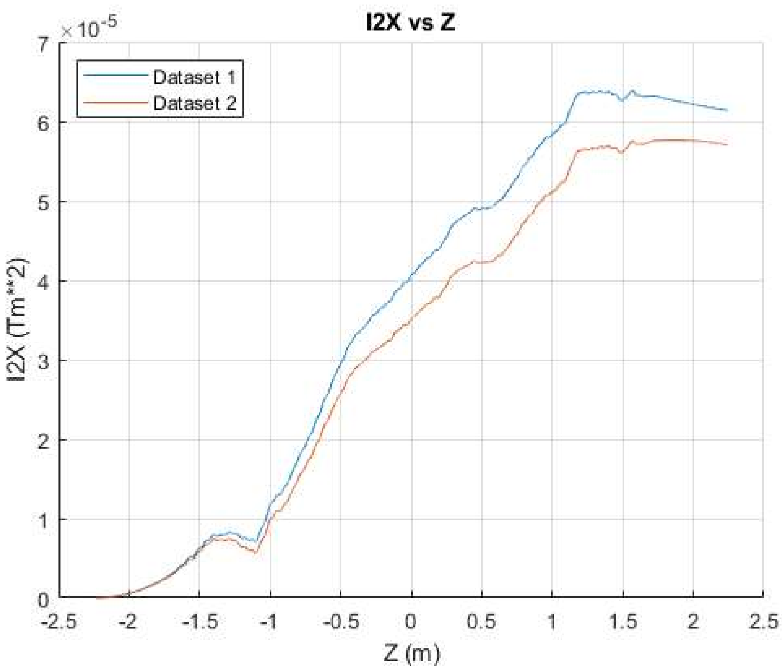

Figure 4: Comparison of the second integral of B_x.

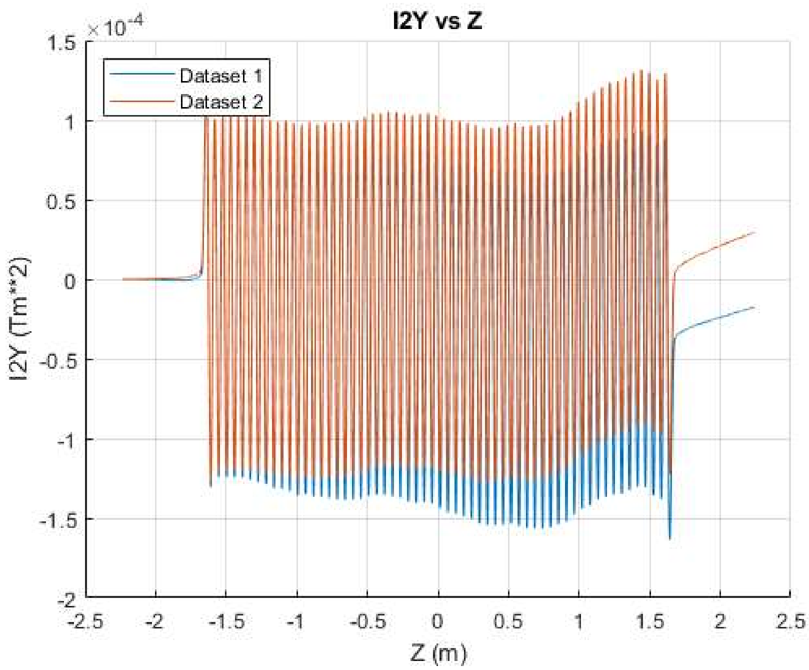

Figure 5: Comparison of the second integral of B_y.

3.3 Measurements As A Function Of Gap

During each dataset, measurements were made at many gaps. In this section we summarize the changes in K value, phase matching error, rms phase error, and field integrals as a function of gap.

The primary concern is that during the transport the K value of the undulator might change. Figure 6 shows the difference in spline fits to the K values as a function of gap. The change in K is well within the tolerance.

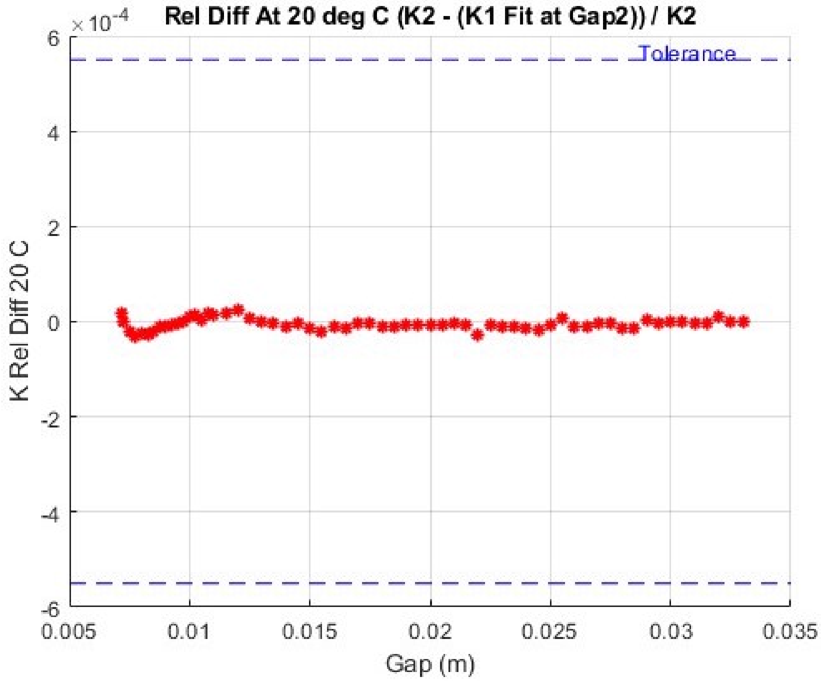

Figure 6: Difference in the K value before and after transport as a function of gap.

Changes in phase matching are also a concern. Figure 7 shows the difference in the spline fits to the cell phase as a function of K. Figure 8 shows the difference in the spline fits to the phase matching error at the undulator entrance as a function of K. Figure 9 shows the difference in the spline fits to the phase matching error at the undulator exit as a function of K. All differences are very small and are less than 1 degree.

The phase errors showed very little change during the transport. Figure 10 is a comparison of the rms phase error as a function of gap for the two datasets.

The field integrals remained fairly constant during the transportation test. Figure 11 shows the measurements of the first integral of B_x. Figure 12 shows the measurements of the first integral of B_y. Figure 13 shows the measurements of the second integral of B_x. Figure 14 shows the measurements of the second integral of B_y. The differences are most likely explained by changes in the straightness of our measurement coil. The differences are small and are well below the tolerance limit.

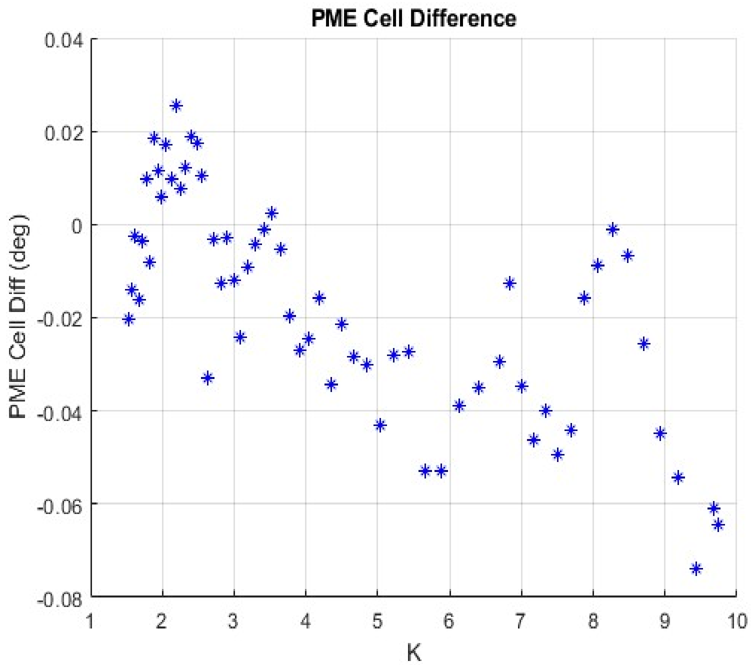

Figure 7: Difference in the spline fits to the cell phase as a function of K.

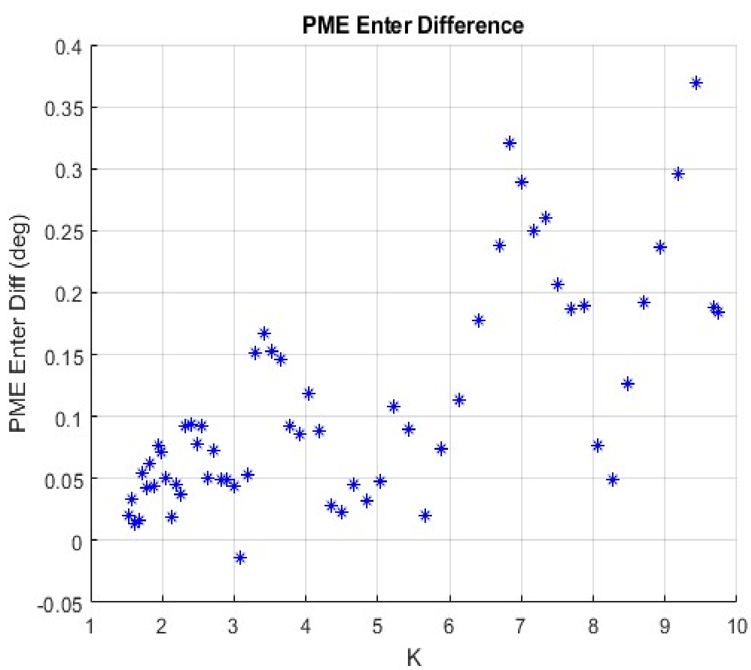

Figure 8: Difference in the spline fits to the phase matching error at the undulator entrance as a function of K.

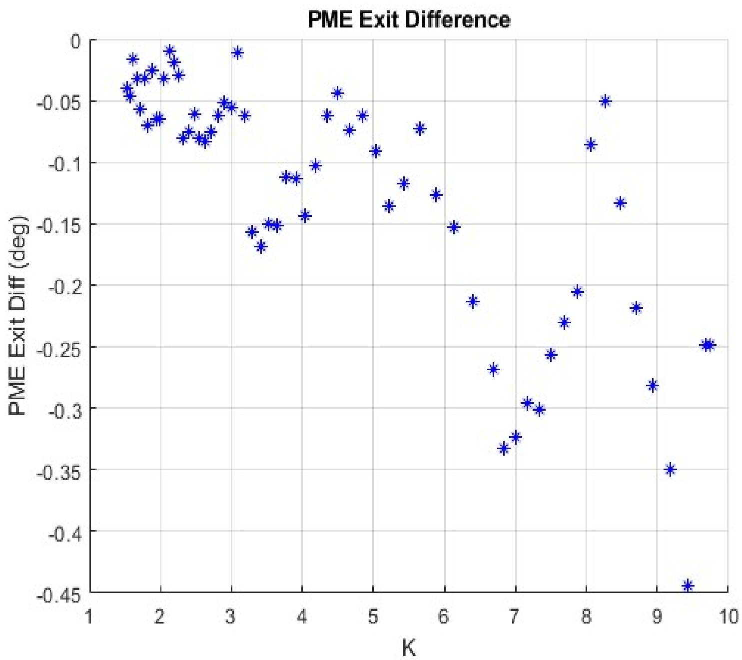

Figure 9: Difference in the spline fits to the phase matching error at the undulator exit as a function of K.

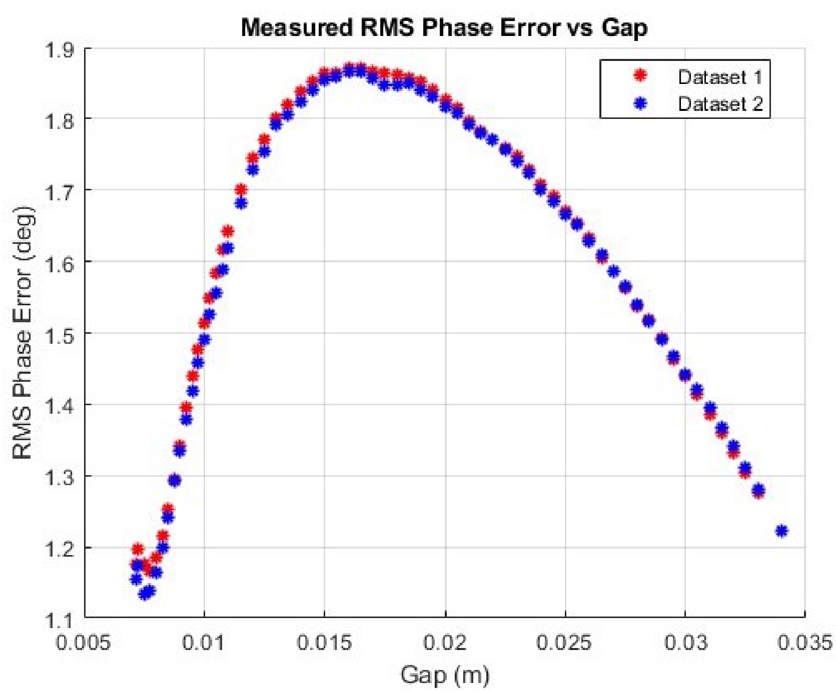

Figure 10: Comparison of the rms phase error as a function of gap for the two datasets.

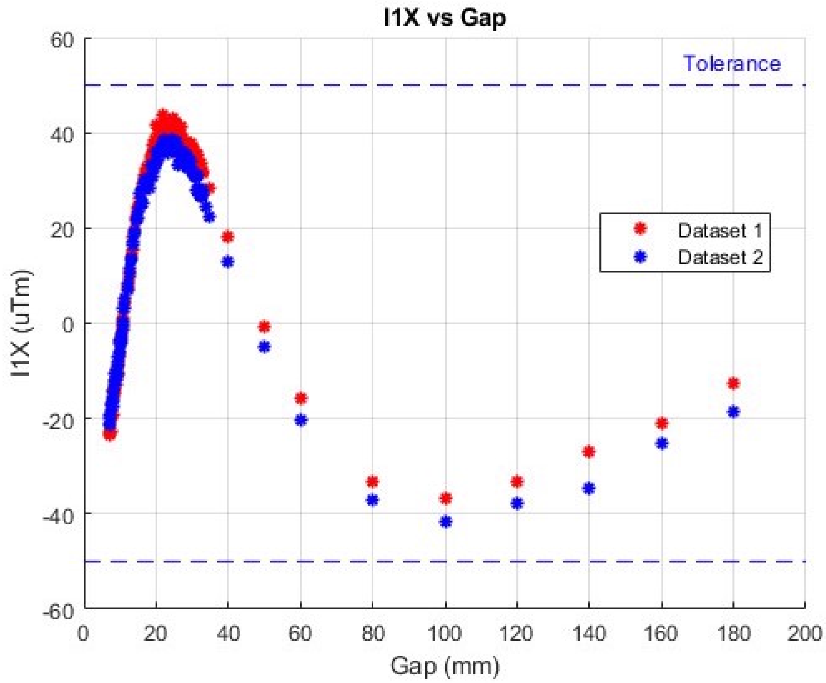

Figure 11: Comparison of the measurements of the first integral of B_x.

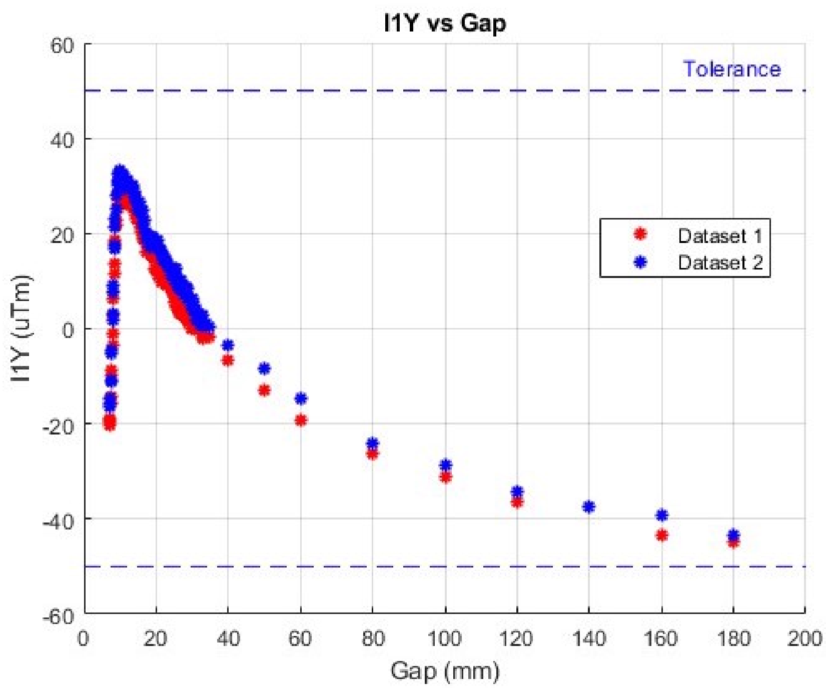

Figure 12: Comparison of the measurements of the first integral of B_y.

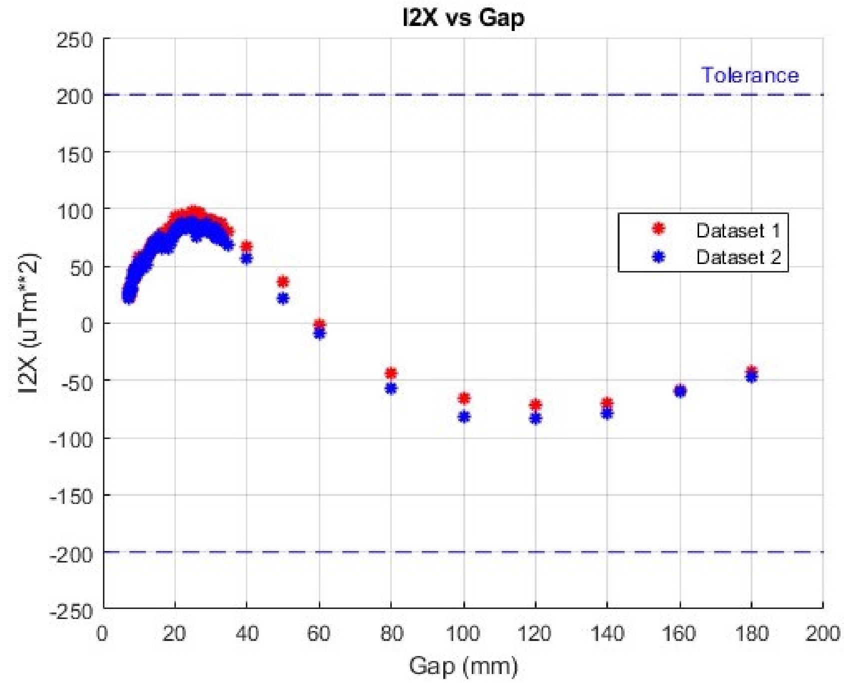

Figure 13: Comparison of the measurements of the second integral of B_x.

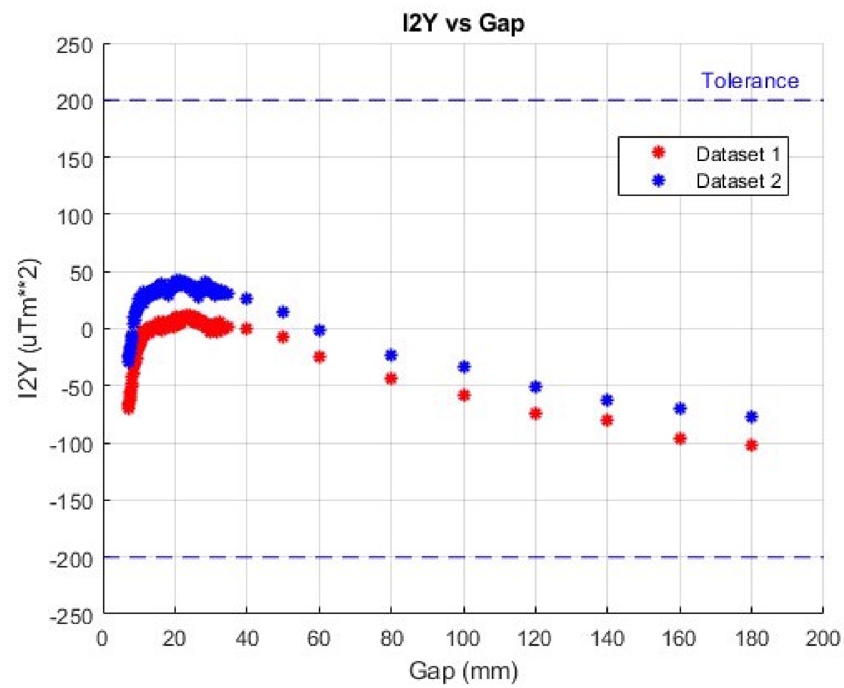

Figure 14: Comparison of the measurements of the second integral of B_y.

4 Conclusion

Measurements were made on HE-SXU-000 after a transportation test to the tunnel. No significant changes were observed.

Acknowledgements

Many thanks to Heinz-Dieter Nuhn for valuable discussions about this note. We also thank Nick Trac for information about the undulator transport.