LCLS-II SXR Undulator Transportation Test Results

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Abstract

LCLS-II SXR undulator SXU-011 was tuned, calibrated, and put into storage representative of all other undulators. The undulator was then transported to the tunnel and installed in the beam line. It was then brought back for measurements. The objective was to see if the transportation and installation caused any changes to the calibration. This note details the measurements after the test and compares them to the original measurements used for calibration.

1 Introduction[1]

The LCLS-II SXR undulators are tuned and calibrated in the Magnetic Measurement Facility (MMF). The temperature in the MMF is stable at 20 ± 0.1 deg C. After calibration, the undulators are moved to a storage area with very modest temperature control. We have verified that the temperature excursions in the storage area do not change the undulator calibrations[2]. After storage, the undulators will be moved to the tunnel for installation in the beam line. In this note we document the results of a test where an undulator, SXU-011, made a practice move to the tunnel and was installed. It was then brought back to the MMF and remeasured. Comparisons to the data before and after transport are given.

LCLS-II undulator SXU-011 was initially calibrated the week of June 20, 2018. It stayed in storage until it was moved to the tunnel on July 31, 2018. On August 2, 2018, SXU-011 was brought back to the MMF and put in the storage area until August 6, 2018. Afterward, the undulator was taken to the temperature conditioning area and then into the lab. The second 'final data set' was completed on August 15, 2018. This note documents the calibration measurements before and after the transportation test. No significant changes to the calibration were observed.

[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, "Repeat Measurements Of SXU-001 After Six Months In Storage", LCLS-TN-18-3, March, 2018.

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 SXR undulators must meet[3]. The undulator will be primarily tuned at a gap of 10 mm, but the requirements must be met for all gaps in the operating range of 7.2 to 22 mm.

1. The K value must be known to $\pm 3 \times 10^{-4}$ 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 $\pm 40 \times 10^{-6}$ Tm. The second field integral of B_x and B_y must be within $\pm 150 \times 10^{-6}$ Tm^2.

3 Measurement Results

3.1 Temperature During Transport

The temperature of SXU-011 was measured during the transportation test. Figure 1 shows the temperature of SXU-011 during the transportation test. The undulator is wrapped in plastic and has a high thermal mass, both contributing to the small temperature excursions. During the time of the test the temperature measurements shown in the plot, from 7/30/2018 to 8/8/2018 varied from approximately 20 deg C to 26 deg C. From 7/31/2018 to 8/2/2018, corresponding to the time the undulator was transported to the tunnel and brought back to the MMF, the temperature was very stable. The undulator stayed in the storage area of the MMF from 8/2/2018 to 8/6/2018 and this is when the larger swings in temperature took place. After the undulator was brought back into the laboratory area on 8/6/2018, the temperature was stable again.

[3] H. D. Nuhn et al., "Undulator System Requirements", LCLS-II Physics Requirements Document LCLSII-3.2-PR-0038-R3.

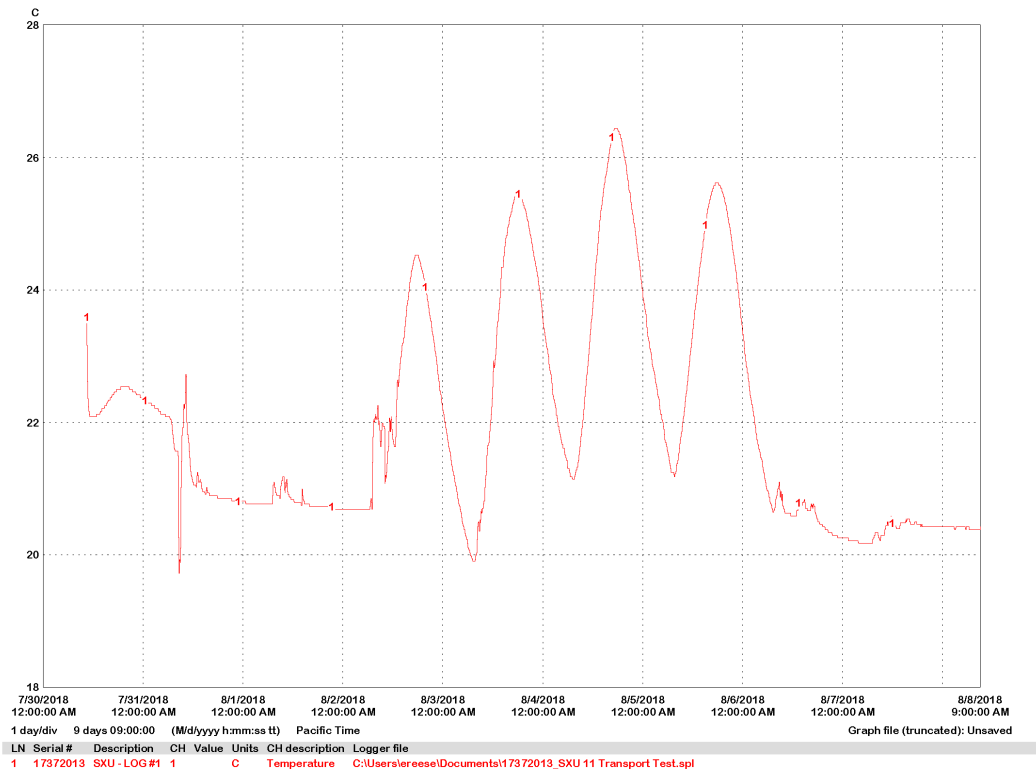

Figure 1: Temperature of SXU-011 during the transportation test.

3.2 Measurements At The Tuning Gap

The initial "Dataset 1" measurements of SXU-011 were made on 6/20/2018 and the repeat "Dataset 2" measurements were made on 8/15/2018. Measurements were made at many gaps, but in this section we compare measurements at the 10 mm tuning gap. The undulator temperature during the 6/20/2018 measurements was 20.14 deg C and the undulator temperature during the 8/15/2018 measurements was 20.10 deg C. Figure 2 shows a comparison of the B_y peak field measurements through the core of the undulator. The

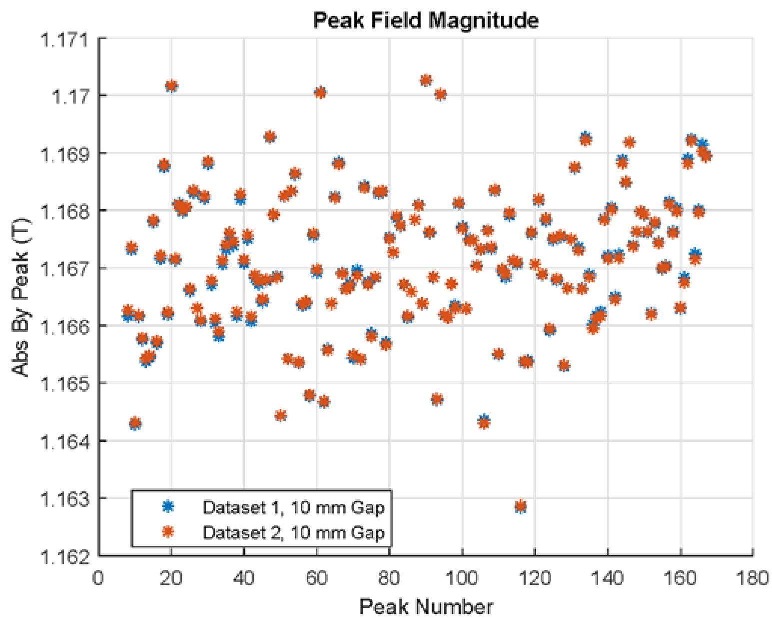

Figure 2: By peak field magnitudes for the two datasets.

difference in the peak fields is shown in figure 3. The difference is generally below 1 Gauss, which is less than 10^{-4} of the field. The K value on 6/20/2018 was 4.224253 and the K value on 8/15/2018 was 4.224287, a relative change of 8.0×10^{-6}.

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

The phase errors at the tuning gap for the two data sets is shown in figure 6. The difference is insignificant.

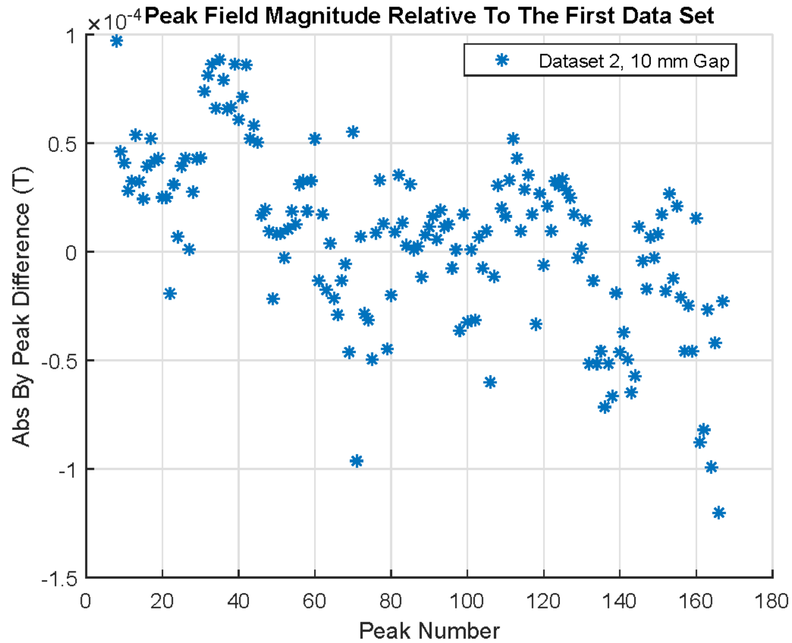

Figure 3: Difference of the peak field magnitudes after the transportation test compared to before the test.

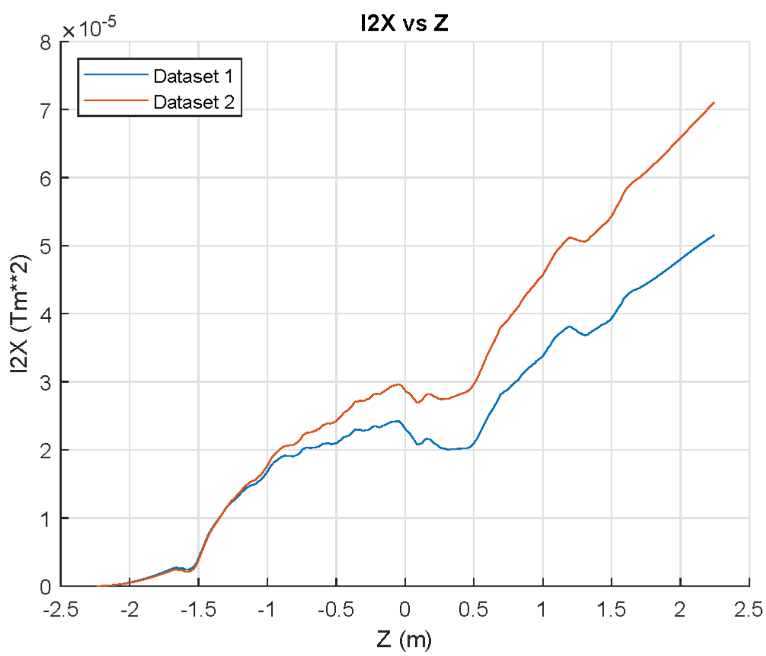

Figure 4: Comparison of the second integral of B_x.

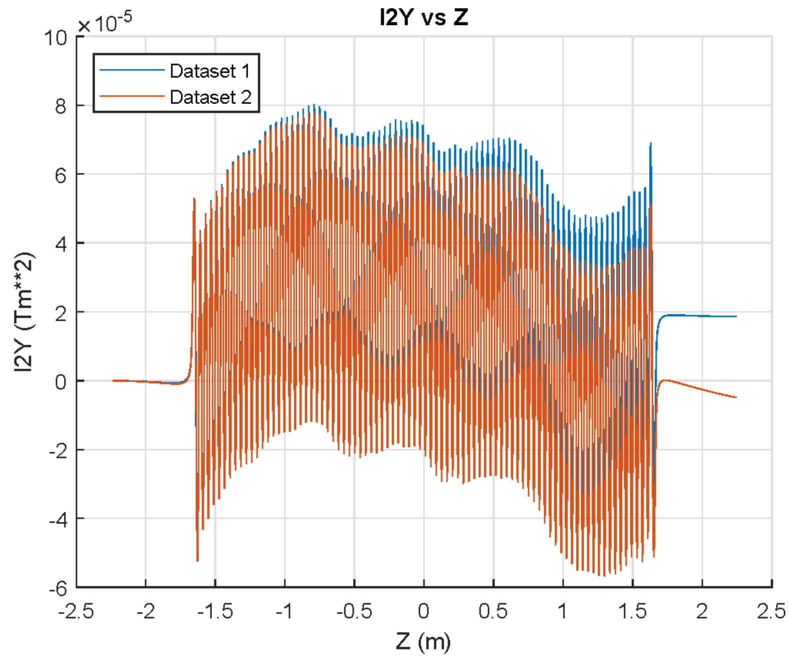

Figure 5: Comparison of the second integral of B_y.

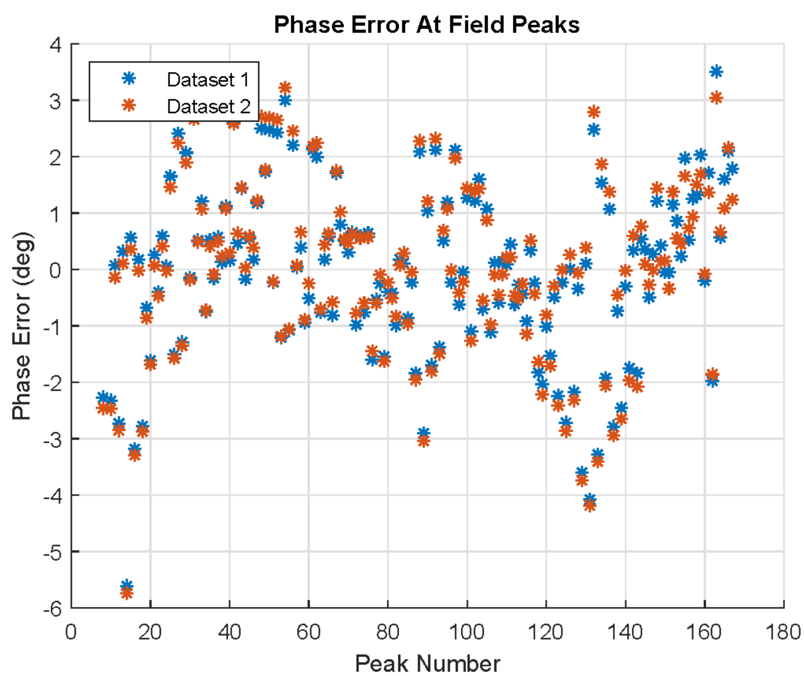

Figure 6: Comparison of the phase errors in the two data sets.

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 7 shows the difference in spline fits to the K values as a function of gap. The change in K is well within the tolerance.

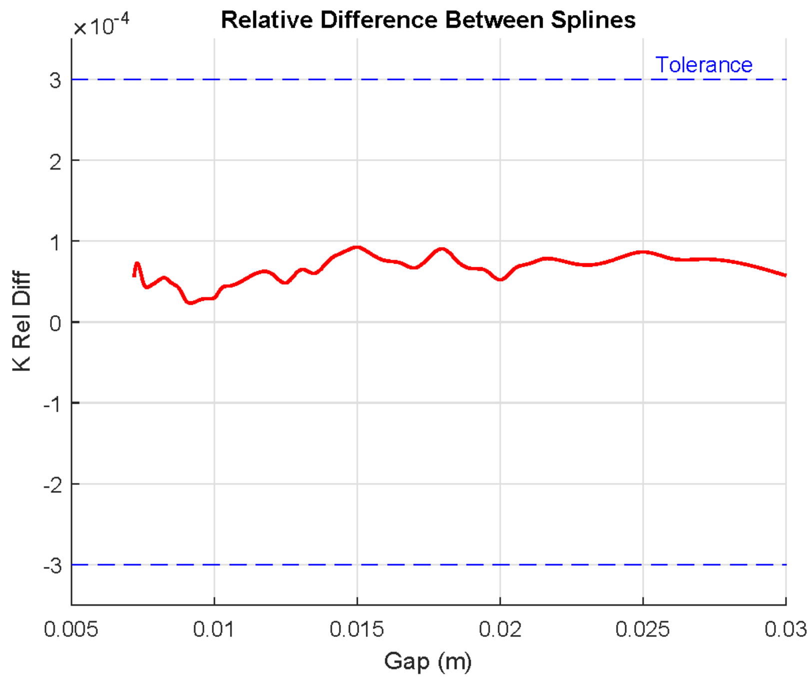

Figure 7: Difference in the K value before and after transport as a function of gap.

Changes in phase matching are also a concern. Figure 8 shows the difference in the spline fits to the cell phase as a function of K. Figure 9 shows the difference in the spline fits to the phase matching error at the undulator entrance as a function of K. Figure 10 shows the difference in the spline fits to the phase matching error at the undulator exit as a function of K.

The phase errors showed very little change during the transport. Figure 11 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 12 shows the measurements of the first integral of B_x. Figure 13 shows the measurements of the first integral of B_y. Figure 14 shows the measurements of the second integral of B_x. Figure 15 shows the measurements of the second integral of B_y. The differences at small gap are most likely explained by changes in the straightness of our measurement coil. The coil can typically only be straightened to ± 100 microns and gradients in the magnetic field

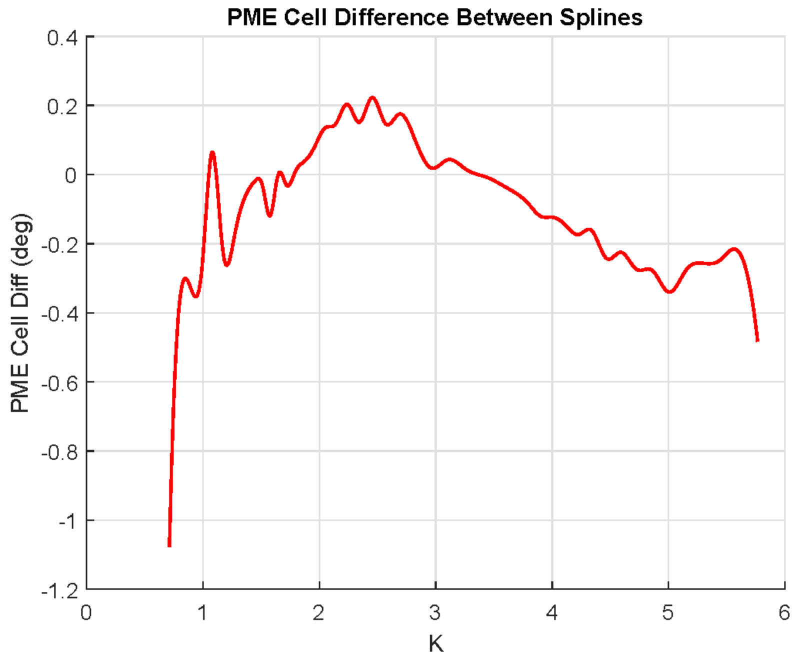

Figure 8: Difference in the spline fits to the cell phase as a function of K.

cause small changes in the measured field integrals as the coil straightness changes. The differences at small gap are well below the tolerance limit and are within the range of being due to coil straightness changes.

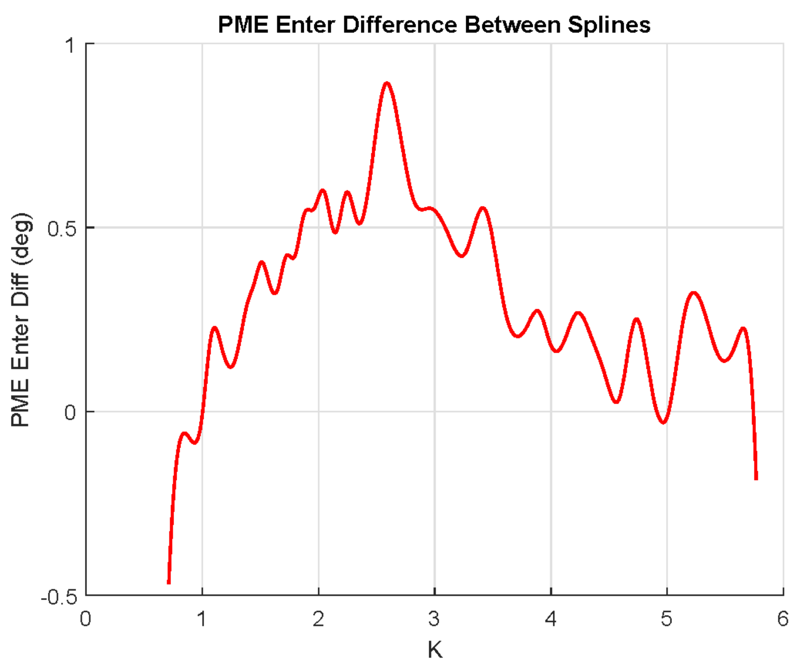

Figure 9: Difference in the spline fits to the phase matching error at the undulator entrance as a function of K.

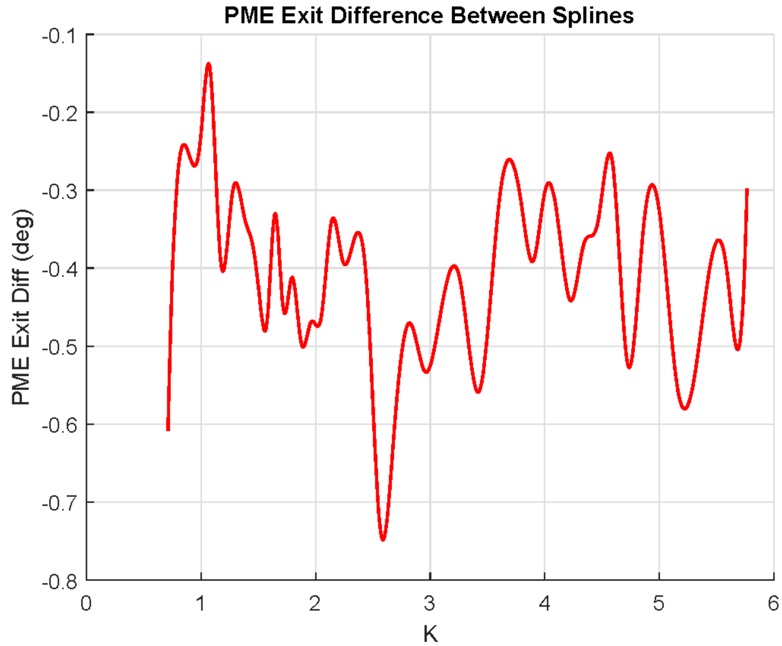

Figure 10: Difference in the spline fits to the phase matching error at the undulator exit as a function of K.

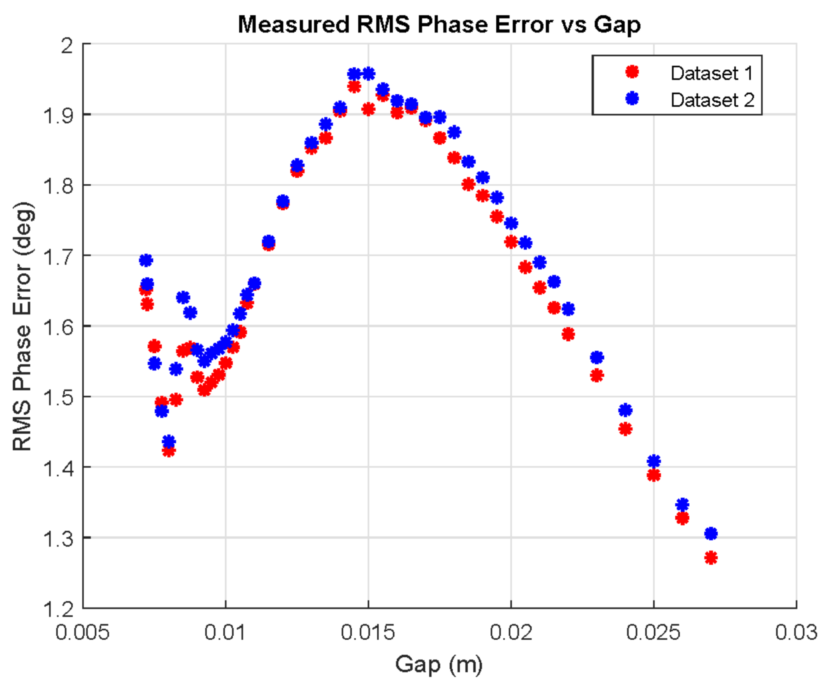

Figure 11: Comparison of the rms phase error as a function of gap for the two datasets.

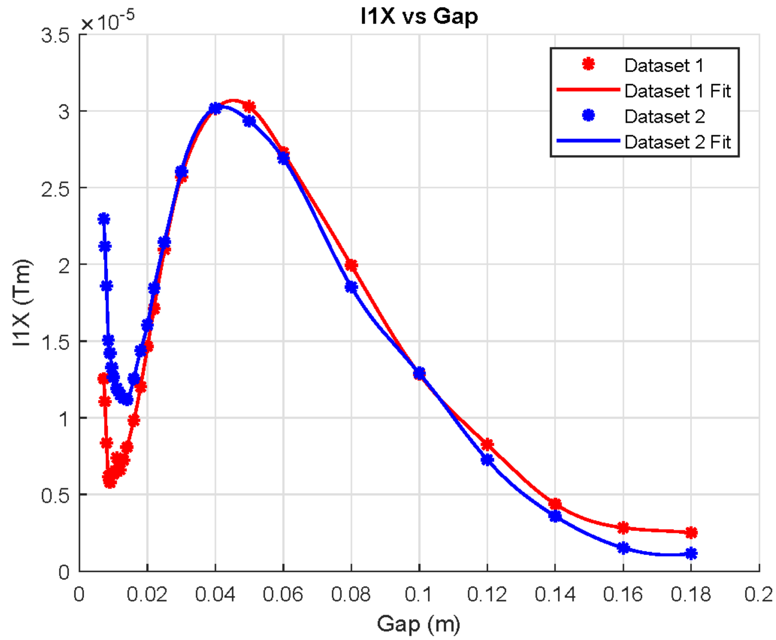

Figure 12: Comparison of the measurements of the first integral of B_x.

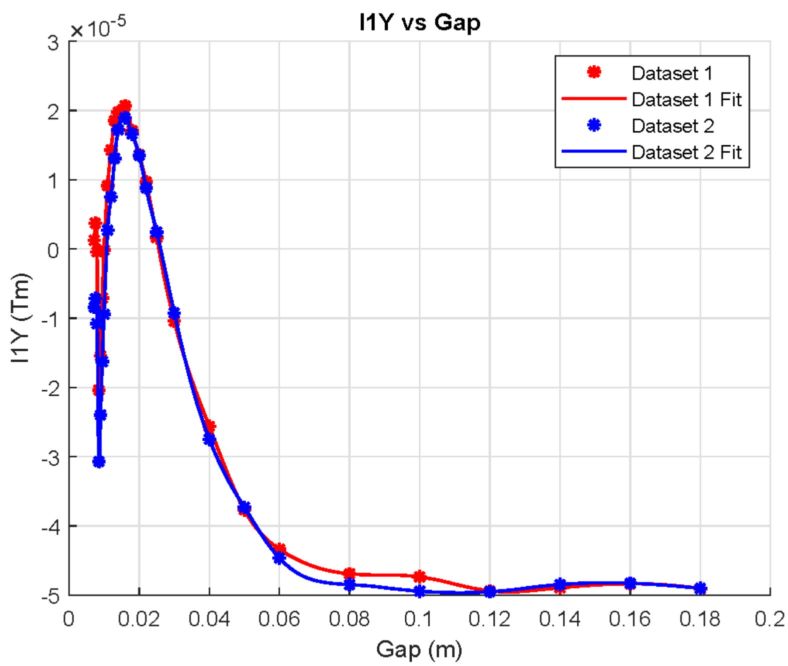

Figure 13: Comparison of the measurements of the first integral of B_y.

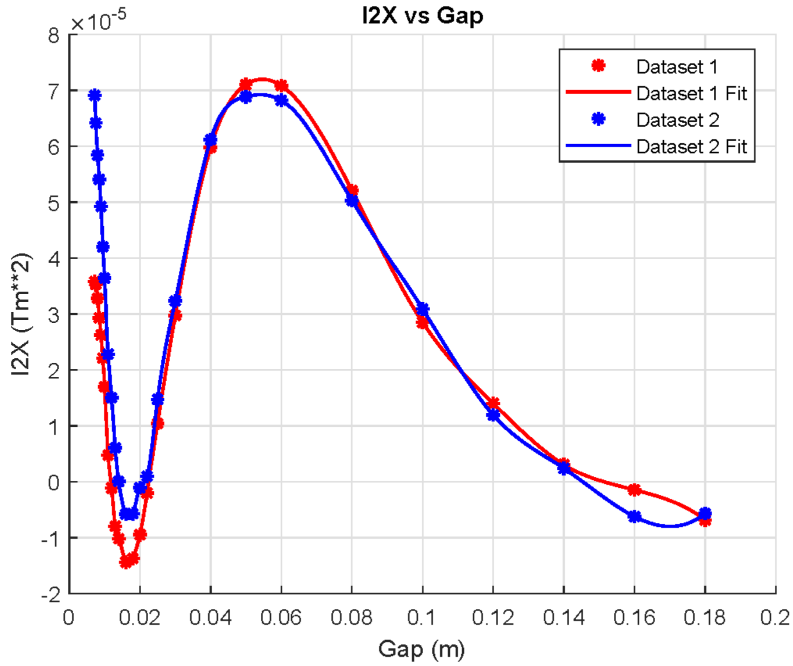

Figure 14: Comparison of the measurements of the second integral of B_x.

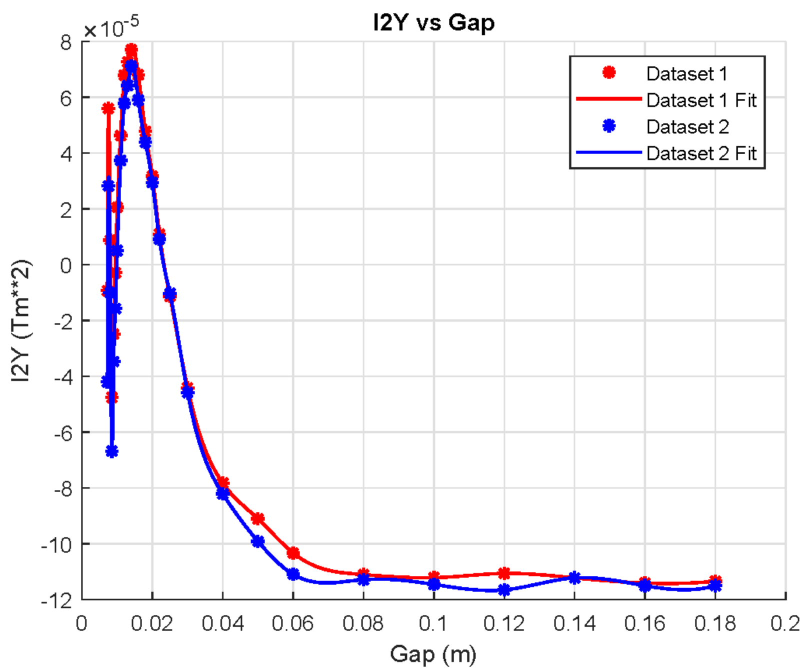

Figure 15: Comparison of the measurements of the second integral of B_y.

4 Conclusion

Measurements were made to SXU-011 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.