

Repeat Measurements Of SXU-001 After Six Months In Storage

Zachary Wolf, Yurii Levashov
SLAC National Accelerator Laboratory

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Abstract

The LCLS-II SXR undulators are stored in building 81 after they are tuned and after the final data set has been measured. The storage area has only modest temperature control, so there is concern that the undulator calibration may change during their time in storage. In this note we document the repeat measurements of SXU-001 after it has been in storage for six months.

1 Introduction¹

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. It must be verified that the temperature excursions in the storage area do not change the undulator calibrations.

The LCLS-I project experienced significant changes to the calibration of the undulators during storage². Most of the undulators had to be remeasured and afterward handled with much attention to their ambient temperature. We wish to know as soon as possible if the LCLS-II project has similar problems.

LCLS-II undulator SXU-001 was remeasured after spending 6 months in storage. This note documents the measurements before and after storage. 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 SXR undulators must meet³. The undulator will be primarily tuned

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

²Z. Wolf, Y. Levashov, E. Reese, "Undulator Changes Due To Temperature Excursions", LCLS-TN-08-8, September, 2008.

³H. D. Nuhn et al., "Undulator System Requirements", LCLS-II Physics Requirements Document LCLSII-3.2-PR-0038-R2.

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. This requirement sets the density of the measurements as a function of gap.
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 $\pm 150 \times 10^{-6}$ Tm².
6. The undulator temperature at which all measurements are performed must be 20.0 ± 0.1 degrees Celsius.

3 Measurement Results

3.1 Temperature During Storage

SXU-001 was stored next to undulator SXU-003 which had a temperature logger attached to it. The temperatures of SXU-001 and SXU-003 should be essentially the same. Figure 1 shows the temperature of SXU-003 in red and the ambient temperature in green. The undulator is wrapped in plastic and has a high thermal mass, both contributing to the smaller temperature excursions of the undulator than the ambient temperature excursions. During the time of the temperature measurements shown in the plot, from 10/26/2017 to 3/15/2018, the ambient temperature varied from approximately 15 deg C to 26 deg C.



Figure 1: Undulator temperature and ambient temperature in the storage area.

3.2 Measurements At The Tuning Gap

The initial measurements of SXU-001 were made on 8/11/2017 and the repeat measurements were made on 2/27/2018. Measurements were made at many gaps, but in this section we compare measurements at the 10 mm tuning gap. The undulator temperature during the 8/11/2017 measurements was 20.15 deg C and the undulator temperature during the 2/27/2018 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 difference in the peak fields is

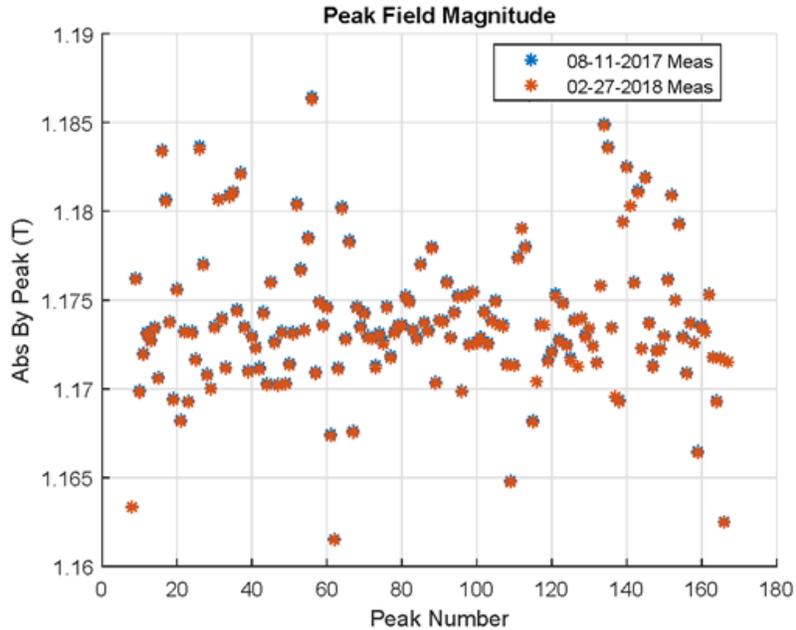


Figure 2: B_y peak fields for the measurements before and after six months in storage.

shown in figure 3. The difference is about 1 Gauss, which is less than 10^{-4} of the field. The K value on 8/11/2017 was 4.245499 and the K value on 2/27/2018 was 4.245214, a relative change of -6.7×10^{-5} .

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.

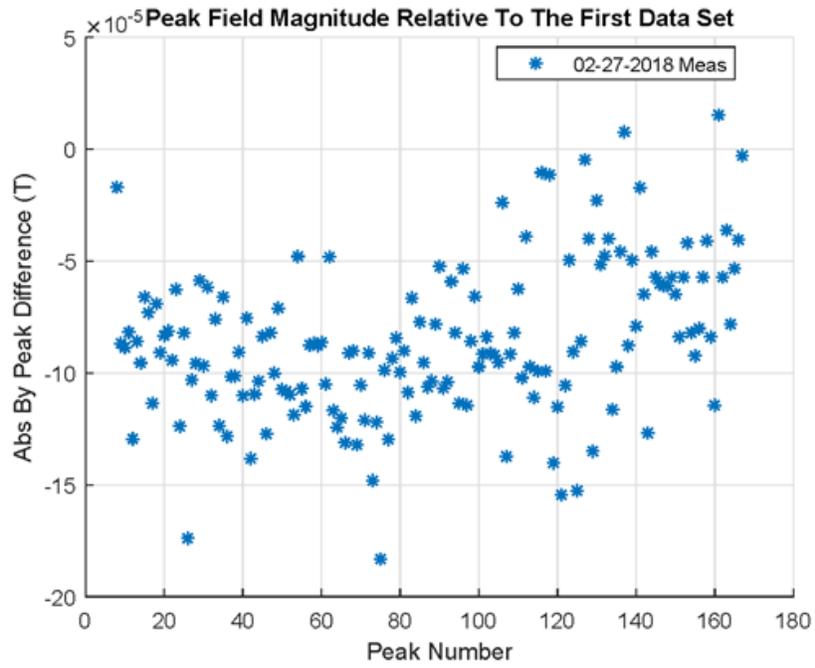


Figure 3: Difference in the peak fields.

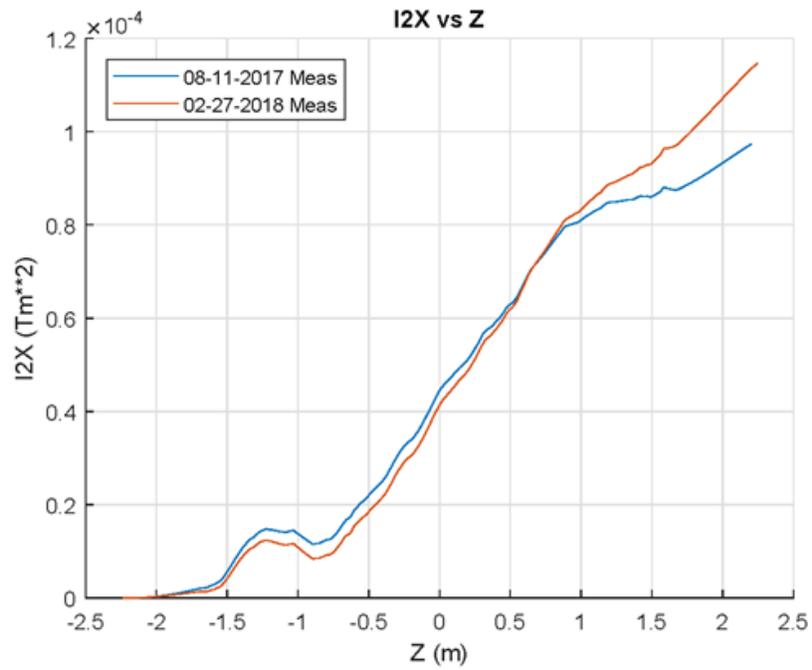


Figure 4: Comparison of the second integral of B_x .

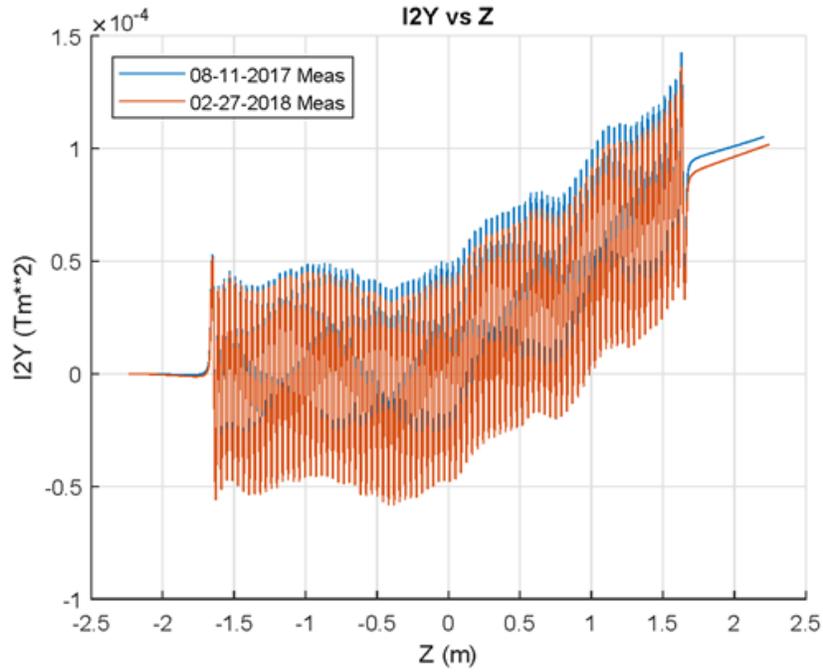


Figure 5: Comparison of the second integral of B_y .

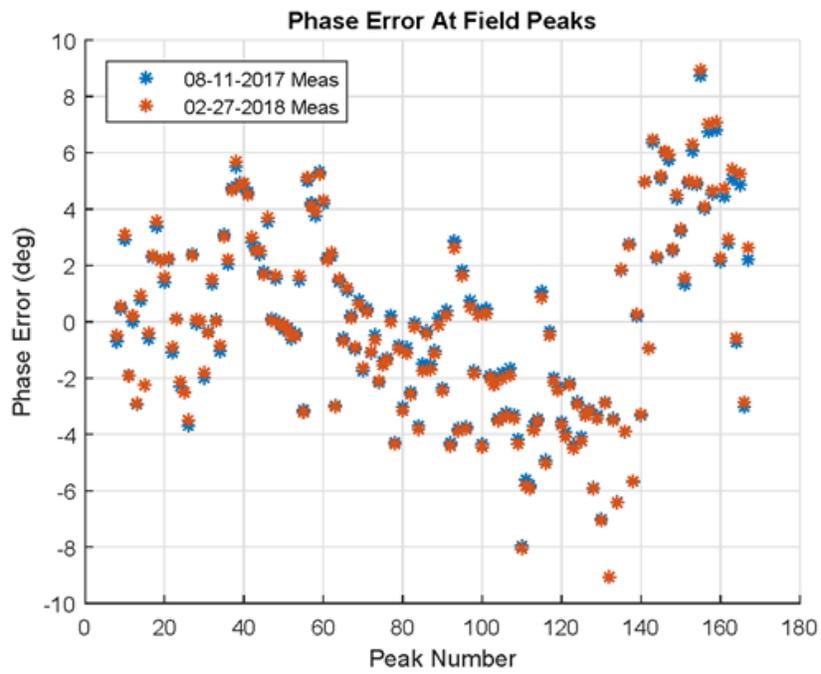


Figure 6: Comparison of the phase errors in the two data sets.

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, and field integrals as a function of gap.

The primary concern is that during storage 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.

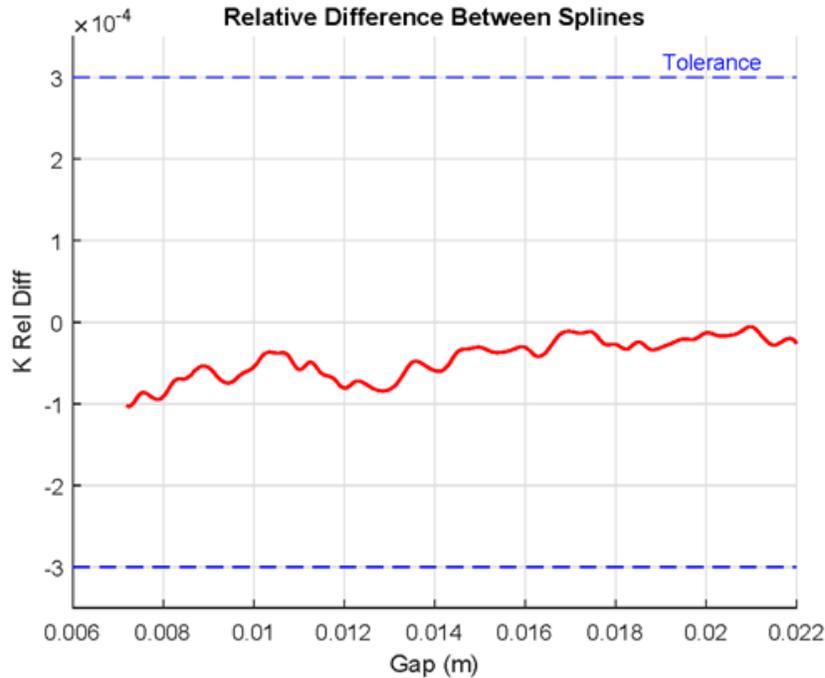


Figure 7: Difference in the K value before and after storage as a function of gap.

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 field integrals remained fairly constant during the storage. The differences are most likely explained by changes in the straightness of our measurement coil. 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 .

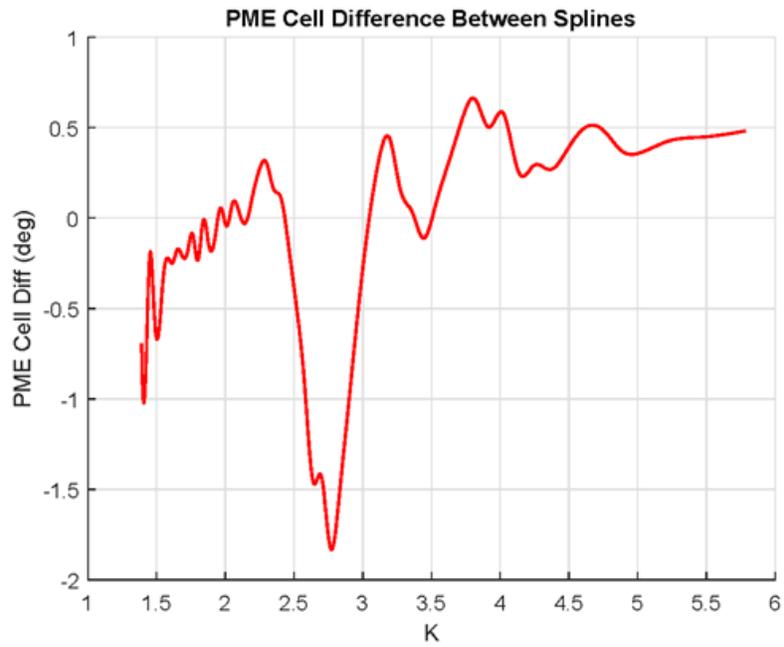


Figure 8: Difference in the spline fits to the cell phase as a function of K .

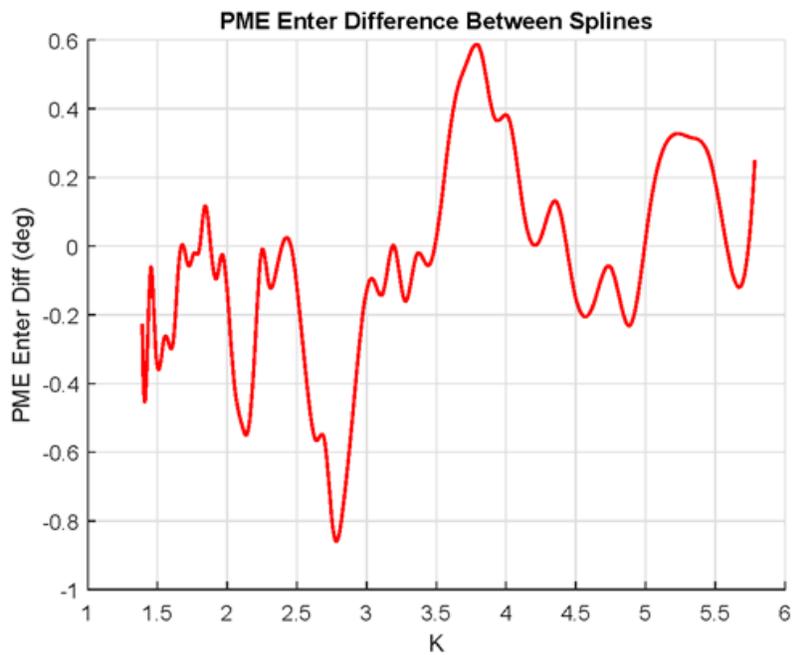


Figure 9: Difference in the spline fits to the phase matching error at the undulator entrance as a function of K .

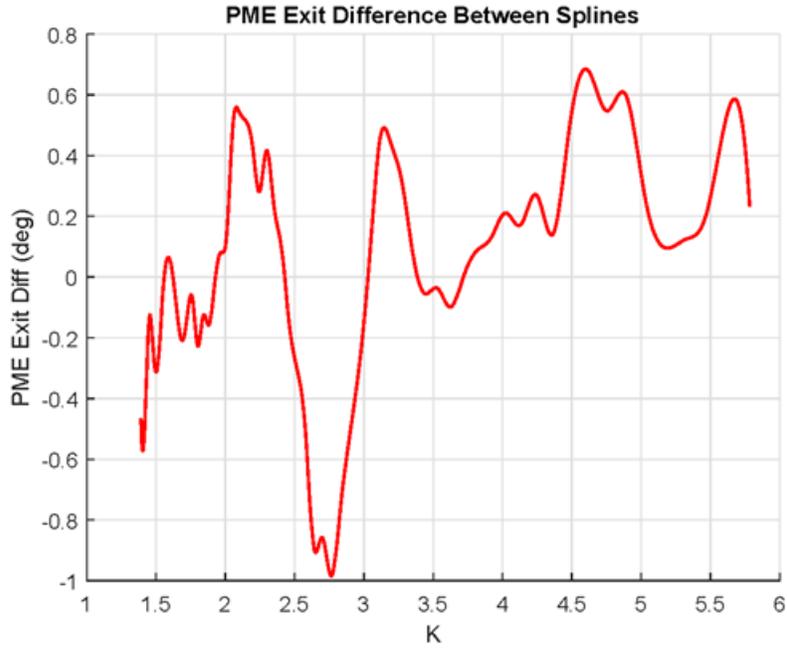


Figure 10: Difference in the spline fits to the phase matching error at the undulator exit as a function of K.

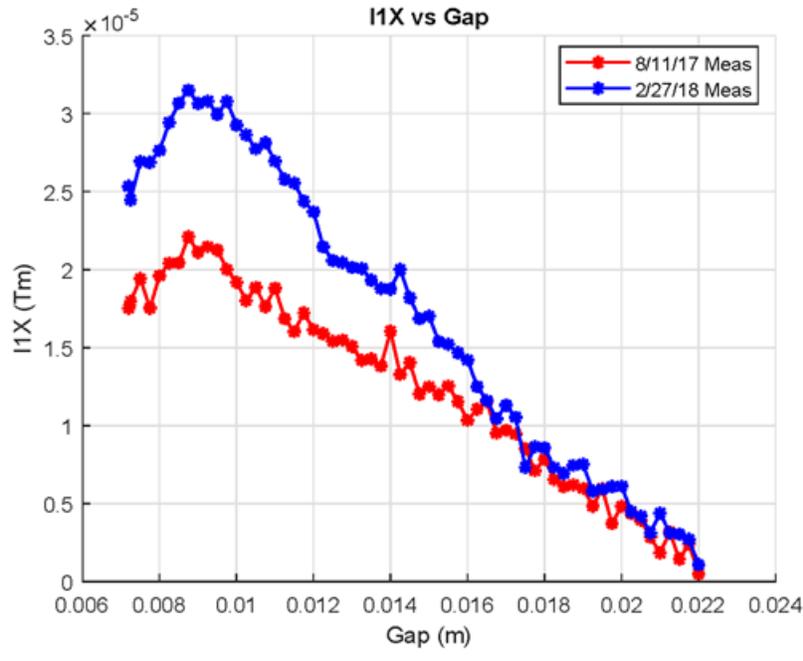


Figure 11: Comparison of the measurements of the first integral of B_x .

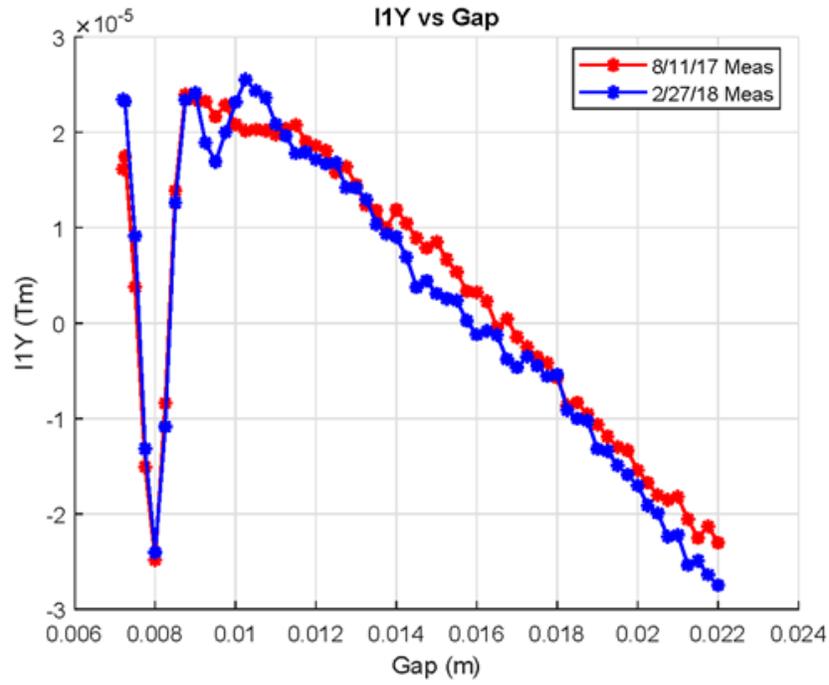


Figure 12: Comparison of the measurements of the first integral of B_y .

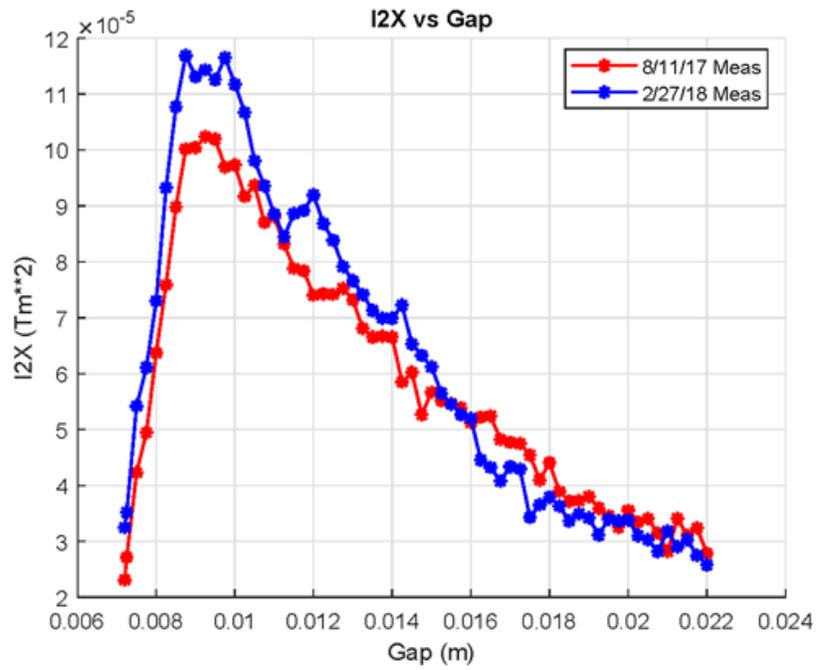


Figure 13: Comparison of the measurements of the second integral of B_x .

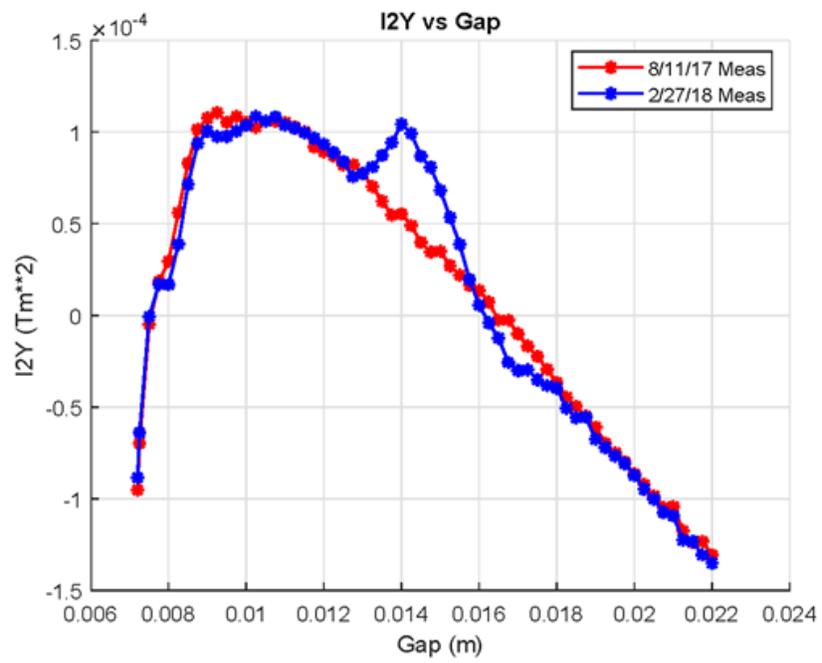


Figure 14: Comparison of the measurements of the second integral of B_y .

4 Conclusion

Measurements were made to SXU-001 after six months in storage. No significant changes were observed.

Acknowledgements

Many thanks to Heinz-Dieter Nuhn for valuable discussions about this note.