HE-SXU Lifetime Test

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Abstract

A lifetime test was performed on HE-SXU-000. For the test, the gap was repeatedly cycled and was set 60,000 times in total. Many measurements were made before and after the gap was cycled. This note summarizes the results of the measurements. No significant changes to the undulator were observed.

1 Introduction[1]

A lifetime test was performed on HE-SXU-000. The gap was repeatedly cycled and set, and many measurements were made to look for changes due to the gap cycling. The results from the measurements are documented in this note.

The undulator was cycled in a manner which simulates the way the undulator is used in practice. The gap sequence used in the test is shown in figure 1. Each cycle consists of sub-cycles in which the gap is set 100 times. The cycle starts with three sub-cycles between 7.5 mm and 12 mm with 6 gap settings in each sub-cycle. The gap is set every 2 mm except for the 7.5 mm setting. After that, there are two sub-cycles between 7.5 mm and 18 mm with 12 gap settings in each sub-cycle. Then there is one sub-cycle between 7.5 mm and 24 mm with 18 gap settings, followed by one sub-cycle between 7.5 mm and 33 mm with 24 gap settings. Finally, the gap goes from 7.5 mm to 180 mm and back to 33 mm with 16 gap settings. The idea is that most of the gap settings in the tunnel will be at small gaps in the operating range of the undulator, while occasionally going beyond this range and even fully opening to 180 mm as will be done for testing or to turn off an undulator. This sequence of sub-cycles was repeated 600 times for the test. (A couple interruptions to the cycling occurred and are discussed below.) In total, the gap was set 60,000 times. This corresponds in the tunnel to setting the gap 16 times a day for 10 years. We believe this is a significant fraction of the life of an HE-SXR undulator.

For this test, a full set of magnetic measurements was made before and after the 600 cycles. Touch probe measurements of the poles were also made in an earlier dataset and at the end of the lifetime test.

During the gap cycling described above, a few notable occurrences took place. The undulator started to make a low noise, but it was not determined to be a problem. After

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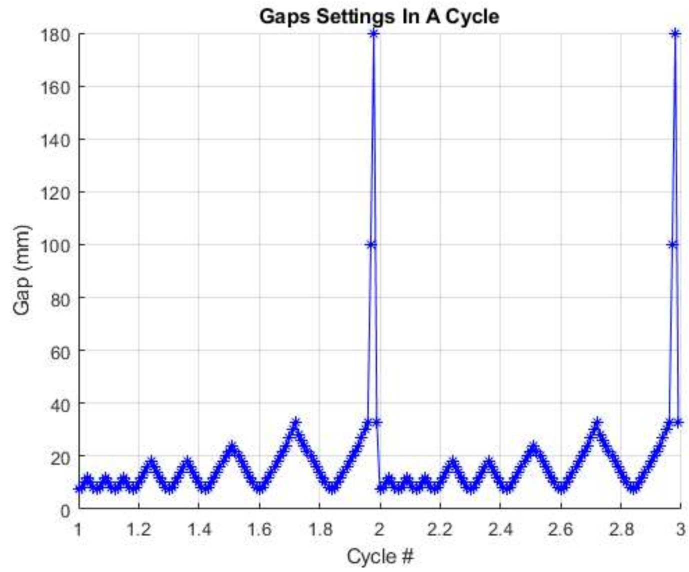

Figure 1: Two cycles of the sequence used to set the gap in the lifetime test.

162 cycles, an intermediate set of measurements was made showing no changes compared to the initial measurements. The undulator then needed to be moved to a temperature conditioning area to allow for reference undulator measurements at the SXU measurement bench. The cycling continued in the temperature conditioning area. The noise persisted. After 351 cycles, the cycling suddenly stopped because the motor controller reported the upstream top motor encoder offset instead of the encoder value. This caused a taper and pitch of the gap leading to a limit switch trip. Control system experts were called and they reset the controller and moved the undulator jaws back to the proper positions. They could not determine the cause of the motor communication problem, but declared the undulator operational again. At this point also, the lead screws and nuts were regreased in an attempt to quiet the noise the undulator made. Cycling continued to 600 cycles with no further noise and no further control system failures.

The result of the test is that no significant changes to the undulator were observed. As we will show, the magnetic measurements before and after the cycling agree well. We determined that lubricating the lead screws should be added to the procedure when the SXR undulators are refurbished to become HE-SXR undulators. No remedy for the control system failure was determined.

2 Touch Probe Analysis

Touch probe measurements of the undulator poles were made in the first dataset and at the end of the lifetime test in dataset 3. Figure 2 shows the difference in the measurements for all the undulator poles. There is a spread in the measurements of the gap change due to limitations of the Hall probe bench being used as a CMM. There is no significant systematic gap change, however.

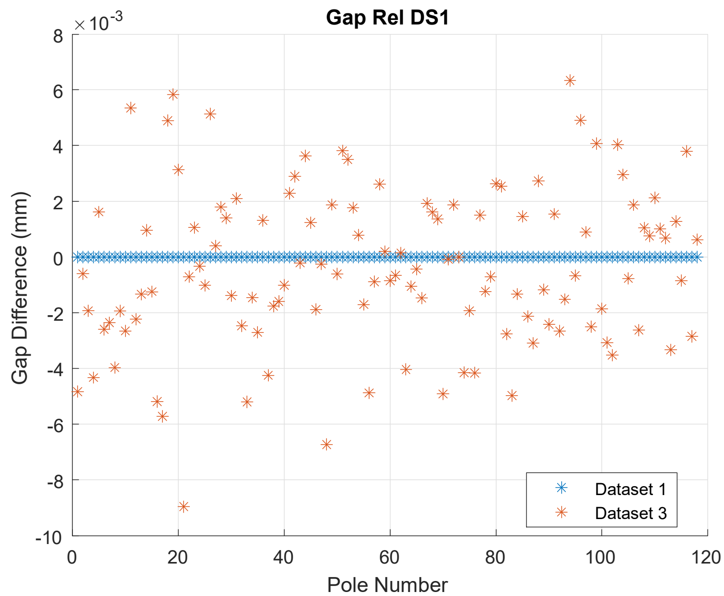

Figure 2: Difference in the undulator gap after the lifetime test compared to measurements made in dataset 1.

3 Magnetic Measurements

The primary quantity of interest for the performance of the undulator is the K value. The measured K value after the lifetime test relative to measurements before the lifetime test as a function of gap is plotted in figure 3. All K values have been corrected to their values at 20 deg C. All values agree with the initial measurements well within the tolerance limit.

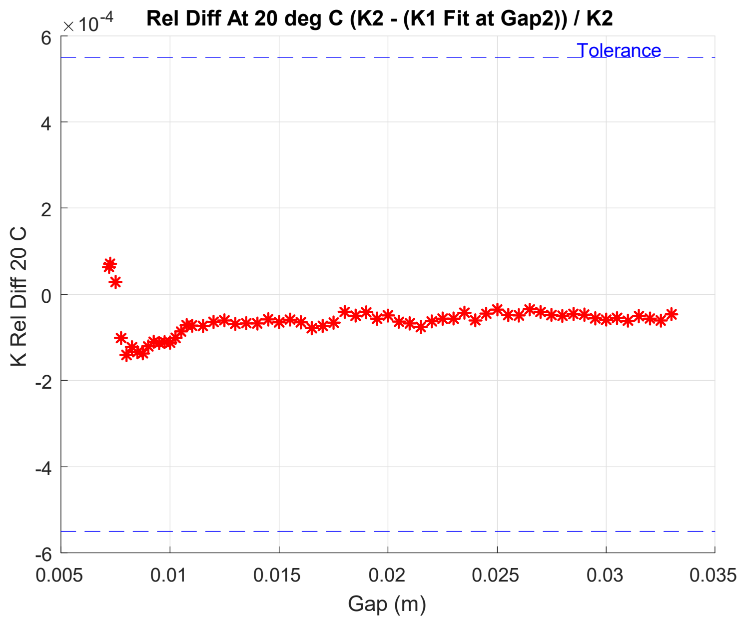

Figure 3: Relative difference in K values before the lifetime test and after the lifetime test, all corrected to 20 deg C.

A concern was whether mechanical hysteresis increases as the gap is cycled. This would lead to hysteresis in the K value. Figure 4 shows the hysteresis in the K value both before the lifetime test and after the lifetime test. For this plot, the K values as the gap is opened are subtracted from the K values as the gap is closed, and then the difference in K values is divided by the K value as the gap opened. This was done both for the initial measurements before the lifetime test and the measurements after the lifetime test. There appears to be a small reduction in the hysteresis due to the cycling, and possibly from the regreasing of the drive screws and nuts. We will study this further on future undulators. Lubricating the drive screws and nuts will be added to the work plan of the HE-SXUs during refurbishment. If precycling the gap changes the hysteresis, we will do the precycling before the final dataset.

The phase errors are sensitive to distortions of the gap (taper, bow, etc.). The phase errors are shown in figure 5. The phase errors are very stable, differing by fractions of a degree during the lifetime test. This indicates that the shape of the gap remained stable.

Figures 6 to 9 show the changes in the field integrals from before the lifetime test to after the lifetime test. No significant changes are observed.

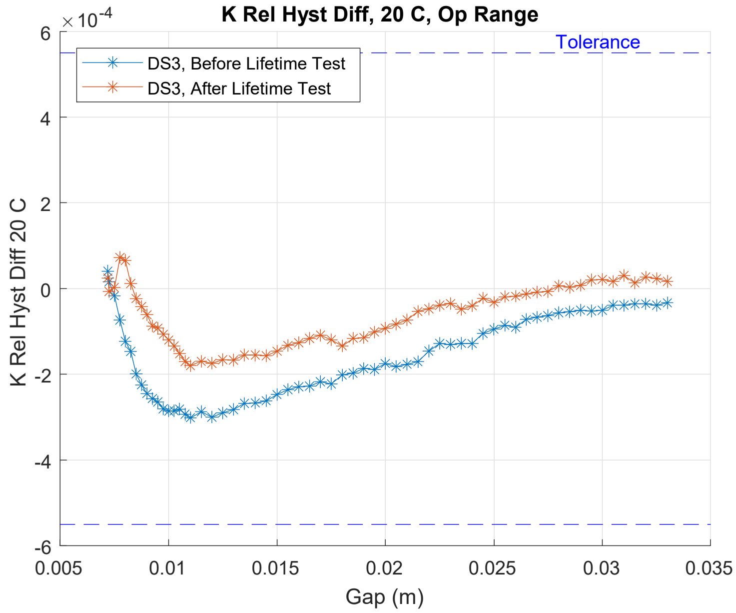

Figure 4: Hysteresis in the K value both before the lifetime test and after the lifetime test.

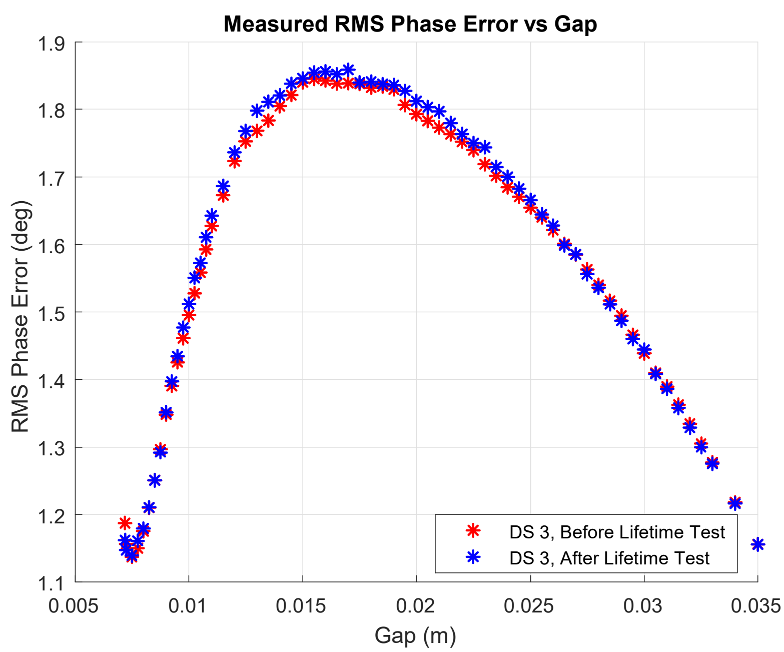

Figure 5: Phase errors as a function of gap.

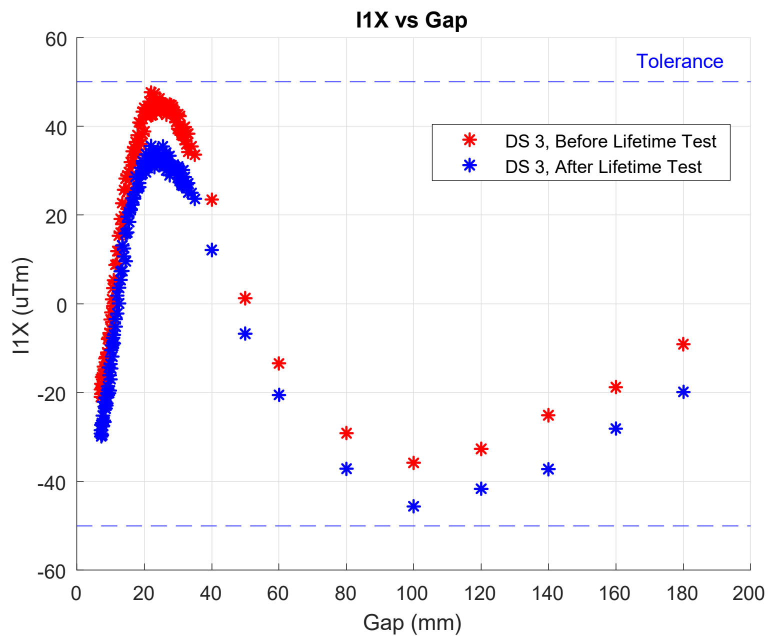

Figure 6: First integral I1X as a function of gap.

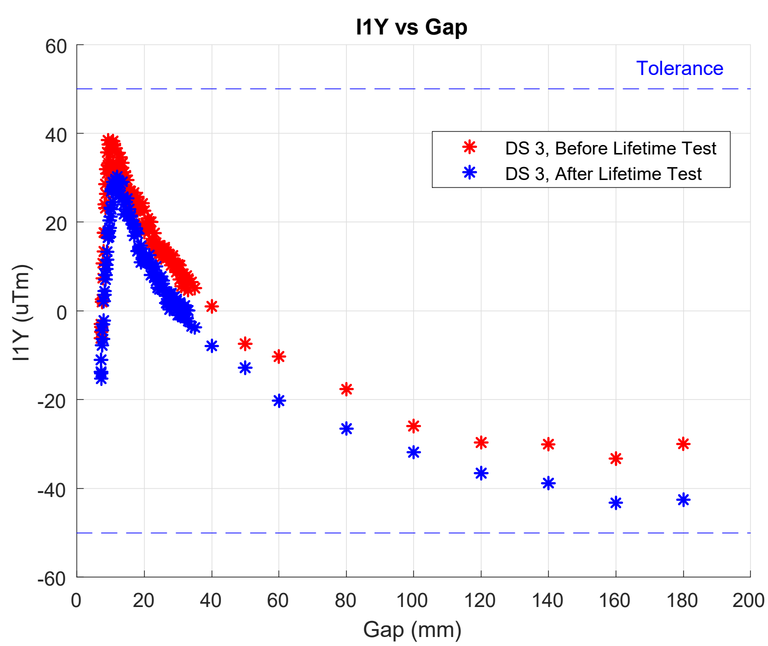

Figure 7: First integral I1Y as a function of gap.

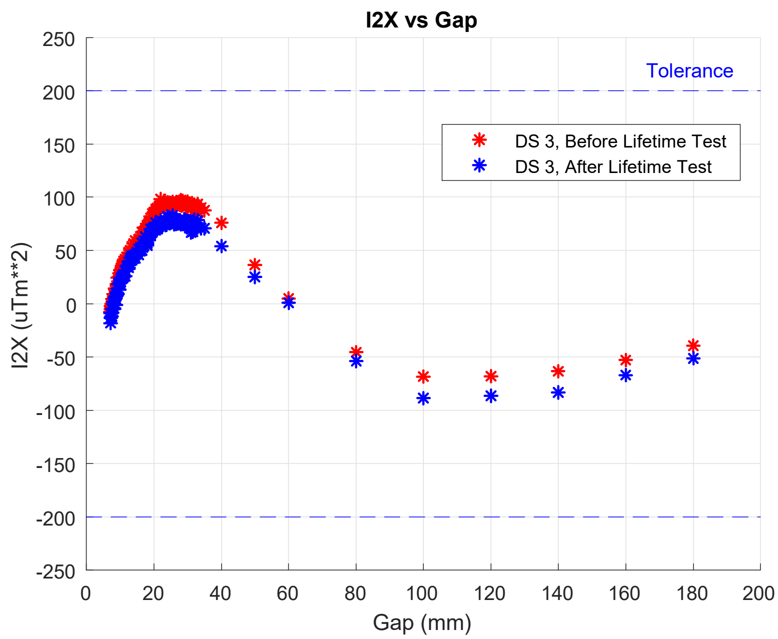

Figure 8: Second integral I2X as a function of gap.

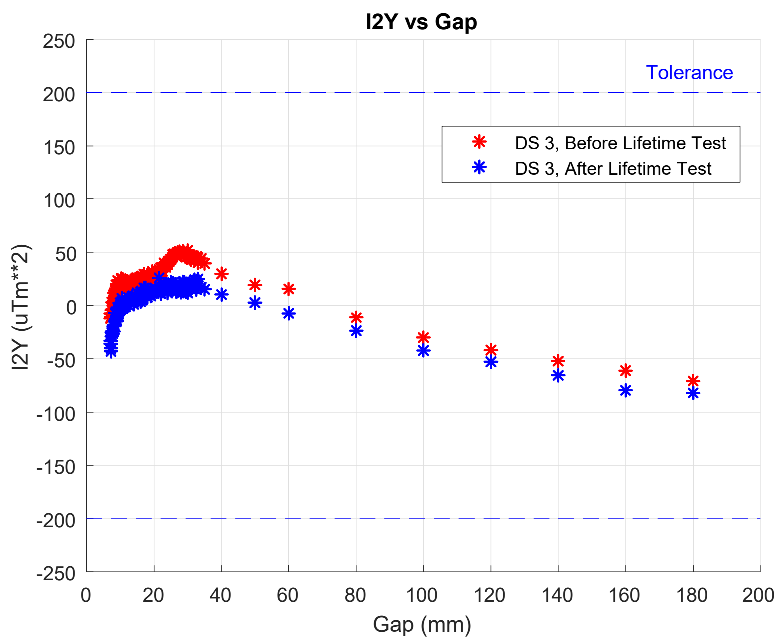

Figure 9: Second integral I2Y as a function of gap.

4 Summary

A lifetime test was performed on HE-SXU-000. The conclusion of the test is that the HE-SXR undulators are stable with use. The gap of HE-SXU-000 was cycled 600 times with 60,000 gap settings and there were no significant changes in the K value, phase errors, or field integrals. We determined that the drive screws and nuts should be lubricated as part of the HE-SXU refurbishment effort. We noted a control system failure during the test, but a remedy was not determined. Further studies will be made to determine if precycling the gap after the lubrication reduces K value hysteresis, and if so, precycling the gap will be done before the final dataset.

Acknowledgements

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