Delta Undulator Prototype Test Plan

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November 25, 2013

Abstract

This note details the test plan for the Delta undulator prototype. The note begins with a set of preliminary tasks which must be done, such as calibrating the Hall probes. Then the setup of the measurement equipment is described. The setup includes tasks such as as setting the alignment of the Hall probes. After the setup, the the measurements can begin. The measurements are done in four undulator polarization modes. Measurement repeatability and checks of the analysis methods are emphasized.

1 Introduction[1]

SLAC is building a Delta undulator[2] which will be placed in the LCLS beam line to produce light with variable polarization. A 1 meter prototype has been constructed, and a 3.2 meter full length device will be built after the prototype is successfully tested. This note describes the test plan for the 1 meter prototype undulator.

The ultimate goal of the Delta program at SLAC is to produce an FEL quality undulator. This means that the undulator meets LCLS type tolerances: trajectories are straight at the 2 μm level at 13.5 GeV, first field integrals are below 40 μTm and second integrals are below 50 μTm^2 at all row phases, phase errors are below 10 degrees, K values are known to 10^{-4}, and the undulator is fiducialized with an accuracy of 20 μm. Measurement accuracy to achieve these tolerances is difficult in the Delta undulator because there is only access to the magnetic fields from the ends of the enclosed bore. In this note we detail a plan to make the required magnetic measurements in the bore of the undulator.

The measurement techniques which are used have been described previously[3]. The calculations of the field parameters from the measurements have been detailed[4]. The notation used in this note is the same as that of the previous notes.

The test plan begins by discussing the required calibrations which must be performed before the measurements can begin. Then a set of checks is presented which must be made after the test setup is complete. Finally, the measurements of the test plan are presented.

2 Calibrations

Before measurements can begin, the following calibrations must be performed.

[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] A. Temnykh, Physical Review Special Topics-Accelerators and Beams **11**, 120702 (2008).

[3] Z. Wolf, "A Magnetic Measurement Plan For The Delta Undulator", LCLS-TN-13-4, March, 2013.

[4] Z. Wolf, "Hall Probe Array Measurements Of The Delta Undulator", LCLS-TN-13-9, November, 2013.

1. Calibrate the B_x and B_y Hall elements for both probes in a calibration magnet. Each element is calibrated independently. Planar Hall effects can not be included at this time. The Hall probes must be calibrated in their final holder. The calibration includes and corrects cosine errors of the Hall elements.

2. Measure the Hall element relative angles and angle errors. Choose one element as a B_x reference. Set up a vertical field standard. Rotate the probe package so the output of the reference B_x element to zero. From the field measured by the other B_x element, calculate its roll angle relative to the reference. Measure the roll rotation angle required to make the B_y elements read zero. Use the signal from the B_z sensors to determine the pitch of the B_z elements. Rotate the probes 90° and use the signal from the B_z sensors to determine the yaw of the B_z elements. Set up a solenoid as a longitudinal field reference. Use the signals from the B_x sensors to measure their yaw. Use the signals from the B_y sensors to measure their pitch.

3. Measure the Hall element's relative positions. Set up a fiducialization magnet on a 3-axis set of stages. Move the zero field point to each Hall element. Record the positions. This will give the three coordinates of each element relative to a reference element.

4. Zero the quadrant positions of the undulator. Move all quadrants so they are in the center of their travel. This sets the mechanical zero position, and it will be close to the magnetic zero position. Leave quadrant 1 fixed as a reference. Move quadrant 2 so B_y under a pole is maximized. Repeat for quadrants 3 and 4. This puts the undulator in linear polarization, vertical field mode. Iterate moving quadrants 2, 3, and 4 until B_y is maximized. This sets the zero of the quadrant positions.

5. Measure B_x and B_y reference magnets using a stretched wire system. They will be used to calibrate the pulsed wire measurements and the moving wire measurements.

3 Checkout

Once the undulator is ready for measurements, perform the following setups and checks.

1. Use a vertical field standard to set the roll angle of the Hall probe package. The reference B_x element from the calibration should read zero.

2. Use reference magnets to verify that each Hall element is giving the correct magnitude of the field.

3. Use a hand held magnet to check the sign of the output from each Hall sensor. The y-direction is up. The z-direction is the beam direction. The x-direction makes the coordinate system right handed. The south pole of a magnet above a B_y element should give a positive output. The south pole of a magnet placed at the end of the probe assembly should make the B_z elements give a positive output. The south pole of a magnet placed on the +x side of the probe should make the B_x elements read positive.

4. Place the probe package in the guide tube. With a micrometer, gently move the tube a known distance. Verify that the laser alignment system gives the correct magnitude and sign of the transverse moves.

5. Use reference magnets to verify that the moving wire system gives correct first and second field integrals. Verify the sign of the integrals.

4 Undulator Measurements

4.1 Pulsed Wire Measurements

Set up the pulsed wire system. Use a calibration magnet and include its signal in each waveform as a way to calibrate the signals.

1. Measure the B_x and B_y first and second field integrals of the undulator. Do this in each of the four undulator polarization modes: linear polarization vertical field, linear polarization horizontal field, circular polarization right hand, circular polarization left hand.

2. Set the undulator in linear polarization vertical field mode. Move the wire vertically and horizontally. Note how several field peaks change value with wire position. Determine k_x and k_y.

3. Repeat step 2 for the other three undulator polarization modes.

4.2 Moving Wire Measurements

Use the pulsed wire setup, but instead of pulsing the wire, move it horizontally and vertically and integrate the signals to determine the field integrals. Use calibration magnets to verify the accuracy of the system.

1. In each polarization mode, measure the first and second field integral using the moving wire.

4.3 Hall Probe Array Measurements

Set up the Hall probe array measurement system. Perform the checks of the system listed in the previous section.

1. Put the undulator in linear polarization vertical field mode. Make the offset between the two probes be in the vertical direction. Chech the repeatability of the measurements. Measure $\widetilde{x}$, $\widetilde{y}$, k_x, k_y, and Δ. Determine the repeatability of these measurements. Determine the beam axis and its repeatability.

2. Leave the undulator in linear polarization vertical field mode. Make the offset between the two probes be in the horizontal direction. Chech the repeatability of the measurements. Measure $\overline{x}$, $\overline{y}$, k_x, k_y, and δ. Determine the repeatability of these measurements. Determine the beam axis and its repeatability.

3. Repeat steps 1 and 2 for the linear polarization horizontal field mode.

4. Put the undulator in circular polarization right hand mode. Make the offset between the two probes be in the vertical direction. Chech the repeatability of the measurements. Measure $\widetilde{x}$, $\widetilde{y}$, δ, and Δ. Determine the repeatability of these measurements. Determine the beam axis and its repeatability.

5. Leave the undulator in circular polarization right hand mode. Make the offset between the two probes be in the horizontal direction. Chech the repeatability of the measurements. Measure $\overline{x}$, $\overline{y}$, δ, and Δ. Determine the repeatability of these measurements. Determine the beam axis and its repeatability.

6. Repeat steps 4 and 5 for circular polarization left hand mode.

7. Analyze the measurements and study their consistency. See if the beam axis position is consistent between modes. Choose the "best" beam axis, which will become the fiducialized beam axis. Calculate the fields on the fiducialized beam axis for each mode.

8. The probe positions at each end of the undulator determine a straight line which defines the measurement coordinate system. The fiducialized beam axis position is given in this coordinate system. Find the probe position at each end relative to tooling balls using fiducialization magnets on stages. Fiducialize the undulator. Relate the tooling balls on the fiducialization magnets to tooling balls on the undulator. Calculate the position of the fiducialized beam axis relative to the tooling balls on the undulator.

9. Measure K and calculate the fields on the fiducialized beam axis as a function of the linear encoder settings in each polarization mode. Do this at a coarse set of points. Test the procedure to set the K value of the undulator in each mode.

5 Conclusion

A measurement plan for the Delta undulator prototype was presented. An extensive set of measurements is required in order to verify that the test plan will work for the full length Delta undulator.

Acknowledgements
We are grateful to Alexander Temnykh for many discussions about this work.