LCLS-II Beam Pipe Corrector

Magnetic And Thermal Tests

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4/28/14

Purpose

These tests are to verify the performance of the corrector coils on the LCLS-II undulator beam pipes. The magnetic strength and field uniformity of the coils will be determined. Comparison will be made to expected results. The heating effect of the coils will also be determined. A simulation of beam heating will be made so that the total power into the beam pipe will be the same as in LCLS-II operation. The temperature of simulated undulator magnet assemblies will be determined.

Test Plan

1. Model the beam pipe corrector using the Biot Savart law. Determine Bx and By on the axis as a function of current. Determine By vs x on the horizontal midplane when the corrector is making a vertical field. Determine By vs y on the vertical midplane when the corrector is making a vertical field. Determine Bx vs y on the vertical midplane when the corrector is making a horizontal field. Determine Bx vs x on the horizontal midplane when the corrector is making a horizontal field. Verify the expected performance as given in the undulator system physics requirements document:



1. Set up the beam pipe with the corrector windings. Connect the windings according to the following figure. Note that diagonal currents are negatives of each other. This means that two power supplies are required, each feeding one of the diagonal loops. The coordinate system has z in the beam direction, y is up, and x is in the direction to make the system right handed. The view in the figure is from the downstream end looking upstream.



Set up stages at each end of the beam pipe in order to do stretched wire measurements. The stages must be set up to measure Bx and By field integrals. Bx and By will be given by the field integral divided by the corrector length.

1. Power the correctors. Start with a low current of .5 A in the two windings and make a By field. Using a handheld Hall probe outside the beam pipe, verify that By is produced, and verify that the sign is correct. Attach a thermistor to the beam pipe. Measure the temperature rise. If the temperature rise is below 1 degree C, increase the current in .5 A steps to 2 A. Verify that the correctors can be powered to 2 A without increasing the beam pipe temperature more than 1 degree C. Repeat this step with the power supplies making a Bx field.
2. Perform the following stretched wire measurements:
3. Run the power supplies to produce By. Step the current from -2 A to +2 A in .5 A steps. At each current, measure the first integral of By on the axis of the corrector. Subtract the 0 A measurement from the others. Calculate By vs I from the 0 A subtracted field integrals.
4. Run the power supplies to produce By. At a current of 1 A, measure By vs x on the horizontal midplane. Do this at x = -2, -1, 0 1, 2 mm. Compare the roll-off to the model’s predictions.
5. Run the power supplies to produce By. At a current of 1 A, measure By vs y on the vertical midplane. Do this at y = -2, -1, 0 1, 2 mm. Compare the roll-off to the model’s predictions.
6. Run the power supplies to produce Bx. Step the current from -2 A to +2 A in .5 A steps. At each current, measure the first integral of Bx on the axis of the corrector. Subtract the 0 A measurement from the others. Calculate Bx vs I from the 0 A subtracted field integrals.
7. Run the power supplies to produce Bx. At a current of 1 A, measure Bx vs y on the vertical midplane. Do this at y = -2, -1, 0 1, 2 mm. Compare the roll-off to the model’s predictions.
8. Run the power supplies to produce Bx. At a current of 1 A, measure Bx vs x on the horizontal midplane. Do this at x = -2, -1, 0 1, 2 mm. Compare the roll-off to the model’s predictions.
9. Determine the transfer function for Bx and for By of the corrector. Calculate the currents to make the Earth’s field go to zero on the corrector axis. Apply these currents and verify that the Bx and By field integrals are zero on the corrector axis.
10. Given the transfer functions for the corrector, calculate the currents to make Bx = +0.6 G and By = +1.4 G from the corrector without the Earth’s field. Set these currents. Attach a thermistor to the beam pipe. Verify that the temperature rise of the beam pipe is below 1 degree C. Measure the field integrals on the corrector axis. Verify that the field integrals are correct.
11. Set up an array of steel strips which simulate the magnetic effect of the magnet poles. Power the corrector to produce By with 1 A in the windings. Measure Bx and By on the corrector axis as the gap between the steel strips is changed from 7.2 mm to 20 mm in 2 mm steps.
12. Set up an array of steel strips which simulate the magnetic effect of the magnet poles. Power the corrector to produce Bx with 1 A in the windings. Measure Bx and By on the corrector axis as the gap between the steel strips is changed from 7.2 mm to 20 mm in 2 mm steps.
13. Attach thermistors to the beam pipe and to the stainless steel blocks which simulate the magnets and poles. The stainless steel blocks have been calculated to have the same average thermal conductivity as the magnet and pole assembly in the undulator. Set up the stainless steel blocks on a mechanism which adjusts the gap centered on the beam pipe. The following drawing illustrates the setup.



Two thermistors are placed on the beam pipe in the gap above the beam pipe, and two thermistors are placed on the beam pipe in the gap below the beam pipe. Two thermistors are placed on each stainless steel block in the gap. One thermistor is placed on each block away from the gap. Two thermistors are placed on the beam pipe away from the stainless steel blocks. One thermistor measures the air temperature.

The minimum gap between the stainless steel block and the beam pipe is 0.6 mm. We require this gap to be accurate to at least 10%, so the tolerances on the gap between the stainless steel blocks, the block flatness, the parallelism between the blocks, etc., must be better than 0.05 mm. This requires significant care in the setup.

1. Set the gap of the stainless steel blocks to 7.20 mm.
2. With no current in the trim windings, measure the temperature from each thermistor for one day (24 hours). Find the average temperature for each thermistor after equilibrium is reached.
3. Repeat step 6 four times. Determine the variation of the room temperature and the measurement system.
4. With 1 A in each trim winding, measure the temperature from each thermistor for one day. Find the average temperature for each thermistor after equilibrium is reached. Determine the rise time of the temperature at each measurement location. Measure the voltage drop on each winding. Calculate the power into the windings. Record the power in the temperature record.
5. With 2 A in each trim winding, measure the temperature from each thermistor for one day. Find the average temperature for each thermistor after equilibrium is reached. Determine the rise time of the temperature at each measurement location. Measure the voltage drop on each winding. Calculate the power into the windings. Record the power in the temperature record.
6. With currents set to produce Bx = 0.6 G and By = 1.4 G from the corrector without the Earth’s field, measure the temperature from each thermistor for one day. Find the average temperature for each thermistor after equilibrium is reached. Determine the rise time of the temperature at each measurement location. Measure the voltage drop on each winding. Calculate the power into the windings. Record the power in the temperature record.
7. Set the gap of the stainless steel blocks to 20 mm.
8. Repeat steps 6, 8, 9, and 10 with the larger gap.
9. String a wire through the chamber to add heat in order to simulate beam loss heating. Put current in the wire such that the power added to the inside of the chamber is 1 W/m. Record the power going into the wire in the data record. Repeat the measurements given above with the 7.20 mm and 20 mm gaps, but with this extra heat source. Verify with Heinz-Dieter that higher beam loss powers are not expected. If so, repeat this test with the highest beam loss power expected.