LCLS-II SXR Undulator Quadrupole Measurement Orientation

Scott Anderson, Heinz-Dieter Nuhn, Zachary Wolf
SLAC National Accelerator Laboratory
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Abstract

This note details the issues and solutions stemming from the choice to turn the SXR quadrupoles 180o after the integrated gradient, harmonics and trim coil field strength measurements on the SXR oriented undulator quadrupoles were complete.

1. Introduction[1]

After the 31 LCLS-II SXR undulator quadrupoles had been measured for integrated gradient, harmonics and trim coil field strength, it was noticed that the x tooling ball for the magnets were in the wrong side of the magnet to be accessed in the tunnel by the alignment group. This was noticed just as the magnetic fiducialization process was about to go into production. Before the magnetic fiducialization started, it was decided that the beam direction arrows would be rotated 180 degrees, so that the quadrupoles would be fiducialized in the correct (SXR) orientation. Having the undulator quads rotated by 180 degrees about the Y axis had the effect that the polarity of the main quadrupole coils and the V trim coils (horizontal field) would be incorrect if left as they were. To make sure the polarity of the quadrupoles would have their proper polarity[2], the labels for the quadrupole main coils and V-trims were swapped, so that the label at the power cable attachment point for a positive input current became negative and vice versa. This change has several effects, with the most notable being that the HXR and SXR quadrupoles are no longer interchangeable. Since the SXR undulator quadrupoles were measured for integrated gradient, harmonics and trim coil field strength in the HXR orientation it becomes necessary to prove that the measurements in the HXR orientation can still be used to characterize the undulator quadrupoles when they are run in the SXR orientation. To this end, one SXR undulator quadrupole, 4066, was remeasured with the correct polarities for a SXR oriented undulator quad. The measurements in the SXR polarity can be compared to measurements made in the HXR polarity and with the HXR measurements data changed to have the proper SXR polarity. Comparing these data sets, one can see if the measurements made in the HXR polarity give the same results as the measurements in the proper SXR polarity, or if the signs of the HXR measurements need to be changed and reanalyzed for the data to match. The details of the sign changes are explained in section *Polarity Sign Flip*.

If either method works, then the HXR measurements of all of the SXR undulator quadrupoles can used for setting the SXR oriented undulator quadrupole parameters.

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[2] LCLS sign conventions 1.1-010-r0.pdf

2. Comparison of HXR, HXR Sign Flipped to SXR Oriented Data

To test if the data taken in the HXR (also LCLS) orientation can be used, undulator quad 4066 was remeasured twice in its proper SXR orientation after having been originally measured in the HXR orientation. By measuring twice one can compare the SXR data to itself to gauge the repeatability of the measurements so that the HXR and SXR comparison can be understood clearly. To compare the integrated gradients of the data sets one could compare the integrated gradient values at each current of the “up” current data (-6 to +6 amps in 0.5 amp steps), but since the current setting of each magnet is performed using a polynomial derived from the up current data it is more informative to compare the integrated gradient data derived from using a 3rd order polynomial fit to the current vs the integrated gradient for each data set and then solving for the integrated gradient at current values from -6 to +6 amps in 0.25 amp steps. Figure 1 shows the integrated gradient % difference ratio, %ΔGL/GL, for the HXR oriented data, HXR oriented data with its signs flipped and the repeat of the SXR data. Also shown is %ΔGL/GL between the original HXR data set and the flipped SXR data set flipped again. Flipping the HXR data set twice is akin to turning the magnet 360 degrees, which should result in the original data and is a check of the flipping method. The run numbers in Figure 1 are:

Table 1: Undulator Quad 4066 Run Numbers and Descriptions

Run #	Data Set Contents
1	HXR orientation data set
7	SXR orientation data set
13	SXR orientation data repeat
21	Run 1 HXR orientation data with signs flipped to SXR orientation
31	Run 21 data with signs flipped back to HXR orientation, should be the same as Run 1.

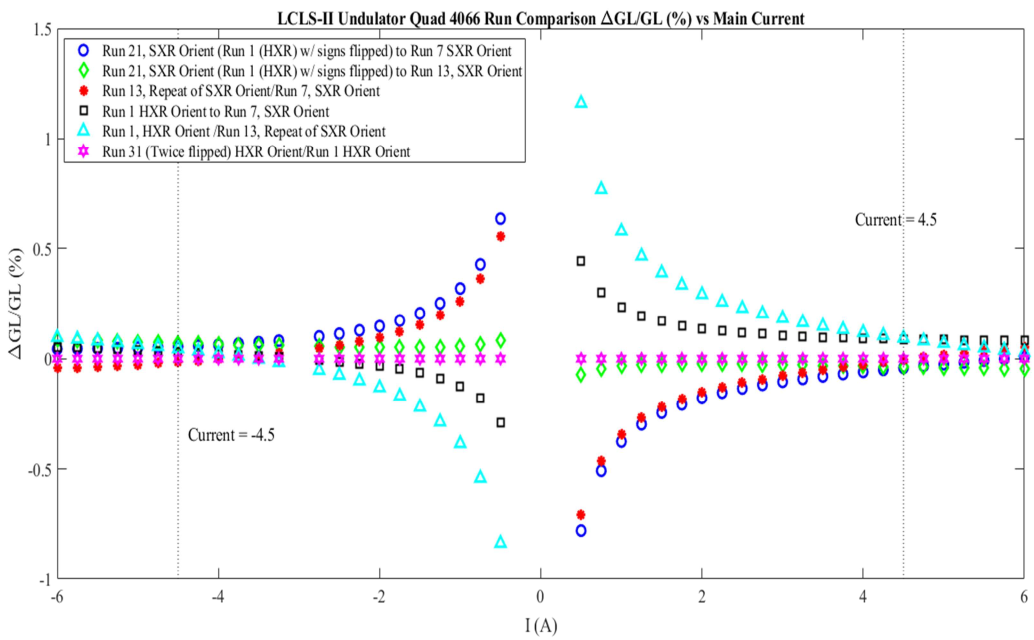

Figure 1: Integrated Gradient Comparisons

Figure 1 shows that the HXR oriented data and the HXR oriented data with its signs flipped data both characterize the SXR orientation transfer function as well as the remeasured SXR orientation data. This means that the HXR oriented integrated gradient data can be used to characterize the transfer functions for all of the undulator quads when they are rotated 180 degrees in the SXR line. The HXR flipped data compared to the SXR measurements, as seen in the blue circles and green diamonds, seems to compare better to the SXR data at low currents, but this might be an aberration of the data fits and the measurement errors of each data set. One can conclude that using HXR data to the SXR orientation is as good as remeasuring the undulator quads in the SXR orientation.

The vertical trim (Vtrim) of the undulator quad is also affected by the 180 degree rotation of the magnet, in that its polarity must be flipped at the magnet terminals for Vtrim field to have the proper direction in the SXR orientation. This is because the Vtrim field is horizontal. The Htrim, which has a vertical field, is unaffected by the 180 degree rotation about the y axis of the quad. Flipping the sign of the Vtrim has little effect on the trim strength measurements. For Quad 4066, integrated field measurements were made with the main coils at 4.5 amps and the H and V trims set to all combinations of 0, +1 and -1 amp. Run 6 is the integrated field data measured in the HXR orientation, Run 12 is the integrated field data measured in the SXR orientation and run 36 is run 6 data with its polarity and field signs switched to be in the SXR orientation. Figure 2 shows the magnitude and angle of each powered combination minus the field with both trims off. This means the vectors in the horizontal are with only the V trim powered, the vertical only the H trim powered and the diagonal are both trims powered. Figure 2 shows that the trim integrated strengths and angles of the field are nearly identical for the three runs. The percent difference of the integrated fields between run 6 and 12 and then 36 and 12 are small and similar, which means one can use the HXR data, as is, to determine the trim field strengths. These percent difference values can be seen in Table 2.

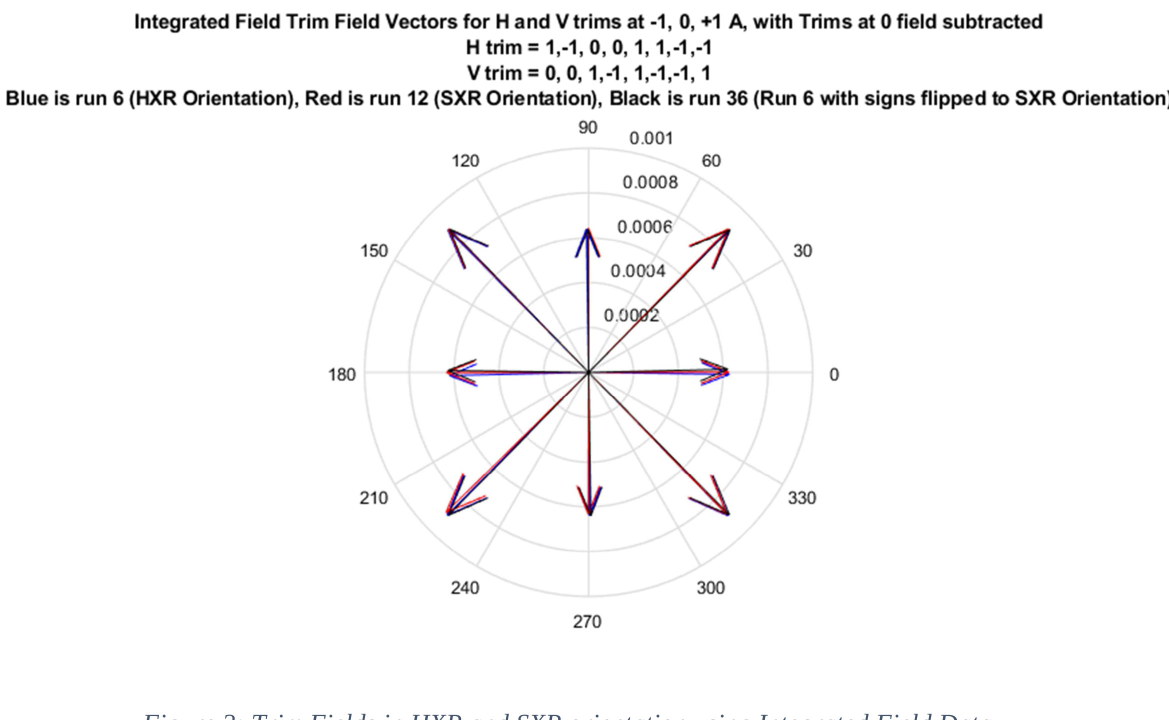

Figure 2: Trim Fields in HXR and SXR orientation using Integrated Field Data

Table 2: Undulator Quad 4066 Integrated Field % Differences for Trim Coils in HXR and SXR Orientation

Htrim (Amps)	Vtrim (Amps)	Integrated Field % Difference Run 6 (HXR) – 12 (SXR)/ Run 6 (HXR)	Integrated Field % Difference Run 36 (SXR) – 12 (SXR)
1	0	-0.56	-0.75
-1	0	1.09	1.28
0	1	0.35	-0.76
0	1	2.2	-1.09
1	1	-0.05	0.10
1	-1	-0.07	-0.22
-1	-1	0.63	-0.02
-1	1	0.67	1.32

3. HXR to SXR Orientation Polarity Sign Flip

For the original HXR measurements to have the correct sign for a SXR undulator quad, several signs in the data must be flipped from positive to negative and vice versa. The signs that must be flipped in integrated gradient vs current measurement files (strdat, strplt) data files are: the current for the main (QMAIN), the current of the Vtrim, the sign of the transfer function (TF) and the signs of south pole angle ($\theta_{South\ Pole}$) must be adjusted using the formula:

$$\theta_{South\ Pole\ New} = \theta_{South\ Pole} + sign(\theta_{South\ Pole}) * -1 * \frac{360}{2 * n} \qquad (1)$$

$\theta_{South\ Pole}$ being the original south pole angle and n = 2, for a quadrupole magnet. For the harmonics measurements (hardat, harplt), the signs that must be flipped are the current signs for the main coil, the V trim and the $\theta_{South\ Pole}$ of each harmonic the signs of south pole angles for each harmonic must be adjusted using the equation 1, where n is the number of poles of the harmonic divided by 2. For the center measurements (ctrdat), the signs that must be flipped are the main coil and the V trim currents. Matlab programs have been written to make these switches, they are: *Swap_strplt_polarity.m*, *Swap_harplt_polarity.m* and *Swap_ctrdat_polarity.m*, which switch the signs in the integrated strength (strdat, strplt), harmonics (hardat, harplt), and center (ctrdat) files respectively.

4. Conclusion

The SXR undulator quadrupoles were measured for integrated gradient, harmonics and trim coil field strength in the HXR orientation. It has been shown that the HXR measurements can be used, as they are, to characterize the SXR oriented undulator quads. The fiducialization of the SXR quads was done in the correct orientation.