An HE-SXR Undulator Alignment Check Using The Midplane Encoders

Zachary Wolf

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Overview

The SXR undulators will have encoders added to the top jaw as part of the high energy upgrade project (HE). At present, without the encoders, the undulator midplane is set to be on the beam axis using potentiometers. Potentiometers generally are not as reliable as encoders, so the new encoders add a valuable check that the undulator midplanes are on the beam axis. In addition, since the potentiometers cannot be used in the MMF, the new encoders allow midplane control during magnetic measurements.

The focus of this note is on using the new midplane encoders to check that the SXR undulator midplanes are on the beam axis during use in the LCLS tunnel. A procedure for using the new midplane encoders for this check is detailed below. This procedure with small modifications can also be applied in the MMF during magnetic measurements. A different but related use of the midplane encoders is for the controls group to check the calibration of the potentiometers periodically in the tunnel. The potentiometer calibration is currently done by hand using gauge blocks. The procedure using the midplane encoders allows automation but is fundamentally similar to a calibration using gauge blocks. This calibration is not discussed here.

The strategy for using the HE-SXR undulator midplane encoders to check that the undulator midplanes are on the beam axis is as follows. We define the beam axis at each undulator as the line between the centers of the quadrupoles neighboring the undulator. After an alignment crew positions the quadrupoles and undulators, we assume each undulator midplane is on the beam axis. We take this as our reference configuration. Afterwards, when the quadrupoles are moved, the beam axis moves. We use a combination of the midplane encoders and the gap encoders to check that the undulator midplanes move the correct amount to stay on the beam axis. We now discuss the details of this check.

Alignment Check

The steps to use the midplane encoders to check the undulator alignment are as follows:

1) Get the z-positions along the undulator line of all the quadrupoles, gap encoders, and midplane encoders. The z-positions are used to calculate the beam axis at the midplane

encoder z-positions, and to calculate the undulator gap at the midplane encoder z-positions.

2) After alignment, record the quadrupole transverse positions, the undulator gap encoder readings, and the undulator midplane encoder readings. These readings should be put in PVs whose name indicates that they are the reference values. Upon realignment, the old values should be archived, and the PVs should contain the latest values.

3) When the undulator midplane positions are to be checked, get the current quadrupole transverse positions, undulator gap encoder readings, and undulator midplane encoder readings. These should all come from PVs whose name matches the reference reading names, but without the reference indication.

4) A Matlab program was written to get all the information for steps 1 to 3. (Contact Zack Wolf for details.) The information is put in an array of structures, one structure of the array per undulator cell. The array of structures is saved for use by an analysis program.

5) A second program was written in Matlab to analyze the quadrupole positions and gap and midplane encoder readings, and the reference values, and to calculate the errors in the midplane positions. (Contact Zack Wolf for details.) The program first plots the quadrupole positions as shown below.
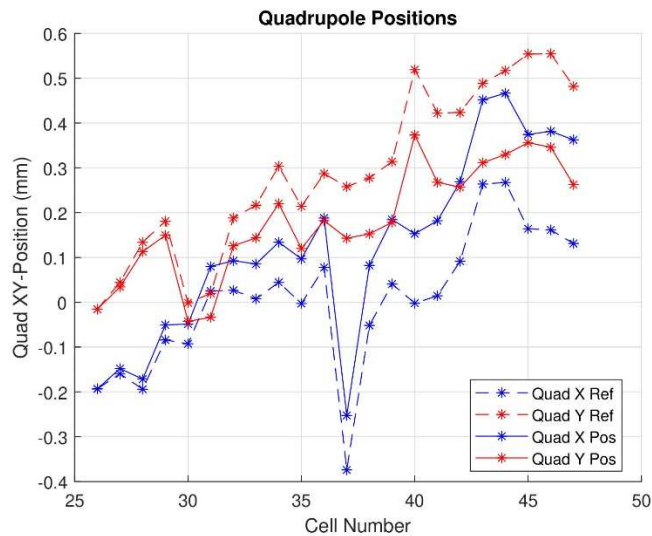

6) The analysis program then finds the difference in y-position between the quadrupole centers in the current configuration and in the reference configuration.

Quadrupole Positions Rel Reference
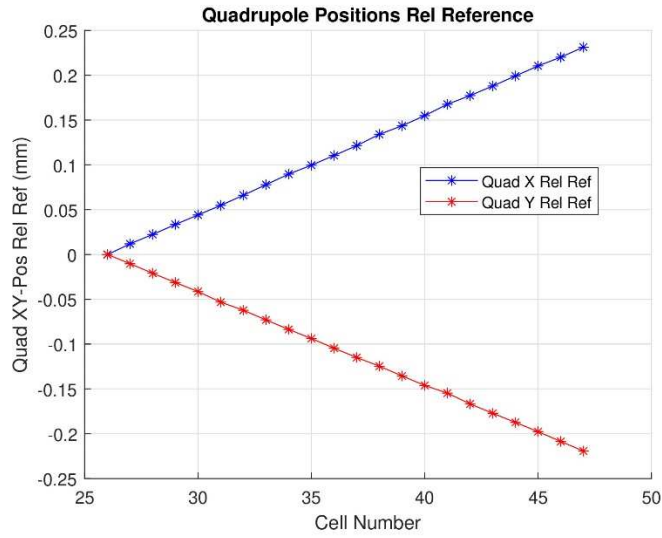
7) A line is formed between the quadrupole center y-positions for both the reference configuration and the current configuration. This line defines the beam axis. Based on the z-positions of the devices, the program finds the y-position of the line at the midplane encoder z-positions. This is indicated in the following figure.


Beam Axis Y-Pos At Mid Enc Z-POS
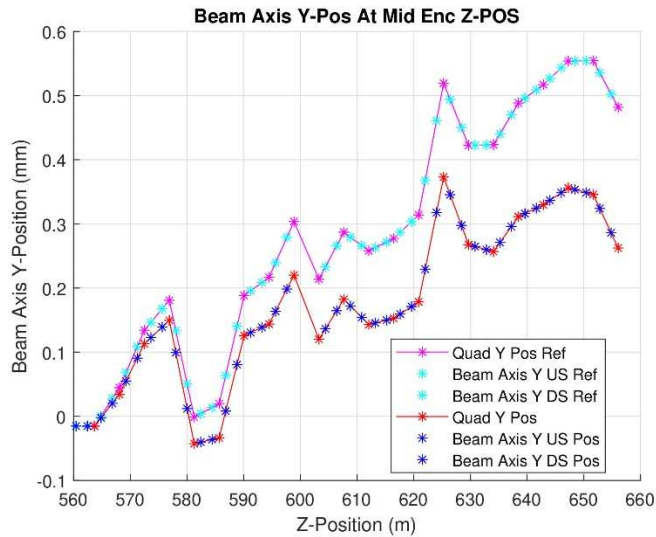
8) Next, the program finds the change relative to the reference of the beam axis y-positions at the midplane encoder z-positions.

Beam Axis Y-Pos Rel Ref At Midplane Encoder Z-Pos
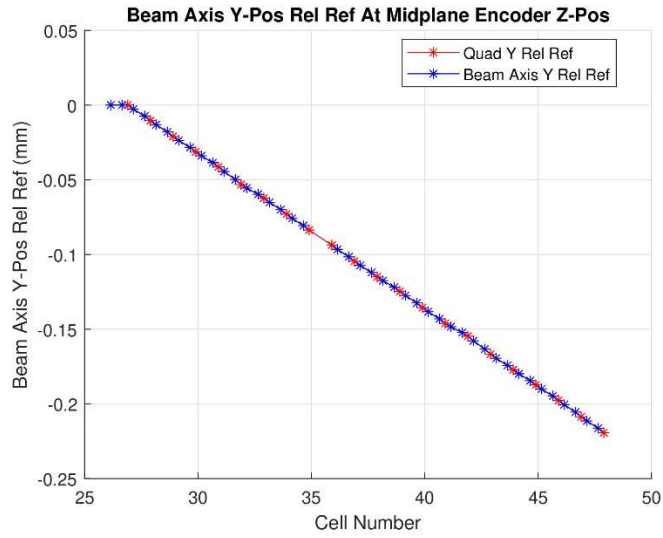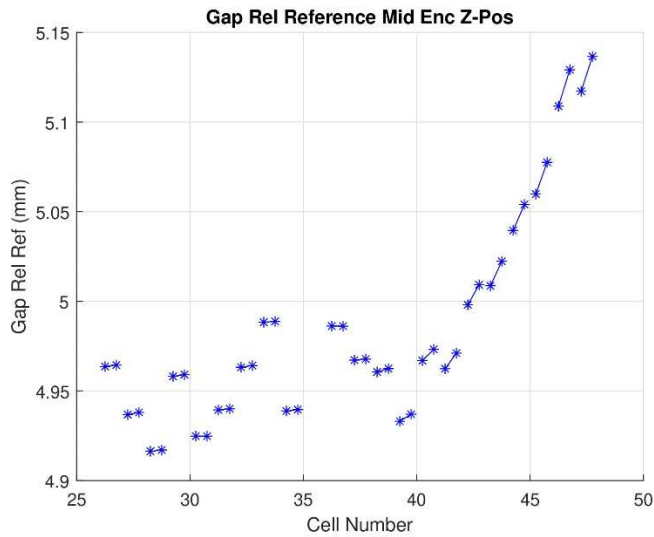
9) The gap encoder values, both current and reference, are then analyzed. These values give the gap at the location of the gap encoders.

Gap Encoder Values
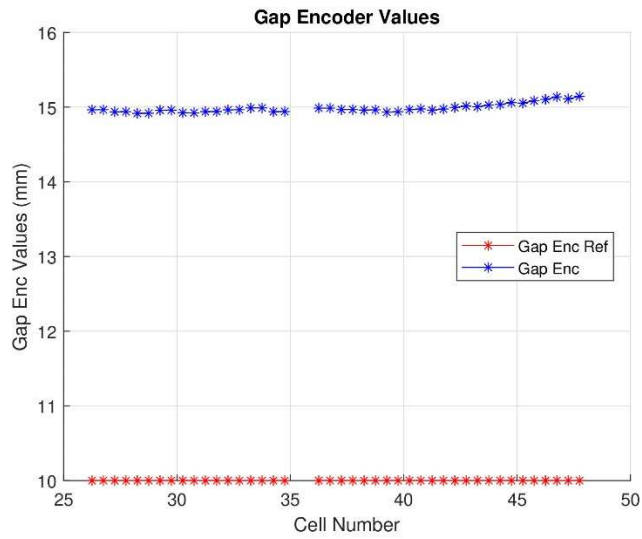
10) The undulator gap and taper, along with the device z-positions, are then used to find the undulator gap at the midplane encoder z-positions.

Gap At Midplane Encoder Z-Positions
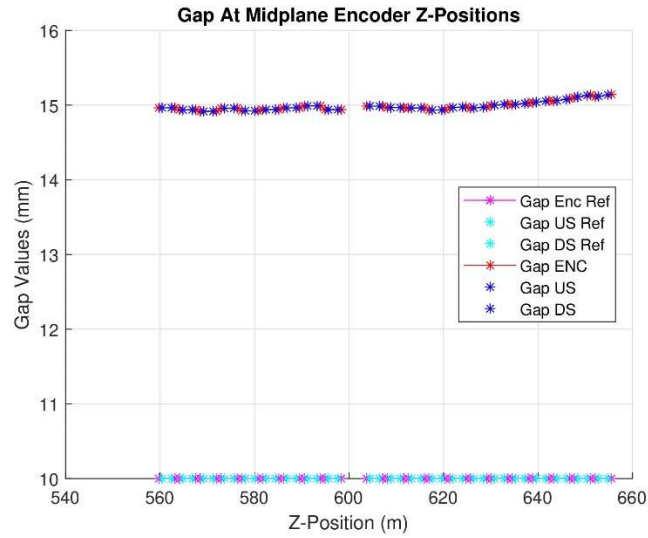
11) Next, the program finds the change in gap relative to the reference value at the midplane encoder z-positions.

Gap Rel Reference Mid Enc Z-Pos

12) The next step is to include the midplane encoder readings, both current and reference. Find the change in midplane encoder readings relative to the reference values. If M is a midplane encoder reading and Mref is the reading after alignment, the change in the reading is

$$\Delta M = M - Mref$$

13) Similarly, if G is the gap at a midplane encoder z-position, and Gref is the gap at the midplane encoder z-position after alignment, the change in the gap relative to the reference value is

$$\Delta G = G - Gref$$

14) A critical step is to realize that the midplane position is given by the upper jaw position minus half the gap. The midplane encoder readings are linearly related to the upper jaw position. Similarly, the gap encoder readings are linearly related to the undulator gap. The gap at the midplane encoder z-positions follow another linear relationship based on the gap at the gap encoder positions. The slopes of the linear relations are well defined, but the offsets are not well defined. By using changes in the midplane position, we eliminate the offsets.

If dYmid is the change in y-position of the midplane at a midplane encoder z-position, dM is the change in midplane encoder reading, and dG is the change in gap at the midplane encoder z-position,

$$dYmid = dM - dG/2$$

Similarly, we find changes relative to the reference values. The change in y-position of the midplane relative to the reference is

$$\Delta Ymid = \Delta M - \Delta G/2$$

15) In step 8 we found the change in the beam axis position relative to the reference position at each midplane encoder z-position. Call this ΔBA. In step 14 we found the change in undulator midplane y-position relative to the reference value, $\Delta Ymid$. We assume that the midplane is on the beam axis after alignment. So, the error in the midplane position is given by the difference of the change in midplane position minus the change in the beam axis position, both relative to their reference values. At each midplane encoder z-position,

$$\text{Midplane Y-Position Error} = \Delta Ymid - \Delta BA$$

The program monitors these errors as a check that the undulator midplane stays on the beam axis. If there is an error in the midplane position, since the motors are very near the midplane encoders, the amount to move the motor to correct the error is just the negative of the error.

Conclusion

The SXR undulator K value has a hyperbolic cosine dependence on the y-position relative to the midplane. If the beam axis is off the midplane, the K value at the beam location is different than the calibrated value. The HE midplane encoders can be used to check that the undulator midplanes stay on the beam axis so the beam sees the K value given by the calibration.

Acknowledgements