MODELING THE EFFECT OF THE EARTH'S FIELD AND AN IRON PLATE ON THE LCLS UNDULATOR TRAJECTORY*

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Abstract

We investigated the effects of the earth's field and an iron plate which might be used as part of a girder for an undulator at the Linac Coherent Light Source (LCLS). Modeling and calculation were performed using the code RADIA[1]. A model with a large solenoid surrounding a seven-period undulator was used for the simulation. According to the calculations, the vertical component of the earth's field at the undulator axis is enhanced by the undulator poles by a factor of 2.5. The horizontal on-axis component, however, is well shielded by the undulator poles and falls to less than 3% of its original strength. The effect of an iron plate located 200 mm below the undulator axis is negligibly small, so final Hall probe measurements can be done without the girder in place. However, the magnetic tuning of the undulator field must take into account the amplification of the vertical component of the environmental field in the LCLS tunnel.

INTRODUCTION

Trajectory straightness through the undulator is critical for the success of the Linac Coherent Light Source (LCLS) project. Environmental fields, including the earth's field, will affect the trajectory. The earth's field works as an external dipole field and, unless it is shielded or corrected, causes a bend in the electron trajectory through an undulator. The undulator segment tolerance for trajectory excursion in both horizontal and vertical planes is 2 μm [2, 3]. Figure 1 shows three possible electron trajectories within tolerance at an electron beam energy of 13.7 GeV and the undulator parameter, K, of 3.5. The blue curve represents an ideal trajectory without an external dipole field. The yellow and red curves represent those with an external dipole field. The maximum allowed external field is 0.15 gauss if the entrance kick is not corrected If the entrance kick is adjusted so that the net displacement is compensated, the maximum field is 0.7 gauss.

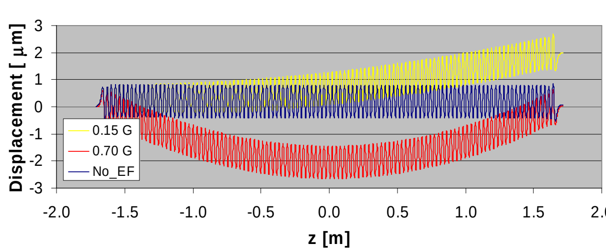

Figure 1: Possible trajectories within the tolerance in an ideal LCLS undulator with/without external dipole field.

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The magnetic measurement and tuning of LCLS undulators will be done in a magnetic measurement facility (MMF) in the Stanford Linear Accelerator Center (SLAC). If the environmental field, including the earth's field, in the LCLS undulator enclosure tunnel is the same as that in the MMF, there should be no problem. However, a slight difference in the environmental field may exist due to, for example, the orientation differences and differences in surrounding equipment, such as quadrupole magnets, vacuum pumps and girders.

In this paper, we present the possible effects of an external dipole field on the performance of an LCLS undulator.

EARTH'S FIELD AND IRON PLATE EFFECTS

In order to simulate the environmental field effect on an undulator, we used a 7-period undulator model, an iron plate, and a large solenoid as shown in Fig. 2.

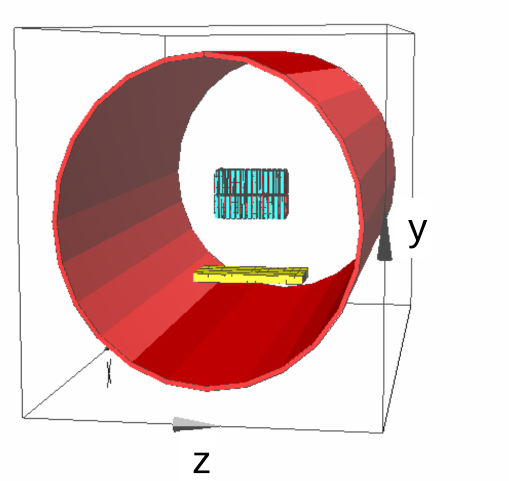

Figure 2: A model for simulating an environmental field effect. Solenoid orientation is set for horizontal field case in this figure.

Field calculations were done for cases both with and without the iron plate, and with the external field oriented horizontally perpendicular to the undulator axis (figure 2 geometry) and oriented vertically. The distance between the iron plate and the undulator axis was assumed to be 200 mm.

Figures 3 and 4 show the horizontal field distributions along the x- (transverse) and z- (longitudinal) axes, respectively. About 0.5 gauss horizontal external field was assumed for the calculation. The undulator gap was assumed to be 6.7 mm. As shown in these figures, the horizontal field is well shielded by the existence of high-

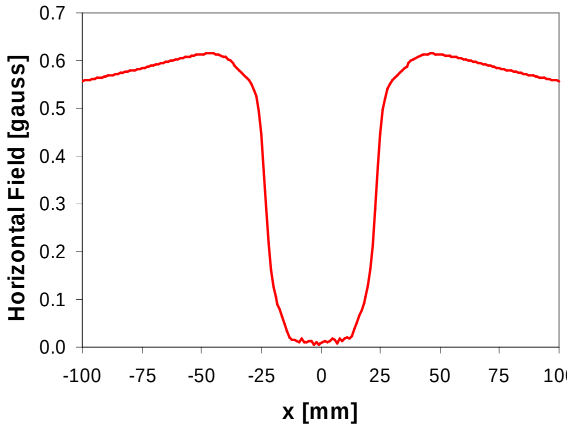

Figure 3: Horizontal (transverse) field distribution along x-axis.

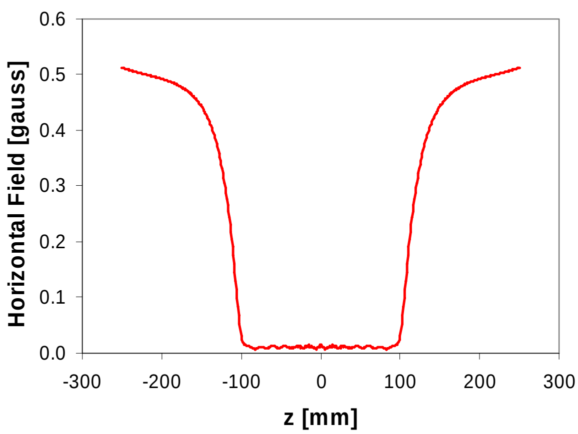

Figure 4: Horizontal (transverse) field distribution along z-axis.

permeability vanadium permendur poles. The effect of the iron plate was not observed in the horizontal field case since the difference was well below the range of error in the RADIA calculation.

Figure 5 shows the vertical field distribution of a 7-period model of the LCLS undulator.

The magnified inset shows the curves at the peak for both with and without a 0.5 gauss vertical external field. The difference between the curves is shown in Figure 6 for the cases with and without the iron plate.

Since high-permeability vanadium permendur poles absorb the magnetic flux, an external 0.5 gauss vertical field results in 1.2621 gauss on average in the undulator gap. In the case with an iron plate, the average increment in the field was 1.2796 gauss. The difference due to the existence of an iron plate was only 0.0174 gauss, which corresponds to a field integral of 6 G-cm for over the whole undulator length. Summarized results for the vertical field effect are listed in Table 1.

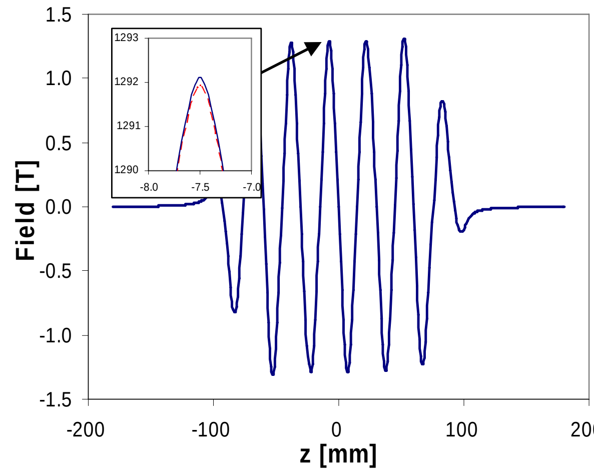

Figure 5: Vertical field variation in a 7-period model undulator. Gap is 6.7 mm. In the inset, the solid curve is for an 0.5 gauss external field and the broken curve is for no external field.

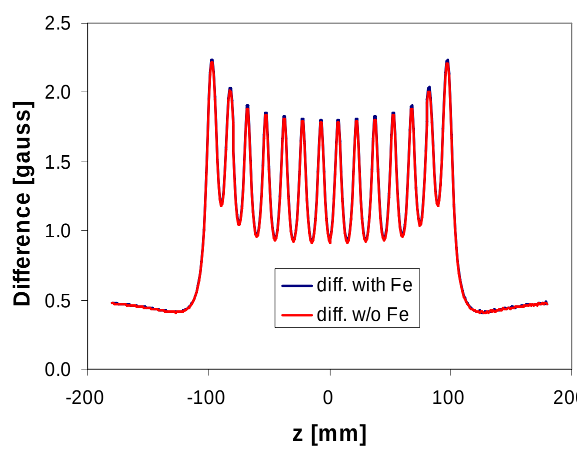

Figure 6: Field differences in the model undulator due to an 0.5 G external vertical field. The red curve represents "without an iron plate," and the blue curve represents "with an iron plate."

Table 1: Calculated results

	Half-period integral [G-cm]	On-axis field increase from 0.5G external vertical field [G]	Enhancement factor of external vertical field
Without iron plate	1.89322	1.26214	2.5243
With iron plate	1.91937	1.27956	2.5592
Difference	0.02615	0.01742	

DISCUSSION

As shown in Fig. 1, the maximum tolerable dipole field in an undulator is 0.7 gauss if the second field integral is compensated at the exit by introducing kicks of the same magnitude but in opposite directions at both ends. Since the enhancement factor for the vertical component of the environmental field is about 2.5, only 0.28 gauss is allowed as an environmental field difference between the MMF and the tunnel. Furthermore, this discussion is valid only if the trajectory is ideally straight after tuning in the MMF. If the trajectory excursion is 1 μm after tuning (this can be achieved, see ref. [3]), the tolerable difference is 0.15 gauss.

From the facts mentioned above, one can recognize the importance of knowing the difference in environmental field between the MMF and the tunnel. Also, it is important to pay special attention to trajectory straightness and second field integral compensation during the tuning.

CONCLUSIONS

In order to effectively tune the LCLS undulator for best performance when installed, the final measurements and tuning of the vertical field integrals must be done in the tunnel. This can be accomplished with a stretched-wire measurement system. The undulator will have been pre-tuned in the measurement facility so the tuning needed in the tunnel will probably be only to introduce two end-field corrections using adjustable screw shims.

The horizontal external field is well shielded, and the field strength is smaller than 0.015 gauss near the undulator axis.

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