Title

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Publication Date

2008

SHIMMING CORRECTION OF DYNAMIC MULTIPOLE EFFECTS ON APPLE-II TYPE EPUs AT THE ALS *

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Abstract

Elliptically Polarizing Undulators [1] that provide full photon polarization control also have fast, intrinsic transverse roll-off of the magnetic field. The roll-off is especially fast for vertical polarization settings, and can have big detrimental effects on the nonlinear single particle dynamics. Particularly low and medium energy light sources and long period EPUs are prone to those effects. The three existing 50 mm period EPUs at the ALS have been retrofitted with shims to correct for these dynamic multipole effects and a new 90 mm period device which otherwise would have caused a huge reduction in dynamic aperture has been shimmed before installation. Beam dynamics measurements on all devices show that the shimming works very well and user operation with the long period EPU has begun.

INTRODUCTION

The Advanced Light Source at Lawrence Berkeley National Laboratory is a 3^{rd} generation synchrotron light sources with a beam energy of 1.9 GeV. As is the case with most soft x-ray photon sources, the trend is to provide variable polarizing undulator sources. The ALS now has four APPLE-II type permanent magnet elliptically polarizing undulators (EPU's) available for users. These include three 50 mm period devices and a recently-installed 90 mm period quasi-periodic device (”MERLIN”).

It is well known that undulators exhibit natural vertical focusing, emanating from a coupling of the transverse velocity and the magnetic field. This ”dynamic” effect is very pronounced in APPLE-II type devices, and in fact varies from focusing to defocusing depending on the polarization mode. Furthermore, the rapid roll-off of the fields results in nonlinear behavior that can have detrimental effects on the beam, resulting in lifetime reduction and/or inefficient injection. The effect is worse for low-energy rings and for long-period and high field devices; the MERLIN device on the ALS is therefore particularly prone to these effects.

To address the issue, magnetic corrections, first proposed at the ESRF [2], have been implemented. A detailed analysis of the impact of EPU dynamic multipoles on the ALS has been conducted in preparation for a conversion to top-off operation mode [3]. The study determined that the introduction of the new quasi-periodic EPU for the ultra-high resolution MERLIN beamline, a 90 mm period device, would have severe consequences for the beam lifetime if left uncorrected, and would have made beam injection with the device closed virtually impossible. Correction using magnetic shims has therefore been studied and implemented at the ALS. Here we begin with a description of the dynamic multipole correction shims. We then provide comparison of calculated and measured shim signatures, verifying that the model faithfully predicts the actual shim magnetization. Finally we present beam-based measurements that validate the design and demonstrate satisfactory characteristics for the ALS move to top-off operation.

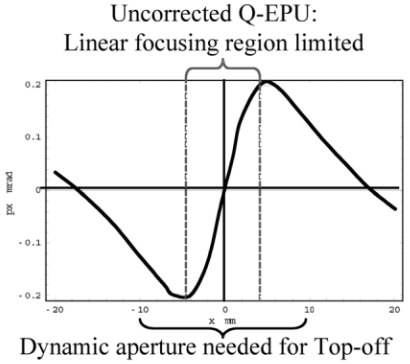

Figure 1: Plot of the angular deflection of the beam provided by the MERLIN quasi-periodic undulator through dynamic effects. Data shown is for vertical polarization mode.

DYNAMIC MULTIPOLE CORRECTOR SHIM DESIGN

The design of the correction shims is based on the premise that the dynamic multipole effect can be compensated through the use of actual (i.e. not dynamic) multipole signatures. The effective multipole effect seen by the beam can be modeled via tracking for all polarization modes. Shims, essentially thin sheets of magnetic steel, are introduced on specific magnetic blocks so as to provide horizontal focus/defocus effects, without affecting the vertical focusing too much. In the vertical polarization mode, in particular, there is a strong nonlinear dynamic multipole effect, as seen in Fig. 1. The size of the shims are optimized to correctly compensate the nonlinearity of the dynamic multipole signature. The analysis is performed using RADIA [5]. Fig. 2 shows an example shim location and associated first-integral profile $I_y(x) = \int B_y(x,z)dz$. Shims are located on negative vertical blocks in quadrants 2 and 3,

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* This work was supported by the Director, Office of Science, U. S. Department of Energy under Contract No. DE-AC02-05CH11231.

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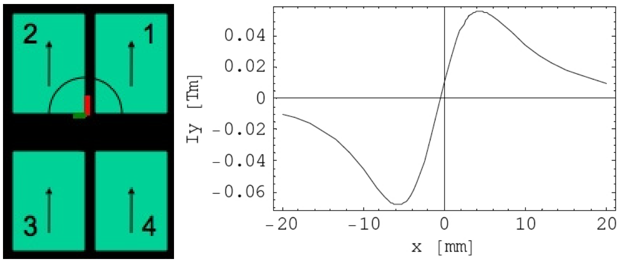

Figure 2: Sketch of the general location of a dynamic tickler (left), and corresponding first integral signature $I_y(x)$. It should be noted that the first integral $I_x(x)$ is non-zero for a single shim; only by correct placement of four shims on the four quadrants can variations in $I_x(x)$ be eliminated on the $y = 0$ axis.

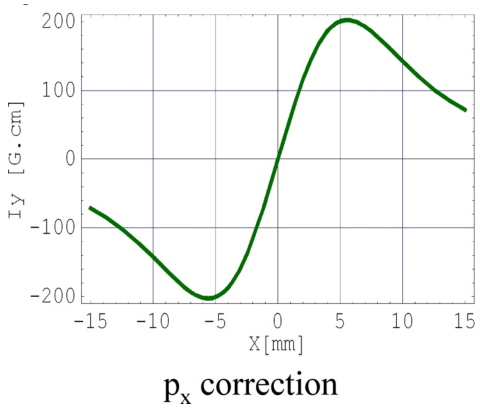

Figure 3: View of the $I_y(x)$ signature of a shim set. The component $I_x(x)$ is identically zero.

Figure 4: View of the magnetic structure of the MERLIN quasi-periodic undulator.

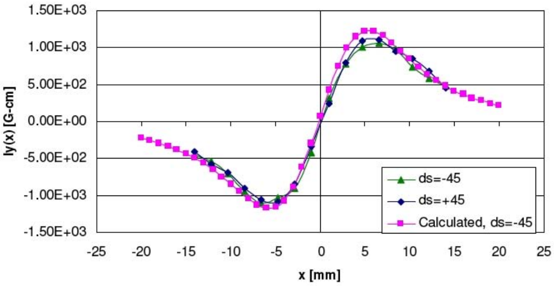

Figure 5: Comparison of measured and calculated first integrals $I_y(x)$. The $ds = \pm 45$ refers to two different quadrant shift settings, both yielding vertical polarization mode.

and positive vertical blocks in quadrants 1 and 4, where the quadrant numbering shown in Fig. 2 are as seen looking at the device from downstream.

A set of shims, composed of one shim on each quadrant, yields a signature with $I_x(x) = 0$ and $I_y(x)$ as shown in Fig. 3. Note that the nonlinearity is located at $x \sim 6$ mm, similar to that of the dynamic effect. To avoid possible contact of shims, neighboring shims (e.g. on quadrants 1 and 2) are positioned 1.5 periods apart. To provide sufficient overall correction, two sets of shims have been applied to the 50 mm period EPUs at the ALS. For the MERLIN 90 mm period device, four sets of shims were used. In both cases the shims were stationed near the ends, motivated by an effort to minimize any possible impact on the photon flux by avoiding significant reduction in the length of the in-phase region within the device. Simulations confirmed that placing the correction at both ends would be sufficient, even though the dynamic multipole effect is distributed all along the device. For the MERLIN device, quasi-periodicity [4] is created by modifying the size of specific vertical blocks in the structure, as seen in Fig. 4. The signatures of the shims during phase shifting is impacted by the different sized blocks; by appropriate placement of the shims on the different quadrants it was possible to maintain the $I_x(x) = 0$ behavior and correctly compensate the dynamic multipole effect.

MAGNETIC MEASUREMENTS OF DYNAMIC TICKLERS

The EPU 50 mm period devices were shimmed after having been installed in the ring, and in fact operating for some time. It was therefore not possible to verify the shim signature profile and amplitude using magnetic measurements. Feedback was provided only from beam measurements. In the case of the MERLIN device, shims were installed prior to installing the device on the ring. Magnetic measurements of $I_y(x)$ were performed before and after shimming; the difference, corresponding to the total value $I_y(x)$ of all of the shim sets, was within 10% of the calculated value, demonstrating reasonable accuracy of the RADIA simulations of the shim magnetization and providing confidence in the reliability of the shim correction model and optimization (see Fig. 5).

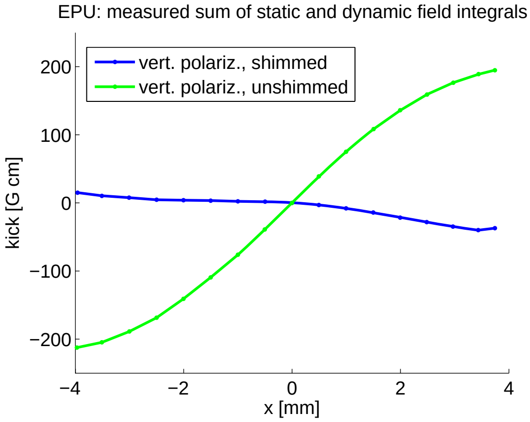

Figure 6: Measured beam kick before and after shimming of an EPU50 device at the ALS.

BEAM-BASED MEASUREMENTS

The dynamic multipole effects can be determined using orbit bumps and measuring the tune-shift. The EPU50 devices were measured before and after shim correction. Fig. 6 shows an example of the improvement obtained by installing the shims. Detailed measurements were also taken for the MERLIN device. Fig. 7 shows the beam-based measurement of the field integral for various polarization modes. The results are in good agreement with the values predicted through RADIA simulations and tracking, and will allow operation of the MERLIN device in most polarization modes. As anticipated from calculations, variable linear modes near 45° will be unallowed, as they may still significantly impact beam lifetime and injection. The scientific program of the beamline does not require those polarization modes. In addition, measurements of the impact of the device on Touschek lifetime (dynamic momentum aperture) and injection efficiency (dynamic aperture) were carried out. The effect on the lifetime was smaller than 5% and the effect on the injection efficiency was below the measurement resolution.

CONCLUSION

Dynamic multipoles associated with the beam trajectory through elliptically polarizing undulators can have a strong and deleterious effect on beam lifetime and injection efficiency. All EPU devices on the ALS now have passive dynamic multipole correction through the use of shims. In particular the MERLIN quasi-periodic device is now fully operational (see Fig. 8). The resulting improvement will allow the ALS to proceed with plans for top-off operation.

ACKNOWLEDGEMENTS

The authors would like to thank the staff at the Advanced Light Source, especially the operations and control system groups for their help in measurements as well as implementation of feed-forward and feedback systems. In addition we are very grateful to O. Choubar, and P. Elleaume, for many helpful discussions as well as a lot of help using RADIA. Finally we would like to also thank J. Chavanne, J. Bahrdt, P. Kuske and B. DiViacco for many helpful hints.

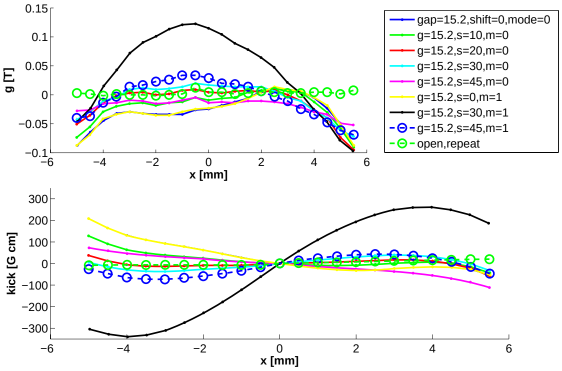

Figure 7: Beam based measurement of the sum of dynamic and static field integrals with tickler correction showing excellent reduction in the nonlinearity for all but one polarization mode.

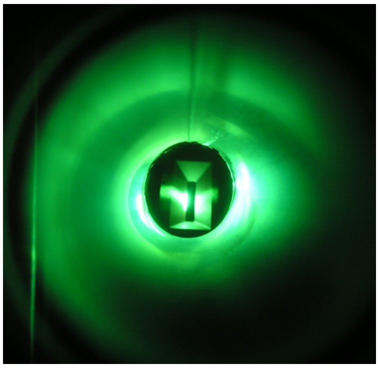

Figure 8: First light in the MERLIN beamline; the beamline is now available for beamlien commissioning.

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