Commissioning of the First Elliptically Polarizing Undulator at the ALS*

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Abstract

A first Elliptically Polarizing Undulator (EPU) has been commissioned at the Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory. This undulator has a period length of 5 cm and is used mainly for magnetic spectroscopy experiments in a photon energy range from about 50 eV up to 1.5 keV. It was designed to provide four polarization modes: circular, elliptical, horizontal and vertical. In addition first tests were carried out to provide linear polarization with arbitrary orientation (between vertical and horizontal). The following sections will focus on measurements of the influence the EPU has on the electron beam (e.g. betatron tunes, chromaticity, coupling, orbit) and which correction methods have been developed to minimize them.

1 INTRODUCTION

The commissioning of the first EPU [1] at the ALS has been successfully completed during the last year. This undulator is a pure permanent magnet device [2] with a period length of 5 cm and a length of 1.85 m and provides full polarization control [3] (see Fig. 1). User operation of the EPU started early this year.

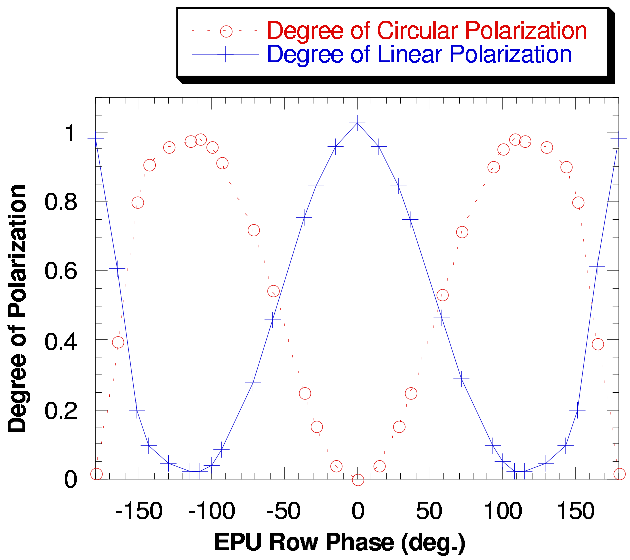

Figure 1: Measured linear and circular polarization of the light emitted from the EPU.

Similar to all the other undulators at the ALS the users have complete freedom to change the gap of the EPU to produce photons of different energies. In addition the users are allowed to shift two opposing halves (one half of the upper and one half of the lower poles) longitudinally for control of the polarization mode (see Fig. 2).

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Table 1: Nominal parameters of the ALS [4] and the EPU.

Parameter	Description	
E	Beam energy	1.5–1.9 GeV
L	Undulator length	1.85 m
$\lambda_{\rm ID}$	Undulator period	5 cm
$d_{\rm min}$	minimum gap	14.9 mm
$d_{\rm y}$	full vacuum aperture	9 mm
β_x	hor. beta function	12 m
β_y	vert. beta function	4 m

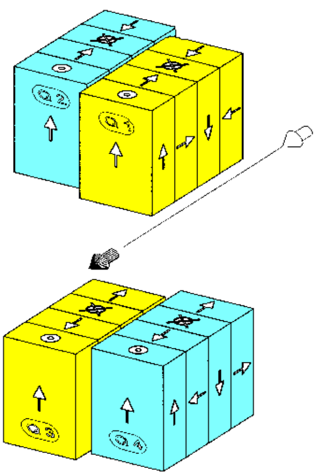

Figure 2: Arrangement of the permanent magnet blocks for the EPU at the ALS.

In order to make optimum use of the limited insertion straight space available at the ALS the EPU occupies only half a straight and is build into a chicane arrangement which separates the beam axes from the two half straights by 2.5 mrad (see Fig. 3). In order to allow a maximum number of independent experiments, polarization switching is performed by mechanically changing the shift parameter of the undulator, in contrast to the concept used at BESSY II, where polarization changes are realized by switching between the light coming from two EPUs at opposite polarization settings. To reduce systematic errors resulting from the polarization switching the EPU at the ALS provides the capability to change the shift parameter fairly fast. The maximum speed is 16.7 mm/s resulting in a change from left to right circular polarization in about 1.6 s.

2 ORBIT DISTORTIONS

Changing the geometry and therefore the field strength and field configuration of the magnetic field of the device

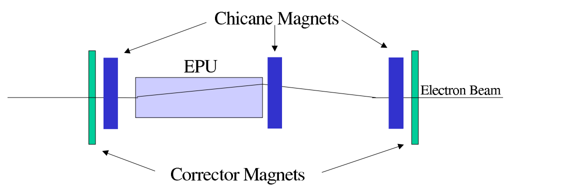

Figure 3: Sketch of the magnet arrangement in the EPU straight.

also changes the (residual) field integrals resulting in uncorrected closed orbit excursions of several hundred μm. Therefore the main focus so far was put on restoring a reasonable orbit stability (like for all other insertion devices). A feed forward algorithm was developed using a two dimensional table (see Fig. 4). As correction elements, two storage ring corrector magnets with very low hysteresis and a bandwidth of about 100 Hz are used (see Fig. 3). The high speed with which the shift parameter can be changed provides many challenges to the feed forward system.

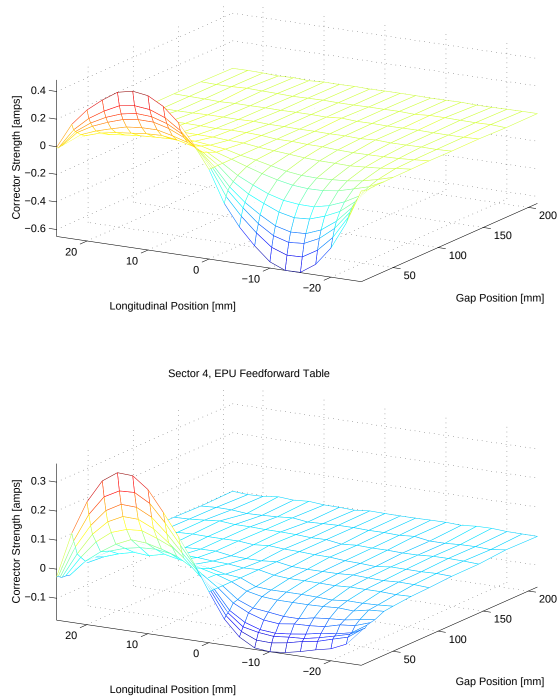

Figure 4: Two dimensional feed forward table used for orbit compensation of the EPU (2 of the 4 correctors used are plotted).

2.1 *Fast, Local Feed Forward System*

A change in polarization direction changes the field integrals of the EPU by about the same amount as changing the gap from fully open to fully closed. Therefore the original orbit feed forward system which is similar to the ones at the other undulators turned out to be too slow. The reason was that the shift parameter is not measured with sufficient bandwidth and that the actual control loop included several network connections and computers.

In order to determine whether the concept of a feed forward system could be preserved or whether a feedback system would be needed, the effect of eddy currents was measured. Fortunately, it turned out to be very small, even at maximum speed. Therefore a new local feed forward system with about 200 Hz bandwidth was designed and has been successfully commissioned (see Fig. 5).

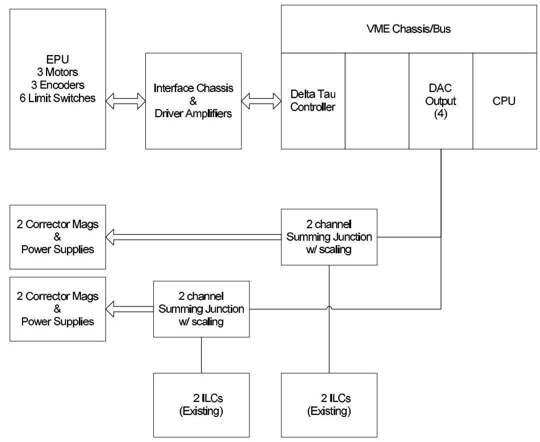

Figure 5: Principle sketch of the new, local feed forward system.

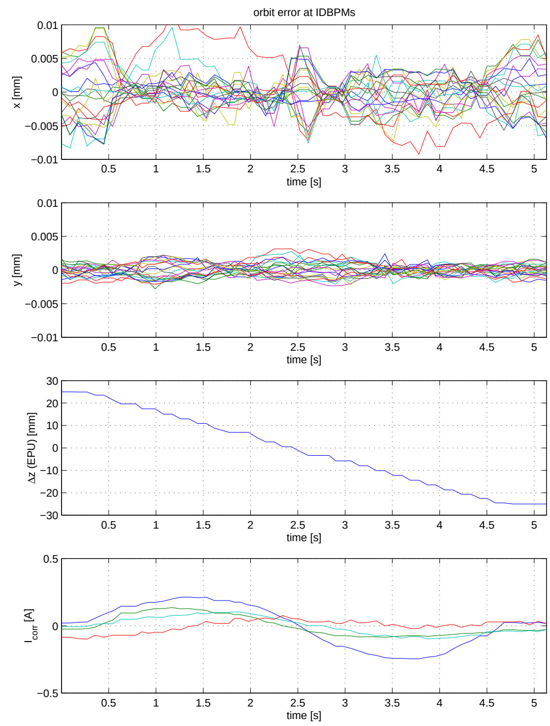

Figure 6: Orbit distortion with the fast, local feed forward system at 1.9 GeV, 14.9 mm gap and a 12 mm/s speed of shift parameter change.

With the new feed forward system the orbit distortion outside the straight of the EPU is now well within the tolerances (see Fig. 6) of one tenth of a beamsize. The peak horizontal orbit distortion in all other insertion device straights is below 10 μm (σ_x is about 200 μm) and the peak vertical distortion is below 3 μm (σ_y is about 30 μm).

2.2 *Improved Chicane Magnet Design*

A second problem for the orbit stability when changing the EPU gap or shift parameter arises from the fact that the chicane magnets show a significant hysteresis. Therefore they are not suited to be used in the feed forward system. Instead two horizontal and two vertical correctors at the beginning of the arcs upstream and downstream from the EPU are used (compare Fig. 3). Because the EPU is located asymmetrically between those correctors, they cannot cancel the orbit distortion within the EPU straight completely. This distortion can be more than 20 μm in the vertical plane. Measurements showed that for the experiments conducted at the moment, the impact is negligible. To solve the problem the design of new chicane magnets has been started. On a shorter time scale a solution has been tested to use four instead of two correctors in each plane.

3 TUNES, BEAMSIZE

In addition to the effects on the orbit all undulators also influence the betatron tunes, chromaticity and emittance coupling. In the last year this has been studied more extensively and some immediate remedies have been implemented. Recently a tune feed forward system has been commissioned, reducing the effect on the beam size for all undulators besides the EPU to values below the resolution of our synchrotron light monitor (about 1% relative vertical beamsize change).

Again, for several reasons the effects of the EPU are the most serious ones. The first reason is that the shift parameter is frequently changed to change the polarization. This causes a distortion in the field integrals of about the same size as changing another undulator from fully open to fully closed. In addition the horizontal beta function in the insertion device straights is about 3 times as large as the vertical one. Therefore the horizontal tune shift from the EPU due to a change in shift parameter is very significant (see Fig. 7). Finally the possible speed of shift parameter changes is fairly high, making slow corrections using the normal lattice quadrupoles very difficult.

To passively cure the problem several other ideas have been tested on the ALS. The most promising one is a lattice with lower vertical beta function. In first tests this lattice provided a lifetime comparable or better than the nominal lattice without requiring any increased coupling. First tests were carried out and showed that a change of the EPU shift parameter in that case did not change the beam size at all.

Independent of the efforts to make the operation of the EPU more transparent to the electron beam a new operation mode has been tested. In this mode the two moveable halves are shifted anti-parallel instead of parallel. This provides linear polarization of arbitrary orientation (in contrast to the fixed horizontal and vertical linear, elliptical and circular polarization one gets in the normal mode). The compensation of the influence on the beam turned out to create no additional problems and the new mode is now also available to users of the EPU.

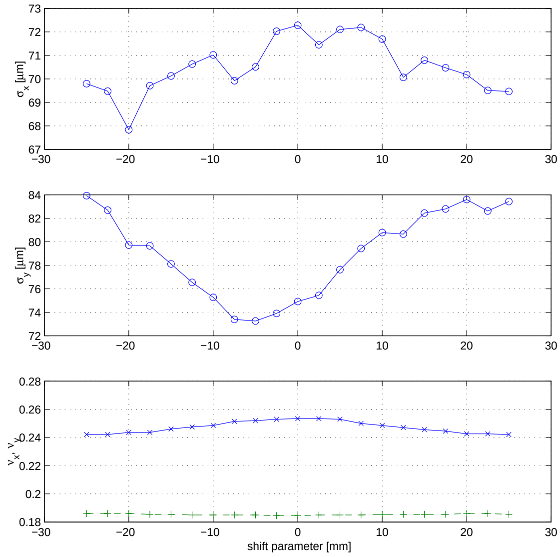

Figure 7: Change in tune and beam size due to longitudinal EPU motion (1.9 GeV, 14.9 mm gap, 3% coupling).

4 SUMMARY

At the ALS a first Elliptically Polarizing Undulator has been successfully commissioned, providing synchrotron light in the energy range between about 50 eV and 1.5 keV with full polarization control to a high resolution spectroscopy beamline. In order to correct for orbit distortions arising when the polarization direction is changed (in about 1.6 s) a two dimensional, fast, local feed forward system has been developed and is now succefully used in user operation, reducing the (peak) orbit excursions below one tenth of the one sigma beamsize. Additional efforts are under way to reduce the influence on the tune in order to achieve a better stability of the vertical beamsize.

5 ACKNOWLEDGEMENTS

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