

SIMULATION OF A LONG-PERIOD EPU OPERATING IN UNIVERSAL MODE AT THE CANADIAN LIGHT SOURCE

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Abstract

The Canadian Light Source (CLS) is implementing an elliptically polarizing undulator (EPU) with period 180 mm for the production of soft x-rays with variable polarization. Two issues arise from implementing such a device. First, a long-period EPU can cause significant loss of dynamic aperture due to strong dynamic focusing. Second, to compensate for polarization effects due to beamline optics, the EPU must be able to produce light with an arbitrary polarization at the source point, which is referred to as universal mode. We present a scheme for operating the EPU in universal mode and discuss the use of BESSY-style current strips in order to compensate for dynamic effects. Tracking simulations suggest that dynamic aperture can be sufficiently recovered for all required operating points in universal mode.

INTRODUCTION

The Quantum Materials Spectroscopy Center (QMSC) beamline requires photons with energy as low as 15 eV. To obtain these photons from a 2.9 GeV electron beam, the beamline will make use of an EPU with period 180 mm, which we refer to as EPU180. EPU180 has a girder length of 3834 mm.

For beamlines operating at photon energies below 100 eV, the beamline optics can cause a significant alteration to the polarization of the photon beam. These effects can be compensated by using the EPU to adjust the polarization of the photons at the source point [1–3]. We must mix the elliptical and linear incline modes of the EPU in order to produce photons with an arbitrary polarization. We refer to this mode of operation as universal mode [1, 4].

UNIVERSAL MODE

The girder labeling convention used at CLS is shown in Figure 1. We define the elliptical, positive linear incline

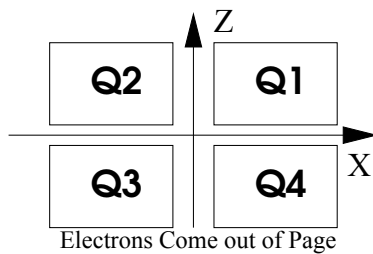


Figure 1: Girder labeling convention.

respectively. We use the three phases to define the positions of the four girders,

$$Q_1 = \frac{1}{2}\phi_E + \phi_L^+ \quad (1)$$

$$Q_2 = -\frac{1}{2}\phi_E + \phi_L^- \quad (2)$$

$$Q_3 = \frac{1}{2}\phi_E - \phi_L^+ \quad (3)$$

$$Q_4 = -\frac{1}{2}\phi_E - \phi_L^- \quad (4)$$

We also define the composite linear incline phase, ϕ_L^c , such that

$$\left. \begin{aligned} \phi_L^+ &= |\phi_L^c| \\ \phi_L^- &= 0 \end{aligned} \right\} \text{if } 0 < \phi_L^c \quad (5)$$

$$\left. \begin{aligned} \phi_L^+ &= 0 \\ \phi_L^- &= |\phi_L^c| \end{aligned} \right\} \text{if } \phi_L^c < 0. \quad (6)$$

These definitions ensure that we will produce photons with a polarization ellipse that has positive inclination for $0 < \phi_L^c$ and negative inclination for $\phi_L^c < 0$. EPUs typically operate with either $\phi_E = 0$ or $\phi_L^c = 0$. When operating in universal mode, we allow ϕ_E and ϕ_L^c to be adjusted simultaneously.

In order to understand universal mode, we model the polarization of photons as an ellipse with inclination and eccentricity. The eccentricity of an ellipse is given by

$$e = \sqrt{1 - \left(\frac{\text{minor axis}}{\text{major axis}}\right)^2} \quad (7)$$

and is a measure of how circular the light is. A circle has eccentricity 0 whereas a straight line has eccentricity 1.

In Figure 2 we plot the eccentricity of the polarization ellipse and in Figure 3 we plot the inclination. We plot these parameters for the EPU operating at a fixed gap of 15 mm. In Figures 2 and 3 we vary the elliptical phase from $0 \leq \phi_E \leq \frac{\lambda}{2}$ and the composite linear incline phase from $0 \leq \phi_L^c \leq \frac{\lambda}{4}$ where $\lambda = 180$ mm is the period of the EPU. This range ensures that no girder moves more than $\pm \frac{\lambda}{2}$, which is their physical limit.

If we use negative values of ϕ_E we get a symmetric plot, but the helicity (i.e. handedness) of the photons will be the opposite. If we use a negative value of ϕ_L^c we will also get a symmetric plot, but the inclination will be negative. We see that we can access any polarization we wish in universal mode. One important piece of information that we have not plotted is the photon energy, which varies considerably with ϕ_E and ϕ_L^c .

and negative linear incline phases to be ϕ_E , ϕ_L^+ and ϕ_L^-

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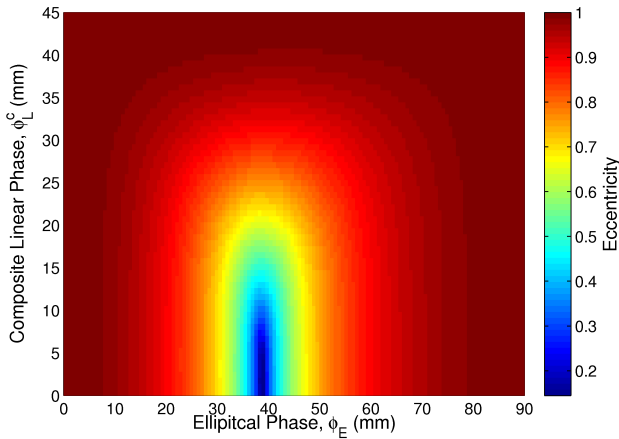


Figure 2: Eccentricity of polarization ellipse for gap 15 mm. Dark blue areas have circular polarization whereas dark red areas have linear polarization.

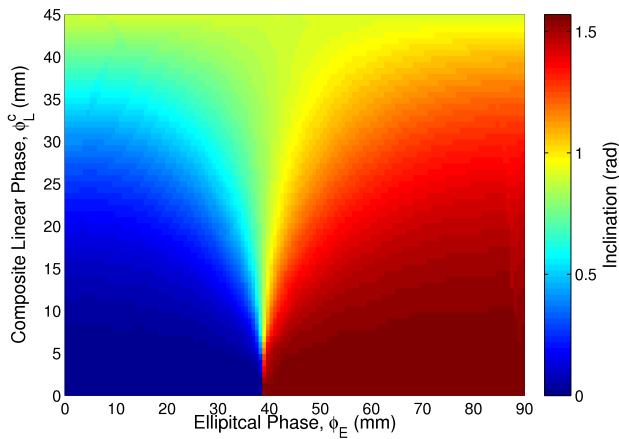


Figure 3: Inclination of polarization ellipse for gap 15 mm. Dark blue areas have horizontal polarization whereas dark red areas have vertical polarization.

BEAM DYNAMICS

A long-period EPU has a significant effect on the electron beam due to dynamic focusing. Dynamic focusing is caused by the transverse motion of electrons through the EPU. It is intrinsic to the design of the device and cannot be removed through the shimming process. We model this effect using the kickmap technique [5]. In Figure 4 we plot the horizontal kickmaps on the $z = 0$ midplane.

Uncompensated, EPU180 will cause large tune shifts and a significant reduction of dynamic aperture. The results of a dynamic aperture scan are shown in Figure 5. This scan was done using the charged particle tracking code elegant [6]. We calculate the dynamic aperture for off-momentum ($\frac{\Delta E}{E} = 0.01$) electrons with an rf cavity and energy loss and damping due to synchrotron radiation. We see a significant loss of dynamic aperture when one moves away from the horizontal polarization at $\phi_E = \phi_L^c = 0$. The on-momentum plot is similar.

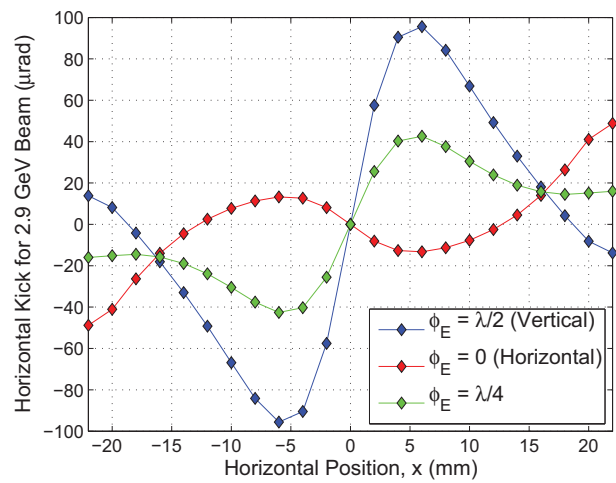


Figure 4: Example horizontal kickmaps on the $z = 0$ mid-plane for EPU180 at a 15 mm gap with $\phi_L^c = 0$ and varying ϕ_E .

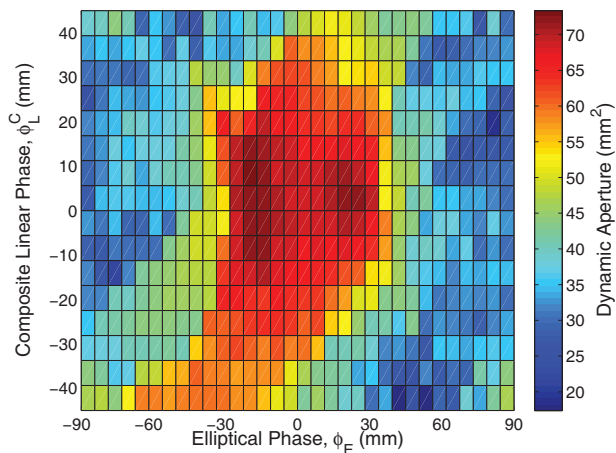


Figure 5: Off-momentum ($\frac{\Delta E}{E} = 0.01$) dynamic aperture with EPU180 operating uncompensated in universal mode. The bare lattice dynamic aperture is 73.4 mm^2 .

In order to recover the dynamic aperture, we use current strips such as those developed at BESSY-II [7] and also used at Diamond [8]. This method uses wires fixed to the vacuum chamber in order to generate integrated multipoles that can cancel the kickmap on the $z = 0$ midplane. The layout of the current strips used in the simulations is shown in Figure 6. This layout is based on the BESSY-II design and the final layout will be similar, but not exactly the same.

Because the kickmap and the integrated multipoles come from different terms in the equations of motion, we cannot exactly cancel the kickmap. Rather, we cancel the kickmap only on the $z = 0$ midplane and we see from Figure 7 that we recover a large amount of the dynamic aperture. We also cancel the horizontal tune shift, but there will be some residual vertical tune shift.

We expect maximum currents of about 14 A, which will occur near the vertical polarizations. Because of the sym-

