STUDY OF NONLINEAR BEAM DYNAMICS EFFECTS FOR DEPU AT SSRF

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Abstract

A pair of EPUs (DEPU) with the period 58mm and 148mm, covering the energy ranges from 20 to 200eV and 200 to 2000eV of arbitrary polarized light, will be developed for the SSRF soft X-ray beam line for ARPES and PEEM. The effects of DEPU to tune-shift produced by the nonlinear beam dynamics are studied and the results are presented in this paper. The corresponding magnet field shimming technology to reduce these effects is also investigated.

INTRODUCTION

With the developments of light source technology, Elliptically Polarizing Undulator (EPU) have become more and more popular, because it can provide full polarization control of the photon beam. A soft X-ray beam line for ARPES and PEEM is being built in Shanghai Synchrotron Radiation Facility (SSRF) which is an intermediate energy (3.5 GeV) light source [1] [2]. The radiation source of this beam line is a pair of EPUs including EPU148 and EPU58 to expand the photon energy range and reduce the heat load to optics instrument simultaneously [2]. The main parameters for Double EPUs are listed in Table 1. Both of two EPU's girders are connected with the same support frame which can be moved transversely so that the user can choose each undulator according to the experimental requirement [2]. The complete layout of DEPU is shown in Fig.1.

Table 1: Main Parameters of DEPU

	EPU148	EPU58
Period Length	**148 mm**	**58 mm**
Number of Periods	**32**	**84**
Magnetic Structure	**PPM APPLE-II**	**PPM APPLE-II**
Max. K for Linearly Polarized Light	**8.75**	**4.25**
Max. K for Circularly Polarized Light	**6.19**	**2.38**
Length of Magnet Arrays	**~4.9 m**	**~5.0 m**
Photon Energy with Linear Polarization	**20- 200 eV**	**200-2000 eV**
Photon Energy with Circular Polarization	**20- 300 eV**	**300-2000 eV**

EPU with APPLE-II type magnetic structure will produce field having very fast, intrinsic, transverse roll-off, which will create nonlinear dynamics effects to electron beam, especially for the vertical polarization mode [3]. The effects of DEPU to tune shift produced by nonlinear dynamics for different polarization mode have been studied with Kick Map [4] [5] approach and the results are presented in this paper. To decrease the tune shift variation with different polarization mode, L-shimming technology is planed to apply to DEPU and the optimized design result is also presented in this paper.

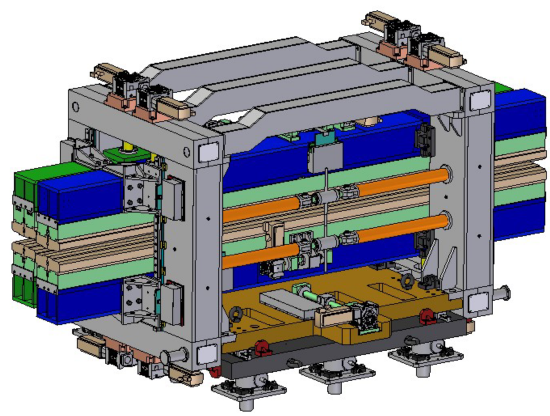

Figure 1: The 3D view of DEPU which share a common support system.

NONLINEAR BEAM DYNAMICS

When undulator gap is closed, three classes of perturbations to the beam are produced: closed orbit distortion (cod), tune shift, reduction of the dynamic aperture resulting in shorter lifetime and injection problems [5]. The cod is induced by the field and positioning errors of the magnets generally measured via the first and second integrated field by the flipping coil. A proper shimming and a suitable design of the extremities can ensure a negligible cod. In fact, the undulator fields have focusing / defocusing effects on passing electrons produced from variations in field strength as seen by a periodically wiggling electron instead of straight line moving electron [6]. An approach called kick map is proposed to study the nonlinear beam dynamics effects in undulator.

From the filed calculated results, it can be seen that DEPU have fast transverse roll-off of their magnetic fields, particularly in vertical polarization mode. In the absence of field errors, the intrinsic horizontal (vertical) angular kick experienced by an electron in DEPU can be derived from the following equation [5]:

$$\frac{d\theta_{x,y}}{dz} \cong -0.57\times10^{-3}\left(\frac{\lambda_0}{E}\right)\frac{\partial(B_x^2+B_y^2)}{\partial x,y}$$

Where E is the electron energy in GeV, λ_0 is the period in meter, Bx (By) is the horizontal (vertical) peak field in T and x (y) is the transverse coordinate while z is the longitudinal coordinate along the undulator axis. The

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calculated variation of horizontal angular deflection with the electron horizontal offset for DEPU are shown in Figs. 2 and 3.

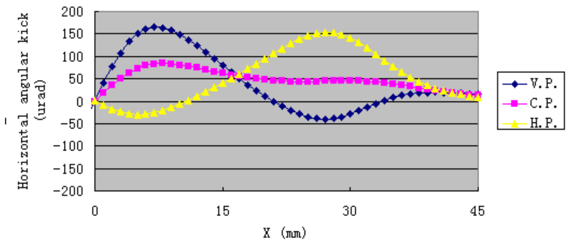

Figure 2: Horizontal angular deflection as a function of the horizontal position in the mid-plane of EPU148.

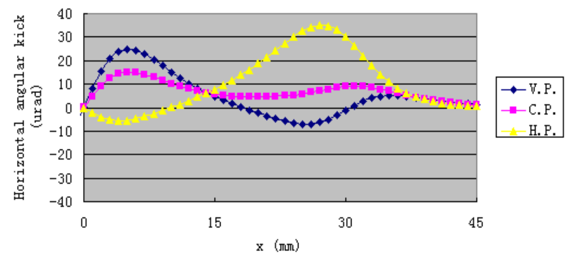

Figure 3: Horizontal angular deflection as a function of the horizontal position in the mid-plane of EPU58.

The focusing effect and tune shift are derived by further derivating transverse angular kick with respect to transverse coordinates x and y. The horizontal and vertical tune shift variations with the horizontal position for DEPU are shown in Fig.4-7 respectively. The tune shift is proportional to the gradient of transverse angular kick with respect to transverse position. From the calculated results, it can be seen that the tune shift along beam central line (x=0) in V.P. mode is larger than the other polarization mode for the higher gradient of angular kick as can be seen from Fig.2 and Fig.3, and it also can be seen that the tune shift in EPU148 is larger than in EPU58 for the longer period, as is consistent with the general conclusion that the nonlinear effects get stronger with longer periods and higher undulator magnetic fields.

The horizontal/vertical tune shifts along beam central line induced in EPU148 range from 0.0076/0.0012 in horizontal polarization, to -0.0147/0.0133 in circular polarization, to -0.0318/0.0231 in vertical polarization modes and the horizontal/vertical tune shifts induced in EPU58 range from 0.0018/0.0044 in horizontal polarization, to -0.004/0.006 in circular polarization, to -0.0068/0.0068 in vertical polarization modes. The large tune shift range should be shortened via field shimming to ensure the electron beam stability while undulator operating in different polarization mode.

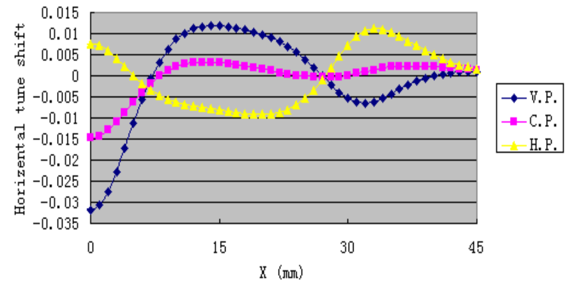

Figure 4: The horizontal tune shift as a function of the horizontal position in the mid-plane of EPU148.

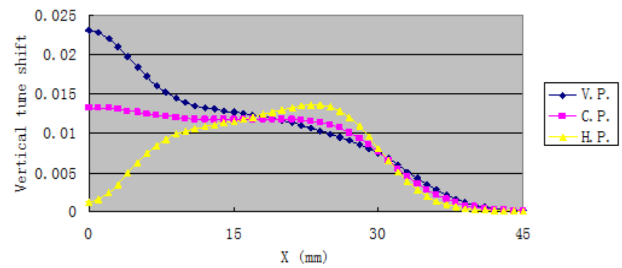

Figure 5: The vertical tune shift as a function of the horizontal position in the mid-plane of EPU148.

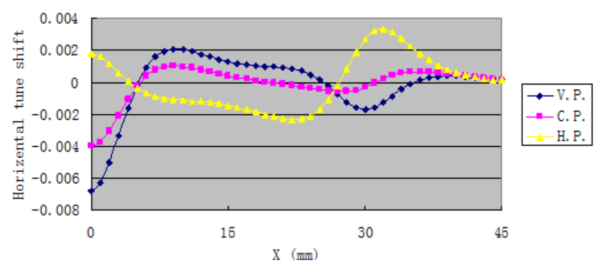

Figure 6: The horizontal tune shift as a function of the horizontal position in the mid-plane of EPU58.

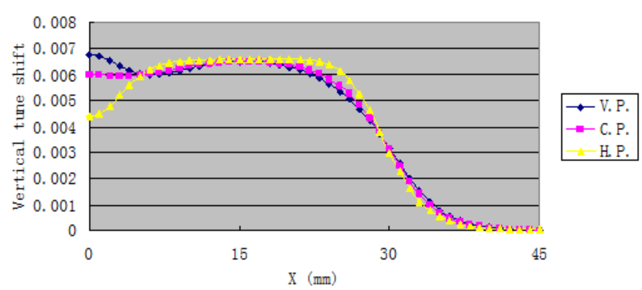

Figure 7: The vertical tune shift as a function of the horizontal position in the mid-plane of EPU58.

DESIGN OF CORRECTION SHIM

L-shimming method, creating a phase dependent quadrupole inside undulator in order to (partially) cancel the intrinsic undulator focusing, is originally proposed at ESRF [5] and has been successfully applied in several laboratory [3] [5].

The shimming steel size, number and distribution among the four magnet array in DEPU are optimized by detailed RADIA models. The shims in EPU148 are small pieces of magnetic steel, 5mm wide, 200 micrometers thick, extending the length of two blocks, and located on the beam-side face and inner wall of certain blocks.

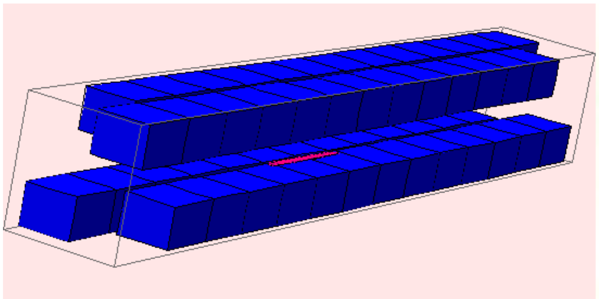

Figure 8: Shim geometry for EPU148 tune shift.

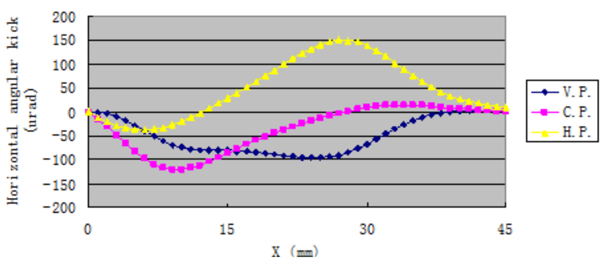

Figure 9: Horizontal angular deflection as a function of the horizontal position in the mid-plane of EPU148 after shimming.

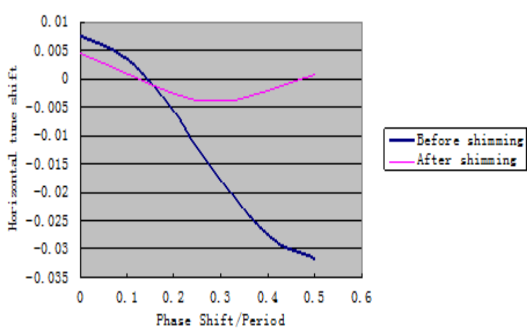

Figure 10: Horizontal tune shift in EPU148 before and after shimming.

The shim geometry is shown in Fig.8 and optimally designed based on the criteria of reducing the gradient of angular kick on axis. The horizontal angular kick in EPU148 after shimming is shown in Fig.9 and it can be seen that the gradient of angular kick is reduced greatly. The comparison of horizontal tune shift in EPU148 before and after shimming is shown in Fig.10 and it can be seen that the range of tune shift is decreased from 0.0394 to 0.0084. The optimization was done rather quickly and it is believed that a deeper study of the question could result in an improved correction.

CONCLUSION

The DEPU nonlinear dynamics effects to electron beam are studied through kick map method. The transverse tune shifts on axis are larger in vertical polarization mode than the other polarization mode for the severer field roll-off. The horizontal / vertical on axis tune shifts in EPU148 are larger than in EPU58 for the longer period. A tune shift effects range of approximate 0.04 is produced with different polarization mode in DEPU. The L-shimming steels have been optimally designed to reduce the tune shift range for all polarization modes.

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