COMPENSATIONS OF DEPU EFFECTS AT THE SSRF STORAGE RING

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Abstract

A pair of Apple-II type EPU (DEPU) is installed in the SSRF storage ring. They introduce closed orbit distortion, tune shift, coupling, reduction of the dynamic aperture and so on. The distortions and the compensations of these effects are described in this paper. Feedforward tables of corrector coils, quadrupole and skew quadrupoles are used to correct the COD, tune shifts and coupling, respectively. Sextupole optimization is used to correct the dynamic aperture.

INTRODUCTION

Shanghai Synchrotron Radiation Facility (SSRF) [1] is a dedicated third generation synchrotron light source with nominal energy of 3.5 GeV. A beam line (named 'Dream Line') of Angle Resolved Photoemission Spectroscopy (APRES) and Photoemission Electron Microscope (PEEM) has been built and installed at SSRF [2]. In order to get very wide photon energy and reduce the heat load to optics instrument simultaneously, two Apple-II type EPUs (DEPU) are used. The lower energy photon from 20 to 200eV is produced by U58 whose period is 58mm and minimal gap is 17mm. The higher energy photon from 200 to 2000eV is produced by U148 whose period is 148mm and minimal gap is 22mm.

EPU is widely used in the synchrotron radiation sources. The effects and compensations are well studied in many labs over the world [3]. There are many effects are introduced by the EPU [4][5]: closed orbit distortion, tune shift, reduction of the dynamic aperture, coupling. The effects and compensation on the real machine are described in this paper.

CLOSED ORBIT DISTORTION

The COD results from the nonzero 1st order integral fields (dipole errors) [5]. The dipole errors vary with the gaps and block position. The integral field of U148 and U58 both are about 200Gs-cm. The peak-to-peak values of the orbit distortion between the gap of 160mm and 22mm are 150um and 80um in horizontal and vertical plane. The large distortion affect the photon position and thus flux not only the dream line but also other beam lines. The integral fields also changes when the frame and shifts changed. Figure 1 shows the orbit positions vary with the shift position. The standard deviation of orbit distortion (COD) varies from 0 um to 25 um in horizontal and vertical plane. The maximum of orbit distortion introduced by frame position is about 200um at the edge of U148. Figure 2 shows the orbit distortion before and after correction when the gap of U58 varies, it rises rapidly when the gap is less than 60mm, the maximum

value is 60 and 120um in horizontal and vertical plane. It seems to be in reverse to the square of the gap and consistent with theoretical calculation.
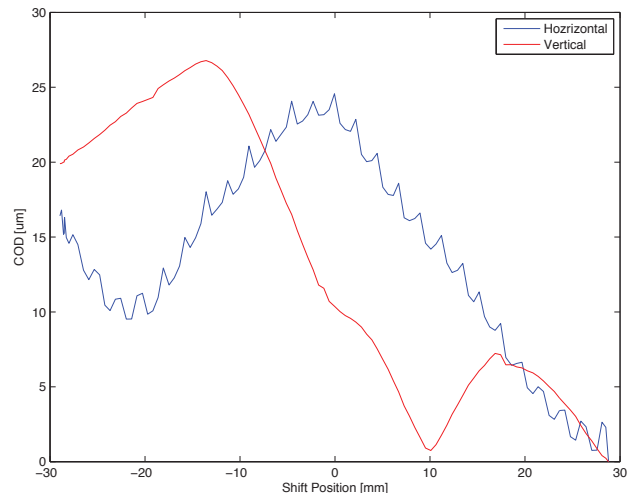

Figure 1: COD varies with the shift position.

There are 2 correction coils in each plane at the entrance exit of DEPU. In order to increase the tuning speed, one select analogy power supply. Scanning the correctors' strength with different gaps and shifts makes a feed forward table. Controller varies the power supply settings when it detects the gap change. This work takes lots of time to get the table data and tests at more and more gaps and shifts are still needed.
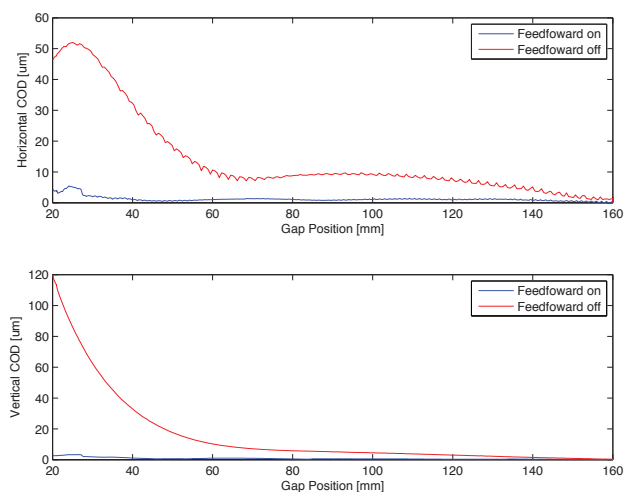

Figure 2: The CODs in both planes before and after correction during gap variation.

The feedforward reduces the COD to 5um. But it's still larger than the requirement of beam position stability. Slow and fast orbit feedbacks are needed during the daily operation to correction these distortions.

TUNE SHIFT

The EPU also affects the twiss parameters, such as the tune shift. It rises from [5]: 1) transvers motion in the insertion device introduced focus effect; 2) roll-off of the magnet field [2]; 3) residence quadrupole components. 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 [6]. The tune shifts produced by nonlinear dynamics for different polarization mode have been studied with Kick Map [4] and the L-shimming is used for compensation of the U148 at SSRF [7][8]. The comparison of horizontal tune shift in EPU148 before and after shimming is decreased from 0.0394 to 0.0084. The measured tune shift when the U148 gap and shift variation is less than 0.001 in each plane. It shows very good compensation by L-shimming.

Comparing to U148, U58 affects the tune shift much larger. The integral 2nd order field is 9900Gs-cm, and the corresponding tune shift is -0.0087 and 0.0151 in each plane. Figure3 shows the measurement tune when U58 gap varies. The maximum tune shift is -0.006 and 0.012 in each plane. It is very close to the values caused by residence quadrupole components. That means it is the most important error source .The Kick Map analysis in [7] also shows the roll-off affects the tune shift less than 0.003. The measurement result supports this calculation. The tune shifts are also in reverse to the square of the gap. The tunes keep almost constant when the shift of U58 changes.
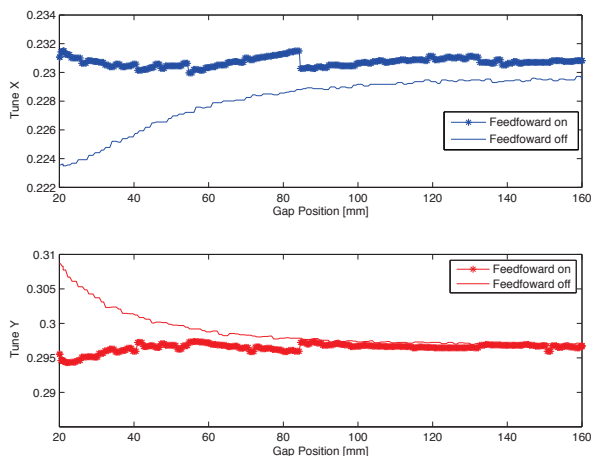

Figure 3: The measurement tune when U58 gap varies.

The quadrupoles and LOCO are used to correct the tune shifts. In order to reconstruction the periodicity and beta function, not only the tune, several correction schemes are tested. Global correction using all the quadrupoles in the ring, 2,4,6 and 10 quadrupoles before and after the straight section are selected to fit the measured response matrix at the smallest gap, respectively. The fit result stands for the quadrupole strength of U58, the changes are set to the machine to counteract the distortion. Tune, beta function and injection efficiency are measured to compare the correction effect. Though the tune shift and beta beating

of global correction is best, but if more insertion devices are installed in the ring, global correction will cause confliction when several gaps are changed at the same time. Finally, 10 quadrupoles (5 before and 5 after the straight section) are selected. After the correction scheme is decided, orbit response matrixes at different gaps are measured. According to the measured tune shift, more data are taken when the gap is small. By fitting all of the matrixes, one gets the feedforward table. Figure 4 shows the quadrupoles power supply settings at different gaps. The mainly changes are on Q3 and Q4. The strength of one family keeps almost the same, it means the periodicity of the ring is good.
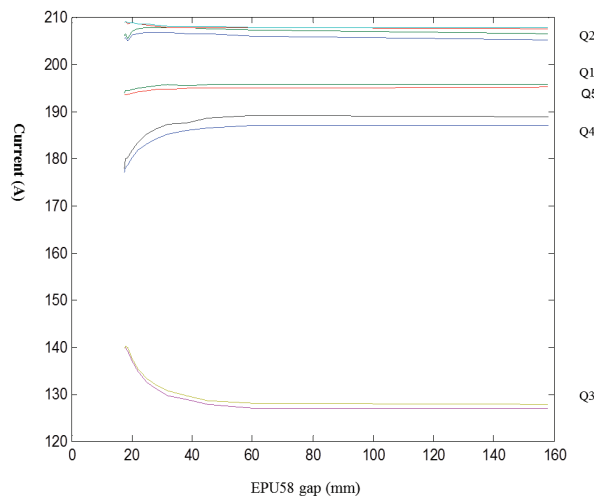

Figure 4: Quadrupoles settings for tune shift feedforward.

DYNAMIC APERTURE

The reduction of dynamic aperture is reserved by injection efficiency. Broken of lattice periodicity, change of the focusing versus injection point, multipole errors and transverse roll-off affect the dynamic aperture [9].
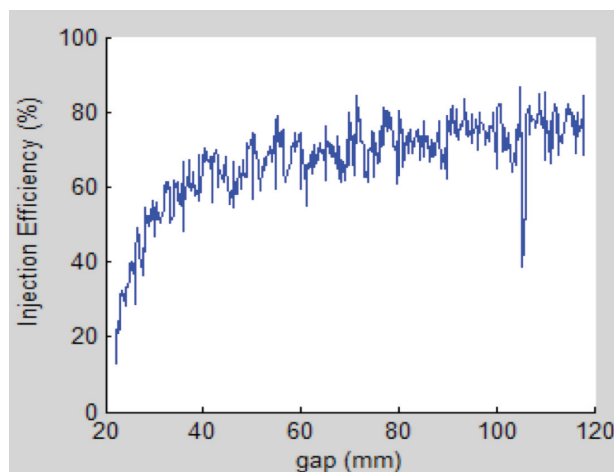

Figure 5: injection efficiency when the gap changes.

Figure 5 shows the injection efficiency when the U58 gap changes. The minimum value is even below to 20% at the small gap. The shift changes don't affect it very much. For a top-up operation, such high beam lost is not

allowed. The reconstruction of beta function and tune shift in last section didn't make any improvement.

Fortunately, one can use the sextupoles for the dynamic aperture optimization. There are 6 families of harmonic sextupole and 2 families of chromaticity sextupole in the SSRF storage ring. An online Multi-objective Genetic Algorithm (MOGA) code is used to find the solutions. The MOGA is used in the nonlinear optimization and lattice design in the SSRF [10]. The main processes is: (1) Initialize population by randomly setting the harmonic sextrupole strengths and correct the chromaticity; (2) Select the elite solutions as parents by the multi-objective function; (3) Create the next generation by randomly and fine adjusting sextrupole strengths of the parents, i.e. gene mutation; (4) Evaluate the multi-objective function of the new generation to be close to the objects; (5) Repeat the selection amongst the children and parents keeping the elitist from generation to generation, mutation until the objects are reached. The only goal of online MOGA is the injection efficiency. After several populations, it can be increased to around 80% at a gap of 22 mm. The injection efficiency increases to more than 95% when the gap changes to 100mm and above. This means the main source of dynamic aperture reduction is multipole errors. But the injection efficiency is very sensitive to the sextupole at gaps below 20mm. Cycling of the sextupole to cancel the hysteresis effect after optimization will cause the injection efficiency drops to 40% from 80%. So the minimum gap of U58 is set to 22mm.

The U148 don't affect the dynamic aperture when the L-shimming works well. Figure 6 shows the injection efficiency while shift changing when the L-shimming is at wrong place. The reduction at small gap and large shift is very clear.
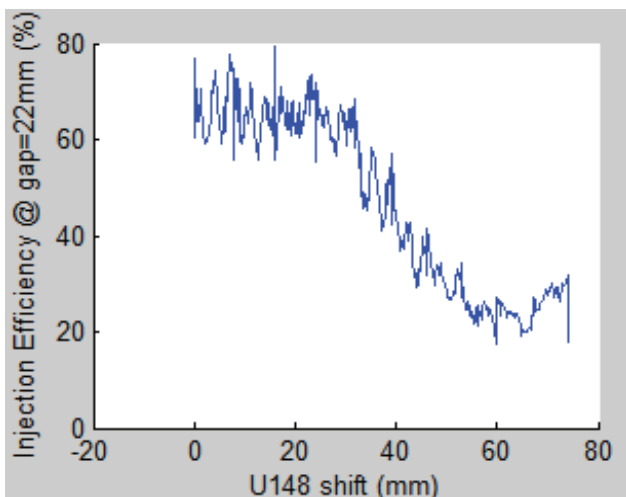

Figure 6: Injection efficiency while shift changing.

COUPLING

If the gap or shift varies, the skew quadrupole strength introduced by EPU changes. The skew quadrupole and caused vertical dispersion lead to coupling change. Figure 7 shows the coupling varies when U58 gap changes. The maximum coupling arises to 0.8% at gap around 40mm. It

drops when gap moves up or down. The coupling changes slightly when the shift varies. The change of gap and shift of U148 don't affect the coupling very much.
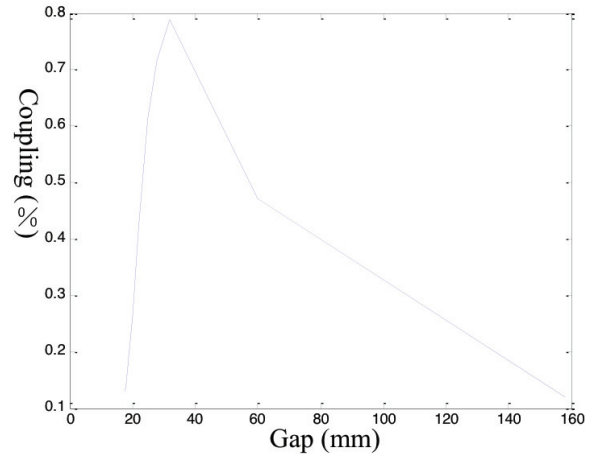

Figure 7: the coupling varies when gap changes.

LOCO is also used for the coupling feedforward table. 3 skew quadrupoles before the EPU and 3 skew quadrupoles after the EPU are included for the fitting. The changes of fitted skew quadrupole strength between any gaps and the gap at 160mm stand for the introduced errors. The data points are more intense when the coupling changes rapidly. Figure 8 shows the correction skew quadrupole strength. After correction, the coupling and beam profile at x-ray pinhole keep almost constant when the gap changes.
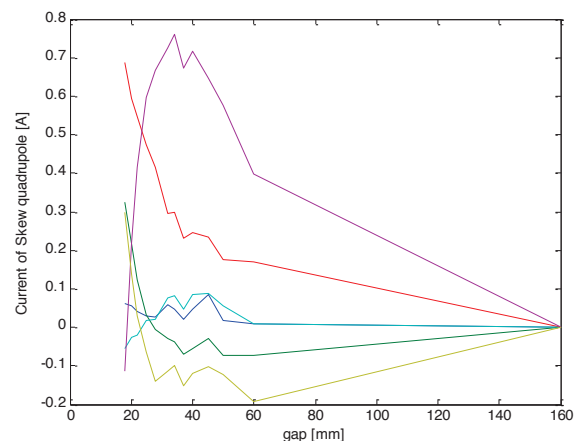

Figure 8: Skew quadrupole settings for coupling correction.

CONCLUSION

The effects of the DEPU are analyzed, measured and compensated in this paper. DEPU introduces closed orbit distortion, tune shift, coupling and dynamic aperture reduction. Feedforward tables of correctors, quadrupoles and skew quadrupoles are used to the COD, tune shift and coupling, respectively. Sextupole optimization is used to correct the dynamic aperture. The compensation shows good performance and works in the routine operation.

5: Beam Dynamics and EM Fields

D01 - Beam Optics - Lattices, Correction Schemes, Transport

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