CANCELLATION OF THE UNDULATOR GAP-DEPENDENT ORBIT AND TUNE SHIFTS AT NEWSUBARU

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Abstract

We report our experience on the automatic cancellation of the undulator effect at NewSUBARU. Feed-forward cancellation of the gap-dependent linear fields, dipoles and quadrupoles, was successful. Special considerations were required to cancel the effect of the 11 m long undulatror.

INTRODUCTION

The 1.5 GeV electron storage ring NewSUBARU [1] has been constructed in the SPring-8 site in 1998. It shares the 1.0 GeV linac of SPring-8 [2] with the Synchrotron as an injector. The ring is a racetrack type with the circumference of 119 m and has two 14 m long (LSS) and four 4 m long (SSS) straight sections. In the LSSs the 10.7 m long undulator (LU) [3] and an opticaionl klystron for FEL (OK) have been installed. In one of the SSSs the 2.4 m short undulator (SU) has been installed. The main parameters the insertion light sources are sum is noin Table I.

Table I: Main parameters of the insertion light sources

Insertion Device	LU	OK	SU
type	planner	planner	planner
magnet	NdFeB	EM	NdFeB
number of periods	198	65/33	30
length of periods	54	160/320	76
K-value	0.3-2.5	0.3-4.4 0.3-11	0.3-5.3
gap	119-26	---	126-26

In 2006 we installed a new control system of IDs, which enables a gap control by users without any change of the stored beam visible from the other beam lines. With this new system beam line users can develop more complicated system, such as XAFS, without any interference with the accelerator control. The system has a feed-forward cancellation, in other words correction, of the tune shifts and the shift of orbit distortions [4]. Its basic scheme had already been reported [5]. The cancellation for OK is not running because the FEL does not share the beam with other synchrotron light users. This paper reports the commissioning status of the system for SU and LU. Please refer to our previous report for details of the design.

CANCELLATION FOR SU

Dipole Correction magnets for SU

The dipole cancellation has two control knobs in each horizontal and vertical direction. They are the 'deflection', which means the same kick at the up-stream and the down-stream of SU and the 'displacement', which means the opposite kick at the up-stream and the down-stream.

The original design for the dipole correction magnets was a set of air-core windings attached to the supporting beam at the up-stream side and the down-stream side for each vertical and horizontal direction. They were strong enough for the cancellation of the deflection error but not enough for the cancellation of the displacement error. The displacement produces smaller COD than that by the deflection with the same error field strengths. However in our case the displacement error required the cancellation. At the stage of the field adjustment we had paid less attention to the deflection error.

For the cancellations of the horizontal COD shift we added shimming plates on the magnet faces at both ends (up-stream end and down-stream end) of SU. They reduced the strength of the active cancellation so that the air-core windings were strong enough.

For the cancellation of the vertical displacement, we changed the system to use windings on a pair of vertical steering magnets nearby. The air-core winding on the supporting beam is used for the correction of the vertical deflection.

The correction accuracy was 6 μm rms of COD. This accuracy was limited by an orbit drift during the time for changing the gap. However at the present, there is no requirement for high accuracy, which was realized at Spring-8 [7].

Quadrupole Correction magnetts for SU

For the correction of the tune shift, we found no problem with the original design. We used pairs of windings on the quadrupole magnets of the ring, one pair of focusing and the other one pair of de-focusing. Magnets at the up-stream and the down-stream of SU made one pair. The correction accuracy was $5X10^{-4}$ in tune.

Correction at 1.5 GeV

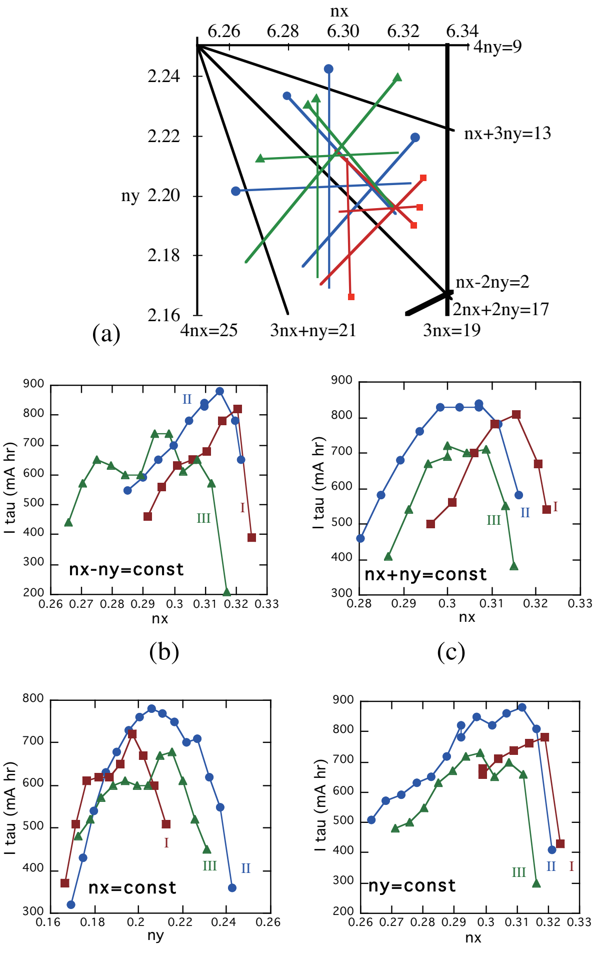
The control system has two correction current tables, one for the 1.0 GeV operation and another for the 1.5 GeV operation. The table gives magnet currents for the feed-forward cancellation for a given undulator gap value. Ideally the current of the dipole correction magnets are constant of the electron energy and those of the quadrupole correction magnets are proportional to the inverse of the electron energy.

The table for 1.5 GeV was calculated from the measured table for 1.0 GeV using the above energy scaling law. The calculated table for SU required a small modification of the dipole correction currents and no modification for the quadrupole correction currents.

CORRECTION FOR LU

Dipole Correction magnets for LU

The cancellation of displacement error by LU did not require strong field because the undulator was long. Therefore the air-core windings on the supporting beam were used. The horizontal windings are separated into two, the up-stream half and the down-stream half. On the other hand the vertical windings are separated into four along the beam direction. At the present, the four vertical windings are grouped into two, one for the deflection and another for the displacement. Two groups are enough to cancel the COD change at the outside of LU. However the system, its software and its hardware, is capable of using the four windings independently. It will be the future step that we will use the four windings to reduce the vertical COD in LU.



(a) (b) (c) (d) (e)

Fig.1 Result of the tune diagram survey. (a) tune diagram. The horizontal and vertical tunes are referred by *nx* and *ny*. The line with a symbol shows surveyed lines on the tune diagram. The circles, squares and triangles indicate those for the (I), (II) and (III) quadrupole configurations, respectively. The other solid lines are the resonance lines upto the 4-th order. (b)-(e) are the stored beam current times the beam lifetime ("*I tau*") along the survey lines. The undulator gap was 35mm.

Quadrupole Correction magnets for LU

In our previous report, we proposed some quadrupole configurations for the cancellation of the tune shift by LU. Three realistic configurations were:

(I) Use two pairs of correction windings on the nearest pairs of quadrupoles to LU, named as QA and QB.

(II) Use quadrupole families distributed around the ring, named as Q1 and Q2.

(III) Use a pair of QB located at the opposite side of LU as an additional correction knob to the configuration (I).

The configuration for LU was not uniquely determined as it was for SU because the large betatron phase advance along LU made things complicated. We experimentally determined the configuration by a tune diagram survey. Fig. 1 shows the beam lifetime in the tune diagram with the tune-shift cancellation using the three configurations. Our choice was (II), which gave the best beam lifetime.

The gap dependent horizontal and vertical tune shifts with the cancellation turned on and off are shown in Fig.2. The vertical tune shifts (*dny*) at the minimum gap (25.5mm) was about 0.08 without the cancellation. This shift was consistent with the theoretical prediction. We observed a horizontal tune shift (*dnx*) of -0.0032, which was obviously produced by a field error. The maximun *dnx* was about 4% of the maximun *dny*. With the cancellation system on, the *dny* was reduced to less than 0.001 and *dnx* to –0.0013. More reduction of *dnx* requires a replacement of one uni-polar power supply with a bi-polar one. However we accept this shift because it is small enough as far as we see Fig.1.

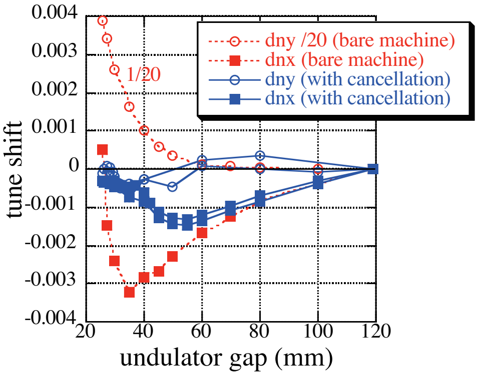


Fig. 2 The gap dependent tune shift by LU at 1 GeV. The open circles and the shaded squares indicate the horizontal tune shift (*dnx*) and the vertical tune shift (*dny*) from the state of the gap opened (119mm). The red broken lines and the blue solid lines show the tune shifts with the cancellation turned off (bare machine) and on, respectively.

Beam-based alignment

According to the decision of using the quadrupole configuration (II), we had to align the beam orbit to the center of the quadrupole magnets around the ring. This reduced a change of COD by a change of quadrupoles. This was necessary because the dipole correctors for the feed-forward cancellation were set only on LU.

Before this alignment, the vertical beam orbit at SSS had been optimized for the better lifetime by Rutherford scattering [8]. However at the present the Touchek lifetime became the main component and the Rutherford scattering was not so important. The vertical orbit change at the BPMs of the SSS were 0.5 mm rms.

The alignment error at each Q were less than 0.2mm. However the alignment errors at Q magnets in the same family had a correlation. This correlation worked to reduce the COD change at the tune cancellation.

Skew Quadrupole Correction of LU

A skew quadrupole correction was also necessary for the good injection efficiency at the top-up operation. First, the skew quadrupole components in LU were reduced by shimming plates and the most part of the residuals could be cancelled out by using windings on the pair of skew quadrupole magnets nearby [9]. However only the cancellation of the error components in LU was not good for the injection because of the skew quadrupole imperfections distributed around the ring. The strengths of the correction skew-quadrupoles were optimized for the better injection efficiency.

Undulator Spectrum of LU

The new dipole field cancellation hardware improved the performance of the undulator spectrum as shown in Fig.3. This was because the new steering system, attached to the supporting beam, reduced the orbit deformation in the undulator.

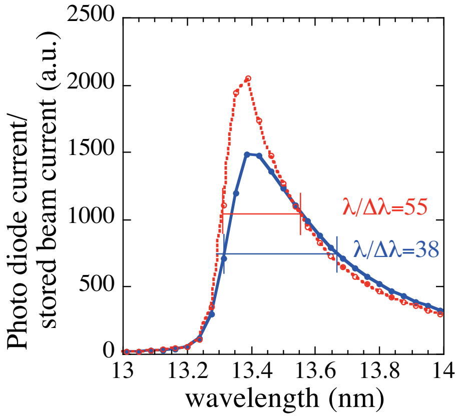


Fig. 3 The 1st undulator spectral line of LU at 1.0 GeV with the gap of 35mm, in the case of using external correction steering magnet (solid line) and in the case of using the new correction coils (broken line).

Correction Table for LU

The energy scaling low did not stand for the tune shift cancellation of LU as shown in Fig. 4. It looks as if considerable part of the tune shift, probably more than the half, was not produced by the undulation field. However, this was not consistent with other data, (1) small horizontal tune shift, (2) the scaling low for SU was correct, (3) the measured shift agreed with the theoretical prediction. (4) The Twiss parameters at 1.5 GeV was roughly the same as those at 1.0 GeV [10].

We have no good explanation for this inconsistency.

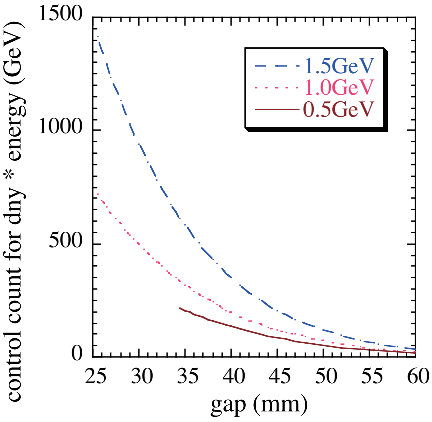


Fig. 4 Required cancellation magnet current for the tune shift cancellation at the different electron energy. The control count (which is proportional to the magnetic field strength) times the energy is independent of energy when the energy scaling is correct.

ACKNOWLEDGEMENT

The authours thank Dr. M. Niibe of BL9, who offered the spectrum data of LU.

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