HIDDEN COD OF NEWSUBARU

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Abstract

We point out one problem of the orbit control of the ring, a shift of horizontal COD, which is not observable with the present beam position monitor system.

1 INTRODUCTION

The synchrotron radiation facility NewSUBARU [1] is a VUV and Soft X-Ray light source at the SPring-8 site. Laboratory of Advanced Science and Technology for Industry (LASTI), at the Himeji Institute of Technology is in charge of its operation, collaborating with SPring-8. Fig. 1 shows the beta functions and dispersion function of the ring. The ring has two operation modes for users. In the 1.5 GeV mode, the beam is accelerated to 1.5 GeV and stored, while in 1.0 GeV top-up mode, the beam current is kept at 250±0.15 mA by an occasional injection with the gaps of undulators closed.

There exists a shift of horizontal Closed Orbit Distortion (COD), which is not observable with the present beam position monitor system. NewSUBARU storage ring has 18 horizontal electric beam position monitors (BPM) and 18 horizontal steering magnets (sth). The steering family is capable of setting beam position to the centre at these BPM locations. However we are blind to the beam position between BPMs.

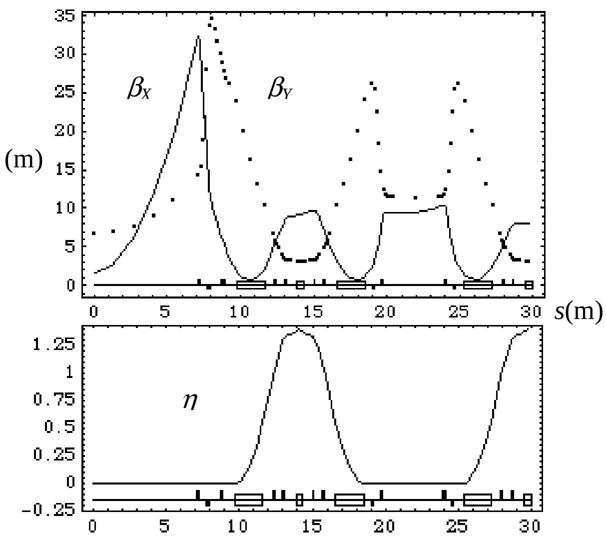

Figure 1: Horizontal and vertical beta functions (above) and the dispersion function (below) along 1/4 of NewSUBARU.

The problem was that the control of the RF frequency does work as the 19*th* horizontal steerers. This one extra degree of freedom could change the orbit between the BPMs. The change of the RF frequency (f_{RF}) produces the energy displacement then the horizontal COD appears, which is proportional to the dispersion function. The 18 steering magnets steer the beam and get it back to the original position at the BPMs although the beam position between the BPMs and f_{RF} do not come back to the initial state.

In this report we explain how we proved the existence and evaluated this hidden COD.

2 ORBIT CALCULATION

2.1 Orbit Displacement

We calculated the expected horizontal orbit displacement, the hidden COD, using the present linear optic model at NewSUBARU.

When the beam energy is displaced by $\delta = (E-Eo)/Eo$, the electron beam is deflected at the bending dipole and COD (ΔX) appeared according to the dispersion function η. Proper deflections at 18 steering magnets steer the orbit to ΔX=0 at 18 BPMs, however the orbit displacement ΔX is not always zero at the other locations (s) than at BPMs. This hidden COD is written by the equation,

$$\Delta X = \eta\,\delta + \frac{\sqrt{\beta_X}}{2\sin\pi\nu_X}\sum_{N=1}^{18}\sqrt{\beta_{XN}}\,\theta_N\cos[\pi\nu_X + \Psi_X - \Psi_{XN}]. \qquad (1)$$

Here ν_X, β_X and Ψ_X are horizontal betatron tune, beta function and the betatron phase. The θ_N, β_{XN} and Ψ_{XN} are deflection, beta function and the betatron phase at N-th steering magnet. The 18 θ_N s are set so that ΔX =0 at 18 BPMs.

The θ_Ns and ΔX are calculated for δ=+1% using the lattice model of NewSUBARU. The results are shown in Fig.2 and Fig.3.

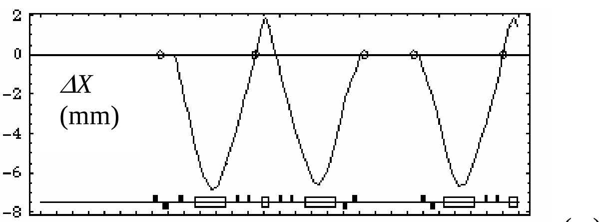

Figure 2: The calculated pattern of horizontal hidden COD in 1/4 of the ring. The circles denotes the locations of BPMs, where ΔX =0. The energy shift is δ=+1%. The circumference of the ring becomes smaller by 44.6mm. This was calculated using the linear lattice model of NewSUBARU.

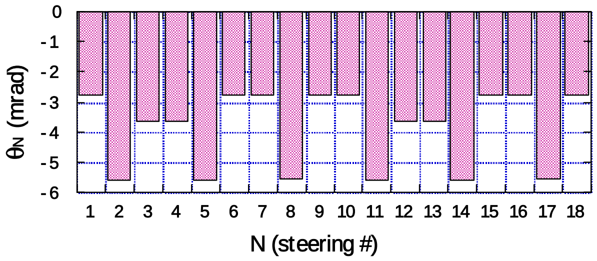

Figure 3: Steering kick (θ_N) for the hidden COD when the energy displacement is δ=+1%. This was calculated using the linear lattice model.

2.2 Shift of RF frequency

The shift of the RF frequency (Δf_{RF}) was absolutely different from that expected from the energy displacement (δ) and the momentum compaction factor (α). The shift by the hidden COD is calculated by

$$\frac{\Delta f_{RF}}{f_{RF0}} = \frac{-\Delta L}{L_0} = \frac{1}{L_0} \int \frac{\Delta X}{\rho}\, ds \,. \qquad (2)$$

Using the parameters of NewSUBARU, calculation gives $\Delta f_{RF}/f_{RF0}$ = 0.0372δ, while α=0.0014. For the same δ the hidden COD produces much larger Δf_{RF} with opposite sign.

2.3 Tune shifts

The hidden COD shifts the betatron tune through two processes; a change of focusing force of Q magnets by the energy displacement ($\Delta\nu_{NAT}$), and the orbit displacement at the sextupole field ($\Delta\nu_{SEXT}$). The horizontal and vertical $\Delta\nu_{NAT}$ are calculated from the natural chromaticity. The $\Delta\nu_{SEXT}$ are separately calculated for the sextupole magnets ($\Delta\nu_{SEXT\text{-}M}$) and for the sextupole component at the edge of B magnets ($\Delta\nu_{SEXT\text{-}B}$). The results of calculations, using the present parameters of NewSUBARU, are listed in Table 1.

Table 1: Betatron tune shift by the hidden COD. The values with * are the shift corresponding to Δf_{RF} of -30 kHz.

calculation			**measurement**		
$\Delta\nu_{NAT}/\delta$	H	-11.67			
	V	-5.55			
$\Delta\nu_{SEXT\text{-}B}/\delta$	H	-0.45			
	V	2.26			
$\Delta\nu_{NAT}$+	H	-12.12	$\Delta\nu_{NAT}$+	H	0.014
$\Delta\nu_{SEXT\text{-}B}$)/$\delta$	V	-3.29	$\Delta\nu_{SEXT\text{-}B}$*	V	0.005
$\Delta\nu_{SEXT\text{-}M}/\delta$	H	-4.54	$\Delta\nu_{SEXT\text{-}M}$	H	0.00
	V	13.45		V	0.025
$\Delta f_{RF}/\delta$ (MHz)		18.7	Δf_{RF}* (MHz)		-0.03

3 MEASUREMENTS

3.1 Beam Displacement at B Magnets

The best way to observe the shift is to measure the beam position in a bending magnet. There exists one beam profile monitor observing the synchrotron light from a bending magnet (we refer it by SR monitor). We intentionally made a shift like that of Fig.2. The f_{RF} was changed while steering magnets were adjusted so that the observed COD at BPMs was not changed. We observed a horizontal shift of beam profile in the SR monitor screen.

3.2 Beam Displacement at Q Magnets

The other way was to use quadrupole magnets as a beam position monitor. We changed the strength of one Q families (Q3) between the bend and the inverse bend by 0.0043 mrad/mm (reduced the horizontal focusing). There are three Q3s in 1/4 of the ring, at s=12.4m, 15.8m and 28.0m in Fig.1. The orbit displacement at Q3 makes a deflection. The strength and locations of the deflection was obtained by analysing the change of COD, assuming that the error locations were at the steering magnets (sth). The results of the analysis are shown in Fig.4. The locations of Q3 families are close to the sths numbered 2, 5, 8, 11, 14 and 17. All of deflections at these 6 locations were negative, which means that ΔX<0 at all locations of Q3. The averaged kick at Q3 was 0.0019mrad. Then the averaged ΔX at Q3 was estimated as -0.44mm. This mean that δ= 0.13%.

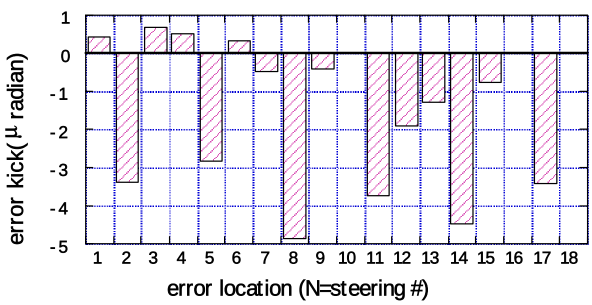

Figure 4: Result of the error analysis for Q3 change of 0.0043mrad/mm. The locations of Q3 families are close to the locations of #2, #5, #8, #11, #14 and #17 in the figure.

3.3 Horizontal Steering Pattern

The horizontal steering deflections at that time, including the deflections to cancel the dipole field error, is shown in Fig. 5 together with the expected for $\Delta E/E$=0.13%. The hidden COD explains why most of horizontal steering magnets had negative deflections.

If this estimation was correct, the RF frequency would be 24kHz higher than that of the ideal orbit. The light source point in the bend would be displaced by -0.9mm at the maximum

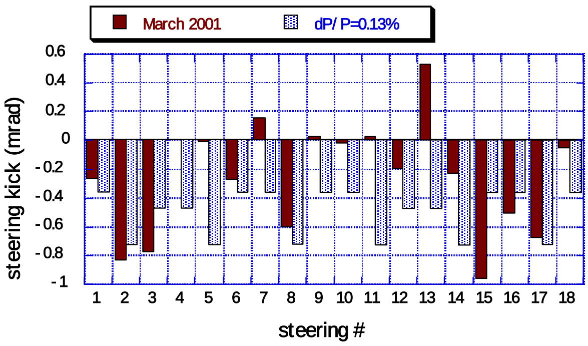

Figure 5: Horizontal steering pattern in March 2001 and the calculated steering pattern for the hidden COD corresponding to δ=0.13%.

3.4 Time Drift

We observed a shift of f_{RF} in a long time range. An analysis of the steering pattern would make it clear if the shift of f_{RF} came from the hidden COD or the ground motion. The steerings were grouped into three, six at the dispersive sections (#2, #5, #8, #11, #14 and #17; group “IB”), four at the non-dispersive long straight sections (#3, #4, #12 and #13; group “LSS”), and eight at the non-dispersive short straight sections (#1, #6, #7, #9, #10, #15, #16 and #18; group ”SSS”). The shifts of the averages of steering deflections of each group for more than a month are shown in Fig.6 (a) with the shift of f_{RF}. The plot of deflections with respect to the shift of f_{RF} made it clear that the most part of the shift of f_{RF} was explained by the hidden COD.

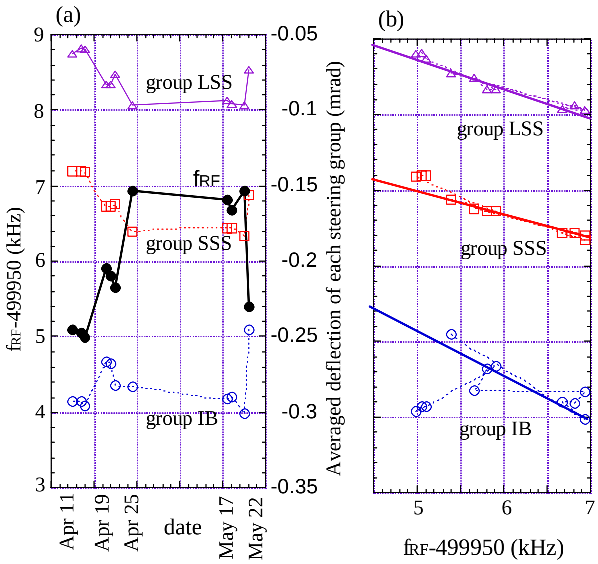

Figure 6: Time drift f_{RF} and the horizontal steering pattern. The left (a) shows a typical drift in 40 days. The right (b) is the re-plot of the same data to see the correlation of the shifts of f_{RF} and the steering. The straight lines are not the fit but the prediction from the calculation of hidden COD.

3.5 Tune Shift

The tune shift by the hidden C.O.D. at the sextupole magnets were measured by comparing the betatron tunes with sextupole magnets turned on and off. The results are listed in Table 1 as $\Delta\nu_{SEXT-M}$, which were consistent with the energy displacement of $\delta\approx$0.15%.

3.6 Shift of RF frequency

We raised the f_{RF} by 30kHz keeping ΔX=0 condition at BPM location. The displacement at Q3 became very small, but was still existed. The betatron tune shift by this change is listed in Table 1. This shift was consistent with $\delta\approx$ 0.15%.

4 CONCLUSION

The existence of the hidden COD at NewSUBARU was confirmed. That produces an shift of f_{RF} more than -30kHz, and the energy displacement of more than +0.15%. The horizontal displacement in the bending magnet amounts to about -1mm.

The other problem was that the hidden COD made the f_{RF} not stable. We developed a steering control program with which the COD is adjusted to zero keeping f_{RF} in 499955500$\pm$300 Hz.

5 REFERENCES

[1]A. Ando, *et al*., J. Synchrotron Rad. 5, 342-344 (1998).