LANDAU DAMPING OF THE VERTICAL COHERENT MOTIONS DUE TO LATTICE NONLINEARITIES IN STORAGE RINGS

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Abstract

The systematic measurements of the vertical coherent motion were made with various chromaticities, octupole magnetic currents, beam currents and betatron tunes to study its damping mechanism at the Photon Factory storage ring (PF-ring). The polarity of the octupole magnetic currents corresponding to the sign of the amplitude dependent tune shift played an important roll in the damping of the vertical coherent motions. This is the same as the horizontal coherent motions.

1 INTRODUCTION

Recently we showed that the sign of the amplitude dependent tune shift produced by lattice nonlinearities played an important roll with the wake force in the damping of the horizontal coherent motions [1]. The Landau damping is suppressed for the positive amplitude dependent tune shift due to head-tail effects at higher beam current, while it is amplified for the negative tune shift. The phenomenon is well understood through both of two particle model and multi-particle tracking simulation compared with the experimental results [2]. Next we will try to understand the damping mechanism of the vertical coherent motion. In this conference we will demonstrate the experimental results on the damping of the vertical coherent motions with various chromaticities, octupole magnetic currents, beam currents, and betatron tunes.

2 EXPERIMENTAL CONDITIONS

The experiment was performed in the single bunch operation mode at the PF-ring, which is a 2.5 GeV dedicated synchrotron light source. The principal parameters of the PF-ring are shown in Table I. The experimental method was quite simple. The stored beam was deflected with a vertical fast kicker magnet, which can give a just single kick to the beam. The kicked beam begins to circulate in the ring with a large amplitude coherent betatron oscillation. The amplitude can be controlled by the voltage supplied to the kicker magnet. During the measurements the voltage was fixed to keep that the initial vertical amplitude becomes about 5 mm at a place of βy=5 m. Then the beam position of the coherent betatron motion was detected with the turn-by-turn monitor system at a place of the ring [3]. The data were taken till 16384 turn (about 10 msec), which is longer than the radiation damping time. The vertical chromaticities was controlled by the defocus sextupole magnets (SD). The amplitude dependent tune shift was arranged with eight octupole magnetic currents and the value is given by the following equation,

$$\Delta\nu_y = 3.3\times10^{-4}\cdot I_{oct}(A)\cdot y(mm)^2$$

where *y* indicates the vertical amplitude. The sign of the tune shift can be changed by the polarity of the octupole magnetic currents. Though the magnets can be excited independently, the same currents were set during these measurements.

Table 1: The principal parameters of the PF-ring

Beam Energy	E (GeV)	2.5
Circumference	C (m)	187
Harmonic number	h	312
RF frequency	f_{RF} (MHz)	500.1
Revolution period	τ_{rev} (nsec)	624
Betatron tune	ν_x, ν_y	8.45, 3.30
Synchrotron tune	ν_s	0.023
Emittance	ε_x, ε_y (nmrad)	125, 2.5
Beam size at β=5m	σ_x, σ_y (mm)	0.8, 0.1
Radiation damping time	τ_x, τ_y, τ_s (msec)	7.8, 7.8, 3.9
Energy spread	σ_ε	0.00078

3 EXPERIMENTAL RESULTS

3.1 Dependence of the octupole magnetic currents

First, we measured the dependence of the octupole magnetic currents. The vertical chromaticity and betatron tune are fixed at ξy=-0.11 and νx=3.30, respectively. Except for octupole magnetic currents and beam currents, other parameters are fixed. The measurements were made at seven different octupole magnetic currents (I_{oct}= +1.0, +0.5, +0.2, 0.0, -0.2, -0.5 and –1.0 A) to three beam currents (I_{beam}=3.0 , 5.0 and 10 mA). Figure 1 shows the measured results at a beam current of 5.0 mA.

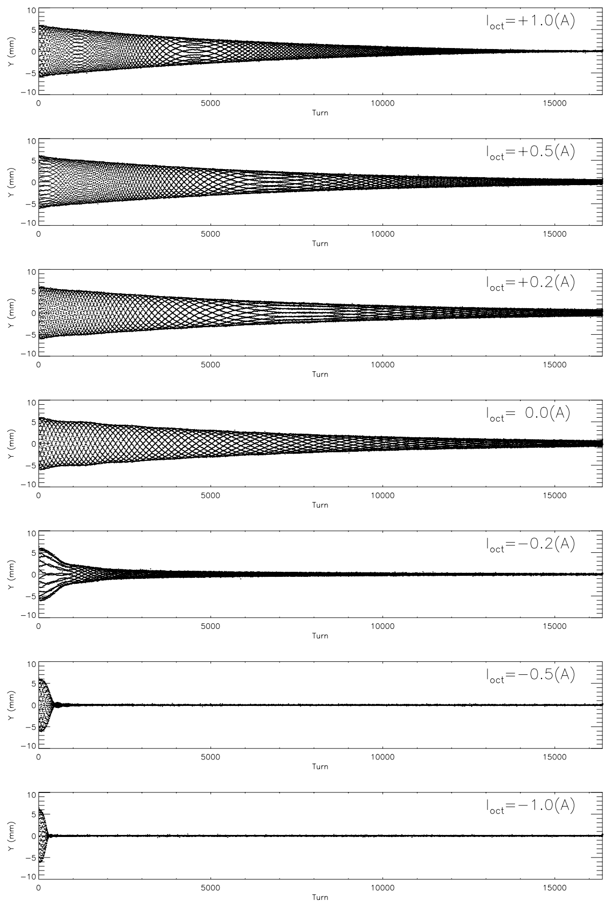

Figure 1: The dependence of the octupole magnetic currents in the damping behavior of the vertical coherent motions is shown. Data were taken at a beam current of 5 mA and the vertical chromaticity, betatron tune and other parameters are fixed.

The damping behavior of the vertical coherent motion was rapidly changed when the magnetic currents became a negative value, which is corresponding to the negative sign of the amplitude dependent tune shift. When the magnetic currents are positive value, the coherent motions damp exponentially. This phenomenon is the head-tail damping. On the other hand, the coherent motions damp very rapidly within 100 turn when the magnetic currents are negative. This is interpreted as Landau damping (nonlinear smear). So it is seemed that the Landau damping of the vertical coherent motion is suppressed for the positive polarity of the octupole magnetic currents in beam currents of 3-10 mA. This is the same situation as the horizontal coherent motions [2].

3.2 Dependence of the vertical chromaticities

Next, we measured the dependence of the vertical chromaticities. The beam current and betatron tune are fixed at I_{beam}=5.0 mA and νx=3.30, respectively. Except for octupole magnetic currents and beam currents, other parameters are fixed. The measurements were made at

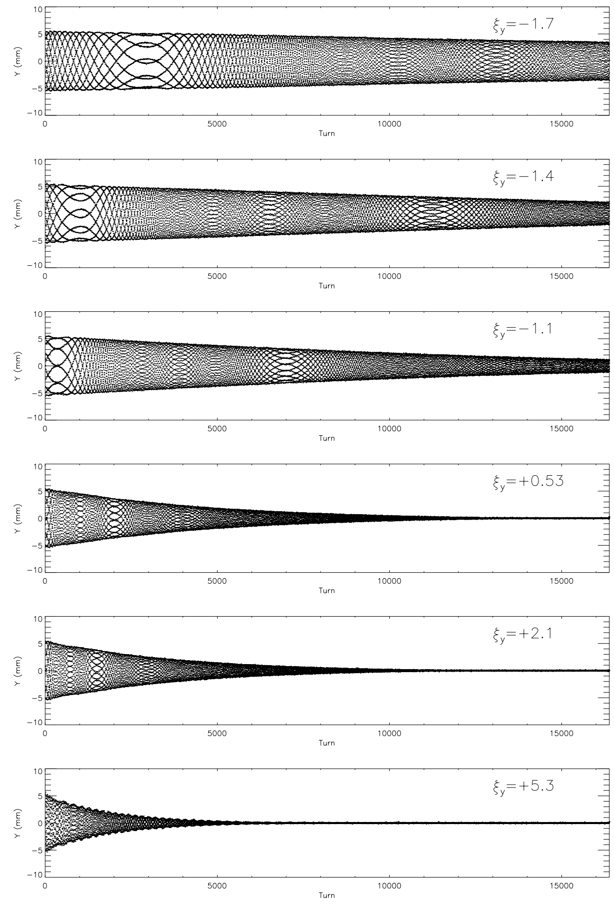

Figure 2: The dependence of the vertical chromaticities in the damping behavior of the vertical coherent motions is shown. Data were taken at an octupole magnetic current of +1.0 A and the beam current of 5.0 mA, betatron tune and other parameters are fixed.

six different vertical chromaticities (ξy= -1.7, -1.4, -1.1, +0.53, +2.1, and +5.3) to three octupole magnetic currents (Ioct= +1.0, 0.0 and -1.0 A), which were selected as the positive, zero and negative polarity of the currents. Figures 2 and 3 show the measured results at the currents of +1.0 and -1.0 A, respectively. Only head-tail damping of the coherent motions was observed at the current of +1.0 A although the damping time depended on the chromaticities. The situation of 0.0 A was almost same as of +1.0 A. On the other hand, only Landau damping was observed at the current of -1.0 A, and then the damping time never depended on the chromaticities.

3.3 Measurements at lower beam current or other vertical betatron tune

We measured the dependence of the octupole magnetic currents and vertical chromaticity at the lower beam

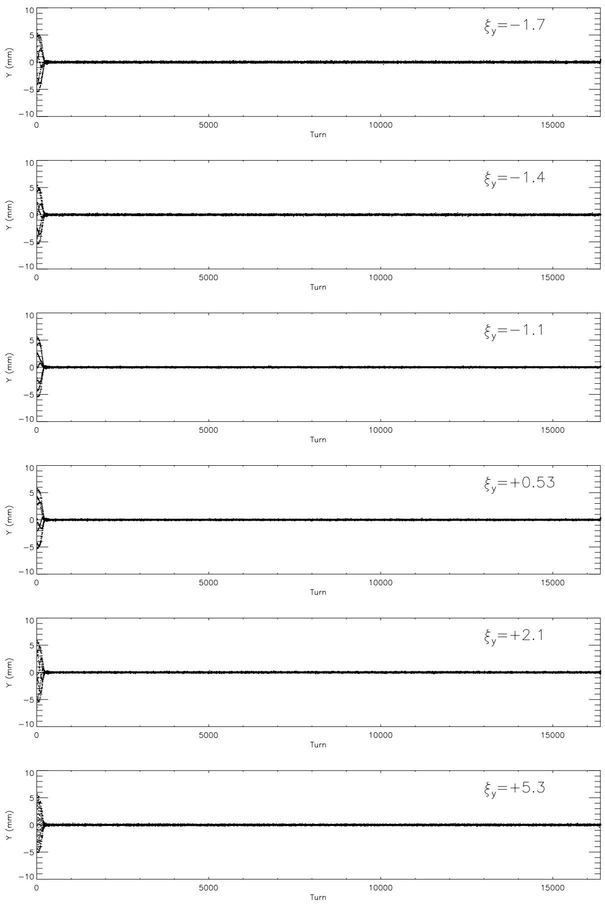

Figure 3: Same as figure 2, but data were taken at a n octupole magnetic current of -1.0 A.

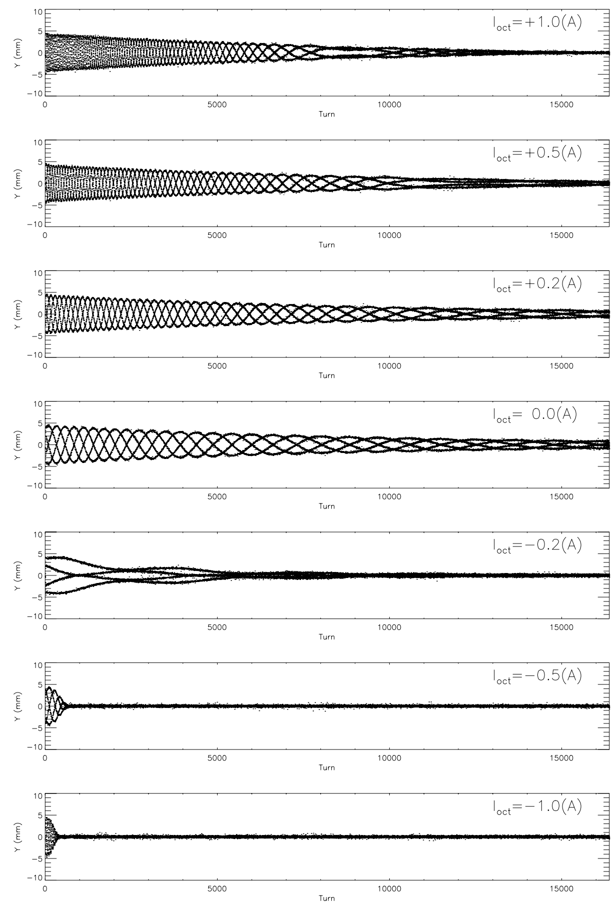

Figure 4: Same as fig.2, but data were taken at a beam current of 1.0 mA and vertical betatron tune was changed from 3.30 to 3.25.

current of 1.0 mA and another vertical betatron tune (νy =3.25). The results are shown in fig. 4 . However, the damping behaviors were not different from those of higher beam currents and νy=3.30. So we may need much lower beam current or more different betatron tune to meet the different behavior.

4 SUMMARY

We measured the systematic damping behaviors of the vertical coherent motions to various chromaticities, octupole magnetic currents, beam currents and betatron tunes. In the beam currents between 0.5 and 10 mA, only head-tail damping was observed for the positive polarity of the octupole magnetic currents and the damping time depended on the vertical chromaticities. On the other hand, only Landau damping was observed for the negative polarity, but the damping time never depended on the chromaticities. Now we are going to make a multi-particle tracking simulation to compare the experimental results quantitatively.

5 REFERENCES

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[3] Y. Kobayashi et al., ' Phase space monitor system at the Photon Factory storage ring', Proc. of EPAC 96