Particle Accelerators, 1990, Vol. 33, pp. 123–128
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CORRECTION OF TUNE SHIFTS AND DISTORTIONS OF BETATRON FUNCTIONS PRODUCED BY THE INSERTION DEVICES AT THE PHOTON FACTORY STORAGE RING

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Abstract The insertion devices installed in the Photon Factory storage ring produce significant effects on the linear optics. These effects have been corrected by changing the currents of the quadrupole magnets neighboring to these insertion devices. The method of the correction and its performance are presented.

INTRODUCTION

The Photon Factory storage ring is a 2.5 GeV electron/positron storage ring dedicated to the synchrotron radiation experiments. In this ring, six insertion devices (wigglers) are installed to provide highly brilliant synchrotron lights[1]. Four of them have rather large magnetic field strengths (greater than 1 T) and the edge-focusing effects in these wigglers produce large tune shifts and distortions of the betatron functions (β's). These tune shifts should be corrected to prevent the operating point from crossing dangerous resonance lines. It is also desirable to reduce the distortions of the β's as small as possible to avoid their effects on the beam dynamics. In this paper, we will briefly describe the method of the correction and present its performance.

INSERTION DEVICES

The parameters of the wigglers are summarized in Table 1. Their locations in the ring are shown in Figure 1. MPW#13[2] and MPW#16[3] are horizontal multipole wigglers. VW#14[4] is a superconducting vertical wiggler with three poles. EMPW#28[5], which has horizontal and vertical magnetic fields, is a multipole wiggler to produce elliptically polarized synchrotron lights. In Table 1, we also show the calculated values of the linear focusing or defocussing forces arising from the edge-focusing effects of these wigglers. In the case of VW#14, the linear forces also arise from the non-linear magnetic field[6].

TABLE 1 Parameters of the insertion devices.

NAME	Bx(T)	By(T)	λ_u(cm)	N	kx	ky
MPW#13	---	1.5T	18.0	13	---	0.038
VW#14	5.0T	---	---	1	0.112	-0.063
MPW#16	---	1.5T	12.0	26	---	0.050
EMPW#28	0.2T	1.0T	16.0	12	0.001	0.014

NOTE: Bx and By are the maximum field strengths in the horizontal and vertical directions, respectively. The λ_u is the period length and N is the number of periods. The kx and ky are the linear focusing forces ($k=B'l/B\rho$ (m^{-1})).

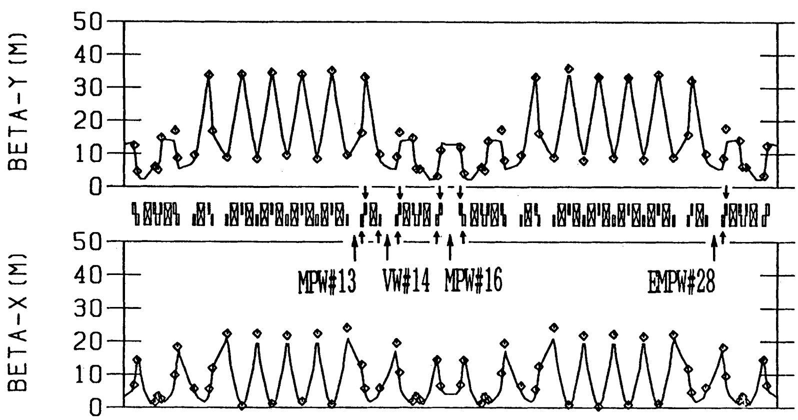

FIGURE 1 The β's of the Photon Factory storage ring. The solid lines the design values, the white squares the measured data without the wigglers. The locations of the wigglers are indicated by arrows with their names. The QM's used for the corrections are also indicated by arrows.

METHOD OF CORRECTION

In this section, we will describe the method of the correction briefly. A conventional way to correct the tune shifts is to change the currents of the quadrupole magnets (QM's) in the normal cell sections. In this case, the distortions of the β's are not corrected well. If the distortions are very large as in the case of VW#14 (see Figure 5), it becomes difficult to keep the otherwise stable operation of the ring. In addition, if one wiggler distorts the β's, the tune shifts produced by another are changed, because the tune shifts are proportional to the β's at the the wiggler. Thus, if there are many wigglers, the procedure of the correction becomes very complicated. To resolve these difficulties, we have corrected the distortions of the β's as well as the tune shifts by changing the currents of the QM's nearby the wigglers. If we use two QM's, we can only correct the

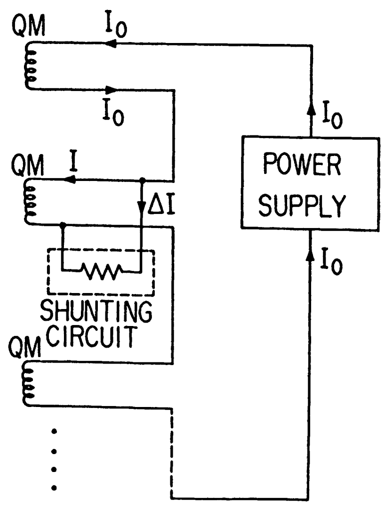

FIGURE 2 Schematic diagram of the system to change the currents of the QM's.

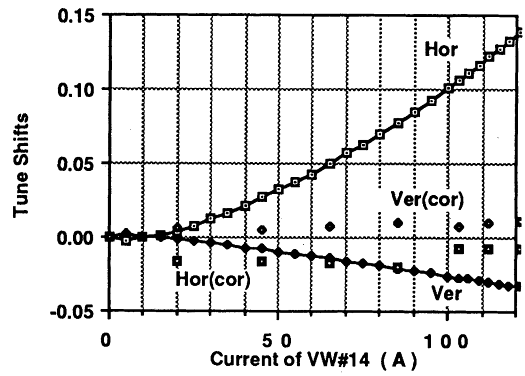

FIGURE 3 Tune shifts produced by VW#14 with and without correction.

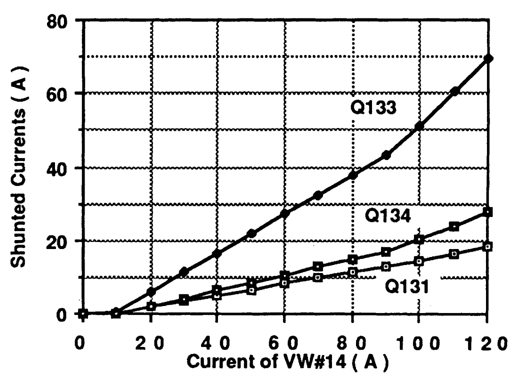

FIGURE 4 Shunted currents of three QM's used for VW#14 as a function of the current of VW#14. The wiggler current of 120 A corresponds to the magnetic field of 5 T.

tune shifts. However, the distortions of the β's are expected to be reduced, if the phase advances of the betatron motions between the wigglers and these two QM's are small. Further, if we use more than three QM's, we can correct the distortions of the β's more accurately. In this case, the currents of the QM's are determined so as to correct the tunes and simultaneously to minimize the distortions of the β's[7]. The QM's used for the corrections are shown in Figure 1. In order to change the currents of the individual QM's, we used electronic loads that can shunt the currents, as shown in Figure 2.

RESULTS OF CORRECTION

In this section, we will present the results of the corrections for some cases. Figure 3 shows the results of the correction of the tune shifts produced by VW#14. The tune shifts are corrected accurately enough for a stable operation. Figure 5, 6 and 7 show the results of the corrections of the β's in the cases of VW#14, MPW#16 and MPW#13, respectively. The β's were measured by a system described elsewhere[8]. In the case of VW#14, the distortions of the β's, which are estimated to be about 100 percent without correction, are reduced to less than 20 percent. In the case of MPW#16, the distortions of the β's, which are

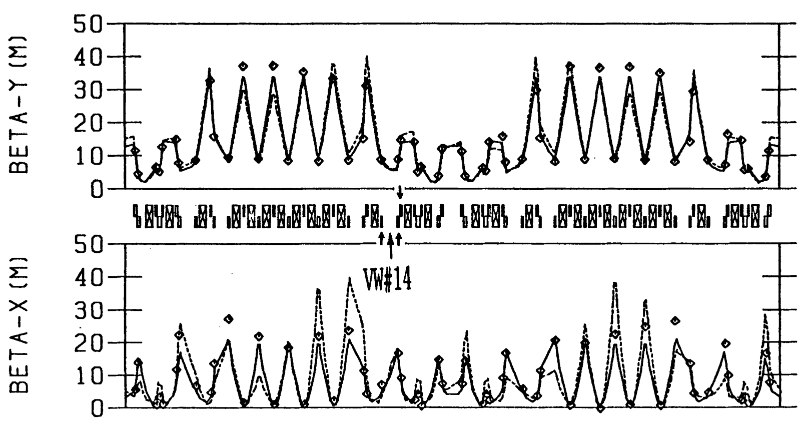

FIGURE 5 The correction of the β's for VW#14 (5 T). The solid lines are design values, the dotted lines simulated values without correction and the white squares measured data with correction.

estimated to be about 30 percent without correction, are reduced to less than 10 percent. In the case of MPW#13, the β's are not corrected so well. However, the distortions are at most 30 percent and acceptable.

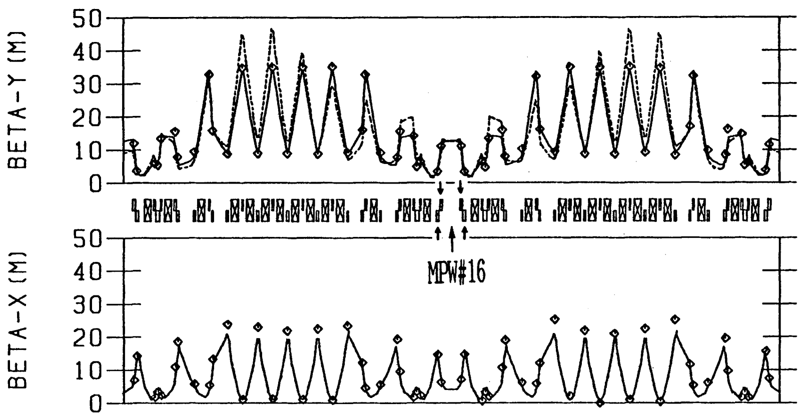

FIGURE 6 The correction of the β's for MPW#16 (1.5 T). The solid lines are design values, the dotted lines simulated values without correction and the white squares measured data with correction.

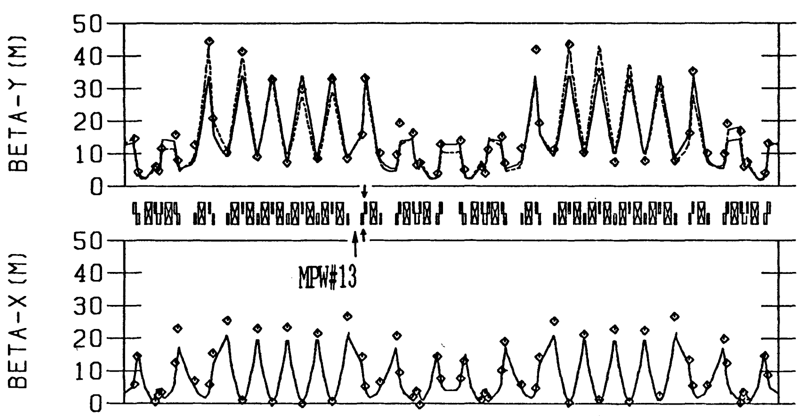

FIGURE 7 The correction of the β's for MPW#13 (1.5 T). The solid lines are design values, the dotted lines simulated values without correction and the white squares measured data with the correction.

SUMMARY

At the Photon Factory storage ring, four of six insertion devices produce significant effects on the betatron tunes and the betatron functions. These effects are corrected by changing the currents of the QM's neighboring to the insertion devices. The tune shifts have been corrected accurately enough for a stable operation. The distortions of the betatron functions have also been reduced to less than a few tens of percent. The effects of the remaining distortions of the betatron functions on the beam dynamics (dynamic aperture etc.) have not been observed.

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