Orbit Collection at SPring-8 Synchrotron

Naoyasu HOSODA, Kenji FUKAMI, Tsuyoshi AOKI, Soichiro HAYASHI, Toshiaki KOBAYASHI, Hiromitsu SUZUKI, Norio TANI, Mitsugu TANIMOTO and Hiroto YONEHARA

Accelerator Division, Japan Synchrotron Radiation Research Institute (JASRI), Kamigori, Hyogo, 678-12 JAPAN

Abstract

The commissioning of the SPring-8 synchrotron was started in December 1996 [1]. After the acceleration of the electron beam to 8 GeV was confirmed, we measured the closed orbit distortion (COD) by using with 80 beam position monitors (BPM). The root mean square (RMS) of the horizontal and vertical COD at 8 GeV are 1.10 mm and 2.57 mm respectively. The COD was corrected by the method based on sensitivity matrix (Smatrix). An Smatrix represents the effect of each correction magnet on each BPM. As the results of correction, the RMS of the horizontal and vertical COD at 8 GeV decreased to 0.47 mm and 0.38 mm respectively. We also corrected the extraction orbit by the local bump method. In March 1997, electron beam of 8 GeV was supplied to the storage ring successfully.

1 Introduction

The synchrotron [2] receives an electron beam of 1 GeV from the linac, accelerates it to 8 GeV and supplies it to the storage ring with a repetition rate of 1 Hz. The circumference of the synchrotron ring is 396.12 m.

There are 80 BPMs which have 4 button type electrodes [3]. The BPM is located in front of every quadrupole magnet. Beam position is estimated from the 4 electrode output signals at the synchrotron main computer [4]. Total measurement time of the 80 BPMs is 30 ms. The error of the position measurement including the calibration and the alignment is 0.3 mm .

There are 40 horizontal correction magnets (CH) and 40 vertical correction magnets (CV). The maximum excitation current of the correction magnets is 7 A. The kick angle per 1 A of the magnets are 0.5153 mrad/A for CH and 0.3473 mrad/A for CV except for 0.3351 mrad/A for CV20. The excitation current and the time interval for the injection and the extraction can be set from the synchrotron computer. The power supplies of the correction magnets near the extraction section (from CH17 to CH20 and from CV17 to CV20) are bipolar type, so the angle and the direction of the kick can be selected at injection period and extraction period individually. The others are unipolar type. The direction of the kick can not changed in a repetition cycle in this type.

2 Smatrix

An Smatrix has the elements which represent the effect of each correction magnet on each BPM [5]. An Smatrix is defined as

$$\delta Z_j = S_{ij} \times \delta K_i, \tag{1}$$

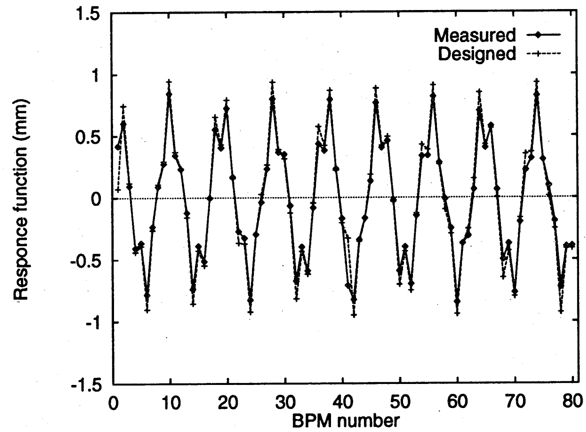

Fig. 1 Response function of CV1. Excitation current is 0.2 A. CV1 is located between BPM1 and BPM2.

where δZ_j is a change in the position at the j-th BPM and δK_i is a change in the kick angle by the i-th correction magnet. If we could know Smatrix in advance, the excitation currents to correct the measured COD is estimated by the position data of BPMs and Smatrix. We treat Smatrix for horizontal and vertical directions independently. The orbit correction by using with Smatrix is the method without any model. If the reappearance of the BPMs and correction magnets are good, the correction works effectively.

3 Measurement of Smatrix

After tuning of the ramping pattern of the dipole and the quadrupole magnets, we confirmed that the beam was accelerated to 8 GeV and its orbit was reappeared. In order to correct the COD, Smatrix must be prepared. We measured three types of the COD data to change the excitation current for each 80 correction magnet. The excitation currents of the magnets were selected to 0.2 A, 0 A and -0.2 A respectively to measure the data of the energy of 1 GeV. The response functions of the each correction magnet are defined to subtract the COD data of 0 A setting from the COD data of 0.2 A (-0.2 A) setting. All response functions were checked graphically, because some BPMs have poor reappearance. Typical response function is shown in Figure 1. Design data was calculated by the orbit simulation program code TRACY V [6]. By changing the timing of the data taking of the BPM, the COD data of 1 GeV and of 8 GeV were measured. The excitation currents to measure the data of the energy of 8 GeV were selected to 1.6 A, 0 A and -1.6 A respectively. We prepared 4 Smatrices for the case of

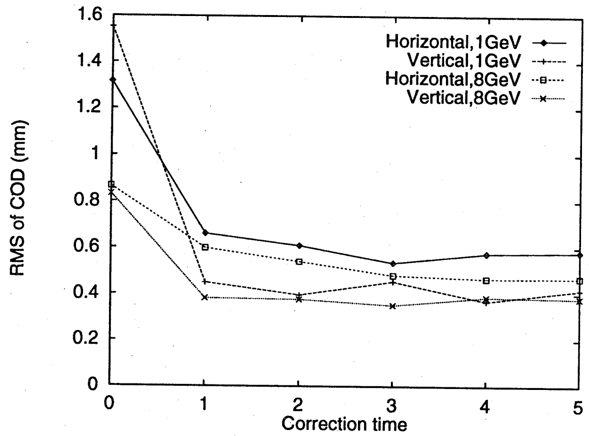

Fig. 2 RMS of horizontal and vertical COD at the energy of 1 GeV and 8 GeV.

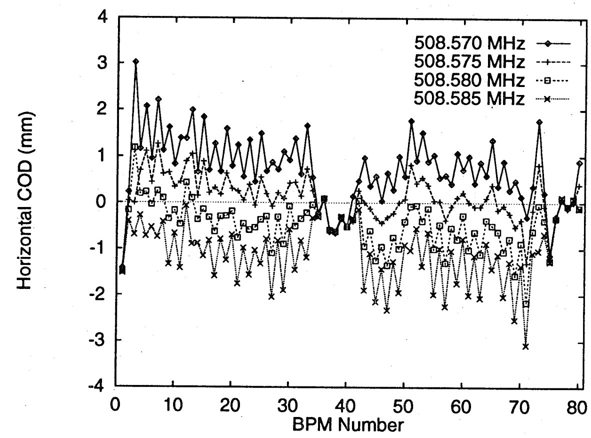

Fig. 3 Horizontal COD against the different radio frequencies.

Table 1
Results after 5 times COD correction. h:horizontal, v:vertical, unit:mm

	RMS		max		average	
	h	v	h	v	h	v
1GeV						
Before	1.31	1.55	3.69	3.74	-0.35	-0.04
After	0.58	0.42	2.07	1.58	-0.48	0.05
8GeV						
Before	1.10	2.57	3.26	5.76	-0.36	-0.03
After	0.47	0.38	2.22	1.40	-0.44	0.04

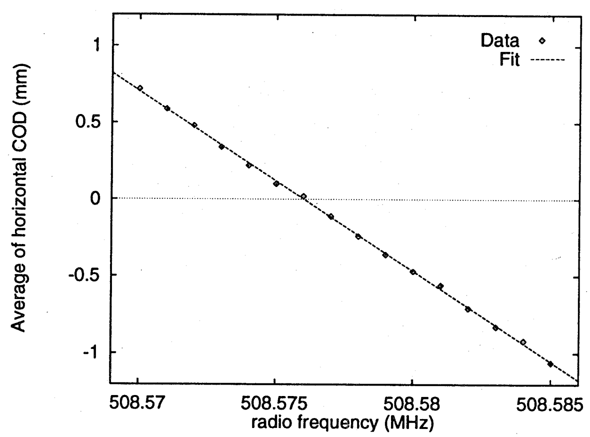

Fig. 4 Average values of horizontal COD against the different radio frequencies.

the horizontal and vertical COD at the energy of 1 GeV and 8 GeV.

4 COD correction

To correct the COD, the excitation current of each correction magnets were evaluated by the most effective corrector method based on the measured Smatrix. We iterated COD correction until the effect of the correction was not recognized. Figure 2 shows the RMS of the horizontal and vertical COD at the energy of 1 GeV and 8 GeV in the COD corrections. The RMS, maximum values and average values of each case are listed in Table 1. The average values of horizontal COD is not negligible small. The reason should be that the circumference of the synchrotron is different from the design value. The horizontal COD was measured by changing the radio frequency as shown in Figure 3. The sections between BPM35 and BPM41 and between BPM75 and BPM1 are the dispersion free sections, so the horizontal displacements by changing the radio frequency are negligible small. Figure 4 shows the average values of horizontal COD against different radio frequencies. By fitting these values, the radio frequency that the average value of the horizontal COD becomes zero is 4 kHz lower than the design value of 508.58 MHz. It proves that the circumference of the synchrotron is 3.1 mm longer than the design value. Figure 5 shows the COD with correction and without correction for each case.

5 Local orbit correction

After the COD correction, the electron beam of 8 GeV was supplied to the synchrotron beam dump. To correct the vertical position and slant of the extraction orbit to the center of quadrupole magnets at beam dump line, the local bump orbit around the extraction section where 4 septum magnets are installed was made by successive 3 CVs. Figure 6 shows the layout near the extraction section. The position of the extraction orbit did not have to be adjusted, because already there was in good position by the COD correction. The slant of the extraction orbit was adjusted to be negligible small by CV20, CV21 and CV22. The vertical COD corrected by the local bump method at the extraction section is shown in Figure 7. The local bump orbit is seen between BPM41 and BPM43. At the other points except for poor reappearance points of BPM3 and BPM45, the difference between the CODs with and without correction is not seen.

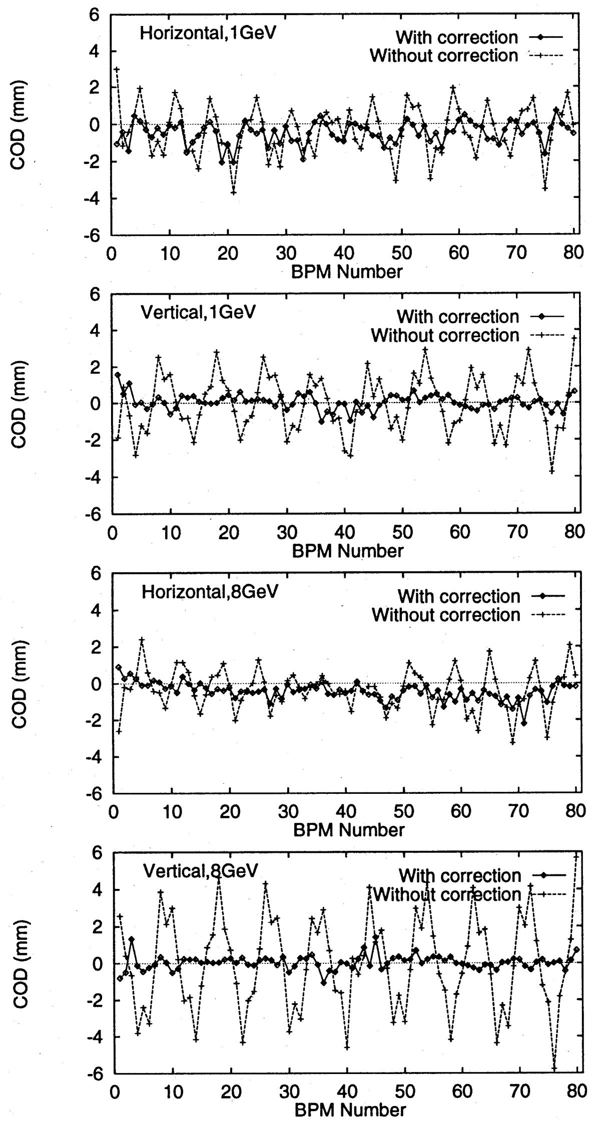

Fig. 5 Horizontal and Vertical COD at the energy of 1 GeV and 8 GeV with correction and without correction.

6 Conclusion

An Smatrix was measured for the 80 correction magnets and the COD was corrected by these Smatrices. The extraction orbit was corrected by the local bump which is made by the 3 CVs. An Smatrix-based orbit correction was very effective at commissioning of the synchrotron.

Acknowledgment

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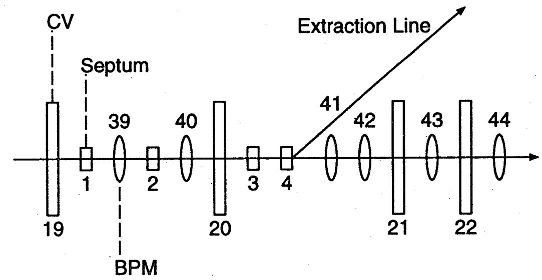

Fig. 6 Layout near the extraction section.

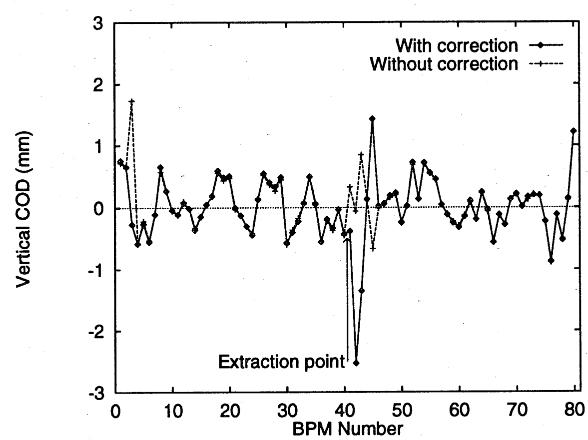

Fig. 7 Local bump at the extraction point. Local bump is made by CV20,CV21 and CV22.

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