Orbit Stabilization in SPring-8 Storage Ring

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1. Introduction

For third generation synchrotron radiation sources, stability of an electron orbit is crucial to increase time-averaged brilliance. To achieve the orbit stability of a few µm, perturbation sources for the orbit movement were suppressed as much as possible in the storage ring design [1,2]. Consequently, without any correction, electron orbit stability of about 50 µm per day is obtained.

To the remaining orbit movement even after the above treatment, a suitable correction of closed orbit distortion (COD) is applied in accordance with a frequency of the movement. Since a main part of the orbit movement is slowly varying components in time, we have introduced one periodic COD correction scheme to suppress main components of the COD. Here, we briefly show our correction scheme and obtained results.

2. Orbit Movement in the Storage Ring

Figure 1 (A) and (B) show respectively the slow changes of the horizontal and vertical orbit at one beam position monitor (BPM) located in the dispersion-free section of #41 cell. The sampling period of data is 30 seconds. In this example, the maximum horizontal and vertical changes per day are respectively 70 and 50 µm. Spikes in the figure correspond to the beam injection. Since the changes don't have a clear periodicity of 24 hrs, both the change of ambient temperature and a sunshine effect are not the origin of these orbit changes. And also, these are usually not described by a single error source except for a special case in a vertical plane. For several times, we have observed a large change in a vertical plane correlated with hard rainfall. In this case, the vertical orbit distortion is expressed by a single kick in #8 cell. This shows that the deformation of the ring due to the rainfall is localized at #8 cell, but the mechanism has not been clearly understood yet.

Figure 2 shows a part of the data in Fig. 1 (A) by magnifying the data about forty in a time scale. We can see the clear periodic movement, of which period is 6 ~ 7 minutes. and amplitude is about 10 µm. This is clearly correlated with the temperature change of the cooling water for the magnet system.

Figure 1 (C) shows that the horizontal orbit at one BPM located in the dispersive section of #22 cell. The maximum change per day is about 50 µm. This pseudo-periodic change can be clearly explained by earth tide [3]. Variation of the circumference due to earth tide causes the energy change of circulating beams and this shifts the orbit pseudo-periodically through energy dispersion.

To check the magnitude of fast orbit movement, signal of the BPM located in #46 cell was measured with the sampling period of 2 milliseconds. Since the noise level of this measurement is about a few µm, we couldn't see clear signal and this fact only shows that the fast orbit movement is the noise level and less.

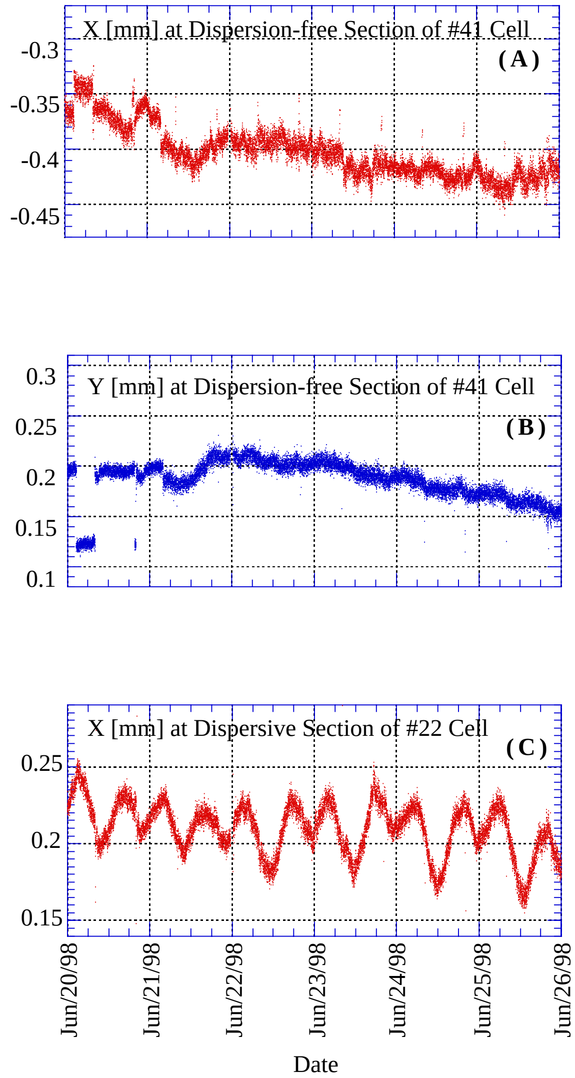

Fig. 1. Slow orbit movement for 6 days in the SPring-8 storage ring without any correction. The graphs (A) and (C) show the horizontal orbit movement at one BPM located respectively in dispersion-free and dispersive sections. The (B) shows vertical orbit movement at one BPM located in the dispersion-free section.

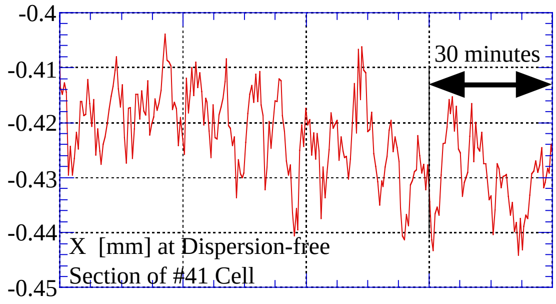

Fig. 2. Magnified data of a part of Fig. 1 (A). Two hours data from June/25/98 12:00:00 ~ 14:00:00 are shown.

3. Periodic COD Correction Scheme

Measured data shows that the magnitude of the slow orbit movement is relatively larger than that of the fast one. We then tried to develop a scheme to correct the slow orbit movement with a period of a minute and longer.

All insertion devices (IDs) are installed in dispersion-free sections and the energy change scarcely affects performance of the IDs. We thus correct only harmonic components corresponding to a betatron tune and its satellite harmonics, which are main components of the global movement.

Although the accuracy of our BPM system is 4 ~ 5 µm in an r.m.s. value [4], the magnitude of random noise is reduced by the square root of the BPM total number through the data integration in harmonic expansion. In the SPring-8 storage ring, we have 288 BPMs and this noise reduction factor becomes about 17. This means that the BPM random noise is reduced down to ~0.3 µm for an estimation of the harmonic components.

3.1 Synthesis of Correction Target

Before starting the periodic correction, reference orbit should be set. The orbit is automatically measured with 288 BPMs along the ring and saved in an archive database. Periodically, the correction program subtracts the reference orbit from the latest one and calculates harmonic components of the difference between the two orbits.

The three harmonics corresponding to the tune and tune ± 1 are used to synthesize target orbit. In harmonic analysis, we use a simple interpolation of the COD data. Although this treatment induces an error of the harmonic expansion especially at high frequencies, this error is corrected by an analytic correction formula at the synthesis of the target orbit.

3.2 Correction Parameters and Algorithm

The period for the correction is a parameter and it is usually set to 1 minute. Available steering dipoles in a horizontal and vertical planes are respectively 96 and 281. All horizontal steering dipoles are in the dispersion-free sections to avoid a cross talk between the corrections of the COD and beam energy. The number of steering dipole used in one correction step is also a parameter. Usually, 24 and 16 are set respectively for the horizontal and vertical corrections.

The best set of steering dipoles are chosen and the strength of each steering dipole is calculated by well known best corrector search algorithm [5]. A coefficient matrix describing the propagation of a steering kick is made of design parameters. Resolution of current setting is 0.15 mA, which is equivalent to ~0.03 and ~0.015 µrad respectively in a horizontal and vertical planes [6].

4 Correction Performance Achieved

Figure 3 (A) and (B) show the amplitude changes of tune-harmonics (51th for Hori. and 16th for Vert.) of the COD respectively without and with the correction of the global orbit distortion. The correction period was set to 1 minute. 24 and 16 steering dipoles were used respectively for the horizontal and vertical corrections. The global COD correction controls amplitudes of the horizontal and vertical tune-harmonics, i.e., correction variables within several and a few µm, respectively. Since the tune-harmonic is a main term of the global orbit distortion in each plane, we predict that the global distortion is controlled at each insertion device within the same order as shown in Fig. 3 (B).

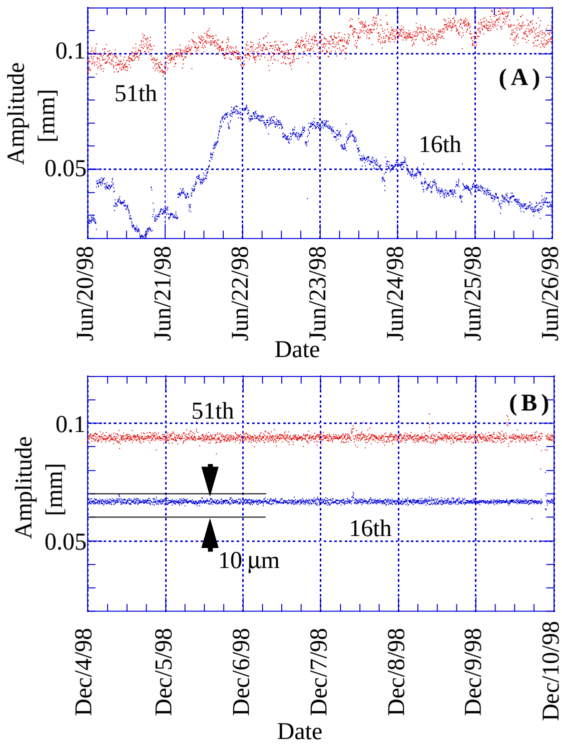

Fig. 3. Slow amplitude changes of tune-harmonics (51th for Hori. and 16th for Vert.) of the COD for 6 days. The upper (A) and lower (B) graphs show respectively the changes without and with the periodic correction of the global orbit distortion.

Figure 4 (A) and (B) show respectively the slow changes of the horizontal and vertical orbit at one BPM of #41 cell with the global COD correction. These data show the local orbit movement under the correction is on. Thickness of each line in the figure is determined by the BPM reproducibility and the slow undulation seems to show the real orbit movement.

The stability of about 10 μm per day was at least obtained by this correction, including the local orbit movement and the position movement of the BPM due to the room temperature change. Spurious horizontal and vertical dispersions here are respectively about 2 and 0.1 cm. Even in a horizontal plane, the deviations due to earth tide is only a few μm.

References

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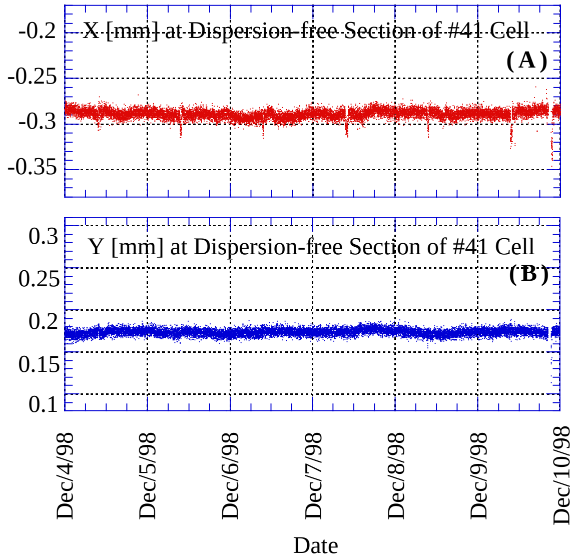

Fig. 4. Slow orbit movement for 6 days with the periodic correction of the global orbit distortion. The correction period is 1 minute. The upper (A) and lower (B) graphs show respectively the horizontal and vertical orbit changes at one BPM located in the dispersion-free section of #41 cell.