LONG TERM VARIATION OF THE CIRCUMFERENCE OF THE SPRING-8 STORAGE RING

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Abstract

The terrestrial tides on the circumference of the SPring-8 storage ring is well recognized. It is also becomes clear that in addition to the tidal deformation the circumference possesses the long term variation. The most distinguished component of the deformation is the seasonal change following the atmospheric temperature. One more noticeable characteristics of the circumference deformation is the contraction with damping over a few years in the early days of the ring.

1 INTRODUCTION

The storage ring of SPring-8, a high brilliant light source facility, was commissioned during the period from March to July 1997 and has been under operation. The most important issue of the operation as a light source is the stability of the electron orbit.

In order to accomplish stabilizing the electron orbit at SPring-8 [1], we measured the closed orbit distortion (COD) by 288 beam position monitors (BPM) around the circumference and correct the orbit by means of around 600 steering magnets. During the user operation the COD measurement is constantly performed with thirty seconds cycle and the COD is corrected every minute. The accumulated data reveals the circumference deformation due to the tidal effect [2], which appears in the position change in the dispersive section. Hence, in the COD correction scheme, to keep the beam position at the center of the quadrupole magnets with preserving the electron beam energy constant, the circumference deformation is corrected by adjusting the rf frequency.

In the machine tuning of the SPring-8 storage ring, we determine the rf frequency to cancel the dispersive component of the COD. In this paper the present knowledge of the circumference deformation over the term longer than a year is reviewed, which is obtained by the rf frequency adjustment.

2 CONFIGURATION OF THE SPRING-8 STORAGE RING

The energy of electrons circulating the SPring-8 storage ring is 8 GeV. The energy loss by synchrotron radiation is feed by the rf system, whose frequency is 508.58 MHz. The circumference is about 1.5 km, and hence the harmonic number of the storage ring is 2436.

The lattice of the SPring-8 storage ring is double bend achromat, *i.e. Chasman-Green* lattice, composed of 48 unit cells. Four of 48 cells lack bending magnets for the purpose of installing the long straight section of 30 m.

Until now, the SPring-8 storage ring is operated in two optics configurations. One is so called the hybrid optics, whose horizontal beta function takes high and low values alternatively at the straight sections. The hybrid optics is used from the beginning of the commissioning of the SPring-8 storage ring to July 1999. The other is called the HHLV optics, whose horizontal beta function takes high values at the straight sections and whose vertical one does low values, respectively. The HHLV optics is taken into service to make more efficient use of the insertion devices.

The dispersion functions of the two optics are the almost same. Hence the momentum compaction factors α's in the both optics are the same value of 1.46×10^{-4}.

3 RADIAL SHIFT AND RF FREQUENCY

The orbit length of particles circulating the storage ring is determined by the rf frequency. As a consequence of the circumference variation ΔC, the particle beam shifts the position in quadrupole magnets. The dipole field resulting from the position change leads to the energy deviation ΔE:

$$\frac{\Delta E}{E} = -\frac{1}{\alpha}\frac{\Delta C}{C}, \tag{1}$$

where α is the momentum compaction factor. Position shift in the dispersive section is given by the dispersion function η

$$\Delta x_{arc} = \eta \frac{\Delta E}{E} = -\frac{\eta}{\alpha}\frac{\Delta C}{C}. \tag{2}$$

Each cell possesses 6 BPM's, two of which in the normal cell are situated in the arc, or, between the two bending magnets. The dispersive deformation of the COD is observed by the radial shift at the BPM's in the arc. The typical dispersion function measured by changing the rf frequency by ± 100 Hz is shown in Figure 1.

Fitting the measured data of COD with the expected radial deformation from the dispersion, we can infer the dispersive component of COD. Then it is a simple task to adapt the rf frequency so as to cancel the dispersive component. In this way we fix the rf frequency of the SPring-8 storage ring.

The tidal effect with psuedoperiodicity of 24 hours is well recognized [2, 3]. In short term the agreement be-

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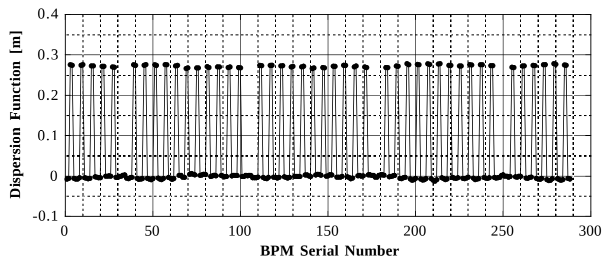

Figure 1: The dispersion function of the SPring-8 storage ring measured by the BPM system.

tween the observed radial deformation and the expected one from the earth tide is fairly well. The long range measurement however shows that the observed radial change departs from one expected from the tide model.

Hence, observing the long term variation of the rf frequency, which is shown in Figure 2, we investigate the origin of the difference between the measured and the expected radial deformations.

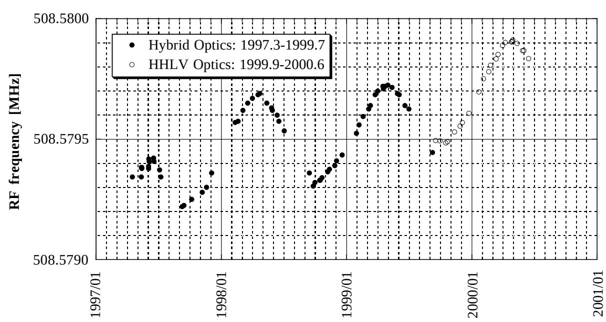

Figure 2: Long term variation of the rf frequency of the SPring-8 storage ring.

4 CIRCUMFERENCE VARIATION

Converting the rf frequency into the circumference, we get the circumference variation shown in Figure 3. At first sight of Figure 3 we aware of the seasonal variation of the circumference. The phase of the circumference change is behind that of the atmospheric temperature by about three months.

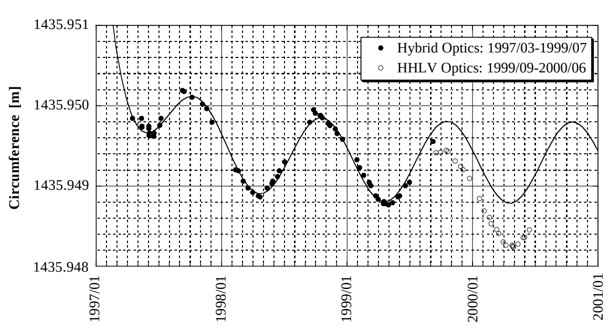

Figure 3: Long term variation of the circumference of the SPring-8 storage ring. The solid line is the expected circumference change from the seasonal temperature variation and the shrinkage of the concrete foundation.

For the purpose of knowing the temperature change of the ground foundation, the observation of the temperature in the ground at depths of 0.5 m, 3 m, 5 m and 10 m, started at February 1999, three of which, 3 m, 5 m and 10 m, are shown in Figure 4. The deeper the observation point becomes, the smaller the amplitude of temperature oscillation is. Further, note that the phase of the temperature oscillation falls behind more as the observation point is deeper. It is emphasized that the phase of the temperature change at the depth of 10 m is reversed to the trend of the atmospheric temperature. Comparing Figures 3 and 4, we find that the change of the circumference is synchronous with that of the temperature at the depth of 5 m. Since the rate of contraction of a rock is about 2×10^{-5} at room temperature and the temperature deviation at the depth of 5 m over one year is about 4 degree, the order of the contraction of the ground foundation is comparable with that of the circumference change.

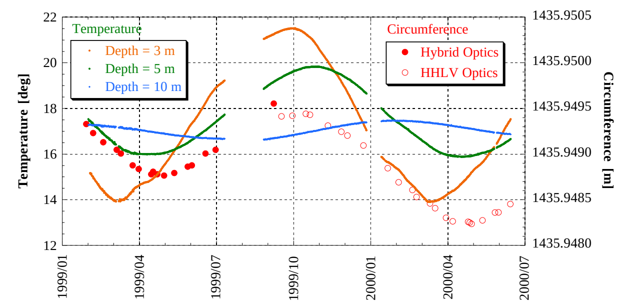

Figure 4: Change of underground temperatures from Feb. 1999 to Jun. 2000.

In early years of the operation of the SPring-8 storage ring the circumference showed the contracting trend with damping. The construction of the building of the storage ring completed around two years before the commissioning. It seems that the concrete foundation was still getting dry after the start of the commissioning of the ring. Modeling the circumference change by a oscillation with an annual periodicity and a damping trend, we fit the data, whose expected line is drawn in Figure 3. The time constant of the damping is consistent with that of the shrinking rate of the concrete foundation.

In September 1999, we changed the optics of the storage ring from the hybrid to the HHLV ones. At that time, we found the jump of the circumference by about 200 μm. We suppose that the difference of the residual COD's in the two lattices gives rise to the change of the orbit length.

5 CONCLUSION

The SPring-8 storage ring is operated so stably that we can observe the various phenomena through the circumference change. The long term behavior of the circumference can be roughly explained by the temperature variation and the concrete contraction. Since the latter has reached bottom these days, the temperature variation becomes the main source of the change of the circumference over long period.

6 REFERENCES

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