Drifting of Closed Orbit in the High Energy Ring*

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Abstract

Since the beginning of this commissioning period (November-December,1998), the closed orbit drift of a few millimeters in both horizontal and vertical planes in the High Energy Ring(HER) has been observed. Because optics, coupling and beam size, in the ring depend on the closed orbit, the drifting of the orbit makes systematic improvement of the machine very difficult if not impossible. It is very difficult to keep any experiments repeatable, which is crucial for studying the instabilities in the machine. In this note, we will present some initial measurements and analysis of the problem.

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1 Introduction

Since the beginning of this commissioning period (November-December,1998), the closed orbit drift of a few millimeters in both horizontal and vertical planes in the High Energy Ring(HER) has been observed. Because optics, coupling and beam size, in the ring depend on the closed orbit, the drifting of the orbit makes systematic improvement of the machine very difficult if not impossible. It is very difficult to keep any experiments repeatable, which is crucial for studying the instabilities in the machine. In this note, we will present some initial measurements and analysis of the problem.

2 Slow orbit drift

To investigate the problem, twenty two closed orbits were recorded as configuration files of beam position monitor(BPM) during a four-hour period starting 11Am in November 25, 1998. The machine was operated at $\mu_x = 24.613$ and $\mu_y = 23.642$, which were near the designed tunes. There were no changes in the machine parameters during the period when the data were taken. The beam current was about 2 mA in a single bunch. The resolution of the BPMs under these conditions was expected to be about $20\mu m$, which was small compared to the drift.

The data were first processed through LEGO[1]. Since we were interested in only the change of the orbits, the first orbit was taken as a reference orbit and twenty one difference orbits were saved sequentially. Then we plotted the measured data using MATLAB[2]. The raw data were showed in Fig.1.

Clearly, there were two bad tracks(orbits) in the raw data. Also there were two noisy BPMs. After we deleted the bad tracks and the noisy BPMs from the raw data, the picture of the orbit drift became very clear in Fig.2. The phases of the orbits were always the same but their amplitudes increased with time.

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Figure 1: *Raw BPM data. Twenty one difference orbits were plotted. The starting point was at the injection point at the middle of the region 10.*

To show the drifting in the amplitudes with respect to time we calculated the standard deviation of each orbit and then plotted them in Fig.3.

The orbit drift in the vertical plane was very linear. The slope in terms of the standard deviation was $9.3\mu\text{m}$ per a minute. The orbit drift in the horizontal plane was slower by a factor of three and started to saturate at the end of the measurement. The orbit drift in the horizontal and vertical planes were highly correlated as shown in Fig.4.

3 Fit using alignment of quadrupoles

Because the orbit drift was correlated in both horizontal and vertical planes, it was unlikely that they were caused by dipole correctors since they are at different locations and have different power supplies. Most plausible explanation was that the orbit drifting was generated by quadrupole magnets moving transversely.

We picked the alignment of QD1L and QD1R as the fitting parameters because we knew that the drifted orbits could be fixed quite well with the dipole correctors near them when the data were taken. The results of the fitting was tabulated in Table 1 and plotted in Fig.5. Two alignments of quadrupoles were needed to fit the phase of the data because the phase between the quadrupoles was not quite 180° since they are not the dominant focusing quadrupoles in the

Figure 2: *Nineteen difference orbits were plotted after two bad tracks were deleted from the raw data. The starting point was at the injection point at the middle of the region 10.*

HER.

Table 1: Fitted alignments using the ideal model.

Alignment	QD1L	QD1R
Horizontal(mm)	-0.108	0.216
Vertical(mm)	-0.108	0.216

The result shown in Table 1 indicated that the support tube that holds the QD1 magnets might be moving along 45^0 transversely. Longitudinally, they moved in the opposite direction with a ratio of two. The fact that the right side moving more than the left side can be explained by the longer level arm from the supporting point on the right side.

The fitting in horizontal plane was better than the vertical was because the machine optics was closed to the idea model, which was known from the result of the phase advance measurement.

Figure 3: *Orbit drifting in the High Energy Ring, The symbol '+' was for the vertical plane and 'o' for the horizontal*

4 Beam induced orbit drift

During the owl shift of December 7, 1998, the machine was run at $\mu_x = 24.5785$ and $\mu_y = 23.6387$, which were different with the tunes at November 25. There was no beam stored in the HER two hours prior to the shift. It was a good time to check if thermal heating is the cause of moving quadrupoles in the interaction point.

We injected a 10 mA beam using a 10-bunch train with the nominal bunch spacing 4.2 ns and then checked the drifting of the orbit in half hour. The drifting was less than $50\mu m$ during the period of the half hour. The drifting was slow at 10mA beam current.

After making sure that there was no fast drifting of the orbit, we stored the beam up 120 mA with "291-gap30" pattern. Every five minutes, we recorded the closed orbit and the temperature of two thermal couples, T_8022 and T_8022_2 which were used to monitor the heating due to synchrotron radiation near the IP.

Opposite to the case of the slow orbit drift, the horizontal drifting was larger than in the vertical plane as plotted in Fig.6. Both the temperature of the thermal couples and the standard deviation of the orbits increased with time. And they were correlated.

Figure 4: *Correlation between horizontal and vertical planes when the orbit drifted*

Although the rates of drifting was quite different for the two cases: the slow drifting and the fast drifting induced the beam, they were generated by the same source as can be seen by comparing with two difference orbits from two different days as shown in Fig.7.

5 Summary

The drifting of the orbit in the HER was measured and analyzed for the cases of the slow drifting and the drifting induced by a high beam current. The conclusion are:

- the horizontal and vertical orbit drifts were highly correlated,
- the orbit drift can be induced by high beam current,
- the set of moving quadrupoles were always same,
- the data were fitted well with the alignments of QD1.

Acknowledgments

We would like to thank Ronald Ruth for his suggestion to look the data in the sequence of the time.

Figure 5: *Symbol 'o' was measured maximum drifting orbits and '+' was the fitted orbits using alignment of QD1 quadrupole near the interaction point*

References

- [1] Y. Cai, M. Donald, J. Irwin and Y. Yan, "LEGO: A Modular Accelerator Design Code," SLAC-PUB-7642, August 1997.
- [2] MATLAB, "High-Performance Numeric Computation and Visualization Software," The MATH WORKS Inc..

Figure 6: *Orbit drifting and thermal heating in the HER with 120 mA beam current.*

Figure 7: *Orbit drifting in the HER at different days and conditions. Symbol 'o' was for a difference orbit when 120 mA beam current stored Dec. 7 and '+' for a reversed difference orbit 2 mA beam current taken Nov. 25*