Orbit Correction and Feedback Systems on the Storage Rings DCI and Super-ACO[1]

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Abstract

We present an analysis of beam position stability and feedback correction for the storage rings DCI and Super-ACO. For DCI, the correction scheme, the implementation of the feedback system and the experimental results are discussed. For Super-ACO, in the expectation of implementing a global real time feedback system in both horizontal and vertical planes, we present numerical simulation and preliminary test results using one orbit beam position monitor and one corrector.

1. PHOTON BEAM POSITION STABILIZATION ON DCI

1.1. Introduction

In this paper we will first present the observed characteristics and amplitudes of uncorrected beam motion, then the implementation of a global correction based on feedback system using photon beam position monitors and beam steering magnets will be discussed. Finally we will present experimental results showing that the peak to peak beam movement can be reduced to less than ± 10 µm for experimental beamlines.

1.2. Observation of Photon Beam Drift

DCI users have complained about slow photon beam drifts over the operational run and especially those occuring during the first hours following the fill.

To solve this stability problem, it is first necessary to be able to measure beam position reliably with high accuracy. It has been demonstrated that the existing orbit beam position monitoring (BPM) system at DCI is not adequate to respond to the user's need. Therefore, sensitive photon beam position monitors have been installed in the beamlines, ten or more meters from the source points to achieve resolution and stability better than ± 10 µm.

In conjunction with the users, efforts were first made to test the reliability of the measurements and to locate the noise sources. After the results of the first sessions we replaced the existing detectors because of their thermal sensitivity and we added a low pass filter in order to reduce the signal to noise ratio.

A beam motion with a period of about 12 minutes and an amplitude of about ± 20 µm has been observed with these detectors. It was identified as being due to the temperature fluctuation of the magnet cooling water. These oscillations as well as those of the beam were eliminated by replacing the shunts by DCCTs in the power supplies regulation.

Various types of drifts, as function of heat and current have been observed. Typical vertical photon beam motion during a user's session measured at 13 m from the source point on line D4 is shown in figure 1, were the majority of the drift occurs during the initial hours following the fill. It is assumed to be due to thermal expansion of the magnets.

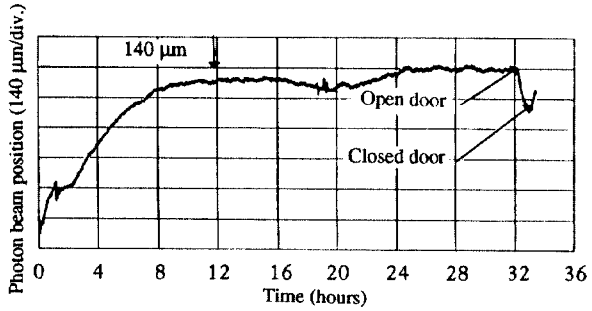

Figure 1. Typical vertical photon beam motion.

Measurements have shown a beam current dependance of the photon beam position (figure 2), but the reason is still unknown.

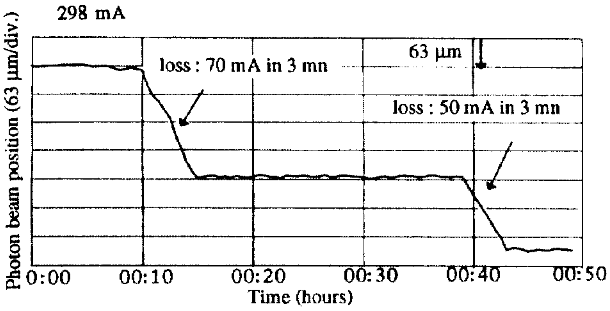

Figure 2. Photon beam position versus beam current.

Simultaneous orbit BPM measurements were made and found to correlate well with photon beam position measurements at the beamlines, demonstrating that the observed measurements were in fact due to orbit motion.

A feedback system has been implemented and is currently operational on the machine.

1.3. Correction Method and Implementation of the Feedback System

The principle of the correction is to measure the photon beam position on one detector of each beamline and to correct these positions simultaneously by action on a set of correctors without disturbing the orbit elsewhere.

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Taking into account the corrector arrangement and the different source points, shown in figure 3, we have created four "local" bumps in this region, which covers about one third of the ring circonference, making certain that the orbit is unchanged elsewhere.

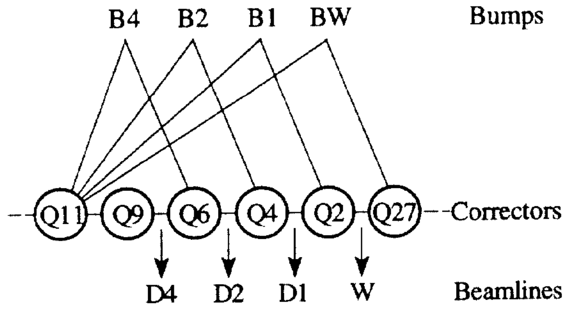

Figure 3. Correctors and source points location on DCI.

The linear relation between the correctors ($\vec{Q}$: Q2, Q4, Q6, Q9, Q11, Q27) and the bumps ($\vec{B}$: B1, B2, B4, BW) is $\vec{Q} = [M1]\times\vec{B}$. The result of these bumps on the four beamlines $\left(\vec{D} : D1, D2, D4, W\right)$ is given by the matrix equation : $\vec{D} = [M2]\times\vec{B}$. Consequently, the efficiency of the correctors on the beamlines can be obtained directly by the following matrix : $[M] = [M1]\times[M2]^{-1}$.

This correction method has been adapted into a feedback system which has been implemented and is in routine use. It monitors the beam position on each beamline once per minute and maintains the position to ± 10 μm at photon monitors located 13 to 20 m from the source points. The servo control of this feedback system is shown in figure 4.

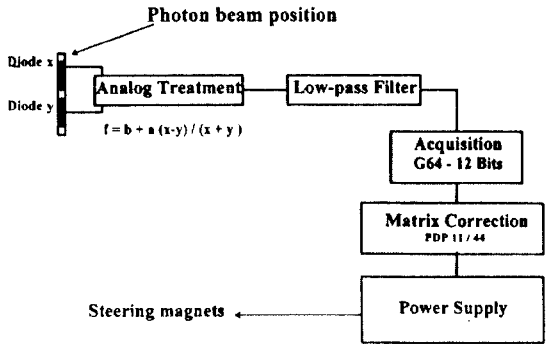

Figure 4. Beam position servo control at DCI.

1.4. Experimental Results

As seen above, prior to the implementation of the feedback system, orbit drifts in the range of 500-700 μm were observed. The feedback system reduces this motion to ± 10 μm (figure 5).

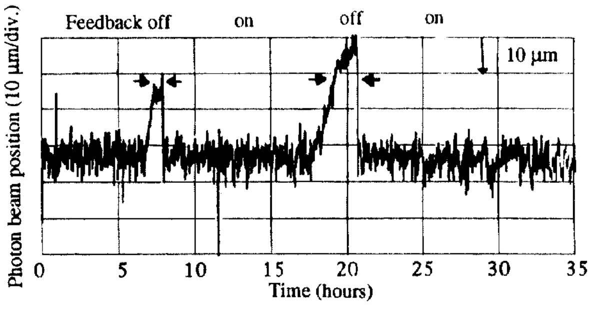

Figure 5. Effectiveness of the feedback system.

2. ORBIT BEAM STABILITY ON SUPER-ACO

2.1. Introduction

In Super-ACO, a closed orbit correction system is operational and a real time global feedback system is currently being developed. It will use a limited number of orbit BPM and correctors. Here we will discuss the principles of the correction method and give some analytical results. Typical noise spectra before and after closing a feedback loop, constituted by one orbit BPM and one corrector, will be shown.

2.2. Orbit Motion Characterization

As already reported [1], horizontal orbit drift with current decay by as much as 400 μm is observed on Super-ACO, while vertical orbit drift is at least ten times smaller. The drift amplitudes are proportional to the total current and follow the intensity variation with a time constant of about 15 minutes.

The harmonic analysis of beam position noise shows several important peaks (especially in the horizontal plane) in the 15 to 25 Hz region, and an additional line at 50 Hz. The horizontal spectrum is shown in figure 6.

In addition to searching beam noise sources, we are developing a feedback system to stabilize the beam. The correction scheme relies on orbit BPM and correctors.

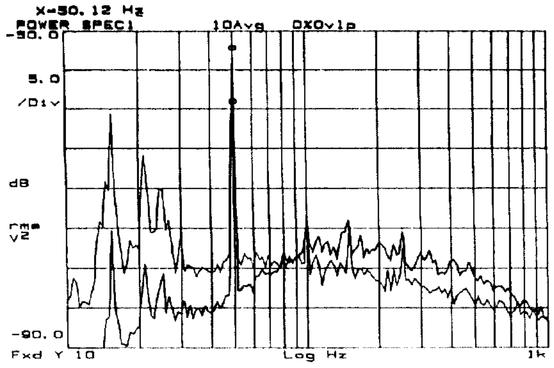

Figure 6. Position noise spectra before and after correction.

2.3. Correction Method and Analytical Results

The aim is to develop a real time feedback system able to reduce global orbit distortion by a significant factor, using a limited number of orbit BPM and correctors.

At NSLS [2], real time global feedback systems based on harmonic orbit correction are currently operating on both the X-ray and VUV rings. The principle is to correct only the Fourier components of the orbit distortion that are nearest to the betatron tune.

Numerical simulations using this method have been made for the vertical orbit of Super-ACO. The tune being 1.7, the orbit distortion is dominated by the first and the second harmonics. Thus, four Fourier coefficients have to be calculated. This can be done with adequate accuracy using eight beam position monitors. To cancel these harmonics we first used four correctors, but we obtained a modest improvement of the maximum orbit displacement (about a factor 2) while the rms displacement was reduced by a factor 4. The reason is that the four correctors generate a high zeroth harmonic which displaces the orbit as a whole. One additional corrector was sufficient to eliminate this harmonic and to reduce the maximum displacement by a factor of 4 as for the rms displacement. Calculations are being carried out in both planes using different numbers and locations of BPM and correctors.

2.4. Preliminary Tests

The present BPM system uses a single peak detector to which all pickup signals are multiplexed. This scheme is slow and at high current is very sensitive to the existing large transverse synchrotron oscillations which exist in the non zero dispersion sections. A new type of detector will be installed and used for the feedback system to overcome this problem. This detector must also ensure high resolution and good reproducibility in a large dynamic range, allowing the feedback system to keep overall beam position variations to within ± 10 µm. To meet these requirements, we built a single prototype narrowband detector for the four electrodes of a BPM, which selects the second harmonic of the RF frequency in the electrode signal and delivers an analog output for the position in each plane (figure 7).

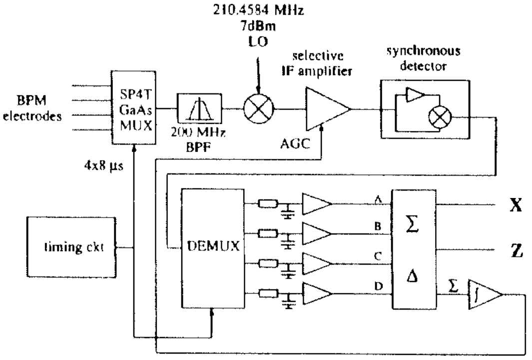

Figure 7. Prototype position detector.

Preliminary tests performed with this prototype detector have shown :

- good linearity in the 3 mm off-center zone,
- sensitivity to position variations smaller than ± 1 µm,
- no dependence on the beam filling pattern,
- dynamic range : about 30 dB (from more than 400 mA to about 14 mA).

The last parameter has still to be improved, as well as coupling between the two outputs (1 percent from X to Z).

In order to test feedback feasibility, a feedback loop has been installed with a single position detector and a single steering magnet in each plane. Figure 6 shows the effect of feedback on the signal power spectrum in the horizontal plane. One can notice an important improvement in the low frequency noise as well as reduction of the major noise components in the 15 Hz to 25 Hz spectrum, but the open loop bandwith is not large enough to ensure significant reduction above 50 Hz.

We now plan to implement a second detector on another BPM (not in the feedback loop), and to measure changes in its spectrum when the feedback loop is closed in the hope of determining whether noise components in the feedback detector signal are real (if reduced) or artefacts of the measurements (if increased).

3. CONCLUSION

Beam position stability has been studied on both DCI and Super-ACO. On DCI, in addition to the identification and the suppression of some noise sources, the implementation of a feedback system led to a stabilization of the vertical slow beam drifts to within ± 10 µm. On Super-ACO, initial numerical simulations show that a significant improvement of the orbit stability (a factor 4) can be obtained both in horizontal and vertical planes, using harmonic correction with a limited number of orbit BPM and correctors. This is encouraging for the development of a global real time feedback system. Open and closed loop tests are in progress.

4. REFERENCES

[1] M.-P. Level et al., "Super-ACO Status Report", in Proceedings of the 3th EPAC, Berlin, Germany, March 1992, Vol. 1, p. 477.

[2] L.H. Yu et al., "Real Time Harmonic Closed Orbit Correction", NIM A284 (1989) 268.

5. ACKNOWLEDGEMENTS

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