SR1 Dynamic Orbit Correction

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1. Introduction

The “static correction system” has been described in part in Technical Design Note 2.1.20[1]. The correction scheme described in that report was designed to correct the deviations in the closed orbit of the synchrotron radiation source (SR1) that arose from the misalignment of the magnetic elements. Assuming “state of the art ” alignment of the magnetic elements, the static correction scheme can correct the orbit to a level suitable for efficient delivery of synchrotron radiation to all the beam lines. The static correction system is also suitable for correcting orbit deviations which may arise from slowly varying alignment of the elements such as those produced by temperature variations and settling of the floor slab.

Note: the static correction scheme places the beam, on average, within 100 microns of the centers of the magnetic elements. This scheme reduces the physical space required to obtain an acceptable dynamic aperture and so leads to reduced constraints on the good field region of the SR1 magnets.

In this note the effect of possible dynamic variations in the magnetic elements is addressed. These variations can be caused by various vibrations that are translated to the magnetic elements. These include slab vibrations, vibrations in the cooling systems and jitter in the magnet power supplies. The system used to correct these dynamic variations will be called the “dynamic correction system”.

The goal of the dynamic correction system will be to correct deviations in the closed orbit such that the movement of the beam will not cause an effective growth of the beam size, at the source points, of more than 5% (10% emittance growth). In this regard, the vertical correction represents the greatest challenge. For example, with 1.0% coupling the vertical beam size in the straight sections is about 30 microns and with 0.1% coupling this becomes about 10 microns. For the two cases, the beam position must be corrected to about the 1 micron level. Beam sizes used in this report are given by $\sigma=(\varepsilon\beta)^{1/2}$ (1 σ of a Gaussian distribution), where ε is the beam emittance and β is the transverse beam function. σ is actually half the width of the beam and is suitable for comparison to the maximum beam oscillation to one side of the beam axis.

2. Dynamic correction system

The dynamic correction system will use some of the orbit correctors (CX,CY) and position monitors (MHV) in place for the static correction scheme[1]. The complete set of correctors and monitors, used for static orbit correction are shown in Figure 1. For the dynamic correction two XY-correctors per cell will be used. The correctors that are part of the sextupole magnets (S) are not used for dynamic correction. For the dynamic correction, only the monitors shown at each end of the cell will be used.

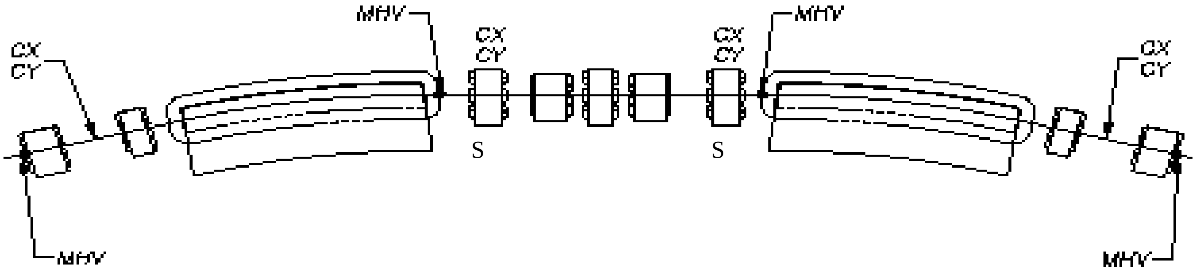

Figure 1 Location of the orbit correctors in one cell.

The XY-correctors will have power supplies that are capable supplying a DC (static) correction and an arbitrary dynamic correction at frequencies up to 100 Hz. Vibrations above a frequency of 100 Hz are not expected to present a problem.

3. Dynamic correction simulations

The dynamic correction system was studied by simulating the system at a given instant. I.e., in the same manner as described in ref. 1. In this report, much smaller random displacements were assumed. The displacements are applied independently to all the positions of all the magnetic elements in the SR1. Random displacements were generated from a Gaussian distribution with an rms value of 1.0 micron and truncated at two sigmas. The entrance and the exit of each element was misaligned in both transverse directions. Random longitudinal displacements with an rms value of 1.0 micron and rotational misalignments (about the beam axis) with an rms value of 1.0 μradian were also applied to each element . (No rotations were applied to the dipoles.) Variations in the dipole strength were set at 3.8 parts per million, the regulation of an 18-bit power supply. Random errors of 1.0 micron in the reading accuracy of the position monitors were also included. The results for five trials are shown in Tables 1 and 2.

Table 1. Beam Position with 1 Micron Errors and Uncorrected (Five Random Trials).

X_{rms}	Y_{rms}	$\|X\|_{max}$	$\|Y\|_{max}$	$\|MY\|_{max}$
μm	μm	μm	μm	μm
9	16	23	50	23
8	19	17	48	26
7	20	18	47	27
13	24	24	78	43
13	33	26	79	47

Table 1 shows that the beam displacement caused by random misalignments at the 1 micron level can cause horizontal (X) and vertical (Y) oscillations of the beam of tens of microns. The situation is particularly adverse in the vertical direction where the oscillations are larger than the vertical size of the beam. Also shown in Table 1 is the maximum value of the vertical beam displacement in any one of the vertical monitors ($|MY|_{max}$). There is a reasonable chance that the signals in most monitors are dominated by the beam motion and not by the random error in the monitor position.

The horizontal (X) size of the beam in the center of the straights, where ID radiation will be produced, is very nearly 400 microns. The uncorrected beam, at the 1 micron error level, therefore almost satisfies the requirement of less than 5% effective beam growth due to vibrations. This requirement is easily satisfied when orbit corrections are made. The analyses of the results of the corrected beam, given in Table 2, concentrates on the vertical beam.

Table 2. Beam Position with 1 Micron Errors and Corrected (Trials from Table 1)

X_{rms}	Y_{rms}	$\|X\|_{max}$	$\|Y\|_{max}$	$\|MY\|_{max}$	$\|SY\|_{max}$	$\|KICK\|_{max}$
μm	μm	μm	μm	μm	μm	mrad
1.5	0.9	6	4	1.8	1.4	< 0.1
1.2	1.3	6	4	1.8	1.3	< 0.1
1.1	1.1	5	3	2.1	1.1	< 0.1
1.3	1.1	6	4	1.4	0.8	< 0.1
1.2	1.2	5	4	1.4	1.0	< 0.1

From Table 2 it is apparent that the maximum vertical beam excursions are about 13% of the vertical beam size. Now, the monitor readings are of the order of the monitor position error. The situation improves, however, when the beam excursions in the centers of the straights are examined. The maximum excursions in any straight in given by $|SY|_{max}$. In the straights, the maximum excursions are about 1 to 1.5 microns. This satisfies the <5% effective beam growth criteria for a 1% coupled beam. It appears that the beam excursions are approximately the same as the magnitude of the errors introduced into the elements and monitors. For 0.1% coupling, the magnitude of the vibrations must be smaller by a factor of 3.

Also shown in Table 2 is the maximum kick required, $|KICK|_{max}$, in the dynamic orbit correction scheme to correct for the 1 micron misalignments. Since the orbit correctors will be designed to produce kicks of 1.4 mrad, the dynamic requirements will be less than 10% of the maximum requirements.

Not shown in Table 2 is the size of the beam in the dipoles where the beam will also be used as a source point. Horizontal and vertical beam sizes in the dipole centers are, respectively, 110 microns by 70 microns (1% coupling). The maximum horizontal and vertical beam excursions, from Table 2, are only slightly larger than the 5% beam growth criteria. If required, one of the vertical orbit correctors in the sextupole magnet nearest the dipole could be used for dynamic correction. In this case, the <5% beam growth criteria is easily met (for 1 micron errors).

4. Conclusion

Random misalignment of the light source have been examined using rms errors of 1 micron in the position of the lattice elements and position monitors. Also included were 1 μradian rotations of the elements and a small and effectively negligible magnet field strength jitter. With these errors it is possible, in the straight sections, to correct the position of the beam to within 5% of the size of the beam in both the horizontal and vertical directions when the vertical coupling is 1% (or greater) . Although the exact values of the beam excursions in the dipoles was not determined, the maximum beam excursions are very close to 5% of the beam size at these source points for 1% coupling. For smaller coupling the amplitude of the vibrational errors must be smaller. Reducing the coupling to 0.1% decrease the vertical beam size by a factor of three. Consequently, correcting the vertical orbit to 5% of this smaller beam size requires (rms) vibrations not in excess of 0.3 microns.

The rms values of the vibrations that can be tolerated are summarized in Table 3. Random errors with the rms values given will produce increases in beam size no greater than 5%. Note that the horizontal beam size is virtually constant over the range of coupling given in the table. Note also that $|X|_{max}$ given in Table 2 is also the value in the center of the straight sections where β_x is maximum.

Table 3. Summary of Tolerable Vibrations for Different Couplings.

	beam size in straights		tolerable vibrations			
Coupling	X	Y	$\|X\|_{rms}$	$\|X'\|_{rms}$	$\|Y\|_{rms}$	$\|Y'\|_{rms}$
%	µm	µm	µm	µrad	µm	µrad
10	390	91	3	3	3	3
1	392	29	3	3	1	1
0.1	392	9	3	3	0.3	0.3

5. Reference

1) Technical Design Note 2.1.20B, “CLS Lattice Performance Analyses”, L. O. Dallin, November 1999.