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Closed Orbit Correction using 64 BPMs

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Closed Orbit Correction using 64 BPMs

Introduction

In the last closed orbit correction scheme in SESAME storage ring, 32 Beam Position Monitors (BPMs) and 32 dipolar correctors in each plane were used [1]. Although that was sufficient from linear and nonlinear optics point of view, nevertheless, for a better orbit control in the Insertion Device (ID) straight sections and for the beam based alignment needs [2], it was decided to add another 32 BPMs in the ID straight sections. Hence, 64 BPMs can be used for the closed orbit correction.

This note will show the closed orbit correction [3-5] using 64 BPMs. A comparison between closed orbit corrections using 32 correctors in each plane and 64 correctors in each plane will be shown too. This note will show also the optimum distribution for the BPMs in the storage ring that achieves the best orbit correction.

1 The distorted closed orbit

To create a closed orbit distortion, 3 rms values of the magnetic alignment errors [1, 5] listed in Table 1 are introduced to SESAME storage ring lattice. The misalignments in the BPMs are not taken into account.

Magnet	Error type	Error value
Bending magnet	$\Delta B/B$	5 X10^{-4}
	Dx = dz = ds	0.1 mm
	$d\varphi_s$	0.1 mrad
quadrupole	dx = dz	0.1 mm
	$d\varphi_s$	0.1 mrad
Sextupole	dx = dz	0.1 mm

Table 1: 3 rms values of the errors used to create a closed orbit distortion.

Although the orbit correction can be done for magnetic misalignments larger than these ones by factor of 2 [1] using the same SESAME dipolar correctors, nevertheless that high error tolerance, mainly for the bending magnets, could make the first beam rotation in the storage ring very difficult. Moreover, according to what has been achieved in other synchrotron light sources we are confident that the tolerances of Table 1 can be achieved.

The resulted analytically evaluated orbit distortions in both planes are shown in Fig. 1 while the probable orbit distortions over 100 samples are shown in Fig. 2.

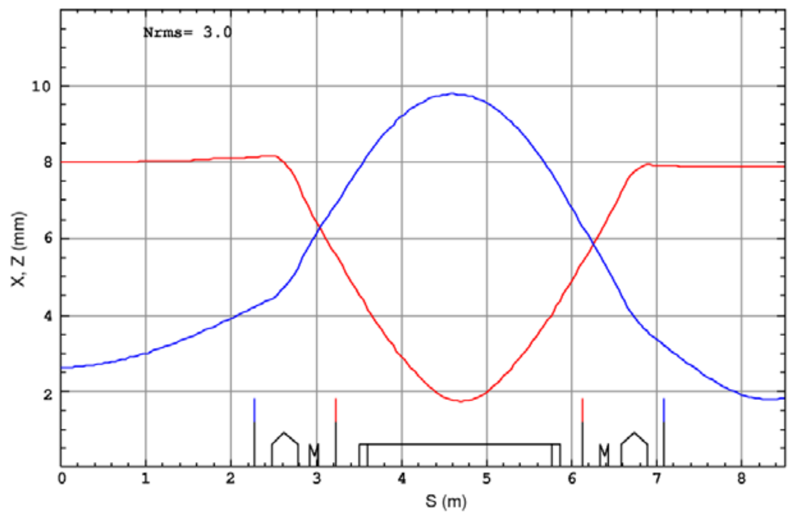


Figure 1: 3 rms values of the statistical horizontal (red) and vertical (blue) orbit distortions in one cell (half super period).

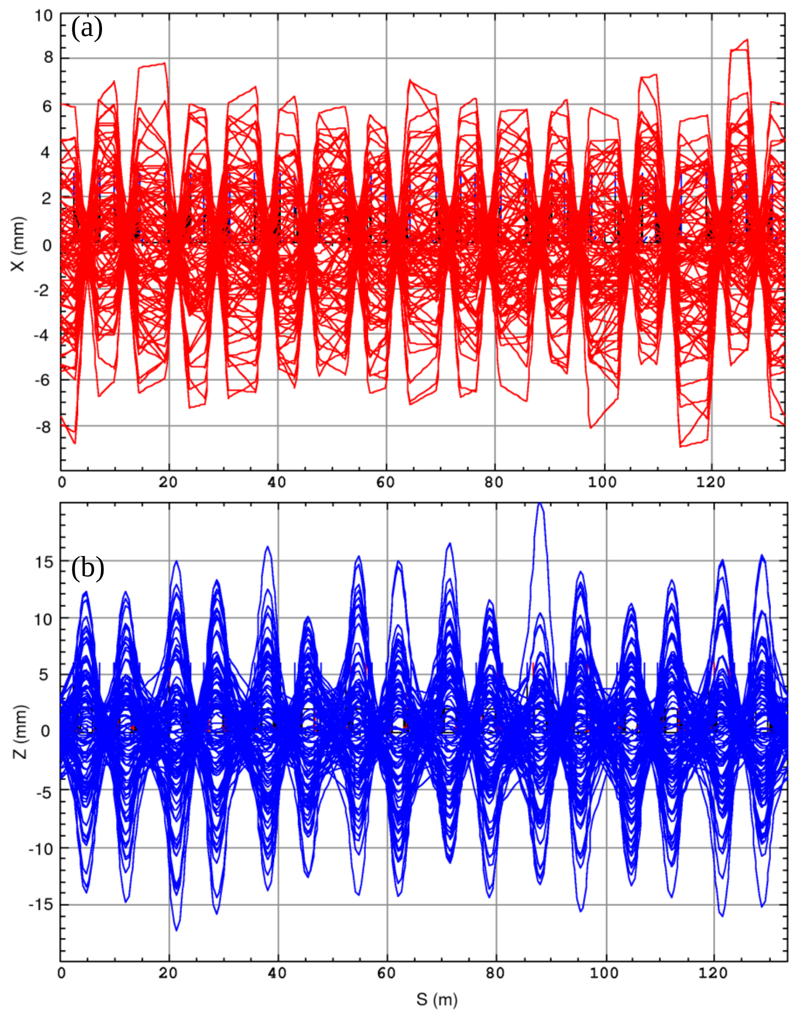
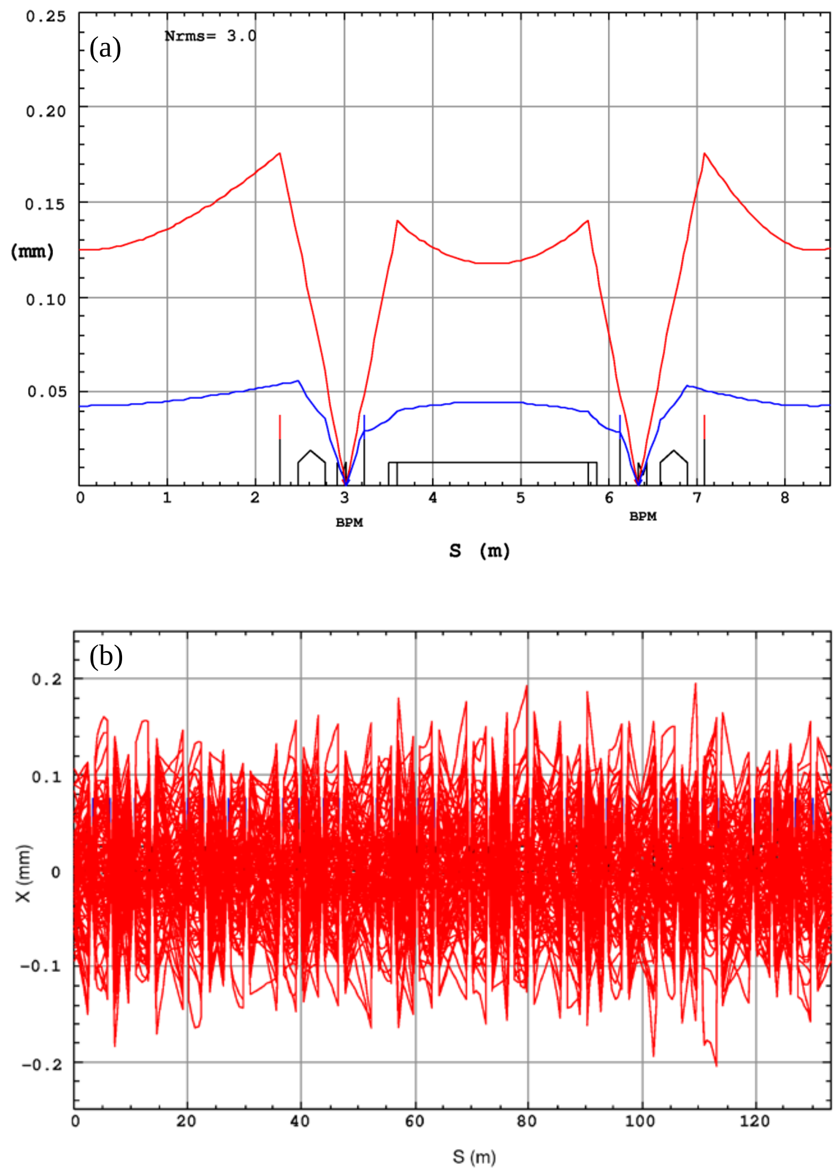


Figure 2: The horizontal (a) and vertical (b) orbit distortions in the storage ring over 100 samples.

2 Closed orbit correction using 64 BPMs

For the sake of comparison, and to see the advantage of using 64 BPMs in correcting the closed orbit, the orbit correction using 32 BPMs and 32 correctors in each plane is shown in Fig. 3, first. In this configuration, the BPMs are placed near to the defocusing quadrupoles as a compromise between the needs to correct the orbit in the straight sections and in the bending magnets [1]. The 32 horizontal correctors are inserted in the focusing sextupoles and marked by red lines in Fig. 3.a, while the 32 vertical ones are inserted in the defocusing sextupoles and marked by blue lines in Fig. 3.a.



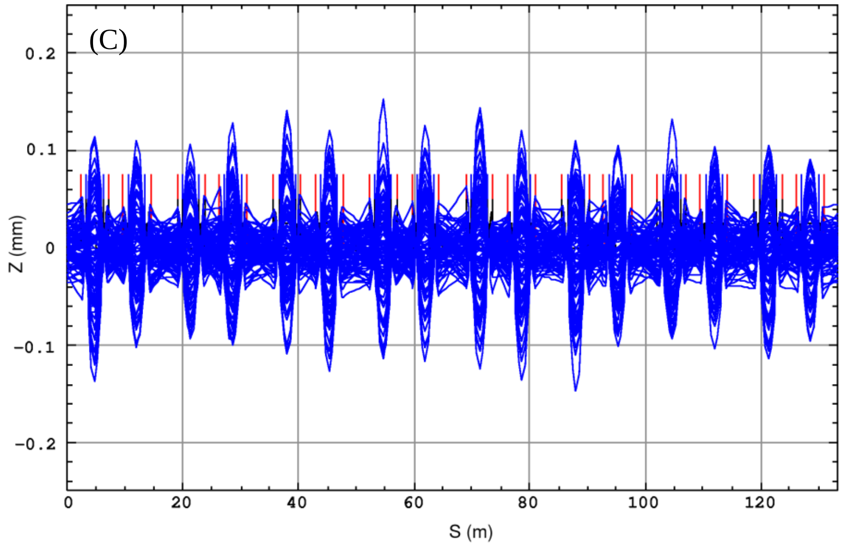


Figure 3: 3 rms values of the corrected closed orbit using 32 BPMs and 32 correctors in each plane. (a) Are the statistical corrected horizontal (red) and vertical (blue) orbits in one cell, (b) and (c) are the probable horizontal and vertical corrected orbits, respectively, over 100 samples.

2.1 Closed orbit correction using 64 BPMs and 32 correctors

By increasing the number of BPMs to 64 (i.e. adding another 32 BPMs in the straight sections) while keeping 32 correctors in both planes, the residual orbit distortions in the straight sections become smaller even though the orbit will not be zero anymore in the BPMs. This can be seen from the statistical corrected orbit that is shown by Fig. 4.

To make the discussion easier the old BPMs are called "*inner*" BPMs, while the new ones added in the straight sections are called "*ID*" BPMs.

On the other hand, Fig. 4 shows that the enhancement achieved in the orbit correction in the straight sections became on the expense of that in the bending magnets where the residual orbit distortions become higher there. So, a compromise can be done by moving the *inner* BPMs to be close to the bending magnets instead of being near to the defocusing quadrupoles, as can be seen in Fig. 5.

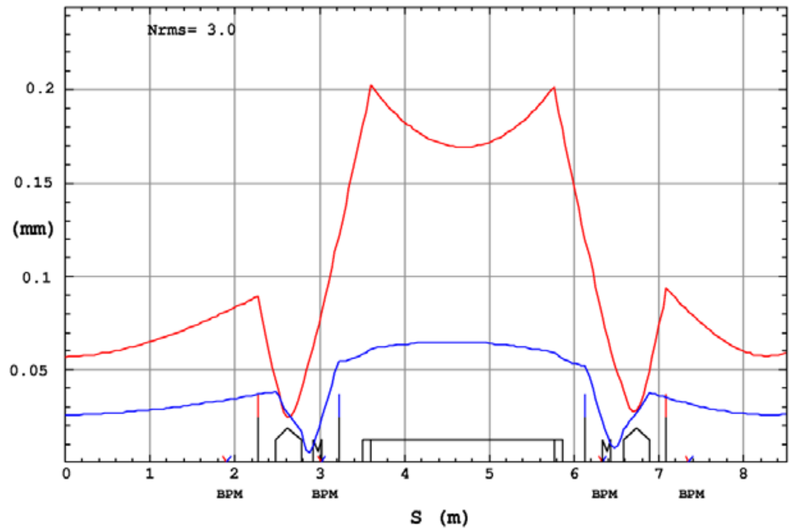


Figure 4: The corrected horizontal (red) and vertical (blue) closed orbits using 64 BPMs and 32 dipolar correctors in each plane. The BPMs are indicated by "v" symbol and by "BPM" name. The ones close to the defocusing quadrupoles are "*inner*" BPMs while the others in the straight sections are "*ID*" BPMs.

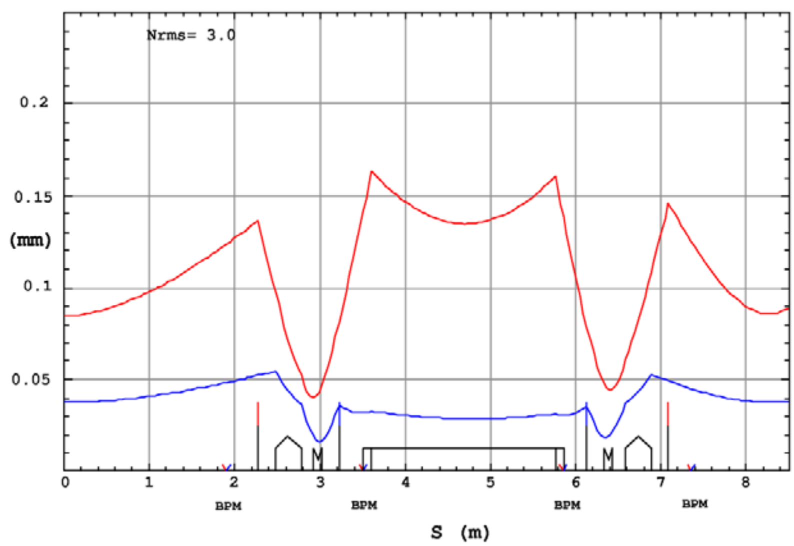


Figure 5: The orbit correction using 32 correctors in each plane and the new recommended distribution of the 64 BPMs, where the *inner* PBMs are close to the bending magnets.

By comparing the performance of the orbit correction in this modified distribution of the 64 BPMs to that of the 32 BPMs, we find an overall enhancement in the orbit correction. This is represented by the smaller residual distortions of the horizontal orbit in the straight sections and of the vertical one in the bending magnets. Hence, this distribution of the 64 BPMs in the SESAME storage ring is preferred and recommended.

The probable corrected closed orbits in the storage ring over 100 samples are shown by Fig. 6. The precision of the BPMs used in the orbit corrections in this note is 10 microns.

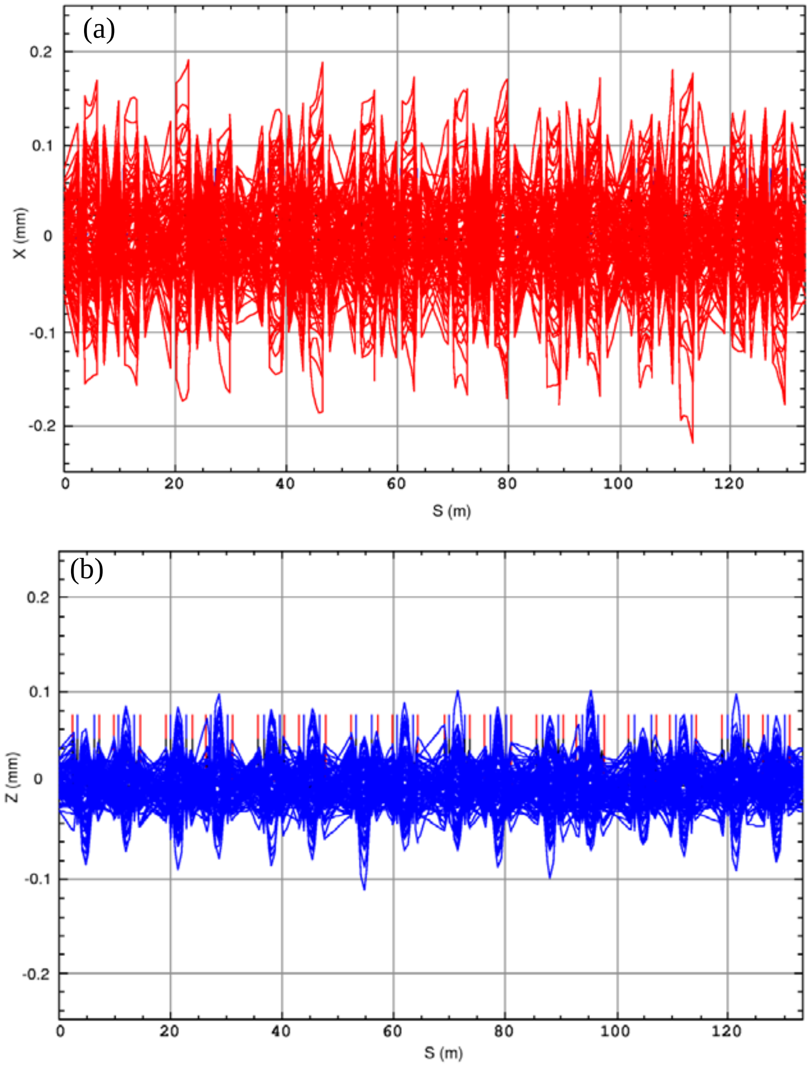


Figure 6: 3 rms values of the probable corrected horizontal (a) and vertical (b) orbits over 100 samples.

The needed strengths of the dipolar correctors in the above orbit corrections are almost similar, with a maximum strength of the horizontal correctors is 0.37 mrad and that of the vertical correctors is 0.3 mrad. These values are within the range of the planned strengths of SESAME storage ring dipolar correctors of 0.5 mrad.

Positions of the ID BPMs

The *ID* BPMs are placed at the ends of the straight sections in asymmetric way; 37 cm and 27 cm from the centers of the sextupoles flanking the ID straight section (see Fig. 4 or 5). The extra 10 cm in the position of the BPM downstream the focusing sextupole was due to the vacuum needs where a crotch absorber is installed between this BPM and that focusing sextupole [6]. Bringing these BPMs closer to or farther from the sextupoles is goverened mainly by the vacuum needs and insertion devices lengths as these BPMs are kept in the straight sections.

Linear and nonlinear optics after orbit correction

To see the linear and nonlinear optical behaviors after orbit correction, the working points and dynamic apertures with corrected closed orbits over 100 samples are shown in Fig. 7. It can be seen that the orbit correction using 64 BPMs and 32 correctors in each plane is acceptable from linear and nonlinear optics point of view since the original working point (Q_x = 7.230, Q_z = 6.190) and dynamic aperture are almost recovered by the applied orbit correction. The mean values of tunes fractional parts after the orbit correction are Q_x = 0.23017and Q_z = 0.18966 while the rms values are 1.32×10^{-3} and 1.54×10^{-3} respectively .The remaining concern is the residual orbit distortion in the insertion device straight sections and to which limit this orbit distortion can be accepted by the users.

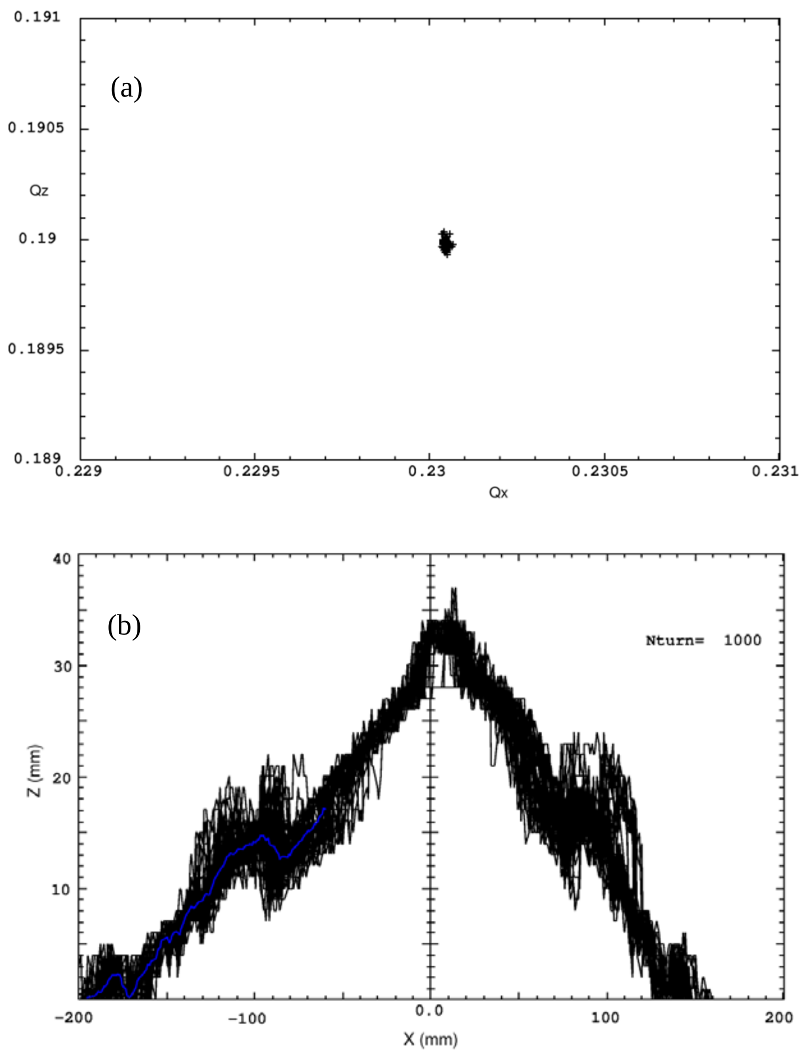


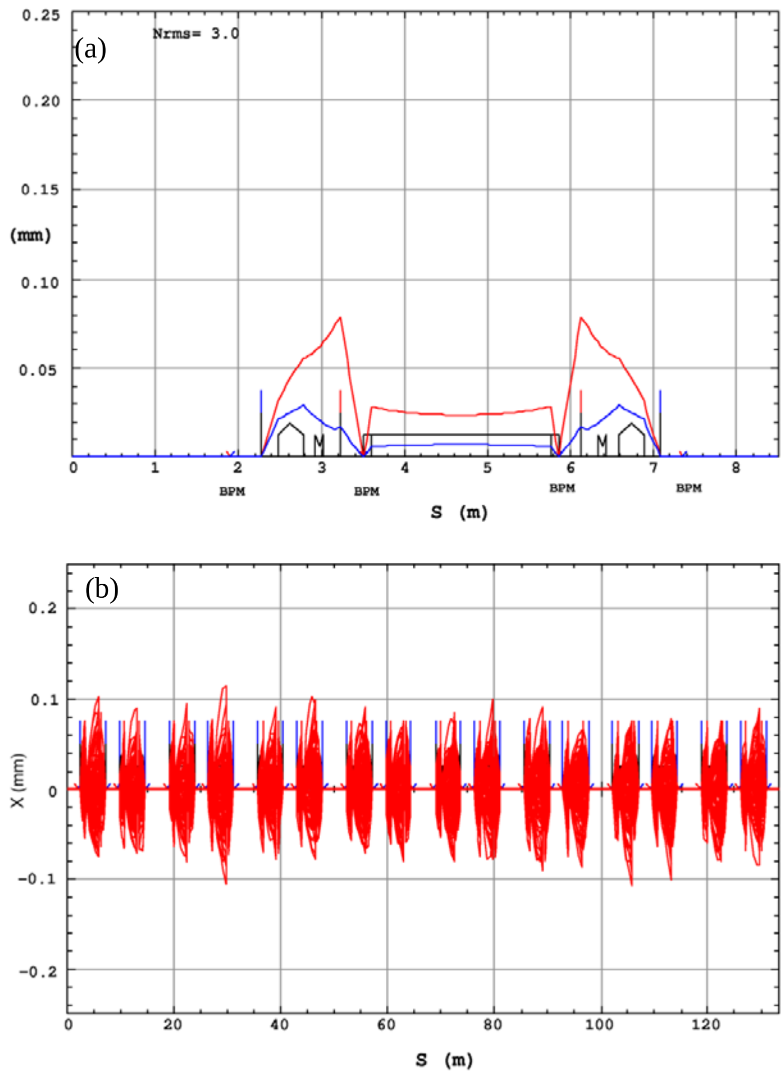
Figure 7: The working points (a) and dynamic apertures (b) that correspond to 100 corrected orbits.

2.2 Closed orbit correction using 64 BPMs and 64 correctors

To obtain zero orbit in the straight sections in addition to smaller residual orbit distortion in the bending magnets, it is recommended to correct the orbit using 64 BPMs and 64 correctors in each plane. This means that each sextupole should accommodate a horizontal and a vertical dipolar corrector.

The analytically evaluated corrected closed orbit in one cell using 64 BPMs and 64 correctors in each plane is shown in Fig. 8.a while the corrected orbits over 100 samples are shown in Fig. 8.b and c.

It should be mentioned here that the closed orbit correction in BETA code [7], which is presented above, is done using the Singular Value Decomposition (SVD) technique and all the eigenvalues of the corrector to BPM response matrix [2-5].



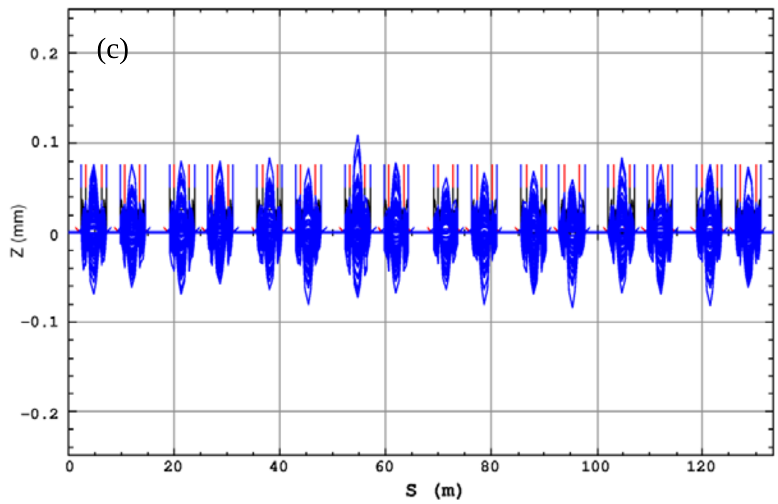


Figure 8: 3 rms values of the corrected closed orbits using 64 BPMs and 64 dipolar correctors in each plane. (a) The analytically evaluated horizontal (red) and vertical (blue) corrected orbits in one cell, (b) and (c) are the horizontal and vertical corrected orbits over 100 samples.

Higher bending magnet errors

If we consider the tolerance of the bending magnet displacement error as 0.2 mm and the rotation error $d\varphi_s$ as 0.2 mrad (3 rms values), then the maximum corrector strengths needed for the above orbit corrections are 0.48 mrad for the horizontal correctors and 0.422 mrad for the vertical ones. This is still within the capability range of the dipolar correctors in SESAME storage ring (0.5 mrad).

Nevertheless, it is highly recommended not to exceed 0.1 mm and 0.1 mrad for the displacement error and rotation error $d\varphi_s$ of the bending magnet due to the produced high orbit distortion which may make the first beam trajectory optimization difficult in the first day of the machine operation. This is because of the high β_z value in the bending magnet (~27 m) and due to the fact that the integrated gradient in the long bending magnet of SESAME affects as a strong quadrupole which has to be taken into account in the alignment process.

3 Conclusion

Installation of 64 BPMs in the storage ring is needed to control the closed orbit in the Insertion Devices and to do the beam based alignment. Moreover, using the 64 BPMs in the orbit correction scheme gives better overall orbit corrections in the bending magnet and the straight sections, mainly when the *inner* BPMs are closer to the bending magnets which is the recommended BPM distribution in the storage ring.

Although the closed orbit correction using 32 dipolar correctors in each plane is sufficient, nevertheless a zero orbit in the straight sections and very well corrected orbits in the bending magnets can be obtained when 64 dipolar correctors in each plane are used.

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