Tolerances on Magnetic Misalignments in SESAME Storage Ring

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Abstract

This note investigates the maximum acceptable magnetic misalignments in the SESAME storage ring which preserves reasonable optics, beam lifetime and injection efficiency.

1. **Introduction**

In a 3rd generation light source the electron high beam quality and lifetime are important requirements. To achieve such requirements the machine errors should be minimized as much as possible. Magnetic misalignments create orbit and optical distortions, reduce dynamic aperture which reduces in turn beam lifetime and injection efficiency.
In practice one should ask for reasonable magnetic alignment that can be mechanically achieved and on the other hand can preserve the good machine performance.

2. **Misalignment tolerances**

Table 1 shows the statistical impact of 1 rms of the main magnetic misalignments on closed orbit in terms of 1 rms of maximum orbit distortion in the storage ring. The number of samples used is 300. These results are given by BETA [1] and Accelerator Toolbox [2] codes.

Error type	**Error value**	**x-orbit distortion**	**y-orbit distortion**	**Amplification factor**	**(ΔQ_x, ΔQ_y)**
Quad dx	0.1 mm	2.3 mm	0	23	
Quad dy	0.1 mm	0	2.5 mm	25	
Quad ds	0.1 mm	0	0	0	(1.3e-4, 1.4e-4)
Dipole dx	0.1 mm	0.5 mm	0	5	
Dipole dy	0.1 mm	0	4.5 mm	45	
Dipole ds	0.1 mm	0.45 mm	0	4.5	
Dipole dϕ_s	0.1 mrad	0	2 mm	20	

Table 1: Impact of different magnetic misalignments on SESAME storage ring orbit distortion.

The red colored row shows the most critical error (dipole vertical displacement) followed by the orange colored ones (quadrupole horizontal, vertical displacements and dipole rotation around s-axis). Table 1 shows that the misalignments impact is more critical in vertical plane. This can be understood through the optics seen in Fig. 1.

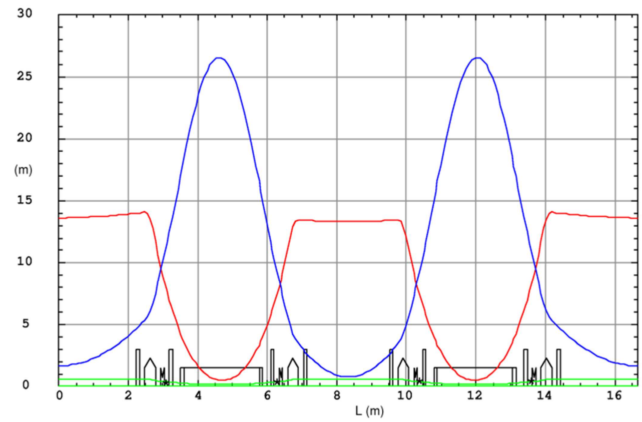

Figure 1: SESAME storage ring optics, with horizontal beta function β_x (red), vertical beta function β_z (blue), and dispersion η_x (green).

Taking into account the expected sizes of injected beam (x = 8-10 mm, z = 1 mm (assuming 10% coupling before correction)) and the apertures defined by the injection septum (x =18 mm) and vertical chamber half-gap (z =14 mm), the maximum acceptable horizontal and vertical 1 rms orbit distortions before correction are 4.3 mm and 4.5 mm respectively. This can be almost achieved if Table 2 tolerances are respected.

It is worth to point out that sextupole misalignments are less critical than the quadrupole ones, but on the other hand their alignment tolerances can be easily achieved if the similar ones are already achieved in quadrupoles.

Error type	**Error value (1 rms)**
Quadrupole, Sextupole dx	0.1 mm
Quadrupole, Sextupole dy	0.1 mm
Quadrupole, Sextupole ds	0.5 mm
Quadrupole, Sextupole $d\phi_x$	0.2 mrad
Quadrupole, Sextupole $d\phi_y$	0.2 mrad
Quadrupole, Sextupole $d\phi_s$	0.2 mrad
Dipole dx	0.5 mm
Dipole dy	0.1 mm
Dipole ds	0.5 mm
Dipole $d\phi_x$	0.5 mrad
Dipole $d\phi_y$	0.5 mrad
Dipole $d\phi_s$	0.2 mrad

Table 2: Tolerances on SESAME storage ring magnets misalignments.

In order to have more realistic figure, the tolerances of Table 2 are included together with the bending field error tolerance $\Delta B/B$ = 1e-3 in all the tracking and calculations done.

3. **Orbit and optical distortions**

The corresponding 1 rms statistical orbit distortions are seen in Fig. 2, whereas the corresponding peak-to-peak orbit distortions of 300 tracked samples are seen in Fig. 3.

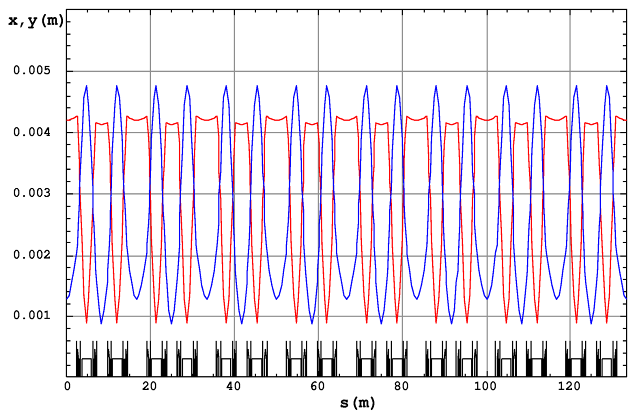

Figure 2: 1 rms orbit distortions due to Table 2 misalignments in addition to dipole field error ΔB/B = 1e-3.

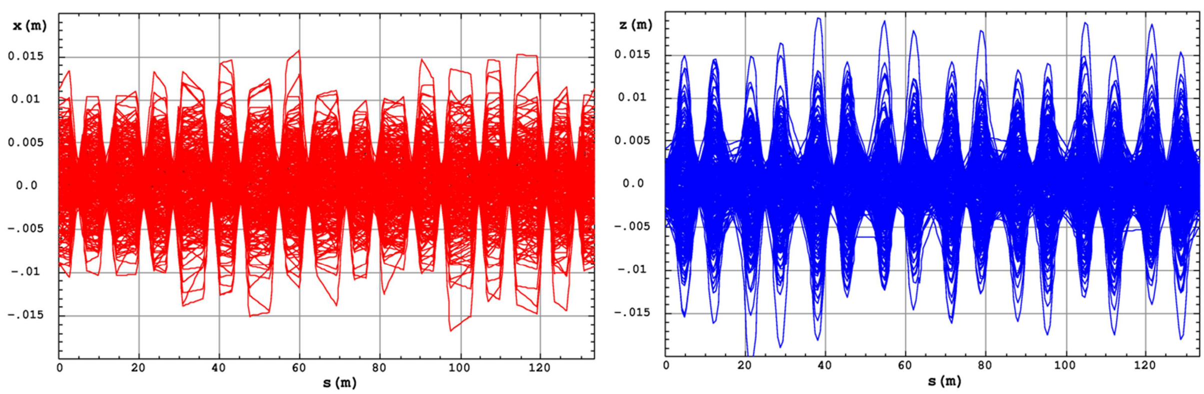

Figure 3: Horizontal (left) and vertical (right) orbit distortions of 300 tracking samples using misalignments of Table 2 in addition to dipole field error ΔB/B = 1e-3.

The optical disturbances resulted from Table 2 tolerances, using 300 tracked samples, are listed in Table 3.

Optical parameter	**Peak-to-peak deviation**
Hor. beta function β_x	2.2 %
Ver. beta function β_y	2.2 %
Hor. dispersion η_x	200%
Tunes (Qx , Q_y)	0.005, 0.005
Coupling	9.8 % (rms)

Table 3: The statistical optical disturbance due to tolerances of Table 2.

Although the dispersion is critically affected nevertheless the dynamic aperture is still acceptable due to the low sextupole strengths (it is worth to remind that dynamic aperture calculations in this case didn't take into account the high order multipole errors). Figure 4 shows the resulted different optical disturbances.

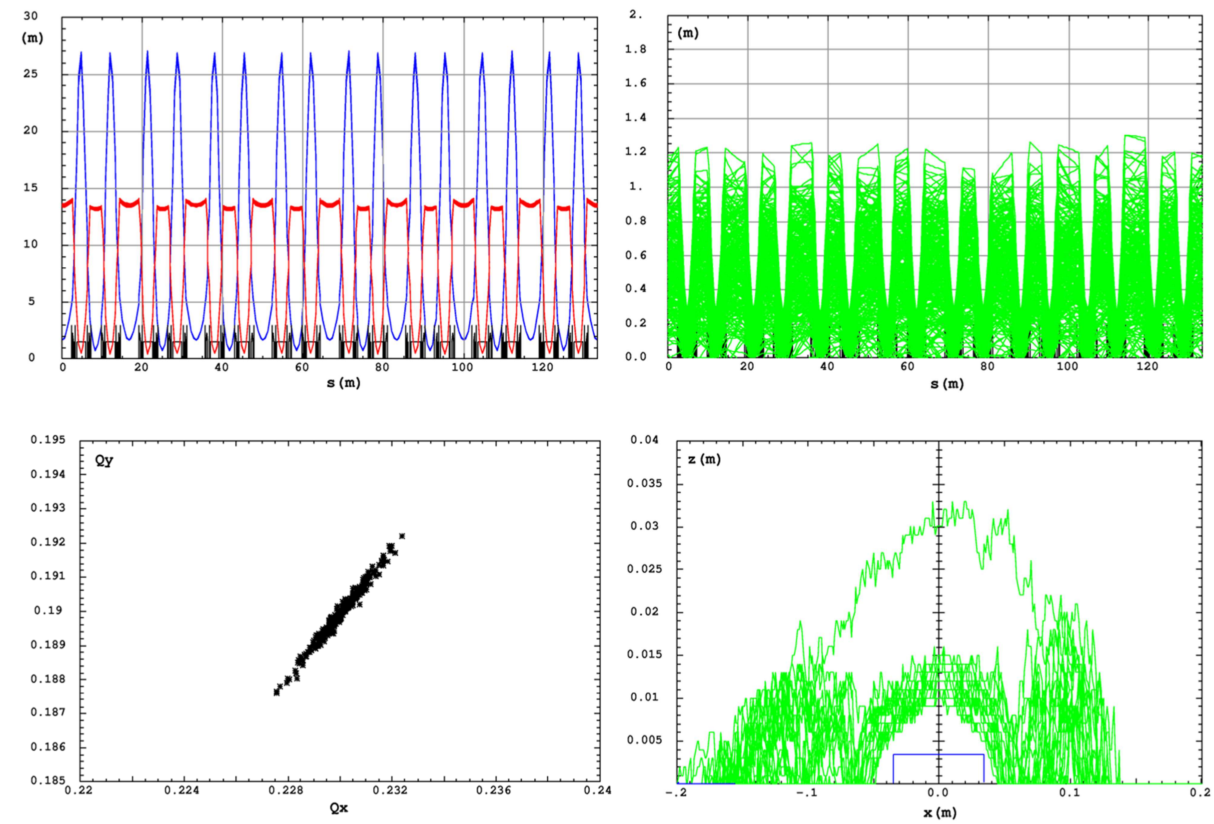

Figure 4: optical disturbances due to Table 2 errors. (Top-left) optical functions with β_x in red and β_y in blue, (top-right) horizontal dispersion, (bottom-left) tunes and (bottom-right) dynamic aperture, with chamber limitations shown in blue.

It can be noticed that Table 2 errors are critical from orbit distortion point of view and not from optics point of view. The rms strength of correctors required to correct the orbit distortion is ~ 0.3 mrad (using 64 correctors and 64 BPMs), while the maximum kick given by correctors is 0.5 mrad. The need for other tasks from correctors (in addition to orbit correction) like creating orbit bumps in Insertion Devices straight sections should not be neglected.

References

[1] BETA, J. Payet. CEA/DSM/ Irfu/ SACM, ftp:// ftp.cea.fr/incoming/y2k01/beta/.

[2] A. Terebilo, SLAC-PUB-8732.