LATTICE STUDIES FOR THE MAX-IV STORAGE RING

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Abstract

The lattice for the future MAX-IV storage rings at MAX-Lab has been studied. The MAX IV facility consists of two similar rings operated at 1.5 GeV and 3 GeV electron energies. The ring consists of 12 supercells each built up by 5 unit cells and matching sections.

The high periodicity of the lattice combined with the high gradients in the small gap dipole magnets yield a small emittance of 1 nm.rad with good dynamic aperture and momentum acceptance [1]. In the matching section, soft end dipole magnet is introduced to reduce the synchrotron radiation power hitting the upstream straight section [2].

In this paper we present part of the cure to the resistive wall related instabilities by over compensation of the chromaticities. Also the closed orbit correction scheme used to compensate for the magnet elements errors is studied.

MAX-IV LATTICE EVOLUTION

The MAX-IV lattice is designed to take advantage of the features of small gap and short period superconducting undulators. This opens the possibility for using small magnet aperture with strong multipoles and hence keeping the ring circumference short with very small emittance.

The original lattice [1] was with high bending field in the matching magnet which constitutes rather high heat load on the upstream superconducting insertion device. The matching section is modified by introducing a soft end bending magnet with 0.2 T [2] in order to minimize the synchrotron radiation power hitting the SC insertion devices.

The principal parameters for the latest lattice are given in Table 1.

Table 1: MAX-IV lattice parameters.

Energy [GeV]	3
Number of cells	12
Circumference [m]	287.2
ID straight length [m]	4.6
Hor. Emittance [nm rad]	1.3
Coupling [κ]	1 %
Tunes *Qx, Qy*	26.59, 9.184
Natural chromaticity ξ_x , ξ_y	-32.7,-30.3
Momentum compaction α	0.000745
Dynamic aperture *Ax, Ay* [mm]	±17, ±10

MAX-IV NONLINEAR OPTICS

The strong sextupoles required to correct the high chromaticity make the MAX-IV lattice a strongly nonlinear system. A large dynamic aperture is required both for injection efficiency and for a good Touschek lifetime. This requires proper technique for cancellation of the geometric aberration and minimizing the higher order chromaticities.

An investigation of the resistive wall instability driven by the small gap ID's has been made. The impact of the their high impedance budget can be minimized by correcting the natural chromaticities to $\xi_{x/y}=\Delta\upsilon_{x/y}/(\Delta p/p)=+2/+2$ [3]. The reason for the low positive chromaticities needed is mainly the very small momentum compaction achieved in the lattice $\alpha = 7.45\times10^{-4}$ and the long bunch achieved $\sigma_l = 5$cm by the low RF system, 100 MHz with 5th harmonic passive cavity, which is foreseen for MAX-IV storage rings [4]. The long bunches limits the power spectrum of transverse coherent oscillations of the beam (rigid bunch oscillation). The frequency shift of the spectrum is given by $\xi_{x/y}/\alpha$. The result is that we have almost no power at negative frequencies which drive the instability. The power spectrum is shifted toward positive frequencies which acts damping [3].

Achieving large momentum acceptance is an essential feature in order to minimise the Touschek losses. The study of the dynamic aperture of the off-momentum particle has shown that keeping the vertical sextupoles in 4 families was necessary for non linear optimisations, i.e. minimizing the driving terms of the 3rd order resonance induced by the strong sextupoles. The dynamic apertures for the off-momentum particles are shown in Fig.1

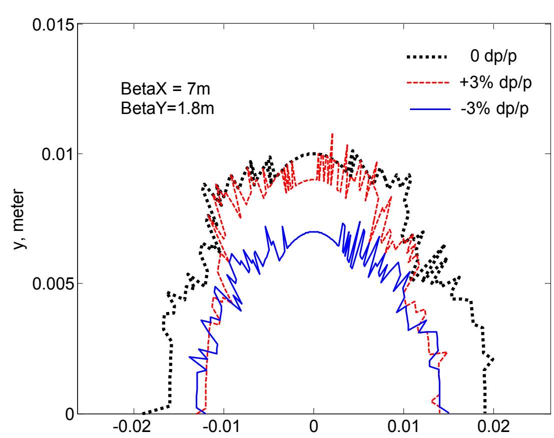

Figure.1 : Dynamic aperture for off-momentum particles.

It is of most importance that the tune of the off-momentum particles doesn't cross any destructive resonance. Also the tune shift with amplitude is important. With the achieved scheme of the sextupole settings, the tune shift with momentum deviation is seen in Fig.2

The tune shift with amplitude, Fig.3, has been corrected by introducing an octupole component in the foucusing quadrupole of the main cell. The octupole field has the effect of minimizing the geometric aberration induced by the strong sextupoles [5]. In this way we can avoid using harmonic sextupoles in the dispersion-free sections for space reasons. The impact of the octupole field on the dynamic aperture is seen in Fig.4

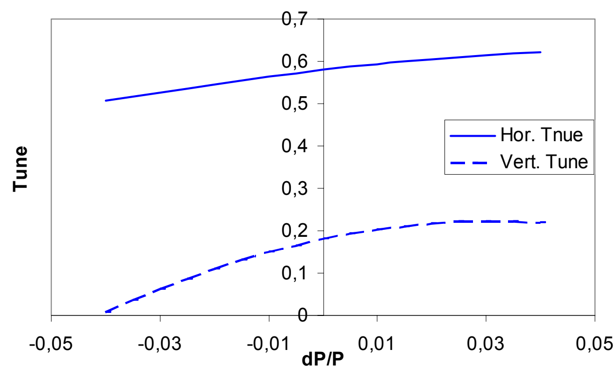

Figure 2 : Tune shift with energy deviation.

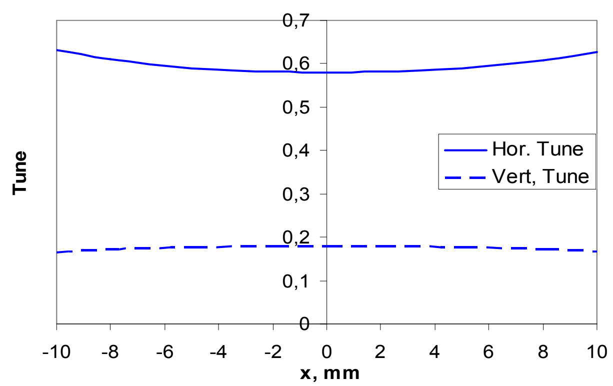

Figure 3 : Tune shift with energy deviation.

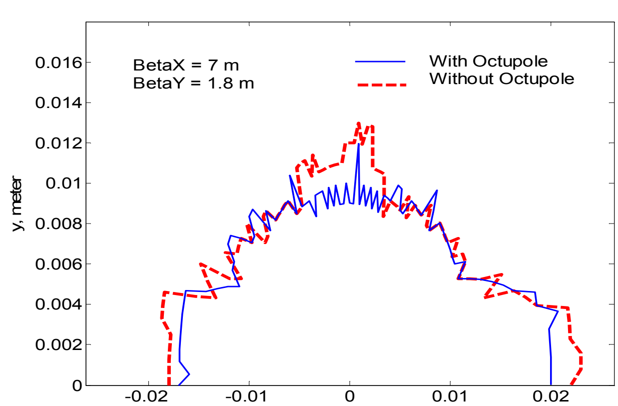

Figure 4 : Impact of the octupole field on the dynamic aperture.

INSERTION DEVICES EFFECT

In order to investigate the effect of insertion devices on the dynamic aperture, two SC wigglers of MAX-II type [6] and 6 SC undulators [7] were introduced into the lattice. The parameters for these ID's are found in Table.2.

Table 2 : MAX-IV ID's (wigglers for 3 GeV)

	K-value	λ (mm)	No. of Period
SC Undulator	2.2	14	200
SC Wiggler	20	60	35

The undesirable effects of the IDs like vertical tune shift and beta beating, which depend on the length and the magnetic field of the ID as well as on β_z in the ID section, were reduced by the low value of β_z (≈1.8m) in the IDs straight sections and zero dispersion. The compensation for the ID's was mainly made by the flanking quadrupole doublet and partly by the gradient in the MAX-III type dipoles [8]. The pole face windings are used to change gradient up to 10%. The impact of the ID's on the dynamic aperture is shown in Fig.5.

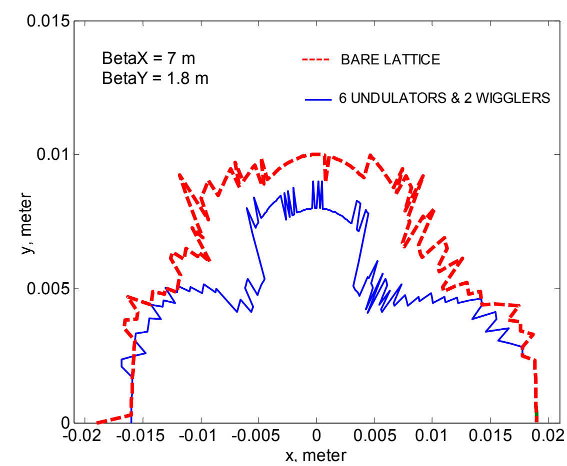

Figure 5 : Impact of the ID's on the dynamic aperture.

CLOSED ORBIT CORRECTION SCHEME

The closed orbit correction scheme proposed for the MAX-IV lattice consists of using 14 BPM's per supercell and 14 correctors (12 in-sextupole correctors). The magnet misalignment errors introduced to the lattice with the corresponding amplification factors are given in Table.3. After the closed orbit distortion has been corrected, the residual closed orbit distortion cause a coupling of $\kappa = 3.3\ .10^{-3}$ in the ring

Table 3 : Magnet misalignments introduced to the MAX-IV lattice.

	RMS value of error	Amplification factor A_x, A_z
Dipole	Field error = 5.10^{-4}	
	Displacement dx = dz = ds = 0.15 mm	7.5 / 28.5
	Rotation around s ($d\varphi_s$) = 0.2 mrad	
Quadrupole	Displacement dx = dz = 0.1 mm	15.3 / 28.9

CONCLUSIONS

Our results suggest that the MAX-IV lattice is able to provide a good dynamic aperture after the successfully applied nonlinear optimization. The effect of the insertion devices could be compensated mainly by using a local matching scheme. The closed orbit distortion has been corrected with different type of errors in the lattice.

The proposed correction scheme for closed orbit distortion provide rather stable beam with different type of errors in the lattice and shows that great care must be taken for the magnet alignment because of their high strengths.

More work on 6D tracking is needed mainly to explore the effect of the higher order momentum compactions on the longitudinal acceptance of the MAX-IV lattice.

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