Updates to the MAX IV 3 GeV Storage Ring Lattice

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Abstract

The MAV IV DDR [1] chapters on the linear and nonlinear optics (Sections 2.2 and 2.3) of the 3 GeV storage ring have been based on the 20090601 lattice. Recently, the 3 GeV storage ring lattice has however been updated and the new 20090901 lattice has been made available [2]. This note details the changes made and summarizes differences between the two lattice versions. Since the changes are minor, most of the information given and the conclusions drawn from it in the DDR remain valid.

1 Summary of the Changes in the new Lattice

For the new 20090901 lattice two main changes were made compared to the previously used 20090601 lattice:

- Instead of eight BPM/corrector pairs in the achromat, there are now ten pairs. The position of the BPMs and correctors has also been changed.
- The model for the 1.5° bending magnet in the matching section (DIPm) uses a different slicing. The integrated field strength remains, but the length has changed very slightly and the gradient profile has been modified.

The first point has sever implications on the DDR chapter on errors and correction (Section 2.4). Hence, this chapter will be updated to reflect the new BPM/corrector layout. This document will however focus on the second point. The next section

[1]This document can be found at: `http://www.maxlab.lu.se/node/999`

will detail the changes to the DIPm magnet. The final section will describe what influence these changes have on the linear and nonlinear optics.

2 The Updated Model for the DIPm Magnet

For technical reasons the field and gradient profile in the soft-end part of the 1.5° bending magnet DIPm have been modified [3]. The dipole field strength and gradient in the remainder of the magnet remain unchanged and hence idetical to the 3° main dipole DIP. The length of the main slice Dm0 has also been changed, albeit very slightly ($\Delta l = -0.08$ mm). Table 1 shows the parameters for the new slicing in the soft-end part of DIPm. This can be directly compared to Table 2 in Section 3.2 of the DDR.

Table 1: Parameters for the slices used to model the soft-end part of the 1.5° bending magnets DIPm in the matching section of the MAX IV 3 GeV storage ring achromat.

Slice	Dipole Field [T]	Gradient [T/m]	Length [mm]	Bend Angle [°]
Dm0	0.523600	−8.668740	204.24	0.612721
s1	0.520683	−8.562347	50.00	0.149165
s2	0.406663	−6.082495	50.00	0.116500
s3	0.269543	−4.299814	50.00	0.077218
s4	0.259229	−4.234943	50.00	0.074264
s5	0.186970	−2.932271	50.00	0.053563
s6	0.007738	−0.005164	50.00	0.002217

The different main field and focusing gradient profiles are shown in Fig. 1. The integrated dipole field is the same for the new and old DIPm which gives the same bending angle. The focusing gradient in the new DIPm has however increased by 3.1% over the previous design.

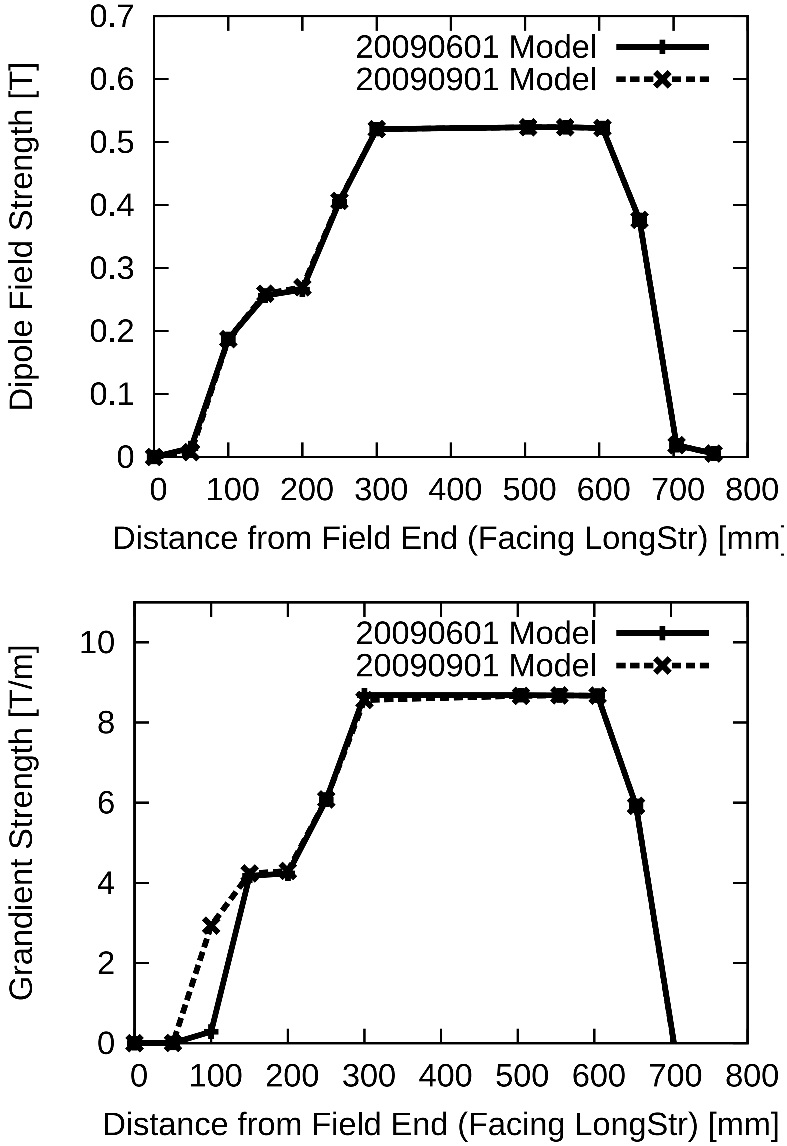

Figure 1: Main dipole field and gradient field profiles for the 1.5° bending magnet DIPm according to the model used in previous lattice 20090601 and the new lattice 20090901.

3 Effect of the Updated Model on the Optics

The new DIPm slicing, because of the different focusing gradient has an influence on the linear and nonlinear optics. Both will be summarized in this section.

3.1 Effect on the Linear Optics

The slightly increased focusing gradient of the new DIPm changes has shifted the working point and changed the beam size as well as the dispersion in the long straight section. All these changes have been compensated in the updated lattice 20090901.

- The dispersion in the long straight section (η_x^*) is restored to zero by adjusting the QFm family.
- The beam size in the long straight is restored by adjusting the QFend and QDend magnets in the matching section until the original beta functions at the center of the long straight ($\beta_{x,y}^*$) have been restored.
- The working point is restored by changing the quadrupole gradients in the achromat; the focusing gradients are determined by the QF family while the defocusing gradients are integrated into the dipole magnets).

Since all dipole magnets are to be connected in series, corrections to the defocusing gradient in the dipoles should be applied equally to both the DIP and DIPm magnets. In the real machine this is done by powering the pole-face windings in the dipoles. In the model it is achieved by scaling all dipole gradients with a common factor f_{QD}.
All these corrections have been applied in the above order and iterated until all conditions have been entirely fulfilled. A summary of the applied changes is given in Table 2.

Table 2: Changes applied to the new lattice with the updated DIPm magnet to restore the linear optics.

Family	Strength			Relative Change
QFm	$k_{\text{QFm}} = 3.779556$	$\longrightarrow$	3.779900	+0.01%
QFend	$k_{\text{QFend}} = 3.533676$	$\longrightarrow$	3.521817	−0.3%
QDend	$k_{\text{QDend}} = -2.239578$	$\longrightarrow$	−2.176206	−2.8%
Dipole Gradients	$f_{\text{QD}} = 1.0$	$\longrightarrow$	1.001293	+0.13%
QF	$k_{\text{QF}} = 4.037809$	$\longrightarrow$	4.037860	+0.001%

Other lattice parameters like emittance ε_x, momentum compaction α_c, radiated power, and damping times have not changed compared to the previous 20090601 lattice.

3.2 Effect on the Nonlinear Optics

Since the resulting changes to the linear optics are very small, only minor differences in the nonlinear optics are to be expected. For the bare lattice (the nonlinear optics used for the bare lattice are the 410 optics) this turns out to be the case as can be seen from the OPA [4] results displayed in Table 3.

Table 3: Nonlinear optics results as calculated by OPA for the updated 20090901 bare lattice using the previous 410 nonlinear optics. Driving terms for the amplitude-dependent tune shift (ADTS) are specified using dimensionless OPA notation.

Effect		OPA result	410 Target	Rel. Difference
Linear Chromaticity	ξ_x	0.99	1.00	−1.0%
	ξ_y	0.98	1.00	−2.0%
ADTS Driving Terms	dQ_{xx}	862.53	700.00	+23.2%
	dQ_{xy}	2451.80	2300.00	+6.6%
	dQ_{yy}	1964.37	2000.00	−1.8%

OPA has been used to find new sextupole and octupole settings to restore the above results to the target values for the 410 nonlinear optics. The SD and SFi families have been used to restore the linear chromaticity while an SVD fit has been used to find new values for the OXX, OXY, and OYY octupoles in order to achive the desired driving terms for ADTS. A summary of the required adjustments is given in Table 4.

The required changes on the sextupoles are very small. Neither the linear chromaticity nor the overall chromatic footprint show any significant changes due to the change of linear optics. Although the driving terms for the ADTS show a more substantial change after applying the new linear optics, the required octupole changes as well as the effect on the tune footprint for amplitude excursions remain very small. It os therefore not considered necessary to re-optimize the nonlinear optics for the updated linear lattice. Although this could be done, it is to be expected that changes applied to the real machine during commissioning will be larger than any of the nonlinear adjustments proposed here.

Table 4: Changes applied to the sextupoles and octupoles to achieve the 410 nonlinear optics target values with the new 20090901 linear lattice.

Family		Strength		Relative Change
SD	$-117.918877\ m^{-2}$	$\longrightarrow$	$-117.927999\ m^{-2}$	+0.008%
SDend		$-134\ m^{-2}$		—
SFi	$214.767155\ m^{-2}$	$\longrightarrow$	$214.699166\ m^{-2}$	−0.03%
SFo		$170\ m^{-2}$		—
SFm		$160\ m^{-2}$		—
OXX	$-131.4266\ m^{-3}$	$\longrightarrow$	$-133.3394\ m^{-3}$	+1.5%
OXY	$218.1429\ m^{-3}$	$\longrightarrow$	$220.6994\ m^{-3}$	+1.2%
OYY	$-68.8567\ m^{-3}$	$\longrightarrow$	$-69.5010\ m^{-3}$	+0.9%

Therefore, for further bare lattice studies the lattice will be modeled with the new 20090901 linear optics but retaining the previous 410 nonlinear settings. The new bare lattice is thus labeled accordingly: 20090901-410.
It is assumed that the same conclusion will hold for the lattice with damping wigglers (411 nonlinear optics) and for the "loaded" lattice (412 nonlinear optics), but a final conclusion will have to be delayed until time is found to complete detailed studies.

References

[1] The MAX IV Detailed Design Report, available at `http://www.maxlab.lu.se/node/1136`

[2] The updated lattice can be found at `http://www.maxlab.lu.se/node/999`

[3] Lars-Johan Lindgren, private communication.

[4] OPA Lattice Design Code, available at `http://people.web.psi.ch/streun/opa/`