MAX IV Emittance Reduction and Brightness Improvement

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In a Nutshell

• MAX IV 3 GeV storage ring commissioning to start July 2015 and design parameters should be achieved by June 2017.

• For the following period 2017–2026, MAX IV Strategic Plan sets several upgrade goals; most important are brightness improvements and a more flexible timing structure.

• Brightness improvements shall be achieved through coupling reduction, better matching of straight section optics to IDs, and an upgraded optics with lower lattice emittance.

• We present a first upgrade candidate that allows for a 33% brightness increase without requiring new power supplies or recabling magnets.

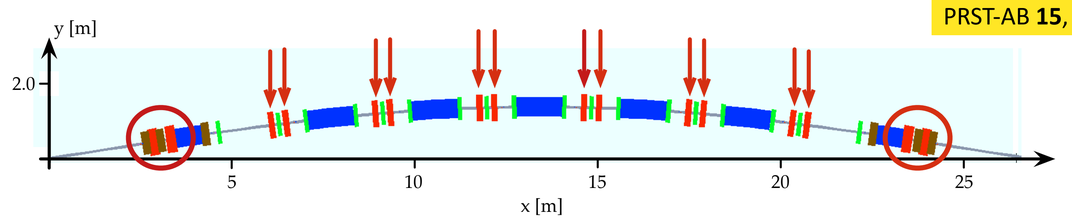
Strategy & Limitations

• Define three stages of optics upgrade: 1) modifications that do not require new power supplies or recabling, 2) allow exchange of magnet power supplies, 3) allow recabling of magnets so existing families can be split.

• This study deals with the first stage: modify strengths of existing quadrupole families in arcs and ID straights within power supply limits.

• DA requirements are considered unchanged since injection scheme shall be retained.

PRST-AB **15**, 050705 (2012)



One achromat of the MAX IV 3 GeV storage ring. Quadrupoles indicated in red. Quadrupole doublets in the straights (circles) and horizontally focusing quadrupoles in the arcs (arrows) are highlighted.

MAX IV 3 GeV Storage Ring

Aerial photograph of the MAX IV site taken on May 15, 2014 (courtesy P. Nordeng).

• Recently: linac beam commissioning commenced.

• July 2014: 3 GeV storage ring building construction completed; immediately followed by start of installations.

• July 2015: 3 GeV storage ring beam commissioning starts.

• June 21, 2016: inauguration of the MAX IV facility.

• June 2017: 3 GeV storage ring post-commissioning activities completed; design parameters achieved.

Optics

PRST-AB **12**, 120701 (2009)

PRST-AB **14**, 030701 (2011)

• Increased focusing strength in the arc quadrupoles ➞ reduced arc dispersion ➞ lattice emittance reduced from 328 pm rad (design) to ≈270 pm rad.

• Vertical beta function in the ID straights can be lowered to 50% (or less) of its 2 m design value by retuning the quadrupole doublets in the ID straights ➞ pay attention to peak value in the matching cell dipoles (limits vertical acceptance, increases natural vertical chromaticity).

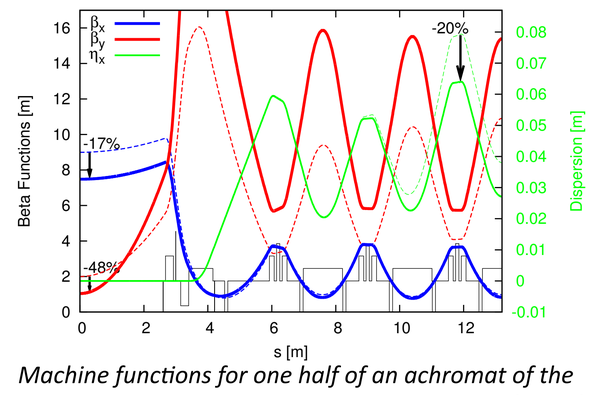
• Horizontal beta function in the ID straights can be lowered to 7–8 m without spoiling DA and hence injection efficiency.

• So far, reasonable DA achieved for candidates where the vertical beta function in the ID straights remains above 1 m while limiting the horizontal beta function reduction to ≈7.5 m.

• Adjustments with the PFSs in the dipoles (allowing +/- 4% overall tuning of the vertical focusing gradient) have so far not been required.

• Peak dispersion reduced by 20% ➞ 18% reduction of emittance.

• Reduction of dispersion ➞ reduction of momentum compaction ➞ increase of RF acceptance ➞ improved Touschek lifetime (in addition to Touschek lifetime growth from emittance reduction!).



Machine functions for one half of an achromat of the MAX IV 3 GeV storage ring. Design optics are indicated with dashed lines, solid lines indicate modified optics.

	Design	Upgrade
ε_0 (bare lattice)	328 pm rad	269 pm rad
ν_x, ν_y	42.20, 16.28	44.20, 14.28
ξ_x, ξ_y (natural)	−50.0, −50.2	−50.7, −76.5
J_x	1.847	1.719
σ_δ (natural)	7.69×10^{-4}	7.29×10^{-4}
α_c (linear)	3.06×10^{-4}	2.60×10^{-4}

	Required Norm. Gradient		
Family	Design	Upgrade	Rel. Change
QF	$4.030\,\mathrm{m}^{-2}$	$4.296\,\mathrm{m}^{-2}$	+6.6%
QFm	$3.774\,\mathrm{m}^{-2}$	$3.781\,\mathrm{m}^{-2}$	+0.2%
QFend	$3.654\,\mathrm{m}^{-2}$	$3.700\,\mathrm{m}^{-2}$	+1.3%
QDend	$-2.504\,\mathrm{m}^{-2}$	$-2.562\,\mathrm{m}^{-2}$	+2.3%
SFi	$207.4\,\mathrm{m}^{-3}$	$211.8\,\mathrm{m}^{-3}$	+2.1%
SFo	$174.0\,\mathrm{m}^{-3}$	$190.0\,\mathrm{m}^{-3}$	+9.2%
SFm	$170.0\,\mathrm{m}^{-3}$	$190.0\,\mathrm{m}^{-3}$	+11.8%
SD	$-116.6\,\mathrm{m}^{-3}$	$-129.9\,\mathrm{m}^{-3}$	+11.4%
SDend	$-170.0\,\mathrm{m}^{-3}$	$-160.0\,\mathrm{m}^{-3}$	−5.9%
OXX	$-1649\,\mathrm{m}^{-4}$	$-3141\,\mathrm{m}^{-4}$	+90.5%
OXY	$3270\,\mathrm{m}^{-4}$	$2410\,\mathrm{m}^{-4}$	−26.3%
OYY	$-1420\,\mathrm{m}^{-4}$	$-944.2\,\mathrm{m}^{-4}$	−33.5%

Results

• Lattice emittance has been reduced to 269 pm rad (-18%) while matching of the straight section optics to IDs has been improved.

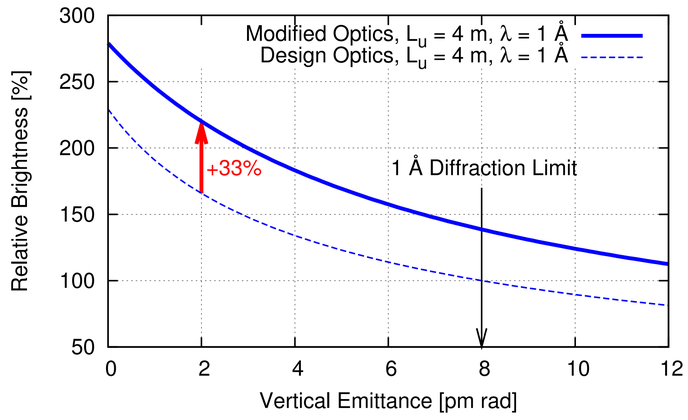
• Resulting optics shows DA that is both compatible with existing injection scheme and gives sufficient Touschek lifetime.

• The overall result is a 33% increase of brightness without requiring any new power supplies or recabling of magnets.

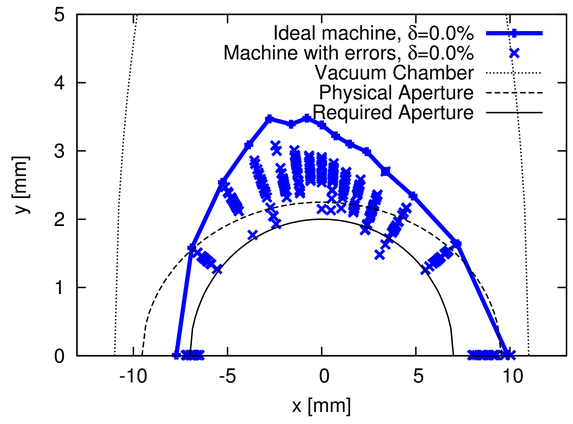
• Emittance blow-up from IBS at 500 mA stored current (5 nC per bunch) will be strong; will necessitate bunch lengthening from harmonic Landau cavities. PRST-AB **17**, 050705 (2014)

• Can expect Landau cavities and IDs to result in equilibrium emittance below 250 pm rad even at 500 mA stored current.

• Future studies will focus on nonlinear optics improvements and a further reduction of lattice emittance.



Brightness increase (at 1 Å) from the modified optics compared to the design optics for different settings of emittance coupling in the MAX IV 3 GeV storage ring.



Bare lattice on-momentum DA for the modified optics. Solid line indicates ideal DA while crosses correspond to 20 error seeds incl. misalignments and magnet errors.

MAX IV Project → http://www.maxlab.lu.se/maxiv