HYBRID MULTI BEND ACHROMAT AT 3 GEV FOR FUTURE 4TH GENERATION LIGHT SOURCES

S.M. Liuzzo, D. Einfeld, L. Farvacque, P. Raimondi, ESRF, Grenoble, France

Abstract

Starting from the Hybrid Multi Bend Achromat (HMBA) lattice designed for the 6 GeV ESRF-EBS we rescale the lattice energy to 3 GeV and optimize the lattice parameters to achieve dynamic apertures sufficient for injection and lifetimes of more than 7 h without errors. The rescaling results to an emittance of roughly 140 pmrad. Further optimizations of bending magnets longitudinal gradient, optics and sextupole fields show the possibility to further decrease emittance and increase the DA and lifetime. A comparison with other lattice designs is also presented.

INTRODUCTION

The frontier for next generation light sources resides in ever smaller emittances, eventually reaching the diffraction limit (about 10 pmrad for a wavelength of 10 Å or 1.2 keV). The evolution of storage ring lattice cells to achieve this ultimate result is very well represented in lattice cells like the multibend achromat (MBA) of MAXIV [1], the hybrid multi bend acrhomat (HMBA) of the ESRF-EBS [2], and other projects [3–6]. This lattices exploit strong gradient quadrupole and sextupoles to achieve emittances of few hundreds pmrad. In this paper we show the rescaling of the ESRF-EBS lattice cell to 3 GeV and a circumference of about 500 m, which are used also for other light sources. The lattice presents some interesting simplifications compared to the ESRF-EBS design: lower gradients, larger space between magnets, no octupoles. In the following it is shown how the cell has been tuned and optimized to achieve a solution technically realizable. The impact of longitudinal gradient dipoles is also addressed.

CELL DESCRIPTION

The layout of the HMBA cell is depicted in Fig. 1. The magnets fields and gradients are reported in Table 1. All the features of the ESRF-EBS lattice cell are conserved: high beta and dispersion at the sextupoles, $-\mathcal{I}$ transformation between sextupoles, combined function magnets to exchange partition number from longitudinal to horizontal. This allow for an easier tuning of lifetimes and dynamic apertures, thanks to the experience gained with the ESRF-EBS lattice.

OPTIMIZATIONS

A slow but rewarding iterative process of optimization led to the lattice presented in this paper. The key optics knobs used to improve dynamic aperture and lifetimes are: horizontal beta at the center of the straight section (ID), beta, alpha, and dispersion at the sextupoles (SF), tunes, phase advance between sextupoles and sextupole fields. As an example, Fig. 2 was used to determine the optimal value

Table 1: Magnets Lengths and Fields for the 3GeV HMBA

name	L [m]	$B_0\,[T]$	$b_2\,[T/m]$	$b_3\,[T/m^2]$
QF1	0.200		42.8	
QD2	0.150		-36.8	
DL1	0.185×5	0.575-0.431		
QD3	0.150		-32.2	
SD1	0.166			-792.0
QF4	0.212		31.5	
SF2	0.200			777.1
SD2	0.166			-911.1
QD5	0.200		-41.5	
DL2	0.185×5	0.431-0.575		
QF6	0.388		55.7	
DQ1	0.679	0.562	-29.0	
QF8	0.484		48.5	
DQ2	0.580	0.400	-25.3	

of horizontal beta at the ID. Considering that larger beta functions at the ID would increase the effective beam size at the ID ($\sigma \cdot \sigma'$), $\beta_x = 7.1\,m$ is an appropriate choice, with high lifetime and a non degraded dynamic aperture.

Similar observations are done for all the parameters of interest, and often the choice is not obvious. Also the tune variation with transverse amplitudes and with momentum are observed during this empiric optimization process.

Dipole fields

The seven dipole magnets in the lattice cell have been optimized both in field and length, keeping the total angle constant and the above mentioned matching knobs fixed to their optimal values [7].

The introduction of a longitudinal gradient in the DL dipoles allowed to reduce the emittance and increase the dispersion at the sextupoles, thus reducing their strength. Figure 3 shows this effect. The longitudinal gradient in the DL is defined by a linear decrease of the field $B_{DL}(s) = B_0 + A \cdot s$, where s is the position of the five DL slices. For each linear slope A of the DL field, the dipole fields of the whole cell have been optimized for a minimum effective emittance at the ID. For $A = 0.25$ the emittance is reduced by 20 pmrad and the dispersion at the SF sextupoles is increased by 5 %.

Similarly, Fig. 4 shows the variation of effective emittance and dispersion at the SF sextupoles when changing the length of the DQ dipoles. The total cell length is kept constant using the drift spaces between the sextupoles SF and SD. When the length of the DQ magnets is increased by $0.05\,m$ the

Copyright © 2016 CC-BY-3.0 and by the respective authors

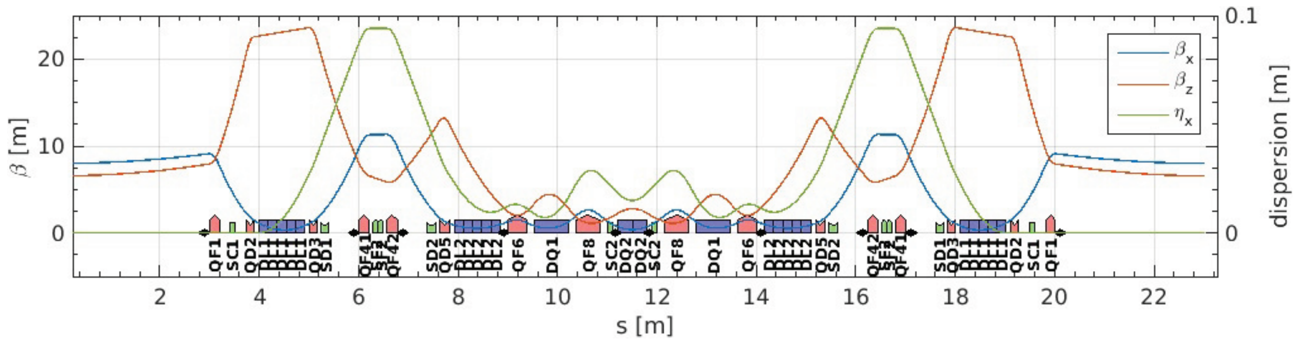

Figure 1: Cell optics, layout and naming convention.

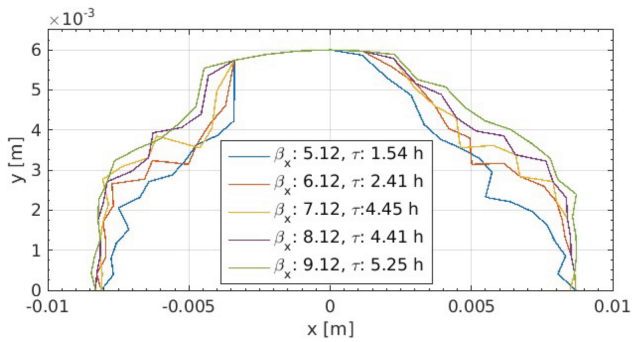

Figure 2: Example of figure to determine the optimal β_x in the straigth sections.

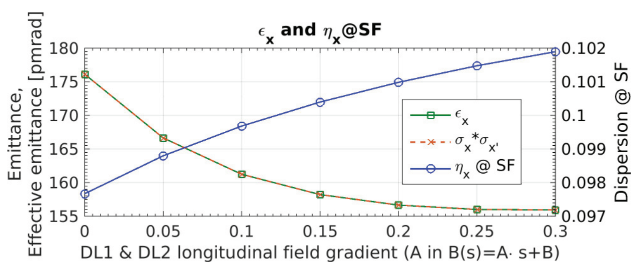

Figure 3: Emittance and dispersion at the sextupole as a function of the linear slope of the field in the DL dipoles.

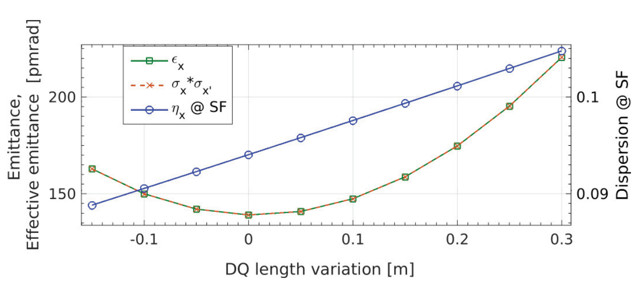

Figure 4: Emittance and dispersion at the sextupole as a function changing the DQ dipoles length.

dispersion at the sextupoles is increased with a small effect on the horizontal emittance.

The achromatic condition is kept true in the HMBA cell shown. However breaking this condition is a widely used technique to reduce the horizontal emittance. Figure 5 shows

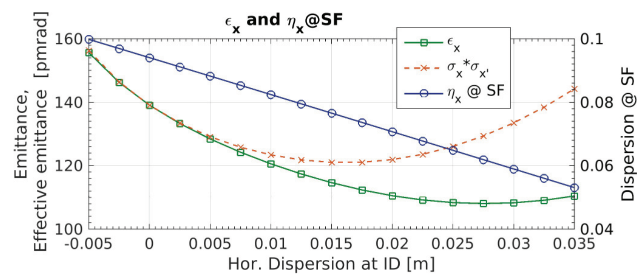

Figure 5: Emittance and dispersion at the sextupole as a function of the dispersion at the ID.

this effect and its consequences on the dispersion at the sextupoles.

Tune working point scan

The tune has been changed in a range of three units in both planes keeping all other key optics parameters constant. Small errors of alignment (5 µm) and field integral ($10^{-4} \cdot K_n$) are added in the lattice and no correction is performed. With these errors the rms orbit is 150 µm in the horizontal plane and 400 µm in the vertical, the rms beta-beating is 10% in both planes and dispersion deviation 5 mm in the horizontal plane and 2 mm in the vertical. Figure 6 shows the variation with tunes of Touschek lifetime and of the dynamic aperture most negative extreme (injection from inside the ring). An optimal working point is found at (53.59, 15.43). To compute Touschek lifetime we assume the parameters listed in Table 2, an RF voltage of 1.6 MV, 5 pmrad vertical emittance, a beam current of 200 mA, an effective impedance of 0.7 Ω for the potential well bunch lengthening and a filling of 518 over 588 contiguous buckets. A more appropriate simulation including several error seeds, a full correction sequence and spanning over more tune units can be developed as done in [8].

DYNAMIC APERTURE AND LIFETIME

Figure 7 compares the dynamic apertures at the ID with that of the ESRF-EBS upgrade lattice version S28C [2]. The dynamic apertures are rescaled to the same beta functions: $\beta_x = 8\,m$ and $\beta_y = 7\,m$ while the horizontal emittances differ only by a few pmrad ($\epsilon_{x,EBS} = 135\,pmrad$). The lifetime without errors is estimated to 9.4 h for the optimized

Copyright © 2016 CC-BY-3.0 and by the respective authors

ISBN 978-3-95450-147-2

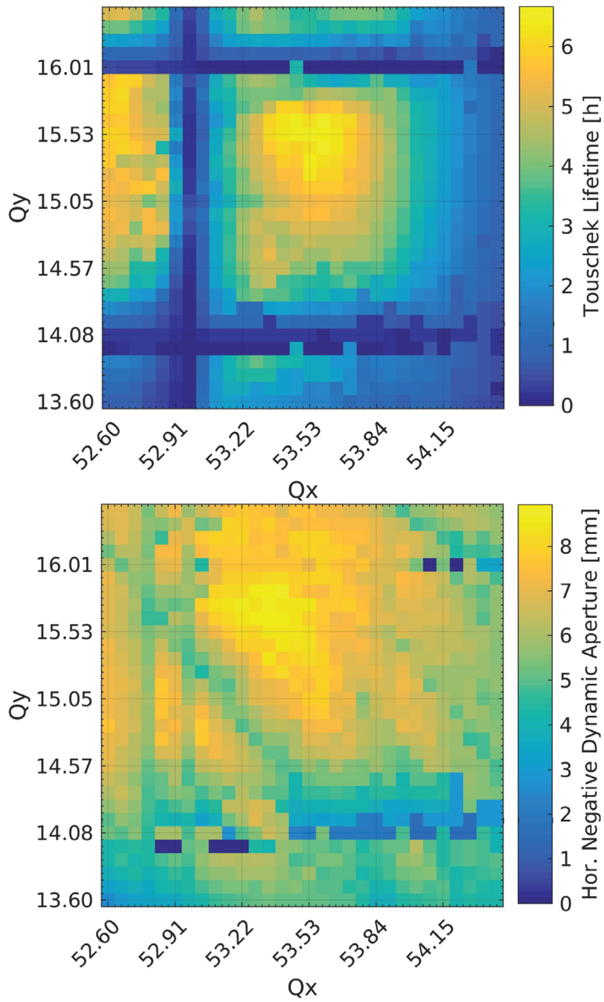

Figure 6: Touschek lifetime and dynamic aperture at straight section center versus tune working point scan. Tracking for 1024 turns, with RF and radiation.

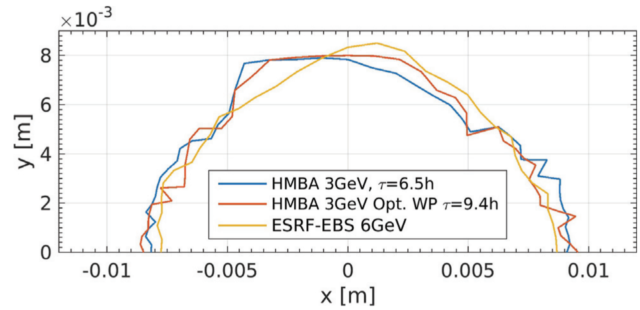

Figure 7: Dynamic aperture at the straight sections center for the ESRF-EBS and the HMBA@3GeV.

working point and 6.5 h for the initial one, showing a net improvement.

Table 2: Lattice Parameters for 3 GeV Storage Rings

	MAXIV [1]	Sirius [3]	DTBA [4]	HMBA	SSRFU [5]
circ. m	528	518.4	561	506	432
# cells	20	20	24	22	20
ϵ_x pmrad	330	280	100	140	203
J_x	1.8	1.31	1.38	1.42	2
Q_x	42.24	44.60	57.20	54.59	43.22
Q_y	16.27	12.40	20.30	15.43	17.31
natural ξ_x	-50.0	-113.3	-105.5	-87.5	-74.2
natural ξ_y	-50.2	-80.2	-78.8	-70.8	-59.3
Drift m	4.728	7.02	8.1	5.8	5.6
Drift %	17.9	27.1	34.7	25.2	25.9
Drift /ϵ_x	54	97	347	179	128

CONCLUSIONS

The investigation of the HMBA Lattice for a 3 GeV storage ring with a circumference of roughly 500 m results in an emittance of 140 pmrad. The beam dynamics results for the 3 GeV HMBA lattice are similar to the ESRF-EBS. The requirements of the magnets are relaxed in comparison to the ESRF-EBS design. Overall, the HMBA lattice is a very good candidate for a synchrotron light source. This has some advantages if compared to the MBA lattice used for MAX IV with an emittance of 330 pmrad. At present there are some investigations for an upgrade at other light sources, like the double triple bend acrhomat (DTBA) lattice at Diamond [4] and the upgrade of the Shanghai synchrotron radiation facility (SSRF-U) [5]. The main lattice parameters are summarized in Table 2. MAXIV, Sirius [3] and SSRF-U do not use, in comparison to HMBA and DTBA, a longitudinal gradient in the dipoles.

For the users there are two main parameters: 1) the emittance which determines the brilliance, 2) the percentage of the circumference dedicated to straight sections. A performance factor of the design is therefore: percentage of drift space / emittance. A high performance factor is in favor to the users, but other arguments, as for example the beam lifetime, must be considered.

ACKNOWLEDGMENT

All simulations are performed using AT [9] and the ASD OAR cluster. The authors wish to thank the ESRF computing group.

Copyright © 2016 CC-BY-3.0 and by the respective authors

REFERENCES

[1] M.Eriksson, et al., "Beam Commissioning of MAX-IV", MOYAA01, *These Proceedings*, IPAC'16, Busan, Korea (2016).

[2] J.C. Biasci, et al. , "A low emittance lattice for the ESRF", Synchrotron Radiation News, vol. 27, Iss.6, 2014.

[3] A.R.D. Rodrigues, et al., "Sirius accelerator status report", TUPWA006, *Proceedings of IPAC'15*, Richmond, Virginia,USA (2015).

[4] A. Alekou et al., "Study of the Double Triple Bend Achromat (DTBA) lattice for a 3 GeV light source", WEPOW044 , *These Proceedings*, IPAC'16, Busan, Korea (2016).

[5] S.Q. Tian et al, "Lattice design of the SSRF-U Storage ring", MOPJE009,*Proceedings of IPAC'15*, Richmond, Virginia,USA (2015).

[6] Low Emittance Rings Workshop, Barcellona, Spain, 2015.

[7] S.M. Liuzzo, "Optimization Studies and measurements for ultra low emittance lattices", Ph.D. Thesis, University of Roma Tor Vergata, Roma, Italy, 2013.

[8] S.M. Liuzzo et al., " Influence of Errors on the ESRF Upgrade Lattice", TUPWA014,*Proceedings of IPAC'15*, Richmond, Virginia,USA (2015).

[9] B. Nash et al., "New Functionality for Beam Dynamics in Accelerator Toolbox (AT)", MOPWA014 , *Proceedings of IPAC 15*, Richmond, Virginia,USA (2015).

Copyright © 2016 CC-BY-3.0 and by the respective authors

ISBN 978-3-95450-147-2