ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPMF009

LATTICE OPTIONS FOR DIAMOND-II

B. Singh[1], H. Ghasem[1], J. Bengtsson[1], A. Streun[2] and R. Bartolini[1,3]
[1]Diamond Light Source, Oxfordshire, UK
[2]SLS, PSI, Switzerland
[3]John Adams Institute for Accelerator Science, University of Oxford, Oxford, UK

Abstract

Generalized MBA (Multi-Bend-Achromat) Chasman-Green type lattices, with a low-dispersion mid-straight, have been studied and refined by pursuing a generalized Higher Order Achromat to control the non-linear dynamics to obtain a robust design. New lattice candidates have been produced aiming for a horizontal emittance of 150 pm rad for off-axis injection and 75 pm rad for on-axis injection, the latter making use of reverse bends. The results of these studies and evaluations have been summarized in this paper.

INTRODUCTION

Chasman-Green type lattices [1], i.e., 2nd order Achromats interspaced with straight sections, dates back to the first dedicated ring based synchrotron light sources, for which various incremental improvements have been pursued over the years. For DIAMOND [2] (dipoles without transverse gradients), after full deployment, an incremental upgrade was done that introduced/replaced one DB Cell (out of 24) with a double-DB & low-dispersion mid-straight cell (with transverse gradients) [3]. From this experience, further work inspired by ESRF-EBS, itself a hybridization of MAX-IV and SuperB (an e^+-e^- collider) [4], eventually, led to a Hybrid-6B (6HMBA) with a low dispersion mid-straight cell (with transverse and longitudinal gradients) as prototype lattice for DIAMOND-II [5] and it is optimized for off axis injection.

The Hybrid-8B (8HMBA) with low dispersion mid-straight cell (similar to Hybrid-6B) and a reverse-bend-6B (6RB-BA) lattice with zero dispersion mid-Straight have been produced as prototype lattices for DIAMOND-II. The 8HMBA lattice to have more knobs for better tenability while later with significantly small emittance and zero dispersion in all insertion straights including mid-straight. These two lattices are being studied assuming on axis injection and an accumulator ring has been designed for this case [6].

DESIGN PHILOSOPHY

To control the nonlinear dynamics for synchrotrons, when chromatic sextuples are introduced for linear chromaticity control, there are two basic strategies; both based on symmetry:

- $-I$ Transformer: introduce sextupole pairs separated by $n \cdot \pi$ phase advance in both planes.
- Higher-Order-Achromat [7]: introduce a Unit Cell, repeat it four or more times to generate a super period, and adjust the total phase advance to $n \cdot 2\pi$ in both planes.

The first approach is standard practice for Collider design and the second, either, by a systematic approach [8] or random search [9], is implicit for high periodicity/performance lattices. An overly numerical trial and error approach, is typically pursued with an ad hoc partitioning of the parameter space, due to a reductionist view and finite computational resources, towards the (robust) design/control of a periodic (essentially) Hamiltonian system

$$H = H_2 + \alpha V$$

where H_2 is the quadratic Hamiltonian (Linear Optics) and αV the nonlinear terms.

LINEAR LATTICE OPTIMIZATION

All lattices have been optimized considering the higher order achromat approach. The lattice super period has been constructed with number of cells and matching half-cell on either side. The cell was then optimized to have small natural chromaticity, small vertical beta function, emittance and cell tunes. Afterwards, the half-matching cells were optimized for periodic solution with desired tunes to obtain lattice with desired beta functions in straights. Then this lattice was further studied to devise chromaticity correction scheme and nonlinear dynamics using sextupoles and multipoles (mainly octupoles) [10]. Three designed lattice candidates have been summarized below.

6HMBA

This is a modified version of an earlier prototype lattice [5]. The lattice was further optimized for lower vertical natural chromaticity, small vertical beta function using the above mentioned approach and was further symmetrized to keep mirror symmetry in half-matching cells also. The optical functions of the lattice are shown in Fig. 1. The main parameters of the ring are listed in Table 1. Initial results of on momentum dynamic aperture (DA), frequency map analysis (FMA) and momentum acceptance are optimized for this lattice with all engineering tolerances with three families of chromatic sextupoles and five families of octupoles are shown in Fig. 2. While DA is not sufficient for off axis injection goal (nonlinear dynamics requires further optimization), though momentum aperture ~2.5% is achievable for better Touschek lifetime.

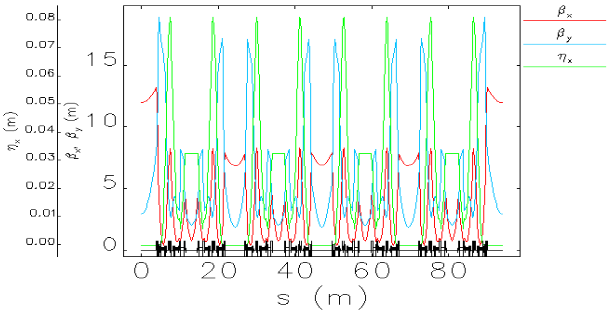

Figure 1: Optical functions in one superperiod of the 6HMBA lattice.

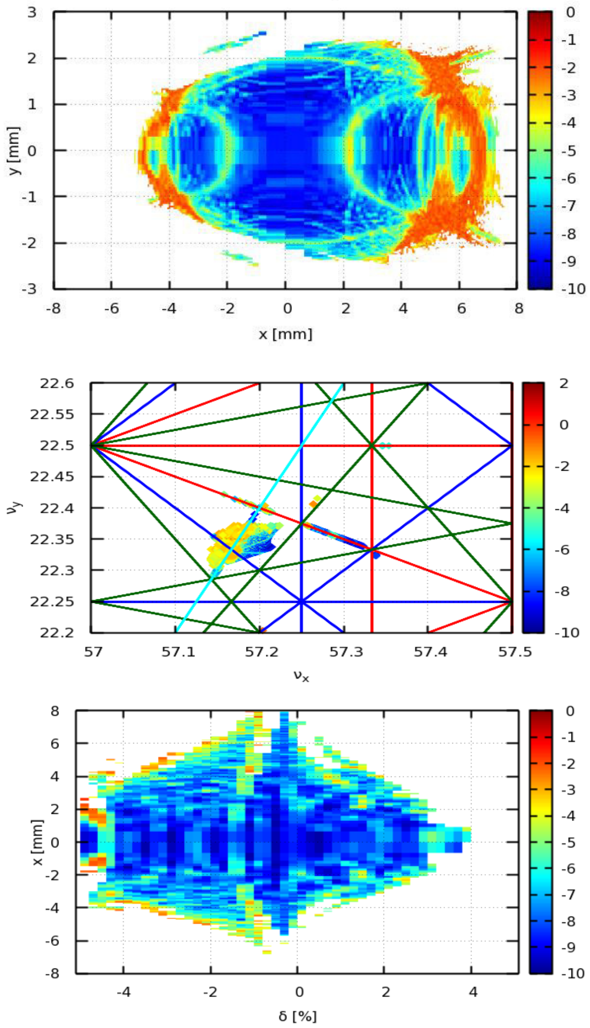

Figure 2: DA (top), FMA (middle) and momentum acceptance (bottom) of 6HMBA lattice with families of three chromatic sextupoles and five octupoles and with engineering tolerances.

8HMBA

It is based on Double Quadruple Bend Achromat (DQBA) or 8BA structure. It is composed of three unit cells which are sandwiched between two matching sections. Layouts of magnets in the matching and unit cells are shown in Fig 3. Starting from the 6HMBA lattice, one short length, low field transverse gradient dipole is added prior to the longitudinal variable bends (LGBs) in the matching section and two of them are used in the both sides of standard straight section of unit cell. The additional dipoles help in emittance reduction while keeping the natural chromaticity in the reasonable range. The optical functions in one super period are shown in Fig. 4 and the main parameters are given in Table 1.

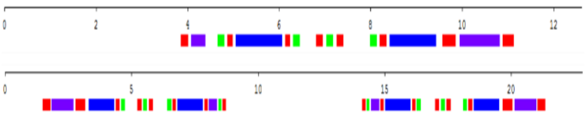

Figure 3: Arrangement of magnets in the matching section (top) and unit cell (bottom) of the 8HMBA lattice. The blue, purple, red and green colours indicate longitudinal, transverse gradient dipoles, quadrupole and sextupole magnets respectively.

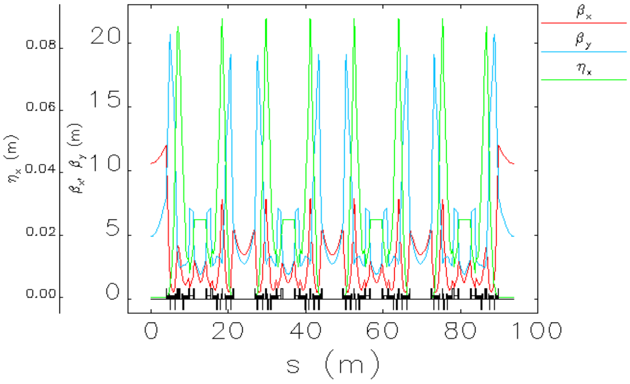

Figure 4: The Optical functions of one super period of the 8HMBA lattice.

Eight families of sextupoles are used to correct the chromaticity to zero and to control the nonlinear beam dynamics. The DA and momentum acceptance (~±1%) calculated with engineering tolerances for zero chromaticity are shown in Fig. 5 and Fig. 6 respectively.

6RB-BA

The reverse bend-6B (6RB-BA) lattice with zero dispersion mid-straight created from SLS LGB-RB based lattice structure [8, 11] which could not be achieved in case of two HMBA lattices. The horizontal dispersion function is zero in all straight sections in this lattice. The layout of magnets from the center of the mid-straight to the middle of the standard-straight is shown in Fig.7. Firstly the horizontal cell tune was optimized for minimum emittance and achromatic conditions achieved using a dispersion suppressor.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPMF009

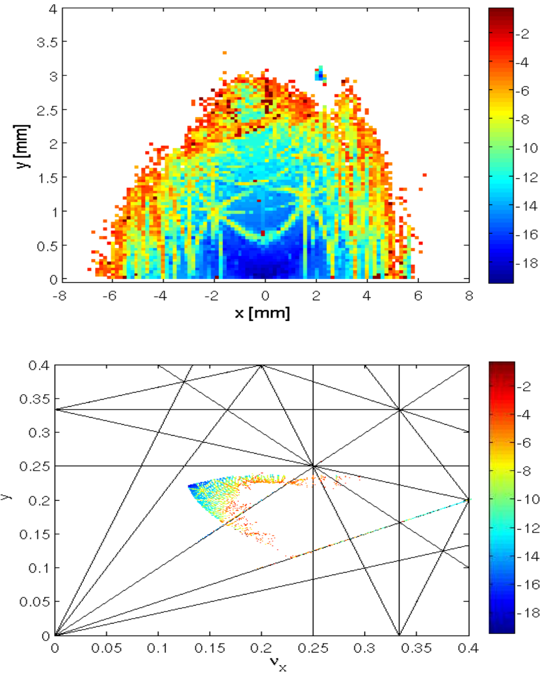

Figure 5: DA (top) and FMA (bottom) for 8HMBA lattice with engineering tolerances.

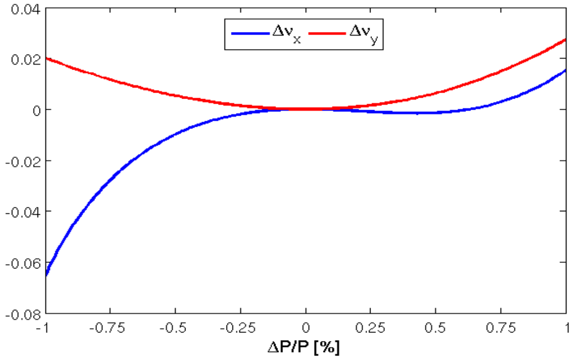

Figure 6: Tune shift due to ±1.0% energy deviation.

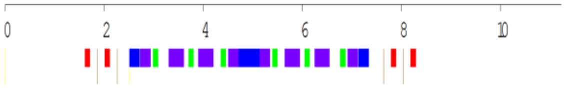

Figure 7: Magnet arrangement from centre of mid straight section to middle of standard straight section in 6RB-BA lattice. The blue, purple, red and green colours indicate to longitudinal, transverse dipoles (including anti-bend), quadrupole and sextupole magnets respectively.

Then using this cell and taking into account acceptable length of different straights and required cell tunes for higher order achromat approach achieved. The optical functions of the optimized super period are shown Fig. 8. The ring parameters of optimized lattice are listed in the Table 1. First results of nonlinear performance optimization are shown in [10] while this solution satisfies higher order achromat conditions.

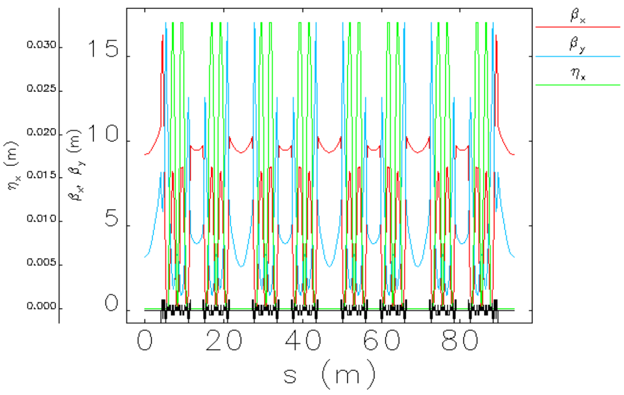

Figure 8: The optical function for one super-period of 6RB-BA lattice.

Table 1: Parameters of Three Prototype Lattices for DIAMOND-II (LS: Long Straight, MS: Mid Straight and SS Standard Straight)

Parameter	6HMBA	8HMBA	6RB-BA
Energy (GeV)	3.0	3.0	3.0
Circumference (m)	563.358	562.74	561.6
Tune-h (total)	57.21	57.13	69.31
Tune-v (total)	22.34	22.22	28.57
Nat. emittance (pm rad)	144	150	62
No. of super-period	6	6	6
Nat. ξx	-89	-74	-105
Nat. ξy	-96	-92	-224
U_0(KeV)	361	334	1167
$\alpha 1$	1.05E-04	1.33e-04	-0.44E-04
η_x (LS/SS/MS) (cm)	0/0/3.2	0/0/2.5	0/0/0
Length of (LS/SS/MS) (m)	7.7/5.2/3.2	7.7/5.4/3	8/5.9/3.1

CONCLUSIONS

Several prototype lattices have been under development for Diamond-II. We presented three lattices, which are currently being optimized. A 6HMBA is developed for off axis injection while other two for on axis injection. The nonlinear dynamics studies are in progress and results presented are initial one. The reverse bend 6RB-BA delivers significantly smaller emittance of 62 pm rad but it has negative smaller momentum compaction factor. It will be augmented by small negative dispersion, which can lead to degradation of emittance. Further work on nonlinear dynamics with multipoles as well as linear lattice optimization is underway. 6HMBA optimized to achieve sufficient dynamic aperture for injection with regular horizontal beta function at injection point.

REFERENCES

[1] R. Chasman, G. Green, E. Rowe, “Preliminary Design of a Dedicated Synchrotron Radiation Facility”, in *Proc. PAC’75*, Washington, USA, Mar 1975, pp. 1765-1767.

[2] R.P. Walker, “Commissioning and Status of the Diamond Storage Ring”, in *Proc. APAC’07*, Indore, India, Feb 2007, paper TUYMA03, pp. 66-70.

[3] R.P. Walker et al., “The Double-Double Bend Achromat (DDBA) Lattice Modification for the Diamond Storage Ring”, in *Proc. IPAC’14*, Dresden, Germany, June 2014, paper MOPRO103, pp. 331-333.

[4] M. Bona et al., “SuperB: A High-Luminosity Asymmetric e+e- Super Flavour Factory”, INFN/AE-07/2, SLAC-R-856, LAL07-15, March 2007.

[5] A. Alekou et al., “Study of a Double Triple Bend Achromat (DTBA) Lattice for a 3 GeV Light Source”, in *Proc. IPAC’16*, Busan, Korea, paper WEPOW044, pp.2940-2942.

[6] I. Martin, R. Bartolini, “Conceptual Design of an Accumulator Ring for the Diamond II Upgrade”, presented at the 9th Int. Particle Accelerator Conf. (IPAC’18), Vancouver, Canada, Apr.-May 2018, paper THPMF008, this conference.

[7] D. Kaltchev et al., “Lattice Studies for a High Brightness Light Source”, in *Proc. PAC’95*, Dallas, USA, May 1995, paper FAB14, p. 2823.

[8] J. Bengtsson, A. Streun, “Robust Design Strategy for SLS-2”, SLS2-BJ84-001-2, 2017.

[9] M. Ehrlichman, “Genetic Algorithm for Chromaticity Correction in Diffraction Limited Storage Rings”, *Phys. Rev. ST Accel. Beams*, vol. 19, 044001, 2016.

[10] J. Bengtsson et al., “Control of the Nonlinear Dynamics for Medium Energy Synchrotron Light Sources”, presented at the 9th Int. Particle Accelerator Conf. (IPAC’18), Vancouver, Canada, Apr.-May 2018, paper THPMF006, this conference.

[11] A. Streun et al., “Design Studies for an Upgrade of the SLS Storage Ring”, in *Proc. IPAC’15*, Richmond, USA, May 2015, paper TUPJE047, pp. 1724-1727.