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EXPLORATORY LATTICE DESIGN STUDIES FOR DIAMOND-II

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Abstract

We pursue Robust Design of a ring-based Synchrotron Light Source as a system. In particular, the design philosophy is based on:

- To control the Nonlinear Dynamics: control the Linear Optics.

In particular, by:

- Optimal control of natural chromaticity.
- "-I Transformer" between chromatic sextupoles for unit cell.
- Higher-Order-Achromat for super period.

In addition, by pushing the Requirements for Robust & Efficient Injection "upstream", i.e., by considering on-axis injection, and by utilizing reverse bends (to not limited by theoretical minimum emittance cell), either:

- the natural emittance can be reduced further,
- or the Touschek lifetime can be improved.

Bottom line, a Design Choice.

INTRODUCTION

The main parameters for the baseline lattice [1] are summarized in Table 1. It is based on the ESRF-EBS style -I Transformer [2], with the center dipole replaced by a dispersive mid-straight; and a Higher Order Achromat over two super periods with the cell tune $\bar{\nu}_{\text{cell}} = [19/8, 14/16]$.

Table 1: Main Parameters for Baseline and Exploratory Lattices

Parameter	Baseline	Exploratory
Energy [GeV]	3.5	3.5
Circumference [m]	560.7	560.7
Tune ($Q_{x/y}$)	57.16/20.24	64.28/18.42
Emittance [pm·rad]	157	97
Energy spread	$7.7.10^{-4}$	$1.1.10^{-3}$
Momentum compaction	$1.17.10^{-4}$	$0.5.10^{-4}$
Natural chromaticity h/v	-76/-90	-109/-97
Energy loss/turn [MeV]	0.67	0.93
Damping times $\tau_{x/y/z}$ [msec]	14.2/19.5/12.0	7.2/14.1/13.6

CONTROL OF LINEAR OPTICS

To improve the control of the Linear Optics, i.e. the Quadratic Hamiltonian H_2, we have [3,4]:

- Introduced reverse bends [5-7] to not limited by the "Theoretical" minimum emittance cell, see Fig. 1.
- Optimized the relative bend angles, and gradient profile for the symmetric longitudinal gradient bends (adjacent to the mid-straight).
- Improved the decoupling of linear chromatic control, see Fig. 2; to the level of ESRF-EBS [2].
- Symmetrized the phase advance for the Higher-Order-Achromat for the long vs. standard straights.
- Reduced the horizontal chromatic tune footprint, by improving local control of the driving term h_{20001}; which drives $\partial_\delta \beta_x$, see Fig. 3.

Nota Bene: this is work in progress; i.e., the linear optics in the straights needs to be fine-tuned.

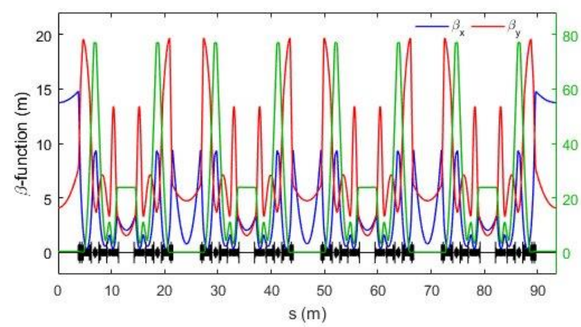

Figure 1: Linear optics functions for 97 pm·rad lattice.

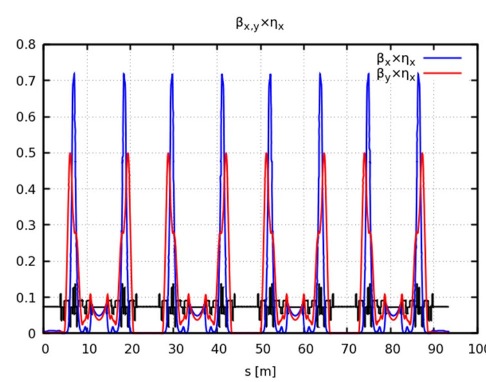

Figure 2: Improved separation for linear chromatic control for 97 pm·rad lattice.

BEAM DYNAMICS BENCHMARK

Our beam dynamics benchmark comprises of:

- Tune footprint, see Figs. 4-6.
- On and off-momentum DA for the bare lattice, see Fig. 7.
- On and off-momentum DA for the real lattice (i.e., with mechanical mis-alignments, magnetic field errors, control of closed orbit, and beta-beat), see Figs. 8-10.

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- On and off-momentum frequency maps for real lattice, see Figs. 11-14.
- "Touschek tracking" will be included, after we have introduced chromatic multipoles; for control of the off-momentum DA.

Besides, as a Guideline for Robust Design of NSLS-II, tune footprint of $\Delta\nu < 0.1$ for stable beam for a fully loaded/deployed lattice was used [8-12]; i.e., based on what's known for medium energy rings, e.g. ref. [13]. Hence, a direct comparison can be made with the baseline lattice, for which we estimate an off-momentum DA of ~1.7% [1]; which is essentially the same as from Fig. 6 for the 97 pm·rad lattice. Contrarily, if we instead relax the linear dispersion action, $\mathcal{H}_x$, the off-momentum DA can be improved beyond the baseline lattice.

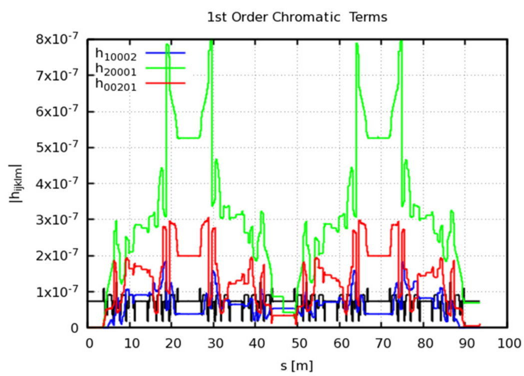

Figure 3: Driving terms $[h_{10002}, h_{20001}, h_{00201}]$ driving $[\eta_x^{(2)}, \partial_\delta \beta_x, \partial_\delta \beta_y]$.

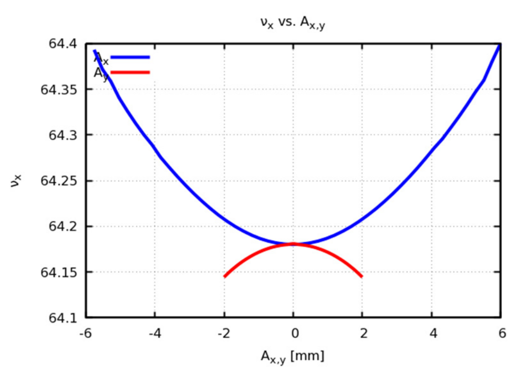

Figure 4: Tune footprint for horizontal plane.

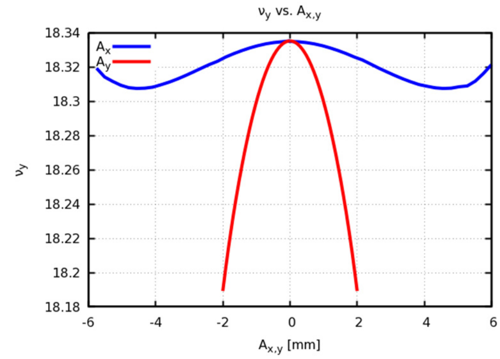

Figure 5: Tune footprint for vertical plan.

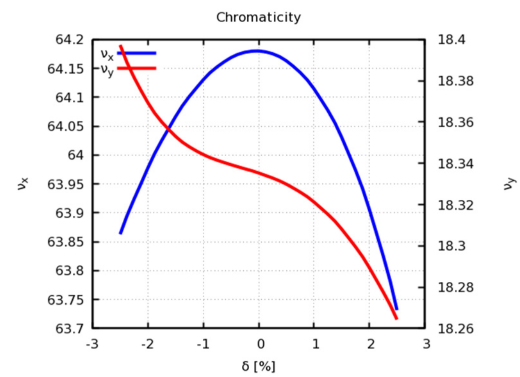

Figure 6: Chromatic tune footprint.

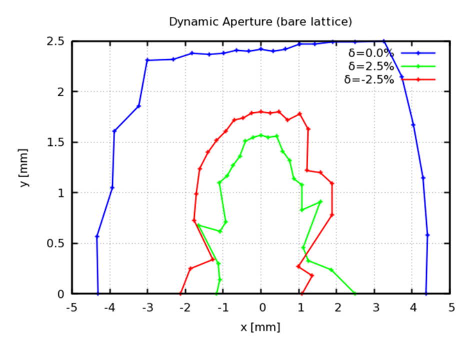

Figure 7: On and off-momentum dynamic aperture for bare lattice.

CONCLUSIONS

We have outlined & demonstrated how to improve the control of the nonlinear dynamics by improving the control of the linear optics, i.e. the quadratic Hamiltonian H_2, by:

- Introducing reverse bends; to not limited by the "Theoretical" minimum emittance cell.
- Improving the decoupling of linear chromatic control.
- Reducing the horizontal chromatic tune footprint, by improving local control of the driving term h_{10002}; which drives $\partial_\delta \beta_x$.

Besides, a Higher-Order-Achromat has been pursued from the start [5, 8-12].

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In addition, by pushing the requirements for robust & efficient injection "upstream", i.e., by considering on-axis injection [14, 15], either [3, 4]:

- the natural emittance can be reduced further,
- or the Touschek lifetime of the CDR lattice can b improved by relaxing the linear dispersion action, $\mathcal{H}_x$.

In conclusion, a design choice.

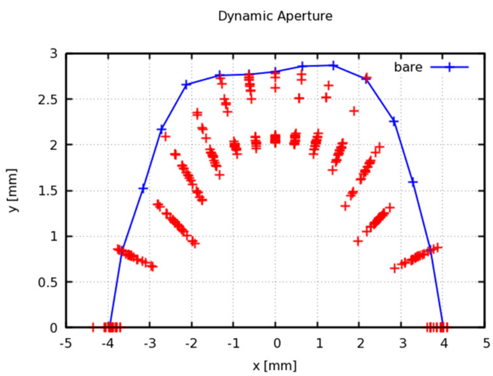

Figure 8: Dynamic aperture for real lattice; 20 Seeds.

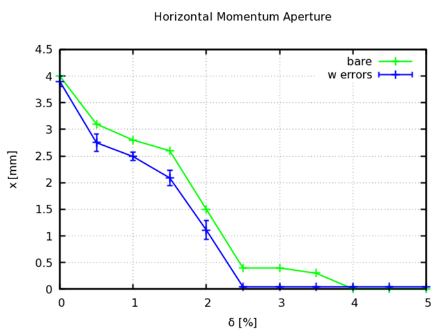

Figure 9: Horizontal off-momentum dynamic aperture for real lattice.

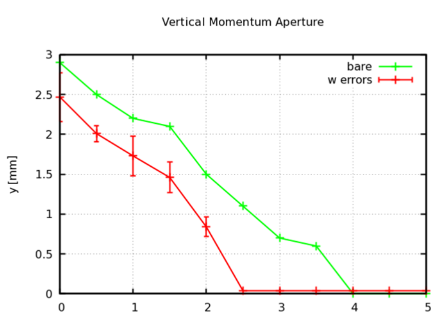

Figure 10: Vertical off-momentum dynamic aperture for real lattice.

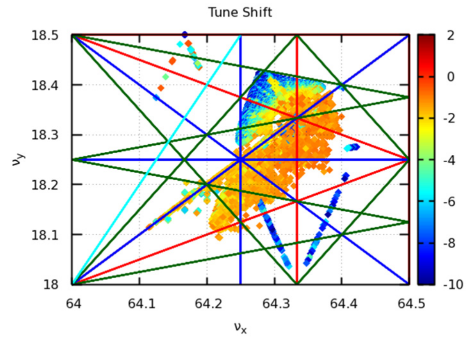

Figure 11: Tune footprint.

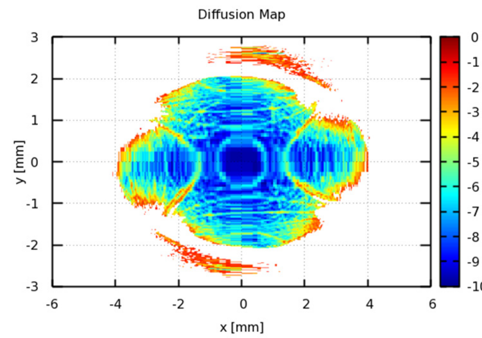

Figure 12: Diffusion map.

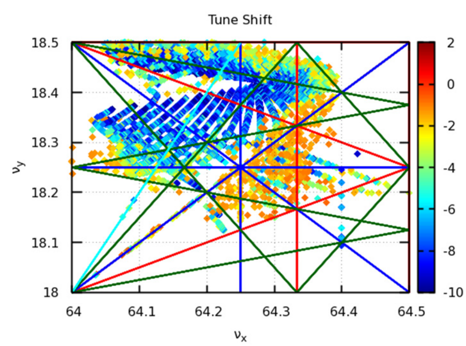

Figure 13: Chromatic tune footprint.

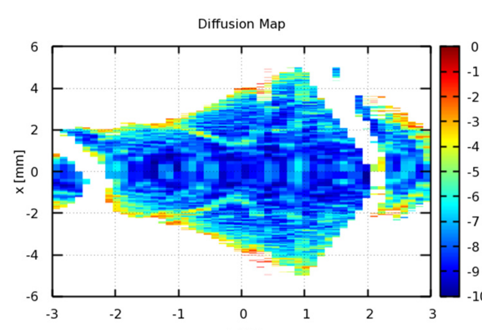

Figure 14: off-momentum diffusion map.

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