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 \( \vec{v}_{\text{cell}} = [19/8, 14/16] \).

Table 1: Main Parameters for Baseline and Exploratory Lattices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>Exploratory</th>
</tr>
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<tbody>
<tr>
<td>Energy [GeV]</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Circumference [m]</td>
<td>560.7</td>
<td>560.7</td>
</tr>
<tr>
<td>Tune (Qx/y)</td>
<td>57.16/20.24</td>
<td>64.28/18.42</td>
</tr>
<tr>
<td>Emittance [pm·rad]</td>
<td>157</td>
<td>97</td>
</tr>
<tr>
<td>Energy spread</td>
<td>7.7⋅10^{-4}</td>
<td>1.1⋅10^{-3}</td>
</tr>
<tr>
<td>Momentum compaction</td>
<td>1.17⋅10^{-4}</td>
<td>0.5⋅10^{-4}</td>
</tr>
<tr>
<td>Natural chromaticity</td>
<td>-76/-90</td>
<td>-109/-97</td>
</tr>
<tr>
<td>Energy loss/turn [MeV]</td>
<td>0.67</td>
<td>0.93</td>
</tr>
<tr>
<td>Damping times ( \tau_{xy/z} ) [msec]</td>
<td>14.2/19.5/12.0</td>
<td>7.2/14.1/13.6</td>
</tr>
</tbody>
</table>

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 \( \delta_8 \beta_8 \), 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.
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 $\sim 1.7\%$ [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, $H_c$, the off-momentum DA can be improved beyond the baseline lattice.

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

**Figure 4:** Tune footprint for horizontal plane.

**Figure 5:** Tune footprint for vertical plane.

**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].
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 be improved by relaxing the linear dispersion action, $\mathcal{H}_e$.

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.
REFERENCES


