

UPDATES ON LATTICE MODELING AND TUNING FOR THE ESRF-EBS LATTICE

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Abstract

The ESRF-EBS lattice model is updated to include the effect of magnetic lengths in dipoles, quadrupoles, sextupoles and combined function magnets. The effect of this modification and the updates to the injection cell are considered with particular focus on injection efficiency and Touschek lifetime. The solutions to introduce new sources of radiation suitable for the existing bending magnet radiation beamlines are also presented.

INTRODUCTION

In 2020 the ESRF storage ring will be upgraded to an Hybrid Multi Bend Achromat (HMBA) lattice with a horizontal emittance of 132 pmrad [1]. This small emittance will increase the brightness of the radiation emitted by undulators by a factor 20 to 40 [2]. The ring is composed by 30 arc cells plus two specific cells to increase off-axis injection efficiency. Figures 1 and 2 show the optics layout of the lattice arc and a detailed view of the high beta straight section used for injection in the storage ring.

LATTICE MODEL UPDATES

Magnetic lengths

The ESRF-EBS (Extremely Brilliant Source) model has been updated to include magnetic lengths. For each magnet, the magnetic field is computed along the trajectory of the electron beam using 3D RADIA magnetic field models [3]. The magnetic length is computed to define a hard edge magnet model with identical integral field (see Fig. 3).

Table 1 summarizes the magnetic length as obtained from the magnet design and the associated magnet gradients computed to match the key optics parameters of the cell [4]. As expected all the magnets are longer than their iron length, thus their gradients are reduced.

Dipole models In combined function dipole quadrupole magnets (DQ), the magnetic lengths of the dipole and quadrupole field components are not the same (see Table 1). This has been taken into account by splitting the magnet in three parts. The central slice has the quadrupole magnetic length and gradient and the two slices at the edges model the missing dipole magnetic length. The total bending angle is respected and the curvature radius is constant over the three slices. Concerning longitudinal gradient dipoles (DL), the above magnetic length definition is not applicable due to the asymmetry of the magnets. The lengths and fields of the individual dipole modules have been adjusted in order to

Table 1: ESRF-EBS Arc Cell Magnet Lengths and Fields

name	units	iron length		magnetic length	
		L [m]	Field	L [m]	Field
QF1	T/m	0.295	53.5	0.312	50.8
QD2	T/m	0.212	-57.1	0.228	-53.5
QD3	T/m	0.162	-52.9	0.179	-48.1
SD1	T/m ²	0.166	-1718	0.180	-1580
QF4	T/m	0.212	52.1	0.228	48.6
SF2	T/m ²	0.200	1657	0.214	1541
OF1	T/m ³	0.090	-36024	0.098	-29019
SD2	T/m ²	0.166	1617	0.180	-1485
QD5	T/m	0.212	-57.8	0.228	-54.1
QF6	T/m	0.388	91.0	0.399	89.4
DQ1	T	1.028	0.568	1.068	0.548
	T/m	1.028	-36.9	1.050	36.6
QF8	T/m	0.484	89.4	0.493	88.6
	T	0.800	0.393	0.840	0.374
DQ2	T	0.800	-31.2	0.824	-30.7

reproduce the trajectory and focusing obtained from RADIA tracking simulations [3].

Injection cell

The ESRF-EBS features a special cell with high horizontal beta function bump at injection. This injection cell has been recently modified to fulfill the mechanical engineering requirements. Concerning optics, the relevant changes are the displacement of the JL long dipole and QD2 quadrupole to leave more space in the injection straight. The optics have been matched and the sextupoles and octupoles in the injection cell re-tuned to recover the periodicity of the off energy optics [4]. The modified cell has higher beta at the injection point (18.65 m instead of 17.4 m), and no evident impact on dynamic aperture and lifetime compared to the previous version of the same cell was observed.

Optimizations

After the introduction of the magnetic lengths and of the updated injection cell, the optimal value of several parameters may have changed. Several optimizations have been performed using the techniques presented in [4]. We report here two of these optimizations: a tune working point scan (Fig. 4) and a scan of sextupoles and octupole strengths at fixed chromaticity (Fig. 5). Both scans have as objective functions lifetime and dynamic aperture and are averaged

Several solutions have been studied to install a radiation source suitable for these beamlines in the drift space between DQ2C and QF8D in the arc cell (see Fig. 1). The solutions are:

- radiation from the combined function magnets (DQ2C or DQ1D, accepting the field reduction),
- a three pole wiggler (3PW),
- a two pole wiggler (2PW) and
- a short bending magnet (SB).

These solutions have different photon beam characteristics and each beamline will decide the most suitable for their experiments [6]. However, the solutions are ordered in increasing requirement for local lattice adjustments. The DQ and 3PW solutions have no impact on the standard cell layout. On the other hand, the 2PW and SB solution require significant local modifications to the lattice cell.

Two pole wiggler

Using the 2PW solution the closed orbit is displaced by about $120\ \mu\text{m}$ after the source (see Fig. 6). The offset trajectory can be recovered in several ways: using the correctors magnets (DA and lifetime shown in Table 2), introducing an additional unbalance in the poles of the 2PW to reduce the stress on the correctors or by tilting and displacing the QF8 quadrupole. The last of these options is shown in Fig. 6. Considering the magnetic length model described above, the required tilt about the vertical axis is $-2.50\ \text{mrad}$ and the displacement is $61.7\ \mu\text{m}$. The required displacement is very similar to the alignment tolerances for the QF8 quadrupoles.

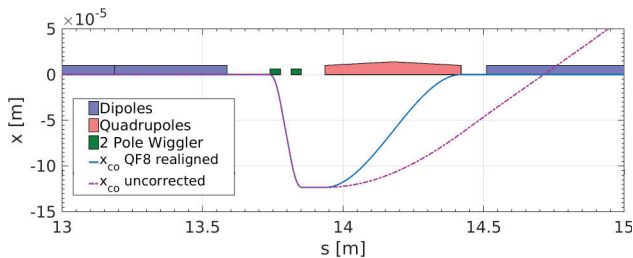


Figure 6: Impact of the 2PW on closed orbit, restored tilting about the vertical axis the near by QF8 quadrupole.

Short bending magnet

The SB solution requires the application of several modifications to the lattice cell. The SB dipole has a total bending angle of about $2.12\ \text{mrad}$, which needs to be removed from the other dipoles in the cell to ensure constant total angle. The DQ1 and DQ2 dipole fields can be reduced by a simple displacement taking advantage of the quadrupole component of the field, however the change in bending angle introduces a modulation in the horizontal dispersion.

There are several possibilities to correct this modulation, and the most effective is to unbalance the gradients of the QF4 quadrupoles (see Fig. 1). In Fig. 7, one of the possible solutions is depicted, showing the modified position in space of the magnets compared to the cell without SB. The correct position of the magnets downstream of DQ1D is recovered

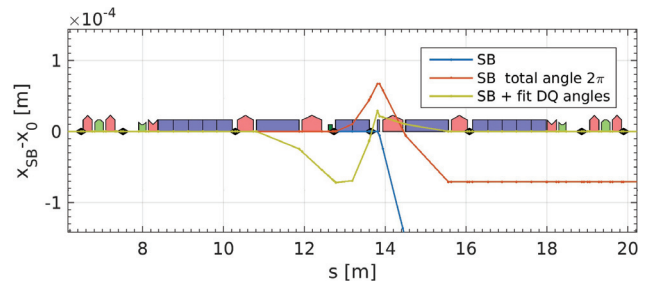


Figure 7: Impact of the SB on magnets survey, restored changing the bending angles of the the near by dipole magnets.

by varying the bending angles of DQ1B, DQ2C and DQ2D. It should be noted that the QF8 quadrupoles also need to be realigned (position and angle) on the new reference trajectory. The required displacement of the DQ dipoles to decrease their field by $1\ \text{mrad}$ is approximately $2\ \text{mm}$, in addition to the value displayed in Fig. 7. To cancel the horizontal dispersion distortion a difference in gradient between the QF4 quadrupoles left and right of the SB of $0.00048\ \text{m}^{-2}$ (0.02%) is introduced.

The DA of the above solution (SB) for the bending magnet beam lines radiation source is shown in Table 2 starting from a lattice using magnetic lengths.

Lifetimes are reported for the multibunch filling mode ($0.23\ \text{mA/bunch}$, $Z=0.35\ \Omega$ and vertical emittance $5\ \text{pmrad}$) and injection efficiency assumes a $30\ \text{nmrad}$ round beam injected with optimal optics at the end of the transfer line [7].

The SB and 2PW will be installed and the modifications described above will be implemented displacing the magnets. A model representing the SB, 2PW and their correction in terms of alignment errors is thus under study. This will be a more realistic model that will provide the total required displacement of each magnet for the installation and commissioning of the sources. The simulations are ongoing and the results may differ from the ones presented above.

CONCLUSION

The EBS lattice model has been updated to include magnetic lengths and an injection cell satisfying the mechanical engineering constraints. An optimized working point and non linear magnets setting were found for this updated lattice. The most recent solutions to produce radiation suitable for the BM beamlines are also presented and require local modifications of the lattice cells, however with a limited impact on dynamic aperture and lifetime.

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