ESRF-EBS LATTICE MODEL WITH CANTED BEAMLINES

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Abstract

The ESRF Extremely Brilliant Source (ESRF-EBS) lattice model is updated to include three canted beamlines. The cells are modified where necessary to include 3-Pole Wiggler (3PW), 2-Pole Wiggler (2PW) and Short Bending Magnet (SBM) sources. Several lattices are obtained for the different stages that will bring from commissioning to operation with users. A scheme for tune modification keeping key optics knobs unchanged is proposed.

INTRODUCTION

In 2020 the ESRF storage ring will be upgraded to ESRF Extremely Brilliant Source (ESRF-EBS) with an Hybrid Multi Bend Acrhomat (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 32 HMBA cells, locally modified for injection and beamline requirements.

ESRF Beamlines

Currently the ESRF Storage ring feeds 42 beamlines (see Fig. 1): 27 undulators beamlines (ID) and 15 bending magnet beamlines (BM). Three of the ID beamlines have two branches introduced by canting the straight sections (SS) with a closed orbit bump implemented using permanent magnets.
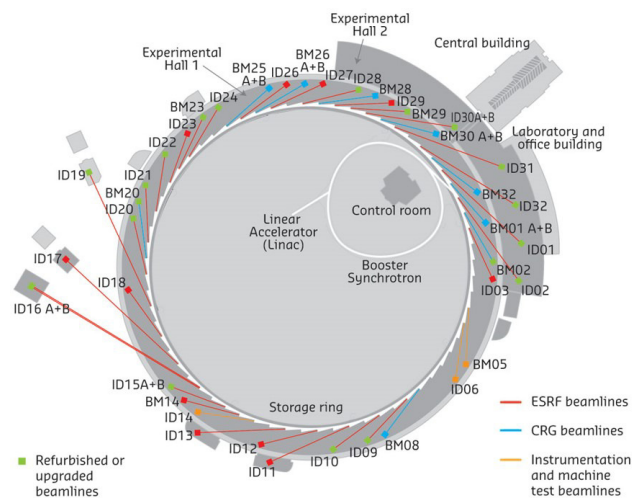

Figure 1: ESRF bamlines [3].

The 15 BM beamlines will be replaced by dedicated devices: Three-Pole wigglers (3PW), Two-Pole Wigglers type A and B (2PWA, 2PWB, according to the sign of the first

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pole) and Short Bending Magnets (SBM). The specific devices are chosen by the users to better fit their experimental needs. The optics adaptation necessary for the introduction of such devices in the standard lattice cell (see Fig. 2) are described in [4]. Table 1 summarizes the features requested for each lattice cell and the stage at which the modifications will be introduced in the lattice during commissioning of ESRF-EBS.

Table 1: EBS BM and SS specificity for each cell. Commissioning phase is indicated by a number representing the chronological order for installation.

Cell	BM type	SS type	Commissioning phase
01	2PWA		2
02	SBM		4
03			1
04		injection	1
05	2PWA		3
06			1
07	2PWA		3
08	SBM		5
09			1
10			1
11			1
12			1
13			1
14	2PWB		3
15		2.0 mrad	1
16	SBM	2.7 mrad	1, (5 for BM)
17			1
18	3PW		5
19			1
20	SBM		5
21			1
22			1
23	3PW		5
24			1
25	2PWA		3
26	SBM		5
27			1
28	SBM		5
29	2PWB		3
30	SBM	2.2 mrad	1, (5 for BM)
31	2PWA		3
32	SBM		5

Only few cells are not modified. In particular 18 out of 32 cells will be non-standard (Fig. 2), noticing that: 1) SS with canting induce modifications of both upstream and downstream cells; 2) there are some cells with both canting
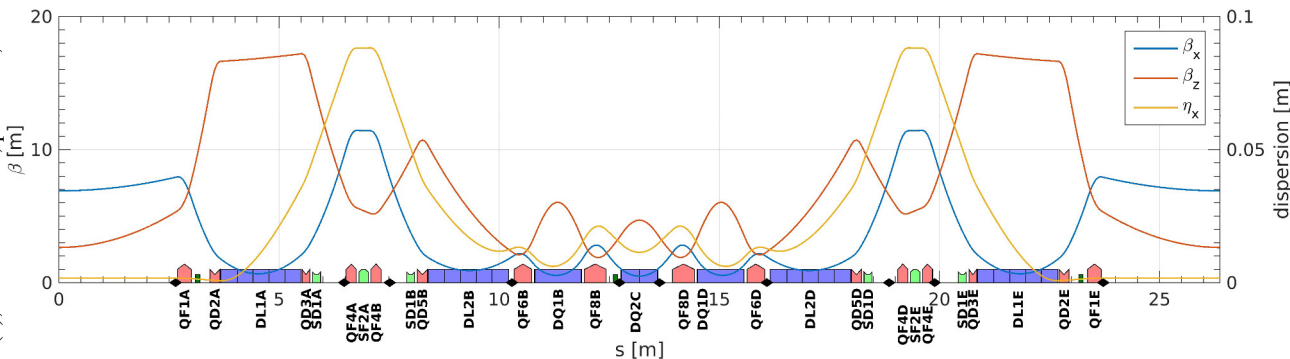
Figure 2: Arc cell optics and layout of the HMBA ESRF-EBS lattice.

and BM source to be matched simultaneously. In the later sections we detail the matching and adaptations to achieve a lattice structure including all these features.

CANTED BEAMLINES

Today's canting takes place within the SS with neither orbit distortion nor seizable betatron optics modification in the neighbor cells (see Fig. 3).
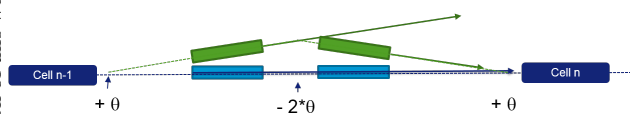

Figure 3: Typical canted SS scheme. Dark blue rectangles represents all magnets of a given lattice cell. Light blue and green rectangles indicate respectively the position of undulators in a normal SS and in a canted one.

For the EBS upgrade this scheme is not possible due to lack of space in the SS. To overcome this problem the two outer kicks are obtained by a reduction of the bending angle of the dipoles at the cell ends (DL1E last module 1 upstream, DL1A first module downstream)[1], see Fig. 2. A comparison between the standard orbit survey and the one of canted SS obtained with this scheme is presented in Fig. 4.
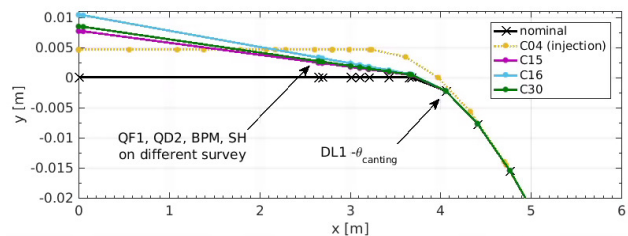

Figure 4: EBS canted beamline survey compared to standard cell and injection cell. Starting at SS center.

All elements between the modified dipoles will have to be aligned on a different reference orbit. These elements

include four quadrupoles, two correctors and two beam position monitors.

Canted Straight Section Matching

The modified dipole arrangement and the presence of quadrupoles within the canting bump introduce a non negligible dispersion modulation. This modulation may be limited to the canted SS by tuning the adjacent quadrupoles and accepting a local beta function variation. The chosen objectives of the optics matching at the SS center are:

- dispersion less than 2 mm,
- dispersion derivative equal to zero,
- phase advance identical to standard cell in both planes,
- α function equal to zero in both planes.

The ten quadrupoles used to obtain this conditions are QF1*, QD2*, QD3*, QF4* and QD5*, symmetrically adjusted with respect to the canted SS. Figure 5 shows the result of the matching. The β functions within the canted orbit are modulated up to 25%, though they are eventually reduced at the center of the SS in both planes. Moreover, with respect to the standard optics, the dispersion beating is localized to the SS and below 1 cm (it would have generated a wave of more than 2 cm along the ring without the local matching).
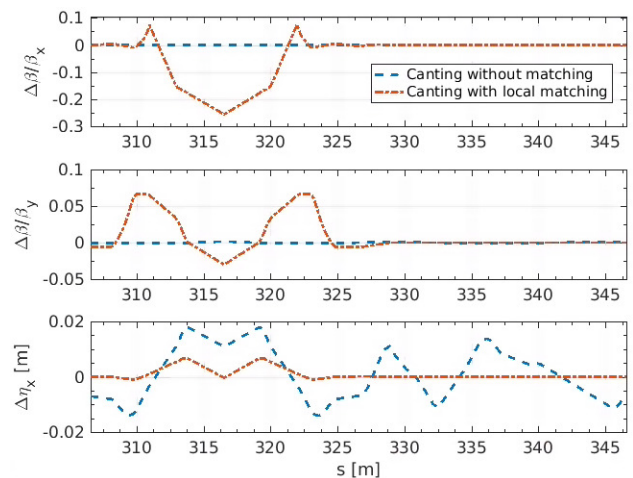

Figure 5: Optics distortion of an EBS canted beam line without (blue) and with (orange) local matching.

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[1] The DL are longitudinal-gradient dipoles comprising five consecutive permanent-magnet modules with different fields, weaker near sextupoles (large dispersion and beta function) and stronger on the SS side (lower dispersion and beta function).

02 Photon Sources and Electron Accelerators

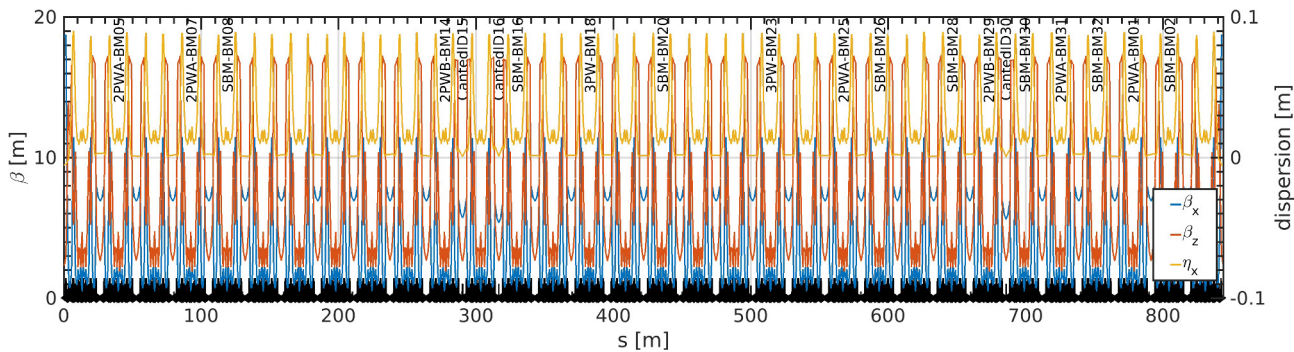**A05 Synchrotron Radiation Facilities**

Figure 6: EBS lattice optics at the final commissioning phase.

The quadrupole gradients are modified by 7% at most for the largest canting angle required.

Canted Cells with BM Sources

Cell 14, 16, 29 and 30, (see Table 1) feature both canting and a BM source, while cell 15 features two different canting angles at the two sides of the cell. Any optics matching requires then a transfer-line approach with given initial conditions, since these cells no longer feature symmetry and periodicity. The number of conditions is doubled to specify lattice optics on both sides of the lattice cell and all quadrupoles are tuned independently. The initial conditions are driven from the final conditions of the preceding cell. The matching conditions are those of the standard arc cell, namely: total phase advance and phase advance between sextupoles, horizontal β functions at the ID, vertical β, vertical α and horizontal dispersion at sextupoles. An image of the final lattice including canting and BM sources is shown in Fig. 6.

COMMISSIONING

The commissioning will take place in roughly five main phases, each one denoted by a number representing the chronological order of installation (see Tab. 1). Phase 1 will include canting but no BM; In phase 2 a single 2PW is installed in a standard cell; In phase 3 all the remaining 2PWs are installed following the lesson learned during phase 2; During phase 4 a single SBM will be installed in a standard cell; Last, in phase 5 all remaining BMs will be mounted. Dynamic aperture (DA), Touschek lifetime (TLT) and injection efficiency (IE) expected at each main commissioning stage are reported in Tab. 2.

Table 2: DA, TLT and IE average over 10 corrected error seeds with physical apertures, for three main commissioning stages. See [5] for detailed description.

commiss. stage	DA [mm]	TLT [h]	IE [%]
reference	−8.2 ± 0.5	24 ± 2	92 ± 3
(1) canting	−8.0 ± 0.5	22 ± 2	93 ± 3
(3) 2PW	−8.6 ± 0.4	23 ± 2	93 ± 6
(5) SB	−8.5 ± 0.6	22 ± 1	93 ± 6

Tune Change

In this version of the EBS storage ring, minor tune adjustments can be still performed by using two quadrupole families. Nevertheless, for large tune variations a whole lattice re-matching including canted sections and BMs will be required. A tune response matrix is computed matching the whole lattice with all BM sources and canted beamlines to $\Delta Q = (+0.1, 0.0)$ and $\Delta Q = (0, +0.1)$. The 2×514 matrix obtained is inverted and used to perform a simulated tune change from $Q = (0.21, 0.34)$ to $Q = (0.34, 0.21)$ with success. This matrix generalizes the standard two families tune change, but grants a smaller impact on optics distortions.

CONCLUSIONS

The EBS storage ring will have to accommodate all existing ESRF sources. Canted beamlines and bending-magnet sources introduce significant optics distortion if not compensated by local matching. Because of the large numbers of non-standard cells (18 out of 32), the concept of quadrupole families is abandoned for a fully independent control of the magnets strengths. Specific optics settings have been computed for each of the five phases of beam commissioning foreseen for the staged installation of those insertions.

ACKNOWLEDGMENTS

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REFERENCES

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

[2] "ESRF upgrade programme phase II", ESRF, December 2014.

[3] Image curtesy of the ESRF communication group.

[4] S.M. Liuzzo et al., "Updates on lattice modeling and tuning for the ESRF-EBS lattice", WEPOW005, IPAC'16, Busan, Korea (2016).

[5] S.M. Liuzzo et al., " Influence of errors in the ESRF upgrade lattice", TUPWA014, IPAC'15, Richmond, Virginia,USA (2015).