LATTICE COMPARISON FOR THE SYNCHROTRON LIGHT SOURCE BESSY II

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Introduction

BESSY II is proposed as a 1.7 GeV electron storage ring dedicated as a low emittance synchrotron light source of the third generation [1]. The storage ring will be optimized for wiggler and undulator insertion devices, delivering high brilliance synchrotron radiation in the VUV and in the soft X-ray region. Additionally, the low emittance radiation from the bending magnets will be used.

Basis of the lattice comparison

A study of three different lattice schemes was done to find out an appropriate solution for the BESSY II lattice [2]. Simple arrangements of achromatic bends like the two or three dipole scheme were considered. More complicated structures, like the FODO type lattice which requires more magnetic elements, were not studied, because of limited ring circumference.

To compare different arrangements we studied 1) a ten-fold triple-bend achromat lattice (TBA10) with a triplet matching the insertion section to the achromat 2) a twelve-fold triple bend-achromat (TBA12) with a doublet as a matching section, and 3) a fourteen-fold double-bend achromat (DBA14) with a triplet as a matching section.

A strict condition for all three lattice types is the fixed circumference of 194.4 m and zero dispersion straight sections of 5.8 m length between the hard edges of the quadrupoles. In the center of the straights the size of the vertical and horizontal beta function should be 3 m and 10 m, respectively. The natural emittance should be less than 8 n rad m. The studied optical solutions differ in the natural emittance, indicating a different strength in focussing and therefore a different nonlinear behavior. This complicates a direct comparison of the lattices.

The energy of the storage ring should cover a range of .75 GeV to 1.9 GeV with a nominal energy of 1.7 GeV. At this energy and a current of 100 mA a beam life time of 10h with respect to Touschek effect and gas scattering should be expected.

The request of dipole radiation for radiometric measurements requires an excellent field homogeneity inside the bending magnets and excludes dipole gradients.

All lattice calculations were done using the computer codes BETA [3], LATTICE [4] and RACE-TRACK [5].

Lattice structures studied

The important lattice parameters of the three different optics are summarized in Table 1 and in the Figures 1 to 3.

TABLE 1: Main lattice parameters:

Name of lattice	TBA10	TBA12	DBA14
Type of the lattice	TBA	TBA	DBA
Nominal energy [GeV]	1.7	1.7	1.7
Circumference [m]	194.4	194.4	194.4
Number of cells/ superperiods	10/10	12/12	14/7
Tunes Qx/Qy	14.25/6.2	14.8/8.75	13.2/6.16
Nat. emittance [nradm]	5.6	7.0	9.3
Damping time x/y/z [msec]	12/12/6	12/12/6	12/12/6
Rf frequency [Mhz]	499.666	499.66	499.666
Harmonic number	324	324	324
Momentum compaction	$1.41\cdot10^{-3}$	$1.46\cdot10^{-3}$	$1.08\cdot10^{-3}$
Nat. chromaticity x/y	-46.9/-13.3	-28.0/-22.0	-31.6/-15.5
Number of dipoles	30	36	28
Bending radius [m]	4.0	4.0	4.0
Number of quadrupoles/families	100/5	96/4	140/5
Number of sextupoles/families	80/4	48/2	98/4

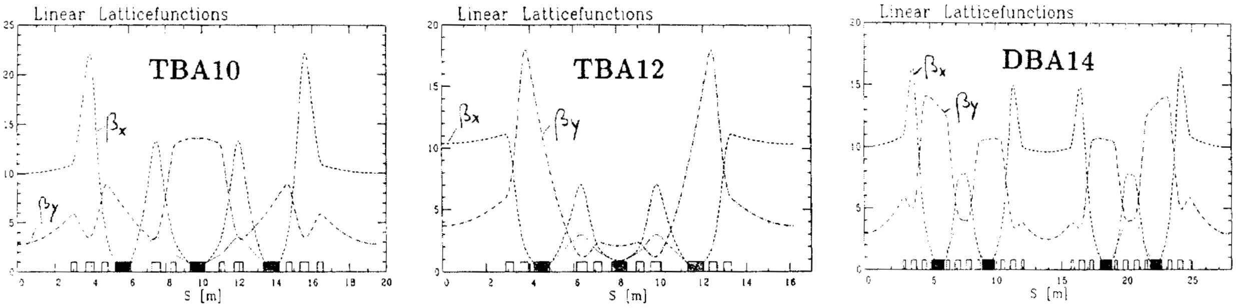

Fig. 1 to 3: The beta functions and the dispersion functions for the lattice studied.

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The TBA10 lattice

The basic structure of the TBA10 consists of: triplet-achromat-triplet, where the achromat is a three dipole arrangement with two doublets inside the arc. The task of the triplet is not only to focus the beam from the insertion straight section into the achromat. The additional lens should provide further flexibility when compensating the linear effects of the insertion devices locally. This lattice easily satisfies the specified design parameters. A rather strong focussing is required to achieve the low emittance of 5.6 n rad m.

Two sextupole families are localized inside the dispersive section to compensate the chromatic effects. Nonlinear distortions are corrected by two additional sextupole families localized inside and outside the achromatic bend, respectively.

The TBA12 lattice

The TBA12 is arranged as a doublet-achromat-doublet structure, the achromat is of the same type as in TBA10. This lattice is built up by a minimum of elements to allow for twelve straight sections. The linear beam dimensions are close to the specified values. Having two additional periods and about 20% less bending per dipole, the natural emittance is 25% larger than in the TBA10 scheme. Therefore, the nonlinear lattice behavior profits due to the moderate focussing.

Two sextupole families are used to cancel chromatic effects. They are localized in such a way, that nonlinearities become acceptably small. No further sextupoles for compensation are required.

The DBA14 lattice

The DBA14 is composed of a triplet-achromat-triplet lattice, with an achromat consisting of two dipoles and two doublets in between. To arrange 14 cells around the circumference, it was necessary to alternate long and short straight sections of 5.8 m and 3.6 m length, respectively. Obviously, this symmetry break does not deteriorate the nonlinear performance of the optics.

The shorter straight sections could be used for injection and RF cavities and for shorter wigglers or undulators. The focussing is moderate to keep nonlinear effects small. The natural emittance of 9.3 n rad m is still within the range of interest. Two families of sextupoles are used for chromatic corrections. The amplitude-dependent tune shifts are drastically suppressed by two additional sextupole families in the zero dispersion region.

This lattice is not as elaborated as the two TBA types; it is a first version to check the potential of a double bend solution for BESSY II. The presented lattice is rather crowded due to a dense magnet packing. Especially this point needs further work. A reduced achromat, with a single focussing quadrupole for example, does not alter the linear and nonlinear performance too much. A disadvantage of the DBA lattice is the poorer access to dipole radiation, compared to the inner dipole of the TBA solution. However, the overall beam dynamics of the DBA14 looks promising.

Nonlinear and Chromatic Effects of the Bare Lattices

The nonlinear behavior of the different solutions was checked by pure transversal tracking calculations at three different momenta. Results of the dynamic apertures are presented in Figures 4 to 6. All three machines show sufficient stable apertures. A further reduction of the dyna-

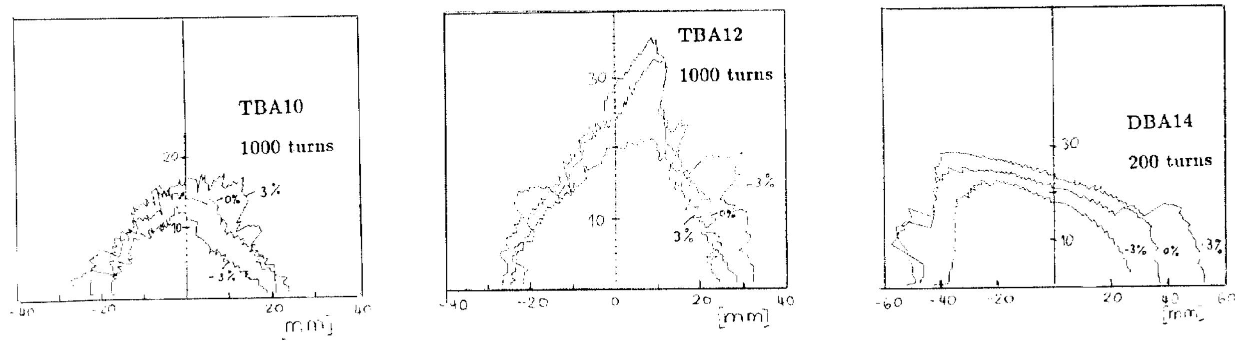

Fig. 4 to 6: Transverse particle tracking at three different momenta. The vertical over the horizontal starting amplitude is given for particles starting in the straight section with x'= y'= 0. The number of stable turns is indicated in the figure. Note the change of the scale.

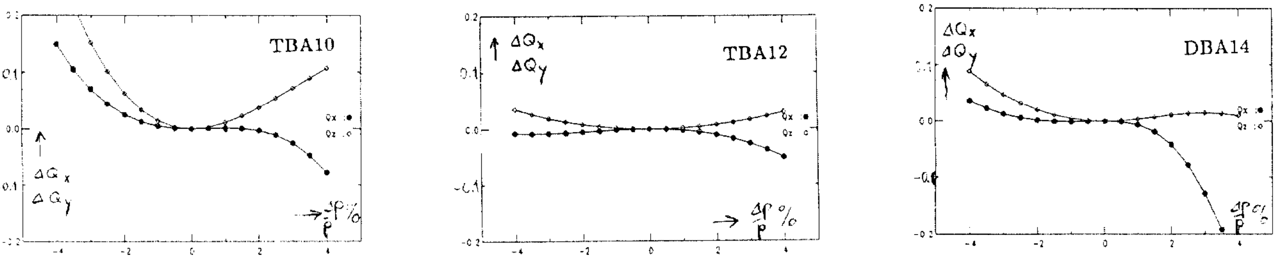

Fig. 7 to 9: Tune shift as a function of momentum at compensated chromaticity.

mic aperture of the bare lattice is expected, when tracking the complete 6-dimensional particle movement.

The chromatic behavior is shown in Figure 7 to 9. The range of the momentum acceptance defines the Touschek lifetime of the electron beam. As a goal a lifetime of 20 h at 100 mA current is required, which transformes into a momentum acceptance of at least +-3%.

Effects of Insertion Devices

The insertion devices alter the linear and nonlinear behavior of the machine. The field of the insertion elements is approximated described as by K. Halbach [6]. Typical insertion devices considered for BESSY II are presented in Table 2.

Table 2: Typical insertion devices

name of insertion	period length [m]	field strength [T]	length [m]
U1	0.130	0.46	4.5
U2	0.070	0.40	4.5
U3	0.037	0.54	4.5
W1	0.200	1.50	4.0
W2	0.130	1.00	4.0
V1	0.077	0.34	4.5
SU	0.600	5.00	0.6

The distortion of the beta functions by the insertions is counteracted in two steps. A local compensation detunes the adjacent quadrupoles in the straight section to cancel the beta beat (alpha matching). A global compensation detunes two quadrupole families out of the non-dispersive straight sections to reset the old tunes.

In the case of the TBA10 a local compensation with the triplet is almost possible. This has the advantage, that there will be no cross talk between the insertions. Depending on the lattice and insertion device, the change of the beta function at the location of the insertion was less than 50%, at the other straight sections the beta function was altered by less than 10%.

In addition to the linear distortions, there are also nonlinear effects of the insertions. The insertions break the symmetry of the machine, enhancing the width of resonances. The beta beat will deadjust the compensation scheme of the sextupoles. Finally, lattice nonlinearities are increased by the multipole fields of the insertions. Overall, the dynamic aperture is reduced by these effects as is shown in Figures 10 to 12.

Conclusion

The different optics studied for BESSY II are all sufficently well within the specifications and are all feasible. BESSY II will be optimized for insertion devices. This favors a higher periodicity. However, the advantage of the TBA lattices compared to the DBA is the better performance of the dipole radiation. The larger number of straight sections of the DBA14 has to be further weighted by the fact that half of them are reduced in length.

The TBA10 satisfies better the required beam specifications and shows more flexibility in compensating the linear effects of the insertion elements. It also offers more space for diagnostics and correction elements. However, the behavior with respect to off momentum particles of the TBA10 is not quite as good as the TBA12 type. In addition the closed orbit of the TBA10 lattice is more sensitive to focussing and alignment errors than the TBA12. A relaxed TBA10 with less focussing strength and a larger emittance might overcome these problems.

The TBA12 lattice is convincing in its linear and nonlinear behavior. With a minimum of elements its main advantage is a 25% increase of available insertion places compared to the TBA10.

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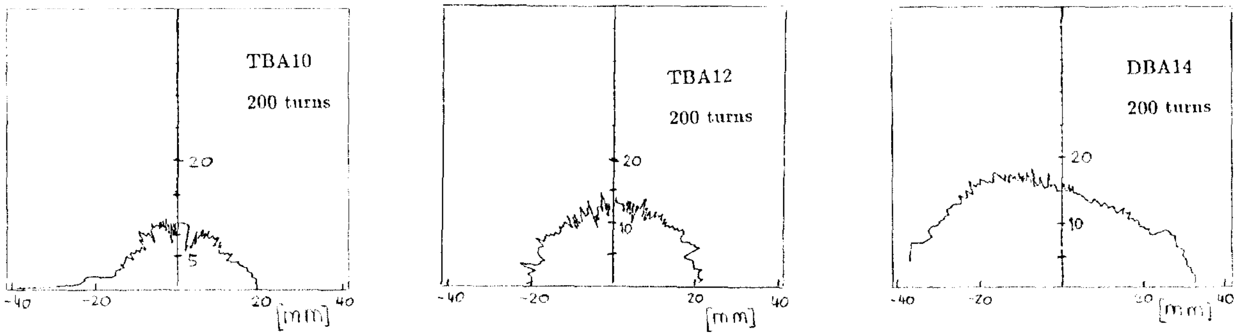

Fig. 10 to 12: Transversal tracking with insertion devices. There are 6 insertions (U1, W1, U2, W2, W1, U1, V1) arbitrarily distributed in the TBA-type lattices, only one wiggler of the type W1 was checked for the DBA lattice. The calculation was done after the correction as discussed in the text.