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STUDY OF SEVEN-BEND ACHROMAT LATTICES WITH INTERLEAVED DISPERSION BUMPS FOR HALS

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Abstract

Previously, we proposed a multi-bend achromat (MBA) lattice concept, called the MBA with interleaved dispersion bumps, which was then used to design a 7BA lattice for the Hefei Advanced Light Source (HALS) storage ring. Recently, such a 7BA lattice was further designed and optimized for the HALS by changing the number of lattice cells, scanning working point and employing octupoles. And two new HALS designs with such 7BA lattices have been made, one with 30 lattice cells and a natural emittance of 25 pm·rad and the other with 28 cells and 33 pm·rad. They had much better nonlinear dynamics performances than the previous design. The detailed study for these two HALS lattices will be presented in this paper.

INTRODUCTION

Hefei Advanced Light Source (HALS) [1] will be a soft X-ray diffraction-limited storage ring with an emittance of tens of pm·rad at 2.4 GeV. The R&D for the HALS is ongoing. To achieve better nonlinear dynamics performance at such an ultra-low emittance, several multi-bend achromat (MBA) lattice concepts have been proposed and studied for the HALS storage ring [2-5]. After a comparison of these lattice concepts, the MBA with interleaved dispersion bumps (IDB-MBA) [3] was chosen as the preferred option for the HALS. Figure 1 shows the schematic of the IDB-MBA lattice concept. In each lattice cell of the IDB-MBA, two pairs of interleaved dispersion bumps are created, and the phase advance between each pair of bumps satisfies the condition for cancellation of nonlinear effects induced by normal sextupoles. The IDB-MBA has one more pair of bumps than the hybrid MBA [6] so that more sextupoles can be accommodated, which is beneficial for enlarging dynamic momentum aperture (MA).

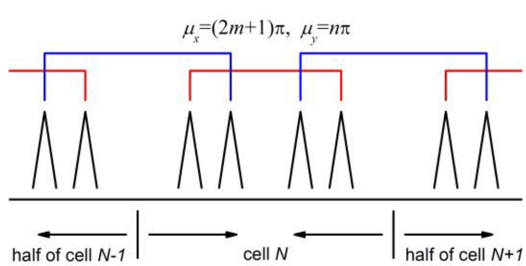

Figure 1: Schematic of the IDB-MBA lattice concept.

We have made a storage ring design with 32 IDB-7BA lattice cells for the HALS [4]. In this paper, some further studies on such an IDB-7BA lattice will be done for the HALS. By changing the number of lattice cells, scanning working point and employing octupoles, the ability of the IDB-7BA lattice will be further explored in the HALS lattice design.

IDB-7BA LATTICE DESIGNS FOR HALS

We will reduce the number of lattice cells from 32 [4] to 30 and 28 to study the IDB-7BA lattice for the HALS.

HALS with 30 Lattice Cells

We first present the storage ring design with 30 identical IDB-7BA lattice cells for the HALS. Figure 2 shows the magnet layout and linear optical functions of the designed IDB-7BA lattice. The phase advances between each pair of dispersion bumps are about (1.5, 0.5)×2π. The first and last two bends, as well as the middle bend, are longitudinal gradient bends (LGBs) with the dipole field profiles shown in Fig. 3. The profile of the second LGB is non-symmetric. The middle LGB has a high dipole field of 2 T as the radiation source for bend beamlines. Note that there is no defocusing quadrupole close to the middle LGB. Besides, there are two reverse bends in the 2nd and 3rd dispersion bumps. Some main parameters of the designed storage ring are listed in Table 1. The natural emittance is 24.7 pm·rad.

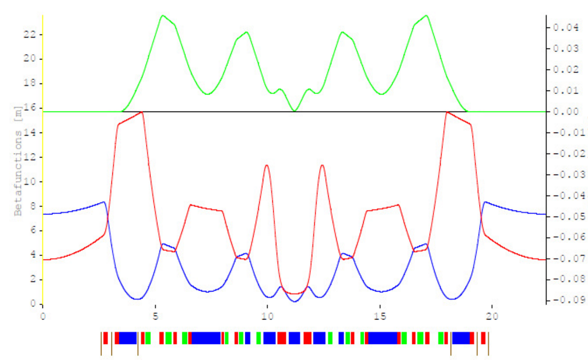

Figure 2: IDB-7BA lattice of the design with 30 cells.

Table 1: Main Parameters of Two HALS Designs

Parameters	30 cells	28 cells
Energy (GeV)	2.4	
Circumference (m)	672	
Nat. emittance (pm·rad)	24.7	33.3
Tune ν_x	71.296	68.172
Tune ν_y	23.296	24.172
Nat. chromaticities	-97, -110	-87, -121
Momentum compaction	5.0×10^{-5}	6.6×10^{-5}
Long straight length (m)	5.4	6.4
$\beta_{x,y}$ at long straights (m)	7.36, 3.63	5.59, 2.94

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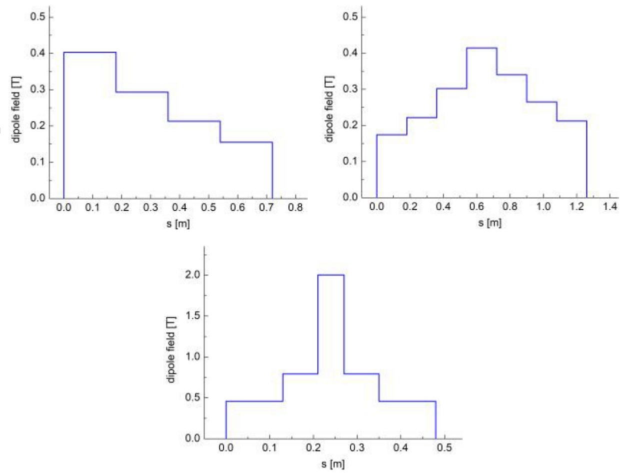

Figure 3: Longitudinal gradient dipole field profiles of the first (upper left), the second (upper right) and the middle (lower) bends. The last two LGBs in the lattice have the same field profiles as the first two ones but with reverse variation.

In the nonlinear dynamics optimization, six families of sextupoles and three families of octupoles were employed. The octupoles were used to minimize tune shifts with amplitude with the arrangement similar to that of the MAX IV light source [7] shown in Fig. 2. The chromaticities were corrected to (4, 3). The optimized dynamic aperture (DA) is shown in Fig. 4 with 4~5 mm in the horizontal direction and 2~3 mm in the vertical, which is much larger than the previous design [4]. The dynamic MA is larger than 6% as shown in Fig. 5, and off-momentum DAs shown in Fig. 6 are also large.

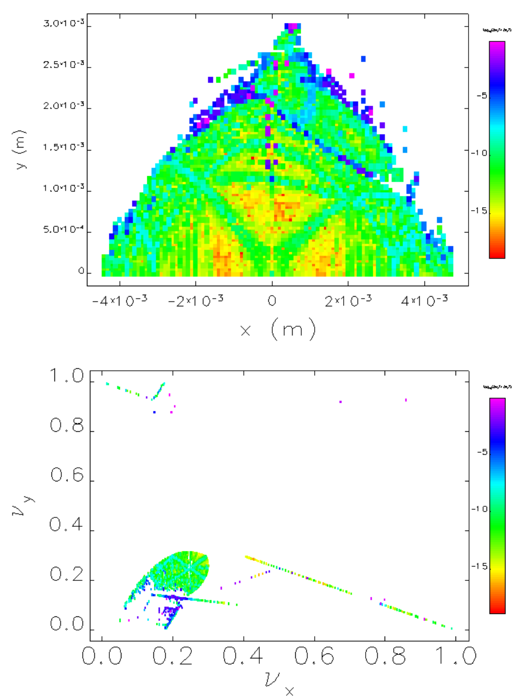

Figure 4: Frequency map analysis of on-momentum DA (30-cells case).

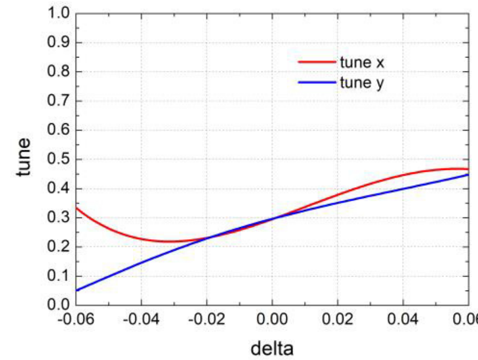

Figure 5: Tune shifts with momentum (30-cells case).

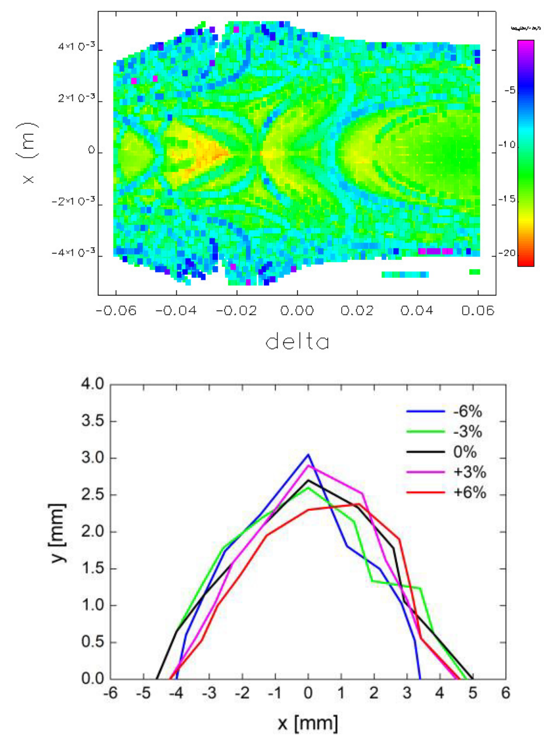

Figure 6: Off-momentum DAs (30-cells case).

HALS with 28 Lattice Cells

Then, we present the HALS design with 28 IDB-7BA lattice cells. The designed IDB-7BA lattice is shown in Fig.7, and the main parameters of the storage ring are listed in Table 1. The natural emittance is 33.3 pm·rad. The length of long straight sections in this design is longer than that in the 30-cells design. Inspired by the nonlinear cancellation scheme of SLS-2 [8], the horizontal and vertical tunes of one IDB-7BA lattice cell were set to near $(2\frac{3}{7}, \frac{6}{7})$ so as to minimize resonance driving terms over seven identical lattice cells. Also, six families of sextupoles and three families of octupoles were employed to optimize the nonlinear dynamics with chromaticities corrected to (3, 3). Figure 8, 9 and 10 show the optimized nonlinear dynamics performance. We can see that on- and off-momentum DAs are large and the dynamic MA is about 6%.

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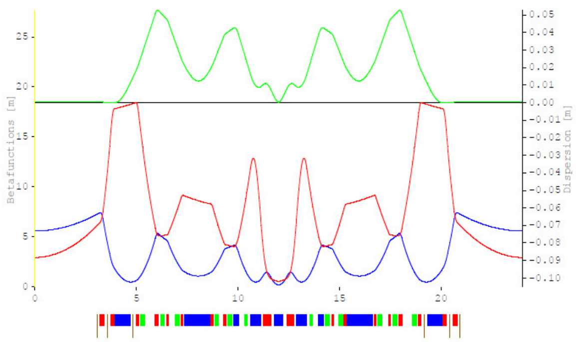

Figure 7: IDB-7BA lattice of the design with 28 cells.

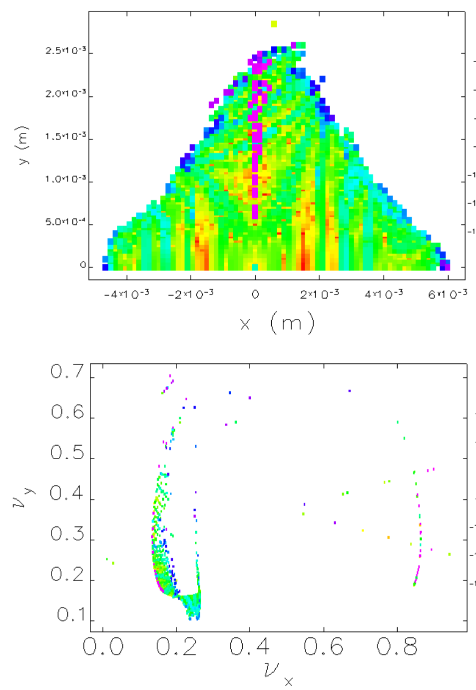

Figure 8: Frequency map analysis of on-momentum DA (28-cells case).

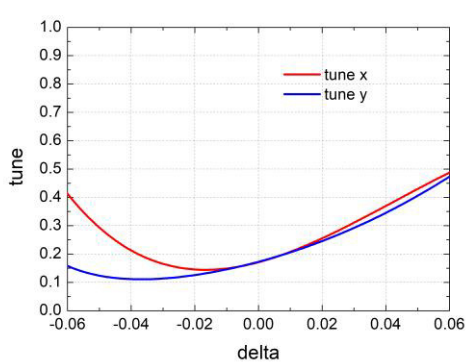

Figure 9: Tune shifts with momentum (28-cells case).

CONCLUSION

The IDB-7BA lattice was further studied for the HALS storage ring, and two HALS designs with 30 and 28 IDB-7BA lattice cells were presented. Compared to the previous design with 32 IDB-7BA lattice cells [4], the transverse tunes of one lattice cell were reduced and octupoles were employed in these two designs. As a result, significantly increased DAs were achieved in the two designs. We will continue studying the IDB-7BA lattice for the HALS.

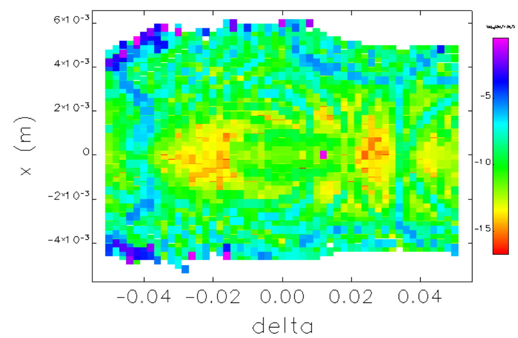

Figure 10: Off-momentum horizontal DAs (28-cells case).

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