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DESIGN OF THE SECOND VERSION OF THE HALS STORAGE RING LATTICE

Zhenghe Bai*, Penghui Yang, Zihui Yang, Weimin Li, Lin Wang†
National Synchrotron Radiation Laboratory, USTC, Hefei 230029, China

Abstract

In this paper, a new multi-bend achromat (MBA) lattice concept that we recently proposed for diffraction-limited storage rings is described, where two pairs of interleaved dispersion bumps are created in each cell and also most of the nonlinear effects produced by the sextupoles located in these bumps can be cancelled out within one cell. Following this concept, two 7BA lattices have been designed for the Hefei Advanced Light Source storage ring as the second version lattices, one with uniform dipoles and the other with nonuniform dipoles. The latter has a lower natural emittance of 23 pm·rad, in which longitudinal gradient bends and anti-bends are employed. The optimized nonlinear dynamics for these two lattices are rather good, and especially the dynamic momentum aperture can be larger than 8% without off-momentum tunes crossing non-structure half-integer resonance lines.

INTRODUCTION

Hefei Advanced Light Source (HALS) [1] was put forward some years ago as a future soft X-ray diffraction-limited storage ring at NSRL, and in the last year the preliminary R&D for the HALS was financially supported by the CAS and local government. At present, some multi-bend achromat (MBA) lattices have been studied for the HALS storage ring [2-4]. In the HALS lattice study, to achieve good on- and off-momentum nonlinear dynamics performance, we have proposed two MBA concepts – the locally symmetric MBA (LS-MBA) [3] and the MBA with interleaved dispersion bumps [4], in which most of nonlinear dynamics can be cancelled out within one cell and also the number of knobs in one cell for nonlinear dynamics optimization can be relatively large. Using the LS-MBA, we have designed the first version of the HALS lattice, and large dynamic aperture (DA) and dynamic momentum aperture (MA) were achieved [3]. Especially, the dynamic MA was larger than 7%. This paper will report the recent progress in designing the second version of the HALS lattice using the MBA with interleaved dispersion bumps.

MBA WITH INTERLEAVED DISPERSION BUMPS

In the concept of the MBA with interleaved dispersion bumps [4], two pairs of dispersion bumps are created in each cell, which are interleaved, like interleaved sextupoles, from the nonlinear cancellation point of view, as shown in Fig 1. For each pair of bumps, many nonlinear effects caused by the sextupoles located in these bumps can be effectively cancelled out. Compared to the hybrid MBA [5] that has one pair of non-interleaved dispersion bumps, this MBA can accommodate more sextupoles in one cell for optimizing nonlinear dynamics.

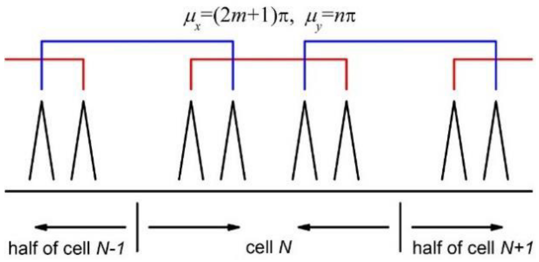

Figure 1: Schematic of the MBA with interleaved dispersion bumps.

HALS 7BA LATTICE DESIGN

The MBA concept described above was applied to design the second version of the HALS storage ring lattice.

Version 2.1: 7BA Lattice with Uniform Dipoles

First, a 7BA lattice with uniform dipoles was designed for HALS, where all bends were dipole-quadrupole combined function ones with uniform dipole field. Fig. 2 shows the 7BA lattice, from which we can see that two pairs of dispersion bumps are created. The phase advances between the 1st and the 4th bumps are about (1.5, 0.5)×2π, and the phase advances between the 2nd bump of the present cell and the 3rd bump of the previous cell also have the same values. The main parameters of the ring are listed in Table 1. At the present energy of 2.4 GeV, the natural emittance is about 32 pm·rad. Six families of sextupoles, three in each pair of bumps, were used in the nonlinear dynamics optimization, where the chromaticities were corrected to (3, 3). The optimized DA shown in Fig. 3 is about 200 sigma, and the local dynamic MA at long straight sections is about 8% as shown in Fig. 4. Besides, from Fig. 5 we can see that the off-momentum horizontal DAs are also large.

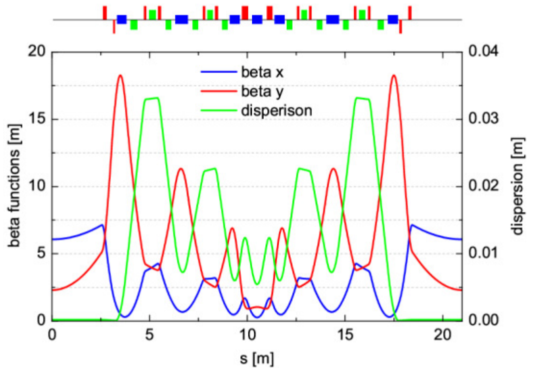

Figure 2: Linear optical functions of the 7BA lattice.

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* baizhe@ustc.edu.cn
† wanglin@ustc.edu.cn

Table 1: Main Parameters of the 7BA Storage Ring

Parameter	**Value**
Energy	2.4 GeV
Circumference	672 m
Number of cells	32
Natural emittance	32.1 pm·rad
Transverse tunes	78.273, 29.345
Natural chromaticities	-103, -117
Momentum compaction factor	5.75×10^{-5}
Beta functions at long straights	6.068, 2.299 m

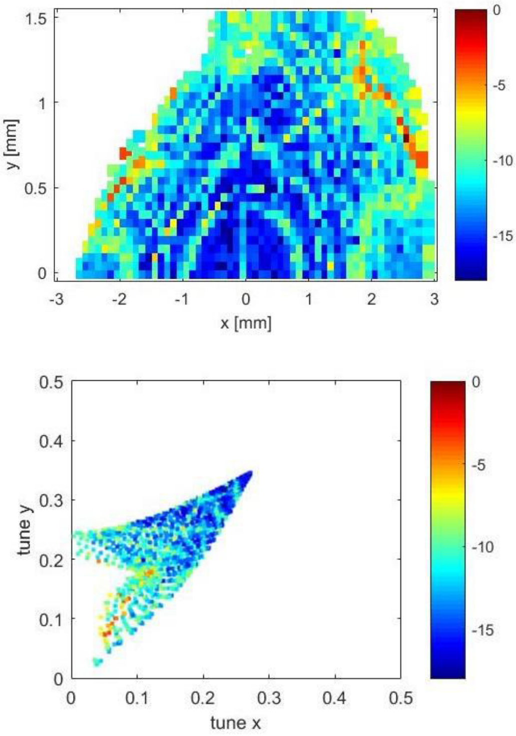

Figure 3: Frequency map analysis for the optimized DA of the 7BA lattice.

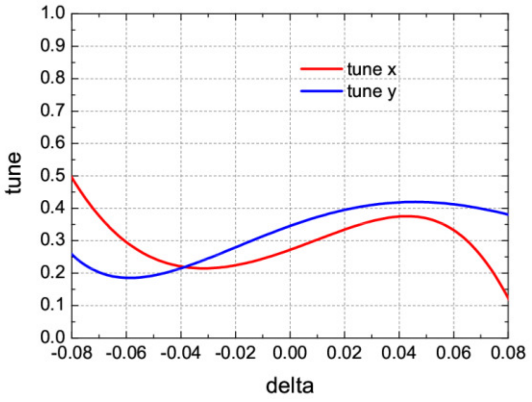

Figure 4: Tune shifts with momentum of the 7BA lattice.

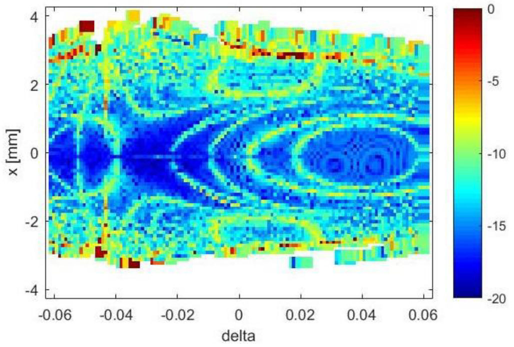

Figure 5: Off-momentum horizontal DAs of the 7BA lattice.

Version 2.2: Lower-Emittance 7BA Lattice with Nonuniform Dipoles

Then, we designed a lower-emittance 7BA lattice for HALS, where longitudinal gradient bends (LGBs) and anti-bends (ABs) were employed. The designed lattice is shown in Fig. 6, where the first two bends and the last two bends are LGBs and two ABs are in the 2nd and the 3rd bumps. The dipole fields of the 1st and the 2nd bends are shown in Fig. 7. Besides, like in Sirius [6], the middle bend complex consists of two defocusing combined function bends and one superbend with a high dipole field of 2 T. A lower emittance of 23 pm·rad has been achieved, and the main parameters of the ring are listed in Table 2. Also, six families of sextupoles were employed to optimize the nonlinear dynamics, and the chromaticities were corrected to (3, 3). Fig. 8, Fig. 9 and Fig. 10 show the optimized nonlinear performance. The on- and off-momentum DAs are all large and the dynamic MA is even larger than 10%.

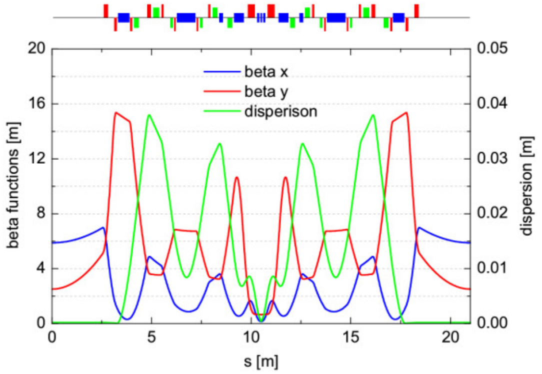

Figure 6: Linear optical functions of the lower-emittance 7BA lattice.

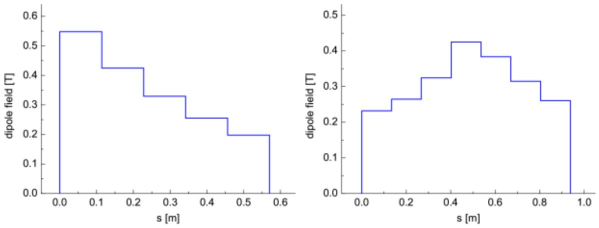

Figure 7: Longitudinal gradient dipole fields of the 1st (left) and the 2nd (right) bends.

Table 2: Main Parameters of the Lower-Emittance 7BA Storage Ring

Parameter	Value
Energy	2.4 GeV
Circumference	672 m
Number of cells	32
Natural emittance	23.0 pm·rad
Transverse tunes	78.304, 29.382
Natural chromaticities	-109, -126
Momentum compaction factor	4.50×10^{-5}
Beta functions at long straights	5.881, 2.507 m

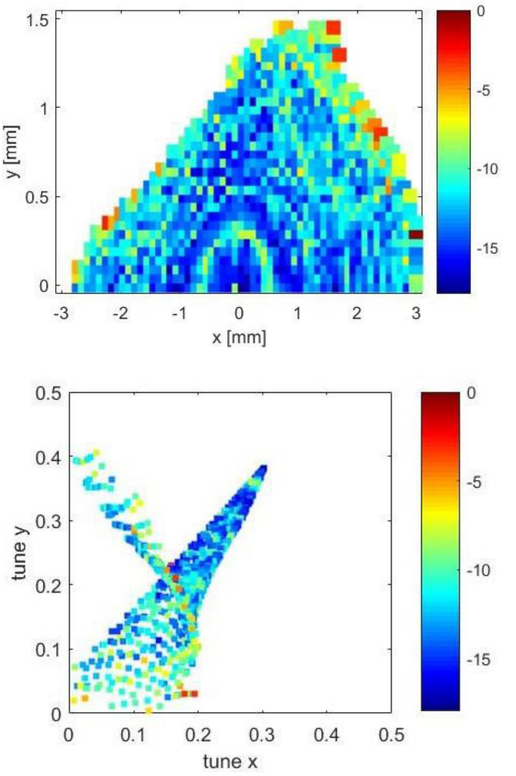

Figure 8: Frequency map analysis for the optimized DA of the lower-emittance 7BA lattice.

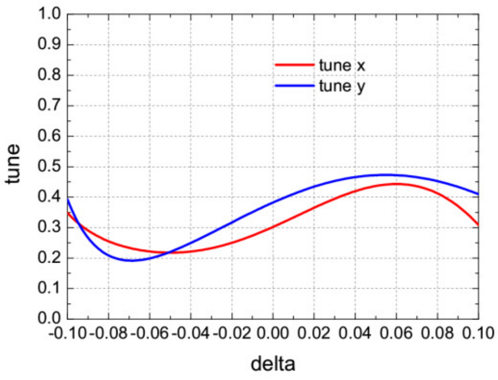

Figure 9: Tune shifts with momentum of the lower-emittance 7BA lattice.

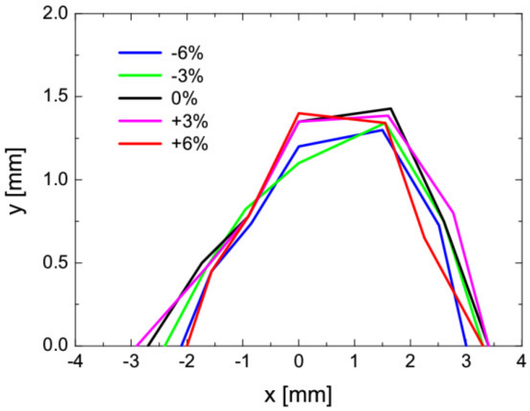

Figure 10: Off-momentum DAs of the lower-emittance 7BA lattice.

The lower-emittance 7BA lattice is presently chosen as the HALS lattice. Note that in the nonlinear optimization for these two 7BA lattices, the six families of sextupoles had not been organized into more families that could be done within some cells. So we can further optimize the nonlinear dynamics by making more knobs with chromaticities corrected to higher values. Due to that rather good on- and off-momentum dynamics performance has been achieved, the longitudinal injection scheme [7] is first considered for HALS, which is being studied.

CONCLUSION

Two 7BA lattices have been designed for the HALS storage ring using the concept of the MBA with interleaved dispersion bumps, which has the philosophy that many nonlinear effects are effectively cancelled out within one cell and also many knobs can be used in one cell for nonlinear optimization. The optimized nonlinear dynamics performance for these two lattices was rather good, showing large on- and off-momentum DAs and large enough dynamic MA, which was even larger than 10%. So the longitudinal injection scheme is presently considered as the first option for the HALS beam injection. The lower-emittance 7BA lattice employing LGBs and ABs is chosen as the present HALS lattice with a natural emittance of 23 pm·rad. Furthermore, we are now extending the concept of the MBA with interleaved dispersion bumps to the case of superperiod lattice, which is being studied to design the future version of the HALS lattice.

ACKNOWLEDGEMENTS

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