DQBA LATTICE OPTION FOR THE KEK-LS PROJECT

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Abstract

KEK-LS is a fourth generation 3GeV light source and will be constructed in KEK Tsukuba campus. The lattice is 20 cells of ESRF type HMBA (Hybrid Multi Bend Achromat) with short straight section that enables to double the numbers of insertion device beam lines. The circumference is about 570m, and the horizontal natural emittance about 133pmrad. The conceptual design report (CDR) was published in October 2016. Adding two quadrupole magnets to the short straight section of the original lattice in CDR, the lattice design flexibility, emittance and dynamic apertures are improved. In this presentation, we show this new DQBA (Double Quadruple Bend Achromat) lattice option for KEK-LS project.

INTRODUCTION

KEK-LS is the 3GeV light source project will be constructed in Tsukuba, Japan. The lattice is HMBA type developed for the ESRF EBS project [1]. We start the lattice design from the example lattice of 3GeV EBS with 20 cells [2]. The short straight section of 1.2 m was added in order to double the number of the insertion device[3]. Since the original example lattice has very small amplitude and momentum dependent tune shifts and results in the large dynamic apertures, the small distortions were accumulated during the lattice studies and the dynamic apertures and lattice flexibility become deteriorated. In order to recover and improve the performance, the two quadrupoles are added to the short straight sections [4]. The similar lattice was already examined for the DIAMOND II as DTBA [5]. Following this, we call the improved HMBA lattice as DQBA. In this presentation, we show the shortage of present CDR version lattice and advantage of the DQBA lattice for the KEK-LS.

SHORTAGE OF CDR LATTICE

The parameters of the CDR version lattice is shown in Table 1 and the optics in Figure 1 (a). Firstly, the Touscheck

Table 1: Parameters of the Ring

		(a) CDR	(b) DQBA	(c) DQBA
Residual dispersion (5m)	[cm]	2.5	0.0	0.0
(short straight)	[cm]	2.0	3.0	0.0
RF voltage	V_{RF}[MV]	2.5		
Bucket height	%	4.5	4.5	4.0
Energy loss	MeV/rev	0.30	0.26	0.26
Momentum compaction	α [x10^{-4}]	2.2	2.4	3.1
Betatron tune (hor.)	ν_x	48.58	47.10	
(vertical)	ν_y	17.62	17.15	
Damping time (hor.)	[ms]	29.3	21.5	23.4
(ver.)	[ms]	38.3	43.1	43.1
(longitudinal)	[ms]	22.6	43.4	37.2
Beam current	[mA]	500	500	500
Hor. emit. (no IBS)	[pm·rad]	133	121	253
(effective, 5m sec.)	[pm·rad]	160		
(effective, short st.)	[pm·rad]	225	204	
(500mA withIBS)	[pm·rad]	315	228	366
Coupling (500mA)	[%]	2.6	3.5	2.2
Vertical emittance	[pm·rad]	8.2	8.0	8.1
Momentum aperture	[%]	2.8	4.0	4.0
Horizontal aperture	[σ]	150	200	200
Touschek lifetime	[h]	2.4	17.0	27.0
Energy spread (0mA)	x10^{-4}	6.4	7.2	6.7
(500mA)	x10^{-4}	7.9	9.7	8.5
Bunch length (0mA)	mm	2.7	2.8	2.9
(500mA)	mm	3.3	3.8	3.8

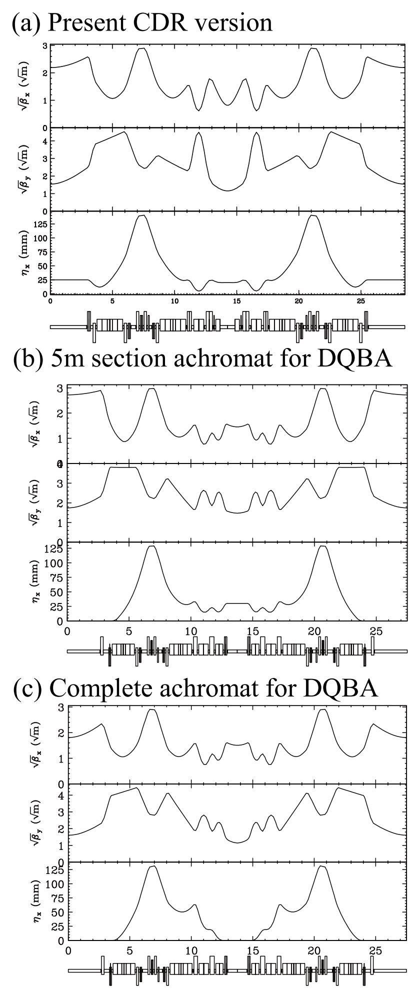

Figure 1: Optics of the normal cell.

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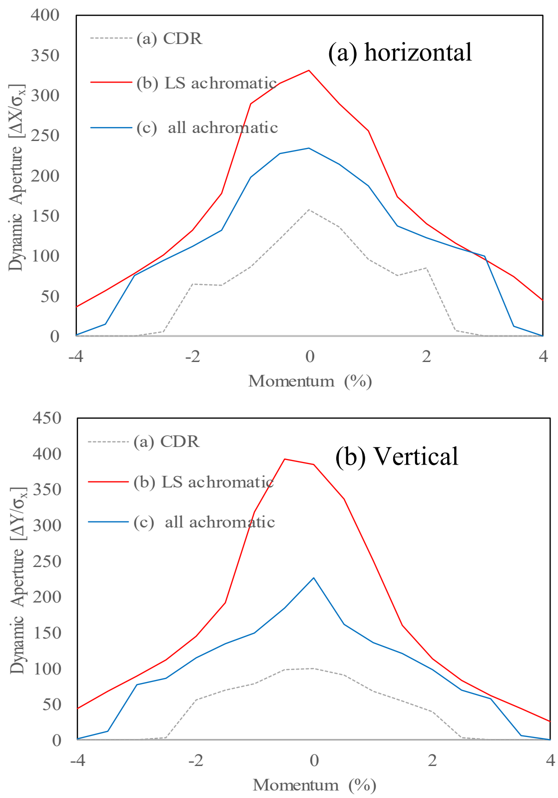

Figure 2: Dynamic aperture.

lifetime is about 2 hours because the dynamic momentum aperture is about 3%. For this lifetime, the estimated beam loss is about three times larger than the present PF ring during the hybrid mode (lowest lifetime mode). It may be permissive but longer lifetime is better. For the second, the insertion device cause the emittance growth [6] because of the low horizontal beta and the residual dispersion at the straight section. Since the achromatic long straight section can be realized by about 15% effective emittance deterioration, the achromat of the short straight section results in the very large emittance. At the short straight section, the residual dispersion is 2.5 cm and the horizontal beta function 0.66 m. With these parameters, The short in-vacuum insertion device of 60 cm length results in the significant emittance growth.

Table 2: Parameters of Typical Insertion Devices

	Periodic length	Period	ID length	Peak magnetic field
	l_w [mm]	N_w	L [m]	B_w [T]
For long straight (5m)				
UL20N250	20	250	5	1.13
UL48N104	48	104	5	0.9
UL160N31	160	31	5	0.5
UL12N416	12	416	5	0.8
MPW	120	42	5	1.8
For short straight (60cm)				
UL20N30	20	30	0.6	1.13
IV MPW	60	10	0.6	2.2

DQBA OPTION

The DQBA option was firstly developed in collaboration with ESRF. It has better emittance and apertures than CDR version. Comparing with CDR version lattice, the two quadrupoles are newly installed to the short straight section and the optics flexibility is improved. For the short straight section, the horizontal beta function can be larger to improve I_2, and dispersion zero to suppress I_5. Figure 1 and

Table 3: Analytic Estimation of the Synchrotron Radiation Integrals

		Ring	UL20N250 5m	UL48N104 5m	UL160N31 5m	UL12N416 5m	MPW 5m	UL20N30 60cm	IV MPW 60cm
CDR (a)	I_2 [m^{-1}]	2.62E-01	3.19E-02	2.03E-02	6.25E-03	1.60E-02	8.10E-02	3.83E-03	1.45E-02
	I_4 [m^{-1}]	-8.08E-02	-3.10E-09	-7.18E-09	-7.60E-09	-2.80E-10	-7.18E-07	-3.72E-10	-4.81E-08
	I_5 [m^{-1}]	3.44E-06	4.00E-07	2.02E-07	3.50E-08	1.42E-07	1.76E-06	2.21E-07	1.63E-06
	i_{50} [m^{-1}]		3.99E-07	2.02E-07	3.46E-08	1.42E-07	1.61E-06	2.21E-07	1.63E-06
	i_{51+53} [m^{-1}]		3.88E-10	7.17E-10	4.22E-10	2.49E-11	1.43E-07	1.38E-11	3.47E-09
DQBA (b)	I_2 [m^{-1}]	2.24E-01	3.19E-02	2.03E-02	6.25E-03	1.60E-02	8.10E-02	3.83E-03	1.45E-02
	I_4 [m^{-1}]	-2.26E-01	-3.10E-09	-7.18E-09	-7.60E-09	-2.80E-10	-7.18E-07	-3.72E-10	-4.81E-08
	I_5 [m^{-1}]	4.13E-06	7.04E-08	3.64E-08	6.69E-09	2.48E-08	5.01E-07	1.57E-07	1.17E-06
	i_{50} [m^{-1}]		6.98E-08	3.53E-08	6.05E-09	2.48E-08	2.82E-07	1.57E-07	1.16E-06
	i_{51+53} [m^{-1}]		5.93E-10	1.09E-09	6.44E-10	3.80E-11	2.19E-07	2.24E-11	5.63E-09
DQBA (c)	I_2 [m^{-1}]	2.24E-01	3.19E-02	2.03E-02	6.25E-03	1.60E-02	8.10E-02	3.83E-03	1.45E-02
	I_4 [m^{-1}]	-1.89E-01	-3.10E-09	-7.18E-09	-7.60E-09	-2.80E-10	-7.18E-07	-3.72E-10	-4.81E-08
	I_5 [m^{-1}]	7.91E-06	2.84E-10	5.24E-10	3.08E-10	1.82E-11	1.05E-07	2.57E-11	6.47E-09
	i_{50} [m^{-1}]		2.90E-22	1.47E-22	2.51E-23	1.03E-22	1.17E-21	4.51E-20	3.33E-19
	i_{51+53} [m^{-1}]		2.84E-10	5.24E-10	3.08E-10	1.82E-11	1.05E-07	2.57E-11	6.47E-09

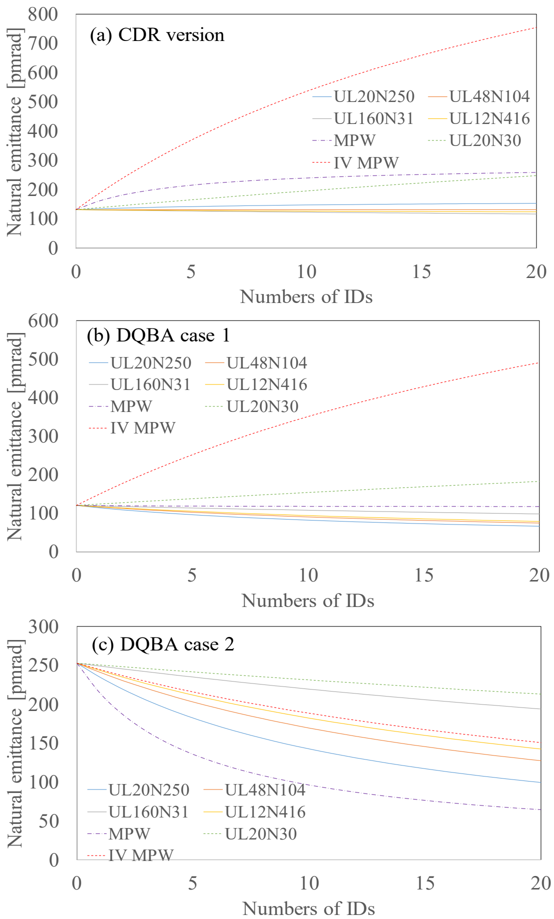

Figure 3: Emittance growth.

Table 1 shows the two cases for DQBA version; the case (b) has the achromatic long straight section but the chromatic short straight section, and for the case (c), both straight sections are completely achromatic. The effective emittance in the Table 1 shows the emittance including the effects of the dispersion function and energy spread. For the case of 500mA, the effect of IBS (intra beam scattering) is considered. Presently, Touscheck lifetime for DQBA cases are very rough estimation and not calculated by LMA (local momentum acceptance) method. It seems that some important effect is not included and calculated lifetime seems to be too long. With larger momentum and horizontal amplitude aperture, the lifetime certainly may be longer for DQBA case than that of CDR case. The dynamic aperture with magnetic errors are shown in Figure 2. The assumed magnetic errors are the Gaussian random magnetic errors of the standard deviation 1σ for the alignment errors of 50μm, the magnetic field fluctuation of 0.05%, and skew rotation of the magnets of 0.1mrad. The results shows the average of 100 random seeds. The systematic magnetic errors like the higher order components of the magnets and the effect of the insertion devices are not included.

INSERTION DEVICE EFFECT

The typical parameters of assumed insertion devices are shown in Table 2. The analytical calculation of the synchrotron radiation integrals are shown in Table 3. In this table, the values for each insertion devices show the contribution of one insertion device to the integral. i_{50} is from the residual dispersion function and i_{51+53} from the dispersion generated by the insertion device itself. The contribution from the residual dispersion is much larger than self generated one.

The emittance growth effect from the insertion device for CDR version is shown in Figure 3 (a) and those for DQBA version in (b) and (c). These analytical approach [6] shown here are only the case study and it may be not the real case that one type of insertion device will be installed to all straight sections. For the CDR version, emittance become more than 700 pmrad with twenty in-vacuum multi pole wiggler of 60cm length to the short straight section. Twenty UL20N30 almost double the emittance. For the DQBA case (b), the insertion device installed to the achromatic long straight section results in the damping enhancement. For the short straight section, since the larger beta function relaxes the effect, twenty UL20N30 results in the emittance growth to about 190 pmrad from 121 pmrad. On the other hand, in the completely achromatic case (c), the insertion device always make emittance smaller. The complete achromat seems to be essential to the medium energy light source.

FURTHER OPTIMIZATION

For the DQBA cases, the maximum quadrupole magnetic field is about 60 T/m. The minimum magnetic spacing is 12 cm core to core. If we can relax these parameters, it is easier to design the hardware. The precise calculation of lifetime and simulation including more types of errors are required. The quadrupoles are only used to optics change from (b) to (c). The matching of beta function is required to select the optics cell by cell.

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