DOUBLE MINI-BETAY LATTICE OF TPS STORAGE RING

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Abstract

Based on our previous design of double mini-betay lattice in one 12-m straight section, NSRRC plan to implement the double mini-betay lattice in three 12-m straight sections in TPS storage ring. Those three locations chosen for double mini-betay lattice still retain the symmetry of accelerator lattice. The two symmetric minima of the vertical beta function will be created in the center of three 12-m straight sections, respectively. We strived to obtain a linear lattice such that there is no significant increase in the natural emittance. Efforts were devoted to optimize the nonlinear beam dynamics with various simulation tools. Preliminary results are demonstrated.

INTRODUCTION

The TPS storage ring is designed as 3-GeV light sources belong to 3rd-generation light source. It is under construction and will be commissioned in the first season of 2014. The fundamental parameters are listed in Table 1 [1].

Table 1: TPS Storage Ring Parameters

Circumference	518.4 m
Nominal energy	3.0 GeV
Revolution frequency	578.3 kHz
Revolution period	1729.2 ns
RF frequency	499.654 MHz
Harmonic number	864
Natural emittance	1.6 nm-rad
Energy Spread	8.86E-04
Momentum compaction	2.4E-04
Energy loss per turn	853 KeV
Damping partition	0.9977/1.00/2.0023
Damping time	12.20/12.17/6.08 msec
Betatron tune	26.18/13.28
Natural chromaticity	-75/-26

The TPS storage ring consists of 6 superperiods. It owns 6 long straights (12-m long) and 18 short straights (7-m long). The total port number of beam line is 48. The double mini-betay lattice is located in three long straight centers, the upstream of port 9, 25, and 41, respectively. Figure 1 shows its locations.

To install two small gap IDs in the long straight section, the vertical beta function with two minimum must be created there to accommodate them. Based on SPEAR3 [4], DIAMOND [2], and SOLEIL [3], we design this lattice. Different from them, these two IDs are tandem not canted. We hope synchrotron light from these two IDs can be coherent, thus the brightness will be increased. The tune shift with momentum, tune shift with amplitude, dynamic aperture (DA) and frequency map are used to evaluate the beam dynamics. The Touschek lifetime issues are also studied. It is longer than 16 hours from the TRACY-II [5] 6-D tracking.

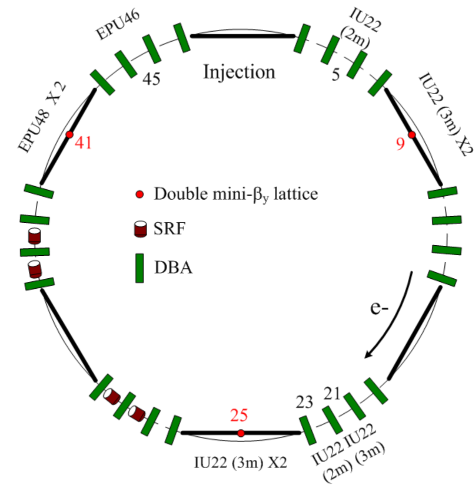


Figure 1: Locations of double mini-betay lattice.

LINEAR LATTICE DESIGN

MAD8 [6] is used to design the linear lattice. The original working tune of TPS is 26.18/13.28, we rematch the linear lattice to the tune of 26.18/12.82. Then add an extra quadrupole triplet (blue color) at the centers of three long straights (the upstream of port 9, 25, and 41), respectively. Original quadrupoles QL1, QL2, and QL3 (renamed as Q1, Q2, and Q3, respectively) plus a quadrupole triplet are used to match the double mini-betay lattice. To obtain symmetric vertical beta function, only 5 of 9 quadrupoles are independent. The final working tune is 26.18/14.26. Figure 2 shows the design optical function with and without a quadrupole triplet. We can see that its optical function is symmetric with respect to the long straight center. The minimum of the betay function can reach 1.788 m.

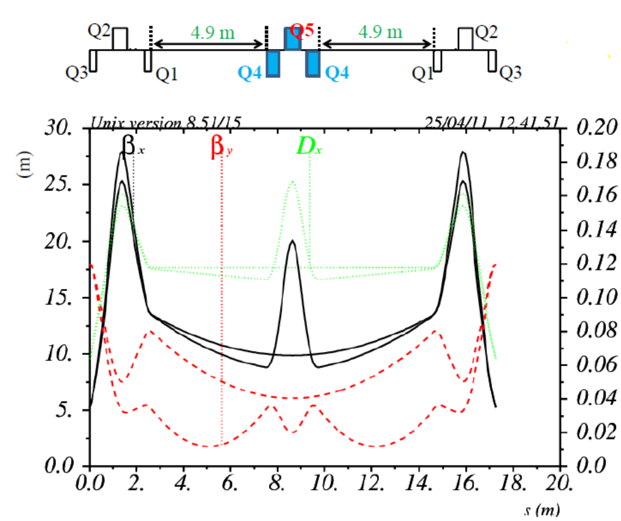


Figure 2: Optical functions with and without double mini-betay lattice.

NONLINEAR BEAM DYNAMICS

Firstly, we use OPA [7] to optimize the chromatic and harmonic sextupole strengths by choosing appropriate weighting factors for the nonlinear driving terms to try to get larger dynamic aperture. Huge amount of different combinations of weighting factors are tried. It is very time consuming. After getting reasonable dynamic aperture, then we use TRACY-II to calculate the tune shifts with momentum, tune shift with amplitude, dynamic aperture and the frequency map. The chromaticities are corrected to small positive values by adjusting the chromatic sextupoles' strengths.

Figure 3 shows the tune shift with momentum. There is no crossover between -4% and 3%. Figure 4 shows the tune shift with amplitude. Particle will get lost if the displacement of vertical direction is greater than 12 mm.

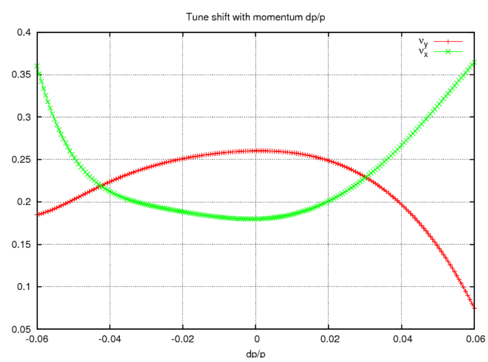
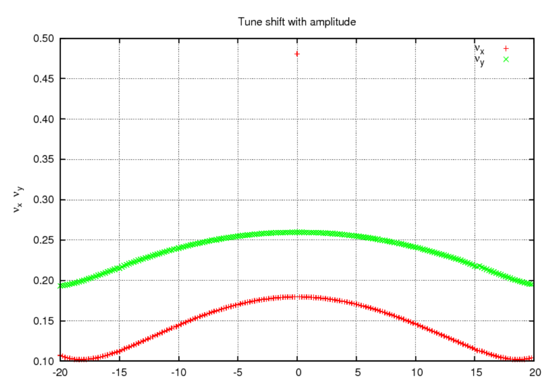


Figure 3: Tune shift with momentum.

(a)



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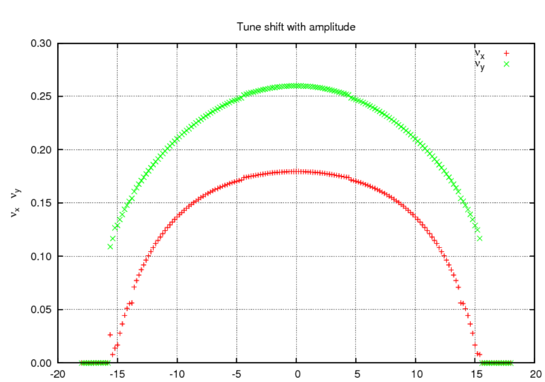
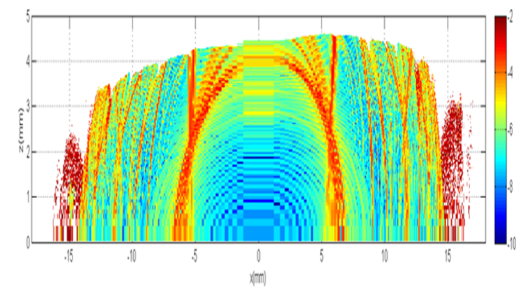


Figure 4: Tune shift with amplitude in (a) horizontal and (b) vertical direction.

Figure 5 shows dynamic aperture and frequency map. The simulation conditions consider multipole errors, 1% emittance coupling, and chamber limit but without ID kick map. The fifth-order resonance line $3\nu_x - 2\nu_y = 107$ cause particle loss. The multiple errors and chamber limit are listed in Table 2 and 3.

(a)



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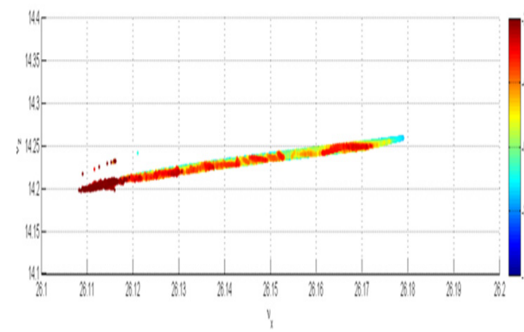


Figure 5: (a) Dynamic aperture (on-momentum) tracked at long straight center with β_x= 9.88m and β_y= 6.08m, and the corresponding (b) frequency map, considering multipole errors, 1% emittance coupling, and chamber limit but without ID kick map.

Table 2: Multipole errors of TPS storage ring (DM: dipole. QM: quadrupole. SM: sextupole)

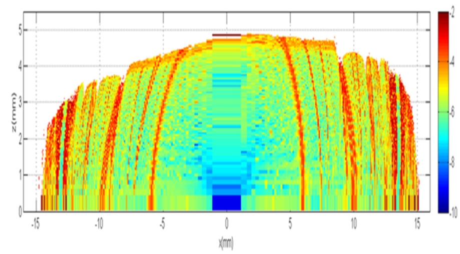
DM		QM		SM	
B1/B0	**±5**	**A2/B1**	**±3**	**B0/B2**	**±5**
B2/B0	**-5±2**	**B0/B1**	**±5**	**B1/B2**	**±10**
B3/B0	**±2**	**B2/B1**	**±2**	**B3/B2**	**±2**
B4/B0	**5±2**	**B3/B1**	**±3**	**B4/B2**	**±3**
B5/B0	**±1**	**B4/B1**	**±1**	**B5/B2**	**±0.5**
B6/B0	**-2±0.2**	**B5/B1**	**0±1**	**B6/B2**	**±0.5**
B8/B0	**-0.6±0.6**	**B9/B1**	**0±1**	**B7/B2**	**±0.1**
rest term	**±0.1**	**B13/B1**	**0±1**	**B8/B2**	**0±1**
		B17/B1	**0±1**	**B14/B2**	**0±1**
		B21/B1	**0±1**	**B20/B2**	**0±1**
		rest term	**±0.1**	**B26/B2**	**0±1**
				rest term	**±0.1**
B_n/B_N @ 25mm (*E-4)					

Table 3: Chamber limit

ID	Length (m)	Vertical (mm)	Horizontal (mm)
IU22	2	±3.5	±34
IU22	3.08	±3.5	±34
EPU48	3.44	±3.9	±34
EPU46	3.8	±6.5	±34
Beam Pipe		±15	±34

The effects of nonlinear beam dynamics caused by IDs are also investigated. IDs are modeled by kick maps, which are generated by RADIA [8]. Figure 6 shows dynamic aperture and frequency. The simulation conditions consider multipole errors of ring magnet, 1% emittance coupling, chamber limit, and ID kick maps of 2 EPU48s and 4 IU22s, located at the double mini-betay lattice. The fifth-order resonance line $3\nu_x - 2\nu_y = 107$ cause particle loss. The multiple errors and chamber limit are listed in Table 2 and 3.

(a)



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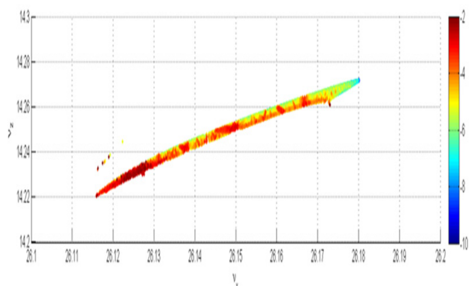


Figure 6: (a) Dynamic aperture (on-momentum) tracked at long straight center with β_x= 9.88m and β_y= 6.08m, and the corresponding (b) frequency map, considering 1% emittance coupling, multipole errors, chamber limit, and ID kick maps of 2 EPU48s and 4 IU22s.

TOUSCHEK LIFETIME

The momentum acceptance of double mini-betay lattice are calculated by TRACY-II 6-D tracking, considering multipole errors of ring magnets, 1% emittance coupling, chamber limit, and ID kick maps of 2 EPU48s and 4 IU22s. Touschek lifetime is calculated by Bruk formula. It is expressed as

$$\frac{1}{\tau} = \frac{r_e^2 cN}{8\pi\gamma^3\sigma_s}\frac{1}{L}\oint\frac{F(x)}{\sigma_x(s)\sigma_y(s)\sigma_{x'}(s)\varepsilon_{ac}^2(s)}ds$$

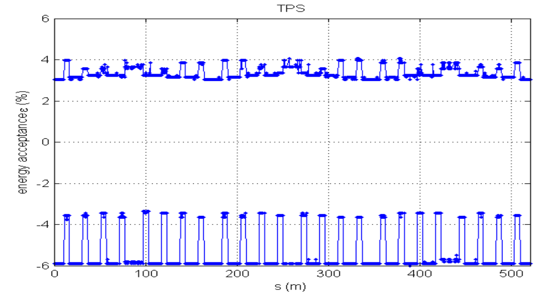
N is the number of electron per bunch, L is the ring circumference, c is the spead of light.

$$F(x) = -\frac{3}{2}e^{-x} + \frac{x}{2}\int_x^\infty \frac{\ln u}{u}e^{-u}du + \frac{(3x - x\ln x + 2)}{2}\int_x^\infty \frac{e^{-u}}{u}du$$

$x = (\varepsilon_{ac}(s)/\gamma\sigma_{x'}(s))^2$, $\varepsilon_{ac}(s)$ is momentum acceptance.

The Touschek lifetime is longer than 16 hours at RF gap voltage of 3.5 MeV. The bunch current is 0.5 mA per bunch. Beam current is 400 mA, 800 bunches. Figure 7 (a) shows the energy acceptance versus longitudinal position and (b) the Touschk lifetime versus RF gap voltage.

(a)



(b)

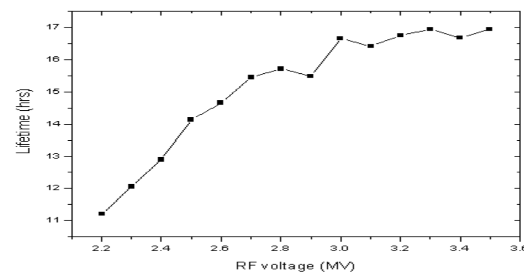


Figure 7: (a) Energy acceptance versus longitudinal position, (b) Touschk lifetime versus RF gap voltage, considering 1% emittance coupling, multipole errors, chamber limit and ID kick maps of 2 EPU48s and 4 IU22s.

SUMMARY AND ACKNOWLEDGEMENT

The double mini-betay lattices are designed to meet the requirement for accommodating two small gap insertion devices as well as less degradation in beam lifetime.The preliminary investigation shows that the Touschek lifetime is longer than 16 hours. To speed up frequency map and momentum acceptance calculations, we modify TRACY-II to parallel code by MPI. Further study is still ongoing.

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REFERENCE

[1] C. C. Kuo, *et al.*, "Progress Report of TPS Lattice Design", PAC2009.

[2] B. Singh, *et al*, "Double mimi-betay plus virtual focusing optics for DIAMOND storage", EPAC 2009.

[3] L. S. Nadolski, 2nd Nonlinear Beam Dynamics Workshop, Diamond Light Source, Oxfordshire, 2009.

[4] J. Corbett, *et al.*, "Implementation of double-waist chicane optics in SPEAR3", EPAC 2006.

[5] TRACY-II, SOLEIL's version.

[6] H. Grote, *et al.*, The MAD program (Methodical Accelerator Design), CERN/SL/90-13 (AP).

[7] A. Streun, OPA manual and program. http://people.web.psi.ch/streun/opa/.

[8] O. Chubar, *et al.*, RADIA program. http://www.esrf.eu/Accelerators/Groups/InsertionDevices/Software/Radia.