DOUBLE MINI-BETAY OPTICS OF TPS STORAGE RING

M.S. Chiu, C.H. Yang, H.C. Chao, H.P. Chang, H.J. Tsai, and C.C. Kuo
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

Abstract

To evaluate the feasibility for installing two small gap insertion devices (IDs) in the long straight sections (12-m long) of the Taiwan Photon Source (TPS) storage ring, two different kinds of the double mini-betay optics (symmetric and asymmetric configurations) are proposed to fulfill this purpose. In the symmetric case, a quadrupole triplet is located at the center of the long straight, while in the asymmetric case, a quadrupole doublet is used. The effects on the beam dynamics, such as the dynamic aperture, and lifetime, etc., are presented in this report.

INTRODUCTION

The TPS storage ring is a 3-GeV 3rd-generation light source. It will be commissioned by the end of 2013. 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).

To investigate the feasibility for installing two small gap EPU48 (3.5-m long with chamber gap of 7.8 mm) in the long straight section, double mini-betay function should be created. Hence, we refer to DIAMOND [2], SOLEIL [3], and SPEAR3 [4], and propose two configurations of optics to modify the betay function in the long straight. One is symmetric, and the other one is asymmetric. Due to the different linear and nonlinear beam dynamics for these two configurations, the investigation and results of these two cases are presented in the following sections. The dynamic aperture (DA) and frequency map are used to evaluate. The Touschek lifetime issues are also studied. In symmetric case, the lifetime is longer than 15 hours; while in asymmetric case, it is still longer than 8 hours from the 6-D TRACY-II [5] tracking results.

LINEAR LATTICE DESIGN

MAD [6] is used to design linear lattice. In symmetric case, an extra quadrupole triplet (red color) is added at the center of the long straight, the minimum value of the betay function can reach 1.906m, while in asymmetric case, a quadrupole doublet (red color) is placed at the center of the long straight and also three quads (blue color) are added for matching. Figure 1(a) and (b) show the two cases of the double mini-betay lattices.

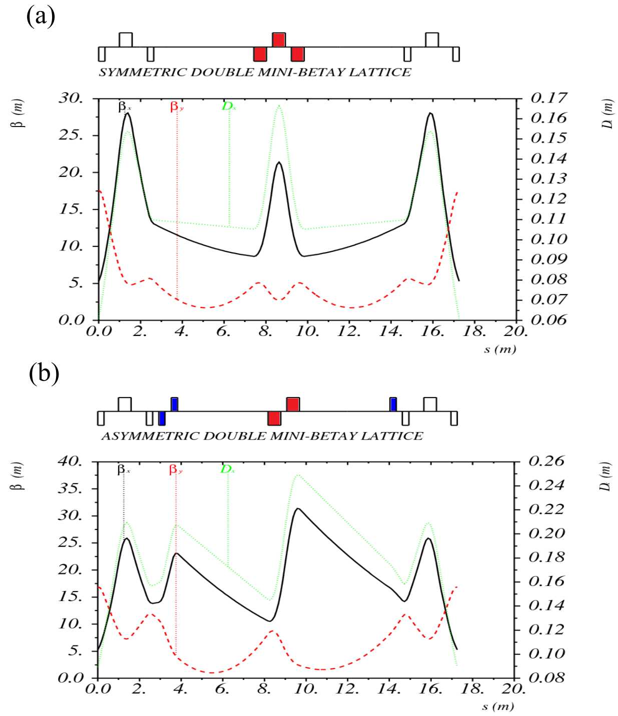


Figure 1: Optical functions of double mini-betay lattice for (a) symmetric case and (b) asymmetric case.

Under the linear optical function matching for these two lattice arrangements, the designed working tunes, natural emittance and chromaticities of the full ring are slightly changed in comparison with the original TPS designed values. These values are given in Table 2.

Table 2: The Lattice Parameters

Symmetric Case

Betatron tune	26.21/13.32
Natural emittance	1.63 nm-rad
Natural chromaticity	-76/-28

Asymmetric Case

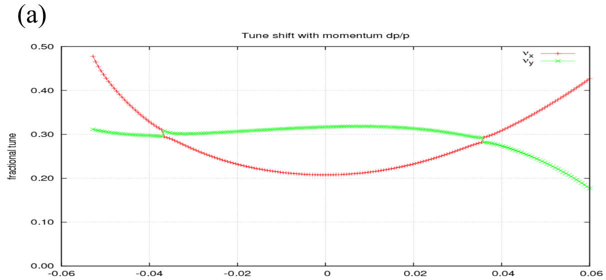
Betatron tune	26.18/13.71
Natural emittance	1.85 nm-rad
Natural chromaticity	-76/-28

NONLINEAR 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. And then we use TRACY-II to calculate the tune shifts with momentum, dynamic aperture and the frequency map. The chromaticities are corrected to small positive values by using chromatic sextupoles as well.

Let's first look at the symmetric case. Figure 2(a) shows the tune shifts with momentum. There is no crossover of the fractional tunes between the energy deviation range from -3.9% to 3.7%. Figure 2(b) and (c) show the DA and frequency map respectively. These results are computed with 1% emittance coupling and multipole errors but without ID. As can be seen, the fifth-order resonance line $3\nu_x - 2\nu_y = 52$ causes the particle loss and degrades the stability of the electron beam.

(a)



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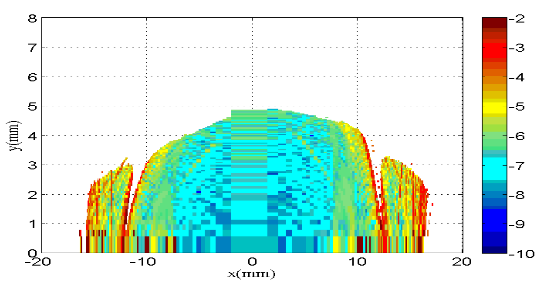


(c)

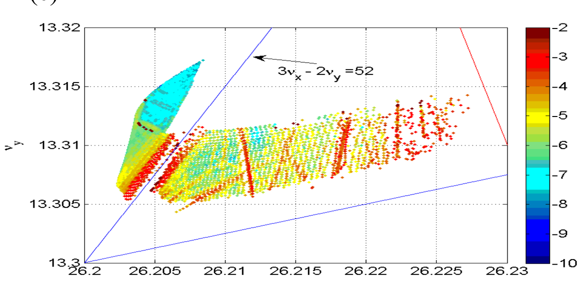
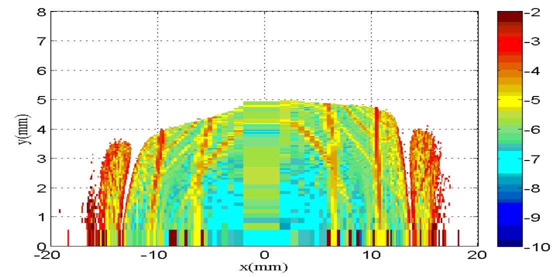


Figure 2: (a) Tune shifts with momentum. (b) DA (on-momentum) tracked at one straight center with β_x= 10m and β_y= 6m, and the corresponding (c) frequency map considering 1% emittance coupling and multipole errors.

(a)



(b)

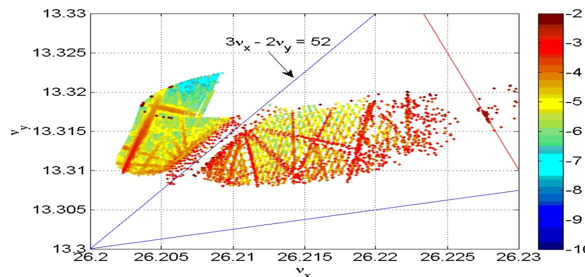
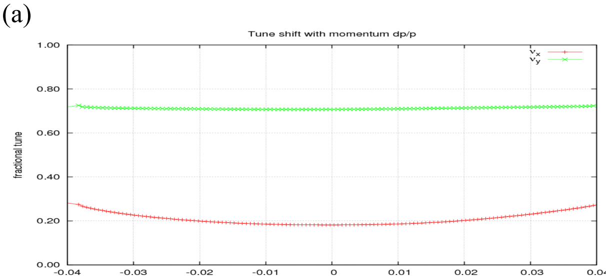


Figure 3: (a) DA (on-momentum) tracked at one straight center with β_x= 10m and β_y= 6m, and the corresponding (b) frequency map considering 1% emittance coupling, multipole errors and kick maps of 2 EPU48s.

The effects of nonlinear beam dynamics caused by IDs are also investigated. The IDs are modeled by kick maps, which are generated by RADIA [8]. In computation, the chamber size is determined by the IDs' length and gap: EPU48 with length of 3.5m and chamber gap of 7.8mm; IU22 with length of 2m and 3m and chamber gap of 7mm. Figure 3(b) shows the frequency map, computed with kick maps of 2 EPU48s. In comparison with Figure 2(c), the tune distribution of surviving particles shift slightly as a result of the effect of IDs. Obviously, the resonance line $3\nu_x - 2\nu_y = 52$ still causes the particle lost as same as the previous case of no ID.

The second one is asymmetric case. Figure 4(a) shows tune shifts with momentum with 1% emittance coupling and multipole errors. There exists coupling lose at about dp/p = 4%. It does not show here. Figure 4(b) and (c) show the dynamic aperture and the corresponding frequency map with 1% emittance coupling and multipole errors without ID. Figure 5(a) and (b) show the dynamic aperture and the corresponding frequency map considering 1% emittance coupling, multipole errors and kick maps of 2 EPU48s.

(a)



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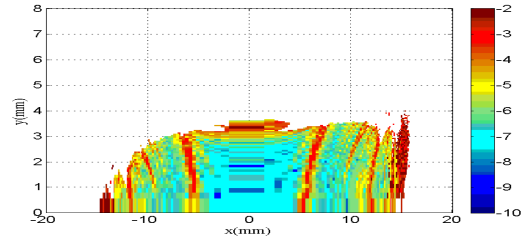


(c)

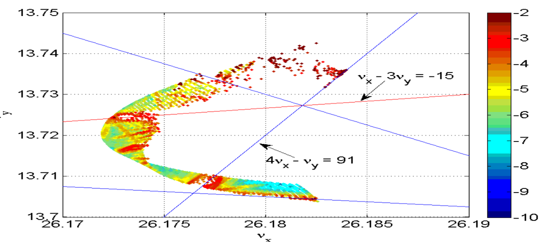
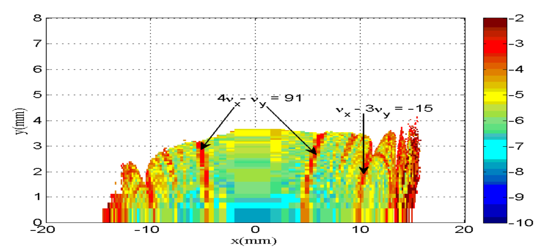


Figure 4: (a) Tune shifts with momentum. (b) DA (on-momentum) tracked at one straight center with β_x= 10m and β_y= 6m, and the corresponding (c) frequency map considering 1% emittance coupling and multipole errors.

(a)



(b)

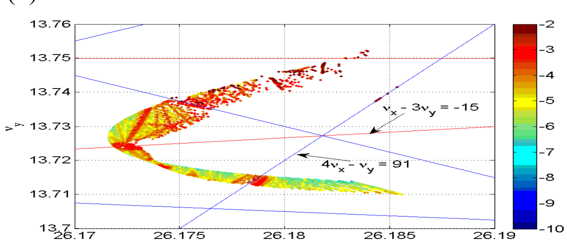


Figure 5: (a) DA (on-momentum) tracked at one straight center with β_x= 10m and β_y= 6m, and the corresponding (b) frequency map considering 1% emittance coupling, multipole errors and kick maps of 2 EPU48s.

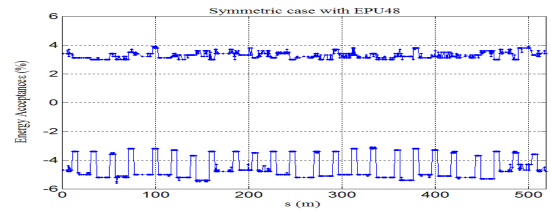
TOUSCHEK LIFETIME

In symmetric case, the Touschek lifetime of double mini-betay lattice has been calculated by TRACY-II with 6-D tracking including kick maps of 2 EPU48s, 1% emittance coupling and multipole errors of ring magnets, the chamber size is also considered. The simulation results are listed in Table 3. Considering both the kick maps of EPU48s and IU22s, the Touschek lifetime of symmetric case is still longer than 15 hours. While in asymmetric case, the Touschek lifetime is longer than 8 hours, considering 1% emittance coupling, multipole errors and kick maps of 2 EPU48s. Figure 6 shows the energy acceptance versus longitudinal position for two different configurations.

Table 3: Touschek Lifetime

Symmetric Case	Touschek Lifetime
Double mini-betay	15.24 h
Double mini-betay +2 EPU48s	15.27 h

(a)



(b)

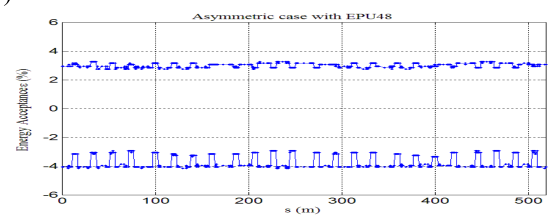


Figure 6: Energy acceptance versus longitudinal position for (a) symmetric case and (b) asymmetric case, considering 1% emittance coupling, multipole errors and kick maps of 2 EPU48s.

SUMMARY

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. In symmetric case, the preliminary investigation shows that the Touschek lifetime is longer than 15 hours. In asymmetric case, the Touschek lifetime is longer than 8 hours. This may result from the difference resonance from the tune shifts with momentum. Further study is still ongoing.

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