THE INFLUENCE OF THE OPERATION LATTICE DUE TO A 6-TESLA SUPERCONDUCTING WAVELENGTH SHIFTER AT TAIWAN LIGHT SOURCE[1]

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Abstract

The Taiwan Light Source (TLS) is a third generation light source with low operating energy, 1.5 GeV, which is used as ultra-violet and soft x-ray light source. Six straight sections and six-fold symmetric lattice made up the storage ring. Four of the straight sections are utilized by insertion devices. One of TLS's major goals is to allow the access of a broad range of science research to the storage ring. Hence, generating high-energy x-ray photons is one of the primary tasks of TLS to fulfil the hard x-ray users' requirements. The installation of Superconducting wavelength shifter is one of the most cost effective approaches to incorporate with the very crowded storage ring. The influence of the beam performance and operating lattice will be summarized and presented.

1 INTRODUCTION

The synchrotron Radiation Research Centre is located at Hsinchu, Taiwan where the first third-generation light source in Asia has been constructed and operation since 1994. The storage ring is a six fold symmetric Triple-Bend-Archomat (TBA) lattice with six straight sections in the storage ring, one section for injection, one for the RF cavities and diagnostic instrumentation, and four sections for the insertion devices. The basic parameters of TBA lattice at TLS is shown in Table 1. The physical properties of installed insertion devices are shown in Table 2 with radiation loss, which is calculated at 1.5-GeV operation energy.

Table 1. The TBA lattice parameters at TLS

Beam energy [GeV]	1.5
Beam current [mA]	200
Working tune H/V	4.13/7.18
Nature beam emittance [rad-m]	$2.56*10^{-8}$
Natural energy spread	$7.5*10^{-4}$
RF frequency [MHz]	499.654
Compaction factor	0.00678
Synchrotron tune	$1.06*10^{-2}$
Bunch length (@800kV) [cm]	0.92

Generating high-energy x-ray is always one of the highest priority at TLS. Currently, only one wiggler was installed in the storage ring to generate high-energy x-ray photons. For a long-term operation arrangement, TLS is planning to replace the wiggler by an undulator such that beam line capability in VUV spectrum regime will be further enhanced. The high-energy x-ray photons will be generated by installation of several Superconducting Wavelength Shifters (SWS) around the storage ring. Photon flux verse the photon energy of radiation spectrum [1] for bending magnet, wiggler and 6-Tesla SWS is shown in Fig. 1.

Table 2. The basic parameters of the insertion devices at TLS

	W20	U5	U9	EPU	SWS
Period λ_{ID}[cm]	20	5	9	5.6	~25
# of periods N_{ID}	13	76	47	6	1.5
Mini. Gap [mm]	22.5	18	18	18	18
Magnetic field [T]	1.8	0.64	1.245	0.67	6
Rad. Loss [keV/turn]	18.5	2.2	9.3	2.4	13.9
Total length [m]	3.04	3.9	4.5	3.9	0.625

The SWS is made of three superconducting coils [2] and iron yoke, which is used to return the magnetic flux and support the coils. The gap height of SWS is optimized to be 17 mm to maximize the field strength and minimize the effect on the Touschek lifetime. The overall length of the SWS is 60 cm and the peak field is 6 Tesla.

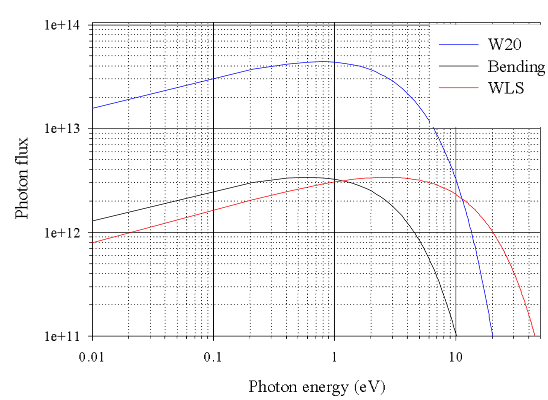

Figure 1. The comparison of spectrum of the bending magnet, wiggler and 6-T wavelength shifter (SWS).

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2 LINEAR OPTICS OF TLS

The third-generation storage ring is characterized as low emittance and best used with insertion devices. Strong focusing from quadrupoles is expected to reduce the beam emittance. Combine function dipole magnets were used to relax optics and reduce the strength of sextupole. The strong focusing of quadrupoles increases beam sensitivity to machine errors and generates larger chromaticity.

2.1 Linear Optics

We evaluate the lattice function and tracking studies of bare lattice and the perturbation from SWS. The tracking simulation was carried out by MAD [3]. The basic parameters of TLS is listed in Table 1. The linear optics function, β_x and β_y, for the TBA bare lattice is shown in Fig. 2, where the operation tune is 7.18/4.13 with chromaticity corrected to zero.

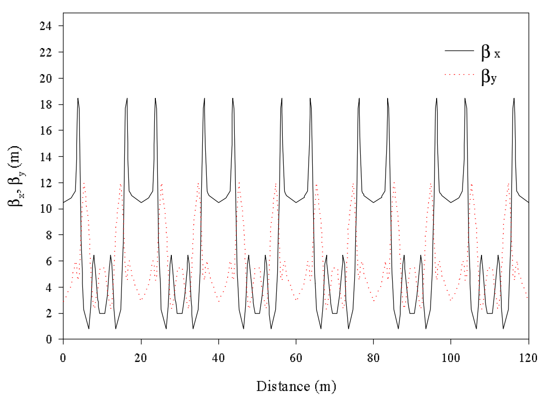

Figure 2: The optics, β_x and β_y of TBA bare lattice

2.2 Particles Tacking Along the Ring

Generally, an electron survives for about 1000 turns in a storage ring, its oscillation amplitude will decrease due to the head-tail damping, Landau damping and synchrotron radiation damping. It is likely to survive indefinitely unless scattered by residual gas or ions or due to quantum excitation. The scattering between stored beam and residual gas or ions, which might cause beam loss, is beyond the discussion.

Using numerical simulation, we will track each particle 1024 turns without explicit inclusion of synchrotron radiation and consequent damping. The physical aperture (80mm*36mm) of vacuum chamber is meshed into 16400 points at the first quadrant in Cartesian coordinate. The initial position of the particle, which has survived 1024 turns tracking, is recorded and plotted. The dynamic aperture of a bare lattice with nominal working tune is shown in Fig. 4 with black dot symbol. For each survived particle, Fast Fourier Transform is performed in both x- and y-plane to find out the characteristic tune. The tune space diagram is plotted accordingly as shown in Fig.3 for the TBA bare lattice.

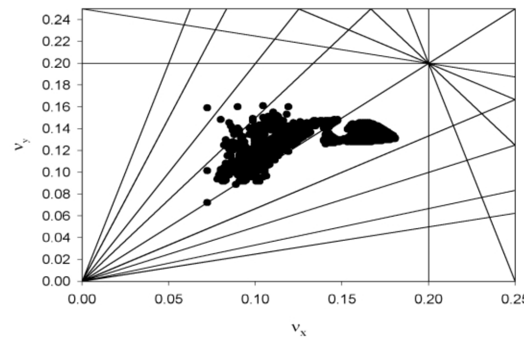

Figure 3: The tune diagram of bare lattice for the particle tracing within the dynamic aperture.

3 SUPERCONDUCTING WAVELENGTH SHIFTER

3.1 The Specifications

The specification of SWS for TSL storage ring is listed in Table 3. The unit conversion and input parameters for simulation program, MAD, also listed in Table 3 as reference. The magnetic rigidity is defined as *Bρ*. The integral multipole components are then defined as :

$$KnL = \frac{L}{B\rho}\frac{\partial^n B_y}{\partial x^n} \text{ and } B_y(x,0) = \sum_{n=0}^{\infty}\frac{B_n x^n}{n!}.$$

The Taylor's expansion for the B_y on the mid-plane ($y=0$) is expressed as above.

Table 3. The multipole component specifications for the SWLS at TLS.

Components	CGS unit	*KnL*
Integral dipole	±20 [G-cm]	$4*10^{-6}$
Second integral	±50000[G-cm^2]	
Integral quadrupole	±25 [G]	$5*10^{-4}$ [m^{-1}]
Integral Skew QP	±25 [G]	$5*10^{-4}$ [m^{-1}]
Integral Sextupole	±50 [G/cm]	0.2 [m^{-2}]
Integral skew SP	±50 [G/cm]	0.2 [m^{-2}]
Integral Octupole	±50 [G/cm^2]	60 [m^{-3}]
Integral skew OP	±50 [G/cm^2]	60 [m^{-3}]

3.2 The Comparison of the Dynamic Aperture

The comparison of the dynamic aperture of bare lattice and lattice perturbed by SWS, with tune correction to 7.18/4.13 is shown in Fig. 4.

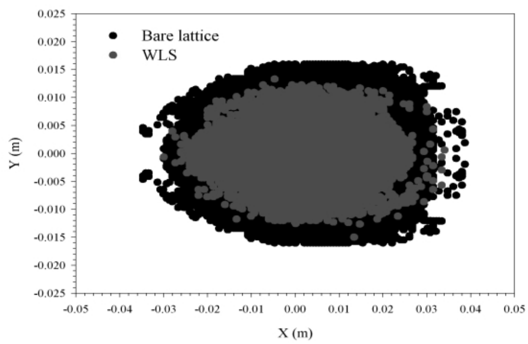

Figure 4. The comparison of the dynamic aperture of bare lattice and the perturbed by wavelength shifter after the tune correction to the bare lattice.

4 EMITTANCE AND ENERGY SPREAD

The perturbations induced by the presence of insertion devices may be divided into two groups. Firstly there are effects due to the magnetic field of the device which does not depend on radiation emission as discussed in Section 3. These results in distortion of the linear optics, tune shifts, excitation of resonance, reduction of the dynamic aperture. There are also effects due to the additional radiation emitted by the beam in the insertion device.

4.1 Emittance

The radiation damping and quantum excitation processes can be affected and further causing changes in the emittance. These effects are produced mainly by insertion device with strong field and long periods, e.g. wigglers. Sometimes, the proper installed and designed wiggler can be used to advantage to reduce the emittance far below that obtainable with other known methods. If we ignore the dispersion, this is always true for the installation of ID in the dispersion free sections. The emittance variation due the radiation effect can be expressed as follow [4]:

$$\varepsilon = C_q \gamma^2 \frac{I_5}{I_2 - I_4},$$

where $C_q = 3.84 \times 10^{-13}$ *m.*

The effects of the 6-Tesla SWS to the TLS's storage ring are shown in Fig. 5.

4.2 Energy Spread

The radiation damping and quantum excitation processes can also affect the energy spread. The root mean square energy spread can be expressed as [4]:

$$\left(\frac{\sigma_E}{E}\right)^2 = C_q \gamma^2 \frac{I_3}{2I_2 + I_4}$$

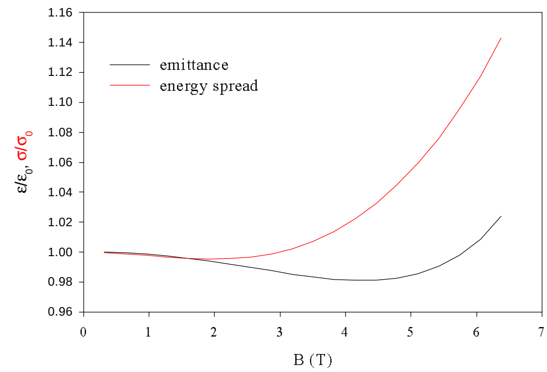

Figure 5. The emittance and energy spread ratio verse the excited magnet field strength of the SWS's on the storage ring.

For the SWS, the energy spread effect is evaluated numerically due to the aperiodic property of the device. The energy spread increase 13% at full excitation magnetic strength as shown in Fig. 5.

5 SUMMERY

Local tune correction scheme has been tried in order to increase the dynamic aperture. The dynamic aperture in the vertical direction increases. Little change in the horizontal direction has been found. More concerns were put on the horizontal dynamic aperture due to the project of increasing operation gap voltage from 0.8 MV to 1.6 MV. The shrinking of horizontal dynamic aperture will limit the energy acceptance, hence affect the Touschek lifetime. A further simulation should be carried out in the area of the beta and alpha matching.

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