DESIGN STATUS OF TAIWAN PHOTON SOURCE

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Abstract

We report the current design status for a 3 GeV synchrotron light source called Taiwan Photon Source (TPS). The lattice type of the TPS is a 24-cell DBA structure and the circumference is 518.4 m. The injector booster will be in the same tunnel that the storage ring is located and its circumference is 496.8 m.

INTRODUCTION

The 3 GeV TPS project was approved in March 2007. The site will be in the NSRRC, where a 1.5 GeV Taiwan light source (TLS) has been in operation since 1993. With the constraint of the existing buildings, the circumference of the storage ring is chosen to be 518.4 m such that we can have space for the accommodation of the storage ring building and experimental area around the existing buildings. The booster ring is inside the storage ring tunnel and its circumference is 496.8 m. Figure 1 is the artist's view of the TPS in the NSRRC site. The civil engineering design is under way.

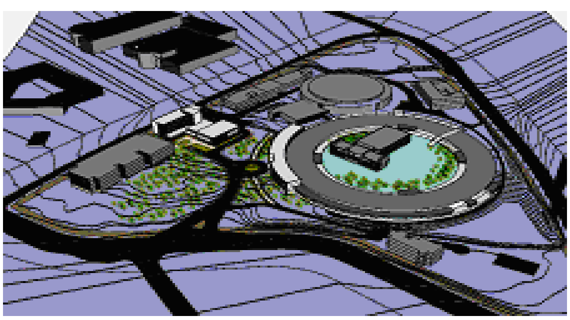

Figure 1: Artist's view of the TPS in the NSRRC site.

LATTICE STRUCTURE

A 24-cell DBA lattice structure with emittance of 1.6 nm-rad is designed. The achromatic configuration is around 4.9 nm-rad. Such a 6-fold symmetry configuration provides 6 long straights for injection, long insertion devices (IDs), and superconducting RF modules. The lattice optical functions are depicted in Fig. 2, and the major lattice parameters are listed in Table 1.

SEXTUPOLE SCHEME

Eight families of sextupole magnets are used for the chromaticity correction and nonlinear beam dynamics optimization. Figure 3 shows the tune shift with horizontal amplitude, and Fig. 4 depicts the tune shift with energy. The changes of the lattice functions with energy are shown in Fig. 5.

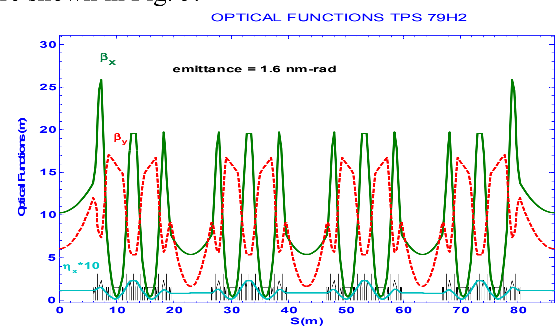

Figure 2: Lattice functions of the TPS lattice.

Table 1: Major parameters of the TPS

Energy (GeV)	3.0
Beam current (mA)	400
Circumference (m)	518.4
Nat. emittance (nm-rad)	1.6
Cell / symmetry / structure	24 / 6 / DBA
β_x / β_y / η_x (m) LS middle	10.28 / 6.05 / 0.117
β_x / β_y / η_x (m) SS middle	5.39 / 1.62 / 0.087
RF frequency (MHz)	499.654
RF voltage (MV)	3.5
Harmonic number	864
SR loss/turn, dipole (MeV)	0.8526
Straights	12m*6+7m*18
Betatron tune ν_x / ν_y	26.20 / 12.25
Synchrotron tune ν_s	6.09×10^{-3}
Bunch length (mm)	2.86
Dipole B/L (Tesla)/(m)	1.1908 / 1.1
Number of dipoles	48
Quad No. / Max. field (T/m)	240 / 17
Sext No. / Max. m*l (m^{-2})	168 / 5.5
Mom. comp. (α_1, α_2)	2.4×10^{-4}, 2.1×10^{-3}
Nat. energy spread σ_E	8.86×10^{-4}
Damping partition ($J_x/J_y/J_s$)	0.997 / 1.0 / 2.003
Damping time (ms) ($\tau_x/\tau_y/\tau_s$)	12.20 / 112.17 /6.08
Nat. chromaticity ξ_x / ξ_y	-75 / -27

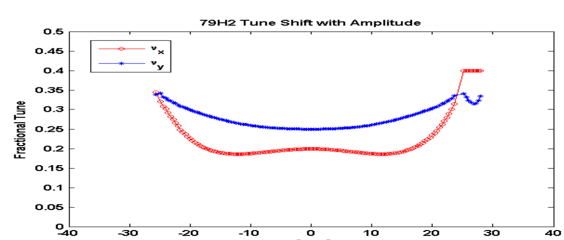

Figure 3: Tune shift vs. horizontal amplitude.

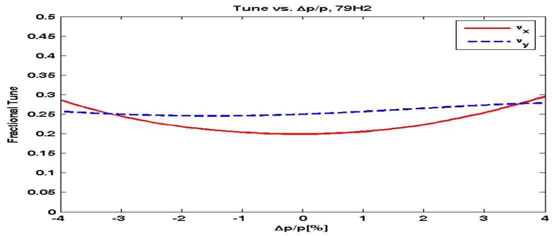

Figure 4: Tune shift vs. energy deviation.

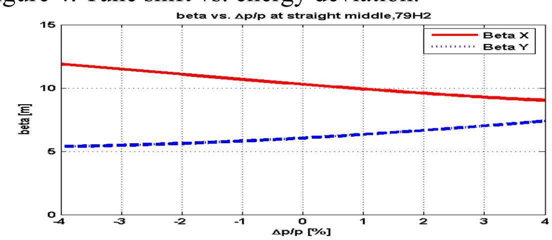

Figure 5: $\beta_{x,y}$ at long straight middle vs. energy deviation.

DYNAMIC APERTURE

With the optimized sextupole configurations, particles are tracked and acceptable dynamic aperture is obtained. Figure 6 gives 4-D dynamic aperture tracking using TRACY-2 for on-energy and off-energy (±3%) particles. Frequency map analysis for on-energy particle is given in Fig. 7 and 8.

With chamber limitation, the 4-D particle tracking shows that the vertical dynamic aperture is reduced due to small vertical ID chambers as shown in Fig. 9 and the corresponding frequency map is given Fig. 10. The vertical dynamic aperture is limited within +/- 3.7 mm due to the small gap chamber +/- 5 mm in the short straights (5m long chambers), where small β_y is located, as shown in Fig. 9.

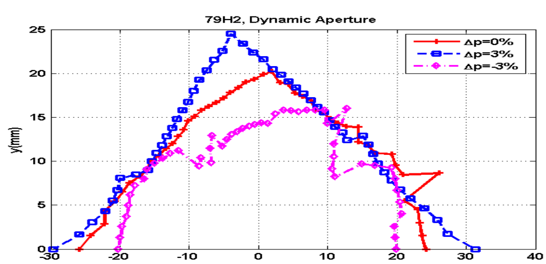

Figure 6: Dynamic aperture tracking for on-energy and off-energy particles at long straight center.

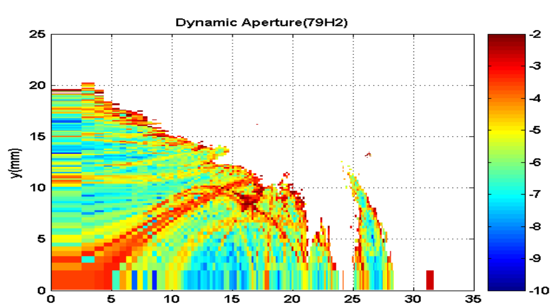

Figure 7: Dynamic aperture for on-energy particle (TRACY-2) at long straight center.

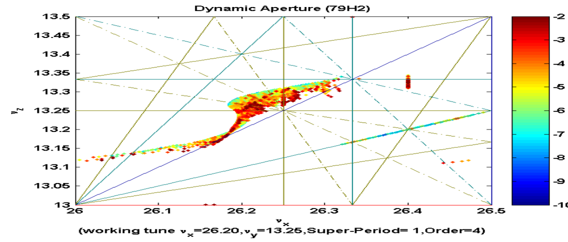

Figure 8: Corresponding frequency map analysis in Fig. 7.

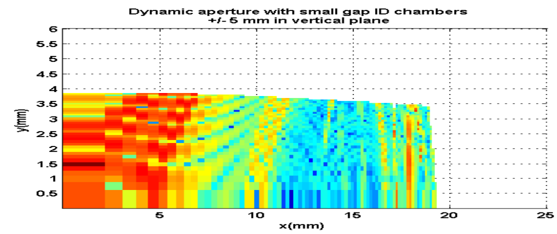

Figure 9: Dynamic aperture at long straight middle in the presence of multipole field errors and ID gap size of +/- 5mm, and 12 m in long straights and 5 m in standard straights.

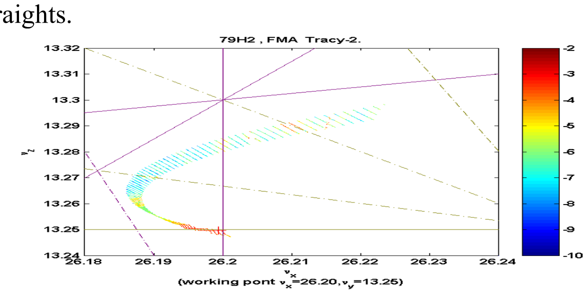

Figure 10: Corresponding frequency map in Fig.9.

6-D TRACKING

Particle 6-D tracking using TRACY-2 determines the energy acceptance and Touschek lifetime is calculated. Due to small α_1 and large α_2, energy aperture is asymmetric. Figure 11 shows the energy aperture in one superperiod. The simulation results are 16.6 hr for 0% emittance coupling (7.8 hr for 1% coupling), 10 mm full gap ID chambers, 0.8 mA bunch current, 3.5 MV rf gap voltage and 1% emittance coupling.

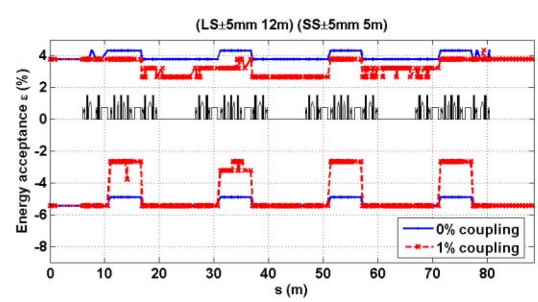

Figure 11: Energy aperture in one superperiod.

COD AND MULTIPOLE ERRORS

Typical closed orbit error sources are given in Table 2. With such errors, COD can be estimated. Before correction, COD are 3.8 mm and 2.2 mm in x and y planes, respectively. Using a set of correctors built in the sextupole magnets, we can correct COD down to 0.068 mm and 0.075 mm in x and y planes. The feed-down effect from sextupoles due to residual off-center orbit can generate beta-beat and tune shift. We can restore optics with small adjustment of quadrupole magnets and the beta-beat can be reduced from 10 % down to 1%. Dynamic aperture tracking results for 10 sampling machines with multipole errors, corrected COD and optics are given in Fig. 12.

Table 2: Typical closed orbit error sources

Error Source (rms)	
Girder trans. displacement (mm)	0.1
Girder roll (mrad)	0.1
Quadrupole and sextupole transverse displacement w.r.t. girder (mm)	0.03
Dipole roll (mrad)	0.1
Dipole integral field error ΔBL/BL	0.001
BPM trans. displacement (mm)	0.1

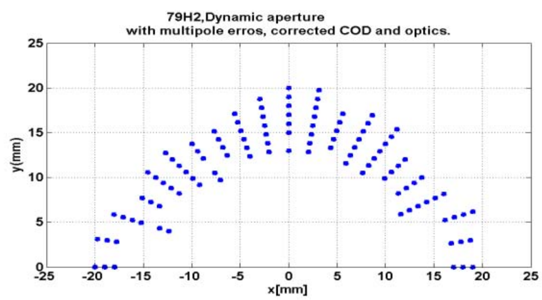

Figure 12: Dynamic aperture tracking for 10 sampling machines with multipole errors and corrected COD and optics. No chamber limitation in the simulation.

FRINGE EFFECT

Instead of using hard-edge field in the longitudinal direction in the model, we apply realistic fringe field in the simulation. It is shown that tune changes can be as large as -0.28 in x plane and -0.20 in y plane compared with the hard-edge model. These changes can be re-matched using quadrupoles and, after re-matching, linear and nonlinear beam dynamics behavior is acceptable. Figure 13 shows the dynamic aperture as a function of chromaticity for the cases with hard-edge and soft-edge models.

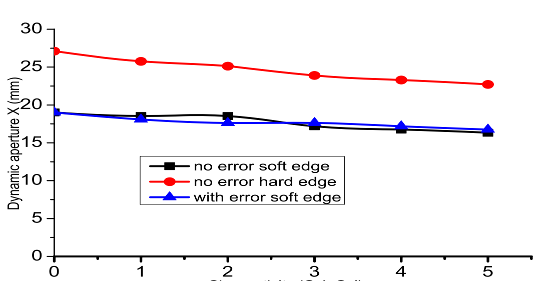

Figure 13: Dynamic aperture vs. chromaticity for the cases with hard-edge and soft-edge models.

INSERTION DEVICES

There will be more than 20 IDs in the ring and their effects on the beam dynamics are also investigated. High-field IDs can induce emittance and optics changes and also cause the reduction of dynamic aperture. Instead of increasing dispersion in the ID sections, we have a configuration of small dispersion in the straight sections and with larger emittance of 2.5 nm-rad. In this operation mode the emittance change is insensitive to high-field IDs.

IMPEDANCE

The impedance of vacuum components in the storage ring has been simulated using 3-D code GdfidL. It is shown that the major contributions are from SRF modules, flanges, bellows, tapers in the low gap insertion devices. The overall broad-band impedance can be controlled within 0.5 Ω and corresponding instabilities are simulated too.

INJECTOR

The TPS injector consists of a 150 MeV Linac and a large booster synchrotron of 496.8 m. The repetition rate is at 2~3 Hz. The booster is inside the storage ring tunnel. Modified FODO lattice is adopted in the booster design and the natural emittance is around 5 nm-rad. Small magnets as well as small chambers can be used for such booster. Acceptable dynamic aperture in the presence of multipole errors and eddy current effect is obtained. Design works for both transfer lines (linac to booster and booster to storage ring) are in progress. Figure 14 is the lattice functions of the booster synchrotron. The booster design is still ongoing.

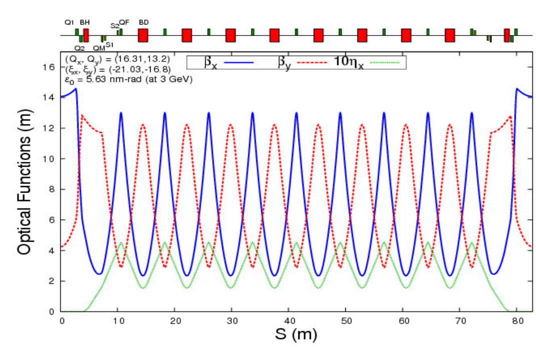

Figure 14: Lattice functions of the booster synchrotron.

SUMMARY

A 518.4 m storage ring and a 496.8 m booster synchrotron have been designed for the TPS project. The beam dynamics issues are fully studied. The storage ring lattice is frozen. Engineering design is in progress. The ground breaking is expected in the coming year.