SIMULATION STUDIES OF INJECTION SCHEME IN TPS STORAGE RING

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Abstract

In order to increase the performance of insertion device in a long straight section, we plan to install two identical insertion devices (IDs) in tandem to gain a factor of four in spectral brightness. Therefore, we implement the double mini-βy lattice in three 12-m straight sections in the storage ring of Taiwan Photon Source (TPS) [1]. The standard off-axis injection is used for storage ring. The injection scheme for double mini-βy lattice is simulated with a Gaussian beam including various error sources. Results of simulation studies are presented.

INTRODUCTION

The baseline lattice design for TPS is reported in Ref [2]. There are six 12-m long straight sections in the storage ring. The double mini-βy lattice is implemented in three symmetrical locations such that the lattice symmetry is preserved. The schematic layout of off-axis injection scheme in TPS storage ring is depicted in Fig. 1. Four kickers are placed in one long straight section to form an orbit bump. There is no magnet between adjacent kickers. The nominal parameters of all plused magnets for injection in TPS storage ring are given in Table 1. A multiparticle beam of Gaussian distribution is used for tracking simulations of injection process. To obtain a realistic estimation of injection efficiency, we include various error sources listed in the TPS design handbook [3]. Results of tracking simulations with a Gaussian beam and error sources are presented.

OFF-AXIS INJECTION SCHEME

The optimum beta function for the injected beam at the injection point is calculated with the Tazzari formula [4],

$$\beta_{xi}^{2} + \frac{n\sigma_{x0} + T}{2\sqrt{\varepsilon_{xi}}}\beta_{xi}^{3/2} = \frac{\beta_{x0}^{2}}{2} \qquad (1)$$

, where β_{xi} is the beta function of the injected beam, ε_{xi} the horizontal emittance of the injected beam, β_{x0} the horizontal beta function of the stored beam, σ_{x0} the rms horizontal size of the stored beam at injection point, T = 5 mm is the effective width of septum including alignment errors. A conservative estimate is used for possible errors.

Using beam parameters of double mini-βy lattice, the optimum horizontal beta function is 2.453 m. Figure 2 depicts the conceptual layout of horizontal phase space at injection point. The distance of injected beam with respect to the bumped stored beam is $A = 5*\sigma_{x0} + T + 3*\sigma_{xi}*2 = 9.724$ mm. If we include orbit distortion and dispersion displacement for off-momentum beam, the acceptance aperture required for injection is 16.84 mm.

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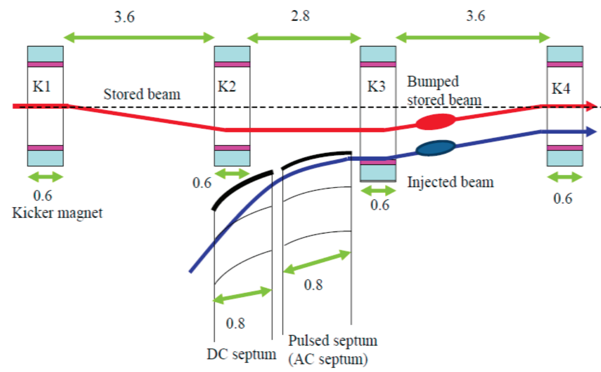

Figure 1: Schematic layout of the TPS injection scheme, units: [m]

Table 1. Nominal parameters of pulsed magnets for injection in TPS storage ring.

Parameters	Kicker	DC septum	Pulsed septum
Length	0.6 m	0.8 m	0.8 m
Bending angle	4.5 mrad	55.5 mrad	55.5 mrad
Field Strength	0.075 T	0.694 T	0.694 T
Width (half sine)	5.18 μsec	300 μsec	300 μsec
Pulse stability	0.1 %	0.1 %	0.1 %
Jitter	± 2 ns	----------	----------

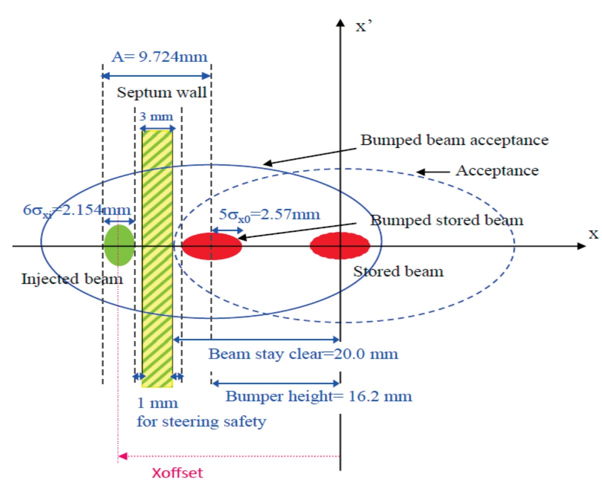

Figure 2. The horizontal phase space at the injection point for the double mini-βy lattice.

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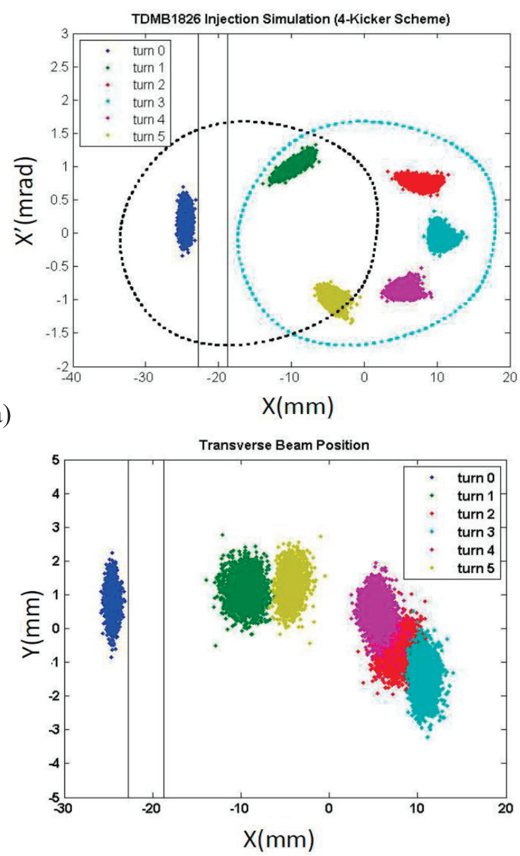
SIMULATION OF INJECTION SCHEME WITHOUT ERROR

4-D multiparticle tracking is performed by using Accelerator Toolbox (AT) for MATLAB [5]. The aperture profile of vacuum chambers in storage ring for phase-I installation of insertion devices is used in the tracking simulation. There are several small gap IDs in straight sections. The smallest vertical gap of vacuum chamber is 7 mm. Particle losses are monitored and recorded in a log file. Beam distribution in both the horizontal and vertical phase space can be recorded at each turn after the injection. Figure 3 depicts the beam distribution in the horizontal phase space and the configuration space at injection and subsequent five turns. No error is assumed in the tracking simulation as shown in Fig. 3. Beam distribution at different turn is depicted by different colors.



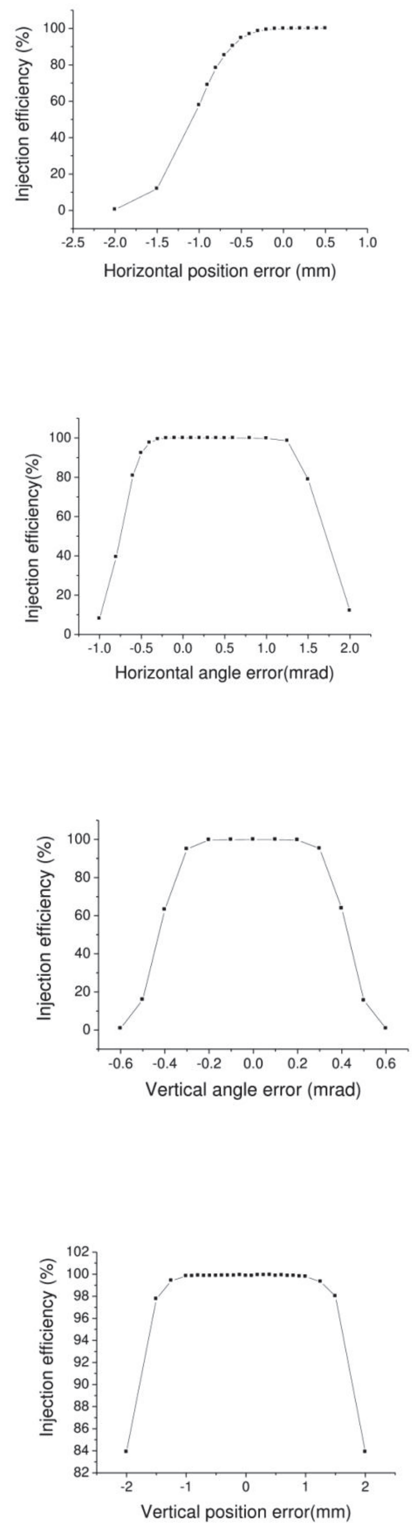
a)

b)

Figure 3. The injection simulation results in ideal case with double mini-βy lattice. a.) The horizontal phase space at the injection point b.) Transverse beam position

SIMULATION OF INJECTION SCHEME WITH ERRORS

The injection efficiency can be affected by errors of injected beam, alignment and field errors of lattice magnets, jitter and fluctuation of pulsed dipole magnets. The launching conditions of injected beam with position and angle errors are scanned for horizontal and vertical



a)

b)

c)

d)

Figure 4. The injection efficiency vs. errors of injected beam for double mini-βy lattice. a.) horizontal position error, b.) horizontal angle error, c.) vertical angle error, d.) vertical position error.

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plane respectively. The simulation results are shown in Fig. 4. Each data point in Fig. 4 is the average of 5 simulation runs. We use 3000 particles to represent a Gaussian beam. For each simulation run, the beam is tracked for 1000 turns. The simulation is performed by varying one injection error at a time. In reality, the injected beam could have combination of various injection errors.

The alignment errors of lattice magnets for TPS is summarized in Table 2 [3]. The multipole field errors of lattice magnets are provided by magnet group [6]. Assuming the injected beam has no steering error, we track the Gaussian beam for 1000 turns in the storage ring with alignment and multipole field errors of lattice magnets included. The results of tracking simulation are summarized in Table 3. After the orbit distortion caused by errors of lattice magnets is well corrected, the injection efficiency is larger than 98%. The main loss is due to scraping by small gap IDs in the vertical direction.

Table 2. The alignment errors of magnets used for TPS storage ring. The girder misalignment is not included.

Magnet misalignment (rms)	**Value**
Dipole (Δx/Δy)	0.5/0.5 mm
Dipole (Δθx/Δθy)	0.5/0.5 mrad
Quadrupole (Δx/Δy)	0.03/0.03 mm
Quadrupole(Δθx/Δθy)	0.2/0.2 mrad
Sextupole (Δx/Δy)	0.03/0.03 mm
Sextupole (Δθx/Δθy)	0.2/0.2 mrad

Table 3. The summary table of injection efficiency with the alignment and multipole field errors of lattice magnets in TPS storage ring. (O.C: orbit correction)

Process	**Injection efficiency**
Case (1): Dipole+ Quadrupole misalignments+ O.C	99.8 %
Case (2): misalignment for all magnets+ O.C	99.6 %
Case (3): (2)+ multipole field errors	99.7 %
Case (4): (3) + O.C	98.5 %

SUMARY AND DISCUSSIONS

The injection scheme for double mini-βy lattice is studied with a Gaussian beam by 4-D particle tracking. We have included the injection errors, alignment and multipole field errors of lattice magnets in TPS storage ring. Once the orbit distortion due to errors of lattice magnets is well corrected, the injection efficiency is larger than 98%. The main loss is due to beam scraping by small gap IDs in the vertical direction. There are other sources of error which have not been included yet. We need to include jitter and fluctuation of pulsed dipole magnets in the injection sector. We also need to consider the effect of leakage field from septum magnets.

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