Robinson wiggler is a special insertion device that can be used to decrease natural emittance of the Taiwan Photon Source (TPS) storage ring. This Robinson wiggler can change damping partition number and then affect the emittance. This study will evaluate practicability of reducing the emittance of TPS storage ring by Multi-period Robinson Wiggler (MRW) in the 7 m long straight section. One period of the traditional Robinson Wiggler include four poles with different field polarity. In the same length, the multi-period Robinson Wiggler has been over four poles in one set of Robinson Wiggler that is different from the traditional Robinson wiggler. Due to the traditional Robinson wiggler cannot be effective to improve emittance in TPS storage ring (the efficiency is only 7% with 6 straight sections). So we adopt to use multi-period Robinson Wiggler, the efficiency can be up to 37% with 6 straight sections, and the linear matching result is better than traditional Robinson Wiggler.

**Abstract**

Robinson wiggler is a special insertion device that can be used to decrease natural emittance of the Taiwan Photon Source (TPS) storage ring. This Robinson wiggler can change damping partition number and then affect the emittance. This study will evaluate practicability of reducing the emittance of TPS storage ring by Multi-period Robinson Wiggler (MRW) in the 7 m long straight section. One period of the traditional Robinson Wiggler include four poles with different field polarity. In the same length, the multi-period Robinson Wiggler has been over four poles in one set of Robinson Wiggler that is different from the traditional Robinson wiggler. Due to the traditional Robinson wiggler cannot be effective to improve emittance in TPS storage ring (the efficiency is only 7% with 6 straight sections). So we adopt to use multi-period Robinson Wiggler, the efficiency can be up to 37% with 6 straight sections, and the linear matching result is better than traditional Robinson Wiggler.

**General Design Concept**

The equation of brilliance is as below:

\[ B = \frac{\text{flux}}{4\pi \sigma_0 \sigma_0} \]

here \( \sigma_0 \) means horizontal electron beam size and is proportional to square root of emittance. The amplitude of Emittance is determined by equilibrium between quantum exciting and radiation damping. Horizontal emittance of non-achromat mode of TPS is 1.6nm-rad. The formula of horizontal emittance of storage ring is given by

\[ \epsilon_x = \frac{C_\text{H}}{J_x \rho} \]

Here, \( \epsilon_x \) is so-called horizontal emittance and \( C_\text{H} = \frac{550}{32\pi \text{mm}} \times 3.33 \times 10^{-7} \text{m} \), the electron relativistic factor in 3GeV TPS storage ring, \( \rho \) is bending radius, \( H \) is H-function, \( J_x \) is damping partition number, the equation of damping partition number is shown as below:

\[ J_x = 1 - D_x \]

where \( D_x \) is damping factor, \( D \) is dispersion function, \( \rho \) is bending angle, \( K \) is quadruple strength. If we increase damping partition number from former equation, then we can decrease emittance. In order to raise the horizontal damping partition number, we use quadruple magnetic field and the bending radius of electron of opposite sign to each other, then damping factor will become negative, so we adopt Robinson wiggler.

**Estimate The Affect of Multi-Periods Robinson Wiggler on Emittance**

Here we consider two methods to roughly simulate the affect of Multi-periods Robinson wiggler on emittance. For the TPS case, Method 1 is use original formula of emittance as below:

\[ \epsilon_x = \frac{C_\text{H}^x}{J_x \rho} \]

As the dipole and quadruple field or length of Robinson wiggler are verified, the damping partition number \( J_x \) will be changed too, and furthermore we can decrease emittance. In Method 2, we introduce the radiation integral formula to calculate the affect result. If we install IDs at the straight section of the ring, we can rewrite the formula of radiation integral as below:

\[ I_x = I_{20} + I_{2v}, \quad I_y = I_{40} + I_{4v}, \quad I_{b} = I_{50} + I_{5v} \]

where \( I_{20}, I_{2v} \) are radiation integrals evaluated in bending dipoles, \( I_{40}, I_{4v} \) are radiation integrals evaluated in Roninson wiggler, so the equation of effective electron beam size can be written down as below:

\[ \epsilon_x = \frac{(I_{20} + I_{2v} - I_{40} - I_{4v})}{(I_{40} - I_{20})} \]

For example, the case in TPS with high energy and non-combined dipole field, assume the K in Robinson wiggler is 0.8 (m^-1) and maximum of dipole field is about 1.3T, so the minimum radius will be 7.7m, the effective emittance formula can be rewritten as below:

\[ \epsilon_x = \frac{1 + \frac{1}{J_x}}{1 + \frac{1}{J_x^{20}}} \]

We compare both methods result with verified dipole field, find out the emittance will decrease as dipole field increase linearly in Method1. But in Method 2, there is a minimum emittance 1.452 (nm-rad) when the dipole field is about 1.1T as shown in Figure2.

**Multi-Periods Robinson Wiggler**

Each pole of MRW is shorter than traditional Robinson wiggler. It has an advantage that the electron beam won't shift too much form the original orbit, and make matching simulation process easier. From effect of ID formula, if the dipole field of MRW is larger than 1.1T, it will cause emittance increase. After simulation, we chose magnetic field of MRW is 0.8T. In the other hand, the limit of technical work on quadruple strength is about 8T/m in the normal conductor dipole magnet. Then we assume the total length of MRW is 6m, one period is 0.4 m, there are 15 periods in one set.

**Conclusion**

Countries are competitive to develop high-brightness high-energy electron accelerator ring, especially the brilliance of the light source provided by the accelerator is more important to user. NSRRC is developing and building the Taiwan Photon Source right now, its beam emittance can reach 1.6 nm-rad, how to improve the emittance will become next issue. We try to use MRW to reduce emittance, and from the simulation result can approach 1.121 nm-rad after nonlinear optimization. We expected to complete the program, which provides higher brilliance to users and improve Taiwan’s competitiveness in scientific research.

**Reference**

[5] Jingyi Li, Gongta Liu, Wei Xu, Weimin Li 'REDUCING H-S.L-II EMITTANCE BY RADIATION DAMPING PARTITION FACTOR EXCHANGE' Proceedings of IPAC2013, Shanghai, China.