# ADJUSTING AND CALIBRATION METHOD FOR TPS LASER PSD SYSTEM

M.L. Chen, M.H. Wu, P.S.D. Chuang, H.C. Lin , H.C. Ho, W.Y. Lai, K.H. Hsu, S.Y. Perng, P.L. Sung, C.S. Lin, H.S. Wang, C.J. Lin, H.M. Luo, D.G. Huang, T.C. Tseng, J.R. Chen
NSRRC, Hsinchu, Taiwan

*Abstract*

Laser PSD positioning system is part of the TPS girder auto-alignment system and is designed for aligning and positioning the straight-section girders of TPS storage ring. Although the components of Laser PSD system are fabricated, assembling and adjusted precisely in advance, the accuracy of the Laser PSD system is still influenced by the quality of the girder fabricated, assembling errors and moving errors by transportation. For system correction, Laser beam positions on four sets of PSDs are formulized as an equation and calibrated with Laser tracker ultimately. According to the PSD calibration formula, the two girders of 18m long straight-section can be aligned and positioned within 25um by comparing with the Laser tracker. This paper describes the assembly, installation and calibration process of Laser PSD system.

## INTRODUCTION

A precise auto-alignment scheme is developed to align and adjust the storage ring girders of Taiwan Photon Source (TPS). [1] The storage ring has a circumference of 518 meter and contents 24 banding sections (one section consists of 3 girders) and 24 straight sections. Laser positioning system, part of auto-alignment scheme, is designed and developed to align two girders on the both sides of a straight section. There are 6 sets of Laser PSD system for 18m long straight section and 18 sets for 12m short straight section. To achieve high accuracy, a laser and four 4-Quadrant detectors (position sensing device, PSD) with the accuracy of micrometer-scale has been designed and arranged for girder positioning [2]. The relative position accuracy of Laser PSD system can achieve 2um every four hours. [3] This paper describes the details of the system assembly, installation, calibration method and precision of laser positioning system.

## LASER PSD SYSTEM ASSEMBLY AND INSTALLATION

The Laser -PSD positioning system is constructed by several main portions, including Laser, PSD, beam splitters and isolation tubes. The Laser, with Gaussian distribution during working propagation distance, plays a role as a reference line of the girders of the straight-section, as fig1. The PSD lens module is designed to split laser beam to PSD. There are four sets of lens PSD module that are adopted in the system. First and second PSD is used to indicate to the position and vector of Girder1. The third and fourth PSD are installed on the downstream girders (Girder2). Girder2 will be aligned to girder1 by calculate the beam positions on PSD.

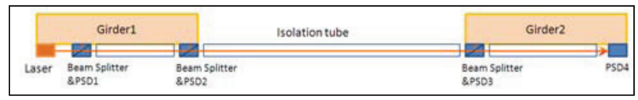


Figure 1: Architecture of Laser -PSD position system.

The lens PSD module contents beam splitter and PSD, it is assembled and adjusted precisely in advance. Then the lens PSD module is positioned on the girder side within 5um accuracy. The assembly and installation procedure is described as following.

### *The Design of Lens PSD Module*

There are beam splitters and glass window fixed on the lens PSD module. The tilt angle of glass window is adjusted for optical path compensation, as fig 2,3. The glass window is held on a double flexure structure for horizontal and vertical angle adjusting, as fig 4. The adjustable range is 2000 sec and the tilt angle is adjusted by a fine-pitch turning screw (130tpi, pitch: 0.2mm). The material of flexure is alloy tool steel SUS631 RH950.

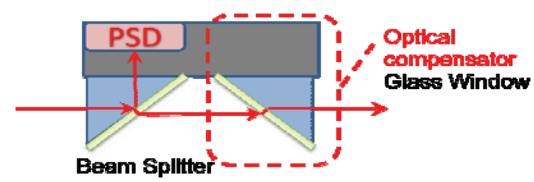


Figure 2: Optical path on lens PSD module.

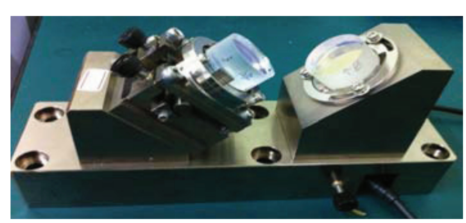

Figure 3: Picture of lens PSD module.

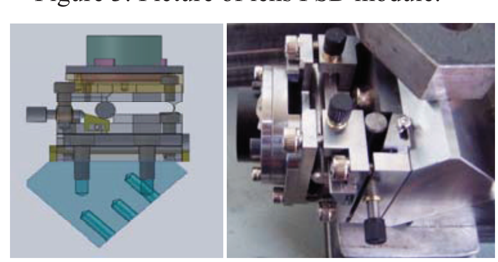

Figure 4: Double flexure structures of lens PSD module.


ISBN 978-3-95450-122-9

### *Lens PSD Module Assembly*

The tilt angle of the glass window on the lens PSD module is adjusted for light path compensation by reference to an ideal laser. A reference jig is built for lens module adjustment. There are vertical and horizontal datum planes on the Jig, as fig 5. Then a reference laser and reference PSD are setup. The reference laser is isometry to jig datum planes. Angle of glass window is adjusted by reference to the Laser position on reference PSD. Then the PSD on lens PSD module is also adjusted to centre by 6pcs fine-tune screws. The lens PSD modules are adjusted within 3um errors.

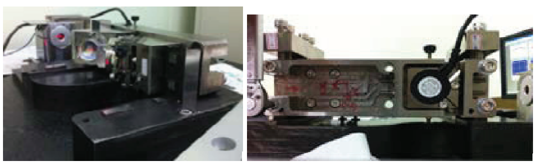

Figure 5: Picture of reference jig.

### *Laser PSD Positioning System Assembly*

The lens PSD module is designed to position on the absolute location of girder by adjusting.A positioning jig is developed for inspecting the distances between the girder datum planes and lens PSD module. The positioning jig contents six touch sensors (accuracy: 2um over 12mm),as fig 6. 4 pcs of touch sensor inspect the horizontal direction and 2 pcs for vertical direction. The material of positioning jig is Invar with very low thermal expansion characteristic. (TEC:1.2 *10-6 /deg C). The repeatability of positioning jig is 5um. [4] The position of lens PSD module is adjusted to an idea position by adding shim and adjusting fine pitch tuning screws (130tpi). The lens PSD modules are positioned at girder side within 5um errors, as fig7.

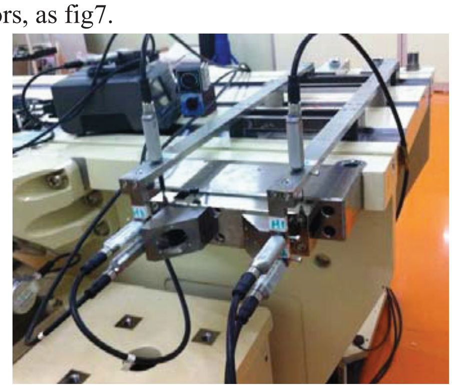

Figure 6:The positioning jig contents six touch sensors.

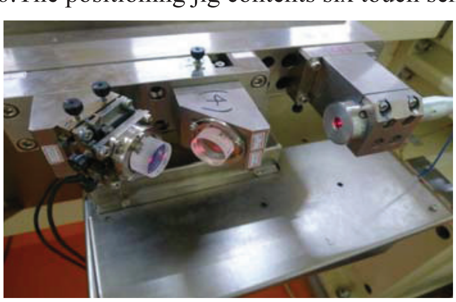

Figure 7: PSD and Laser are positioned on girder side.

After 4 sets of lens PSD modules are positioned on the side of the gider, the Laser is adjusted and positioned according to PSD1& PSD2's positions. The position and tilt angle of Laser are also adjusted by the shim and fine pitch tuning screw(130tpi).

Finally, isolation tubes, support fixtures and isolation boxes are installed for air disturbance elimination, as fig 8.

Figure 8: Outward appearance of Laser PSD system.

## CALIBRATION PROCEDURE

To achieve absolute position accuracy, a series of calibration procedure are proceeded. The detail is illustrated as below.

### *Beam Profile Measurement and Transfer Function*

The PSD adopted on the system is composed by 4 piece of sensor, shown as fig 9. Since the beam position is calculated by power weighting on 4 sensors. The PSD transfer function is not a linear function and relative to the beam distribution.

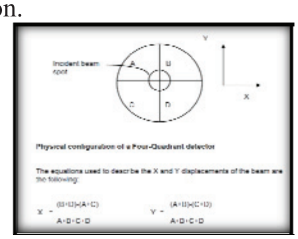


Figure 9: PSD structure and respond equation.

The beam distribution of every section is different. For every section of laser PSD system, the beam profiles are measured at 4 different locations. According to the beam profile data, the transfer function can be calculated based on PSD displacement equation. The calculation result is drawn as fig 10. Due to the Laser focusing on PSD2, the beam size on PSD2 is the smallest so the transfer curve on PSD2 is the most sensitive. In order to describe transfer function precisely, one transfer function is separated to 20 sets of polynomial equation. The curve fitting error is under 1 um.

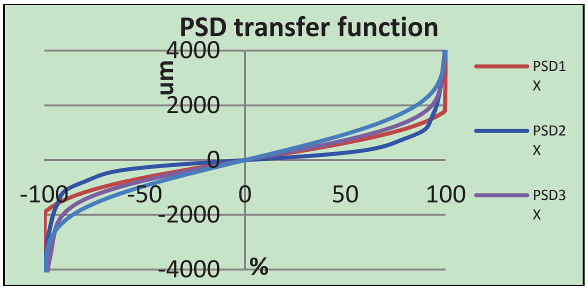


Figure 10: The curves of transfer function of 4 PSDs.

### *Local Calibration by Comparing with Touch Sensor*

To upgrade the system accuracy, PSD transfer function is calibrated with absolute touch sensor. The girder1 with Laser source and PSD1&PSD2 keeps in static state, and the opposite girder installed with PSD3 and PSD4 is moved. There are also touch sensor installed at the side of girder. When the girder moves, both touch sensor and PSD have response for girder displacement variant. Compare two data, the relative coefficient between touch sensor and PSD can be calculated and formulized, as fig11.

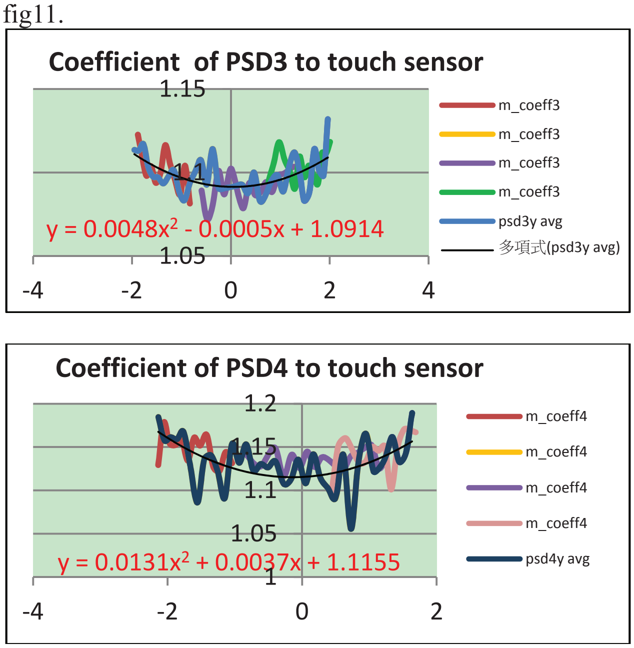


Figure 11: The relative coefficient of PSD3&PSD4 between touch sensor and PSD.

### *System Calibration by Comparing with Laser Tracker*

Since PSD1, PSD2 and Laser are installed on the same girder, the transfer function of PSD1&PSD2 can't be calibrated with touch sensor. Therefore Laser source is shifted successively to vary the beam position on PSD1&PSD2. The beam position relationship between PSD1, PSD2, PSD3 and PSD4 are described as following two formulas.

$$PSD3 - \Delta G3 = C_1[(f_2 PSD2 - O_2 - O_{x2}) - (f_1 PSD1 - O_1 - O_{x1})] + (f_1 PSD1 - O_1 - O_{x1})$$

$$PSD4 - \Delta G4 = C_2[(f_2 PSD2 - O_2 - O_{x2}) - (f_1 PSD1 - O_1 - O_{x1})] + (f_1 PSD1 - O_1 - O_{x1})$$

The coefficient $\triangle G_3$ and $\triangle G_4$ are the girder position at PSD3 and PSD4 by comparing to ideal space which is constructed by girder1. The coefficient $C_1$ and $C_2$ are the magnification factors relative to Laser propagation distance. The coefficient $f_1$ and $f_2$ are the correction factors which are interested. Coefficient $O_1$ and $O_2$ are PSD assembly offset value. Coefficient $O_{1x}$ and $O_{2x}$ are the PSD offset value by other uncertainty.

The beam position data on each PSD is collected during Laser shift process. Coefficient $f_1$, $f_2$, $O_{1x}$ and $O_{2x}$ are calculated by MATLAB. To check the calculation accuracy, compare the girder position data to Laser tracker. The difference between Laser PSD system and Laser tracker are within 25 um and conform to Laser tracker resolution, as fig12.

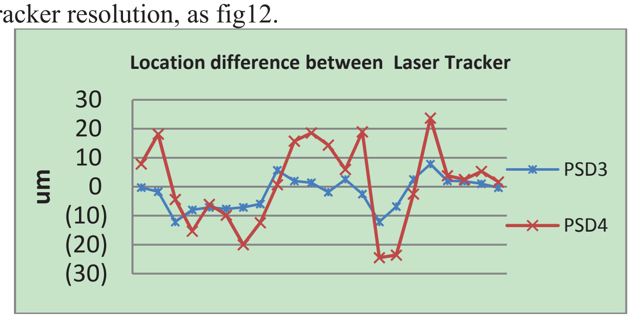


Figure 12: The difference between Laser PSD system and Laser tracker are within 25 um. Horizontal axis is for different test case.

## SUMMARY

To achieve the girder auto-alignment propose of straight section, there are several tasks done. First, the lens PSD modules are adjusted within 3um errors in advance. Second, the lens PSD modules are positioned at the side of the girder within 5um errors. Finally, the PSD correction factors are calibrated. The absolute displacement accuracy of the Laser PSD system can be within 25 um by comparing to Laser tracker. Until now, there are 14 sets of the Laser PSD system assembled and calibrated and 10 sets will be done within year 2013.

## REFERENCE

[1] W.Y. Lai and others, "Design and Prototype Tests of AutoAlignment of a Whole-ring Girder", Proceedings of PAC09, Vancouver, BC, Canada, pp.3663~3665.

[2] H.S. Wang and others, "Design and Test of a PSD System for TPS Girder", International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (2008).

[3] M.L. Chen and others, "Design Improvements and Tests of a Laser Positioning System for TPS Girder System",MEDSI2010.

[4] H.C. Lin, and others," The Position and Correction System of Laser PSD" 2012 1st International Conference on Intelligent Technologies and Engineering Systems, Changhua, Taiwan.