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Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e36
DOI: 10.1017/S2044820110000602, Published online: 15 December 2010

Link to this article: http://journals.cambridge.org/abstract_S2044820110000602

How to cite this article:
Keng-Hao Hsu, Mei-Ling Chen, H. C. Ho, H. S. Wang, Y. L. Tsai, W. Y. Lai, T. C. Tseng, S. Y. Perng, K. H. Hsu and J. R. Chen (2011). Design improvements and tests of a laser positioning system for the Taiwan Photon Source girder system. Diamond Light Source Proceedings, 1, e36 doi:10.1017/S2044820110000602

Diamond Light Source Proceedings, Vol 1, e36, page 1 of 5
MEDSI-6 2010
doi:10.1017/S2044820110000602

Poster paper

Design improvements and tests of a laser positioning system for the Taiwan Photon Source girder system

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(Received 14 June 2010; revised 6 October 2010; accepted 4 November 2010)

A precise laser positioning system had been preliminarily developed for the girder system of the Taiwan Photon Source. This laser positioning system, a part of a girder auto-alignment scheme, will be installed on the girders located at both sides of each straight section of the storage ring. The system is composed of a laser and four sets of a position sensing device (PSD). The laser, held on one girder, propagates 13 m along the girder and plays the role of a reference line of girders of the straight section. Based on the laser linear characteristics, the other girder can be adjusted and aligned by a cam mover according to PSD data. To achieve superior precision, the whole laser positioning system should be constructed stably. After making some improvements to eliminate the unstable terms, the precision of the laser positioning system can achieve 2 μm at 13 m propagating distance every 4 h.

1. Introduction

A precise auto-alignment scheme is under development to align and adjust the storage ring girders of the Taiwan Photon Source (TPS) (Lai *et al.* 2009). The storage ring has a circumference of 518 m and contains 24 bending sections (one section consists of three girders) and 24 sections of straight sections (six long and 18 short). The laser positioning system, a part of the auto-alignment scheme, is designed and developed to align two girders on both sides of a straight section. To achieve high precision, a laser and four four-quadrant detectors (position sensing device, PSD) with micrometre-scale accuracy were designed and arranged for girder positioning (Wang *et al.* 2008). This paper presents details of improvement and optimization of the laser positioning system.

2. System design and improvement

The laser–PSD positioning system is made up of several main portions, including a laser, a PSD, beam splitters and isolation tubes. Figure 1(*a*) shows the

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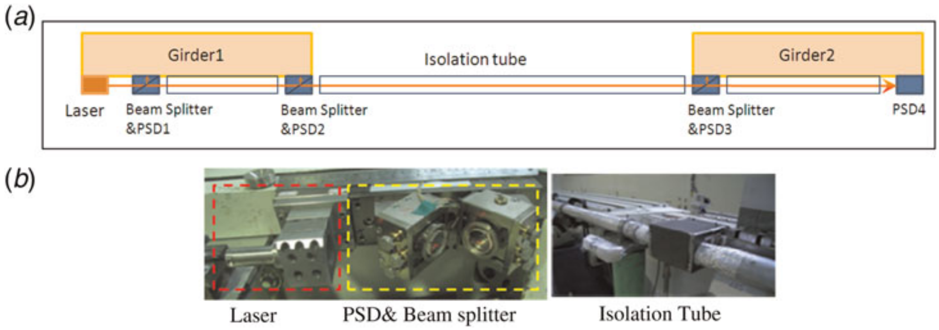

FIGURE 1. (*a*) Architecture of the laser positioning system. (*b*) Main portions of the laser positioning system.

architecture of a laser positioning system. Both the laser and the PSD are held on the girder by a rigid holder. The laser, with Gaussian distribution during working propagation distance, plays the role of a reference line of girders of the straight section. There are two working distances for the long straight section of the TPS, 13 m and 19 m, respectively. The beam splitter module is designed to connect the laser beam and the PSD. Four sets of the PSD are used to recognize the beam position on straight-section girders (Girder1) and indicate the position and vector of Girder1. The third and fourth PSDs are installed on the right side of the straight-section girders (Girder2). Girder2 will be aligned to Girder1 by signal analysis.

The system is covered by an isolation tube to eliminate air disturbance and temperature variation. The isolation tube is composed of an alumni tube and thermal isolation material.

For achieving better precision and extending stable hours, three main improvements were introduced:

(i) Stray light reduction: The isolation tube is designed to prevent air disturbance and temperature variance for better stability. When a laser beam propagates on the tube, there are some interactions between the laser and the tube. Figure 2(*a*) shows laser beam distribution when the laser only

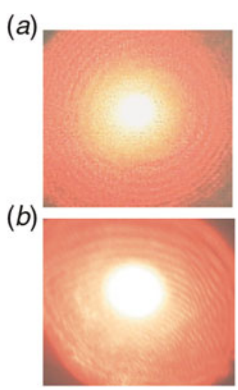

FIGURE 2. (*a*) Laser beam at PSD3 when the laser propagates in free space. (*b*) Laser beam at PSD3 when the laser propagates on the isolation tube.

passes through beam splitters. Once the isolation tube is installed, the halo of the laser is incident and reflected on the tube surface. Stray light is induced in the meanwhile. Figure 2(*b*) shows beam distribution with the stray light caused by the isolation tube. When the laser drifts or the isolation tube deforms, more stray light is produced and will induce an error signal on the PSD. Therefore, stray light reduction is an important issue for precision improvement. Several thermal isolation materials have been tested for preventing incorrect signal production. As shown in figure 3, foam influences beam size slightly and is the best for stray light reduction.

(ii) Mechanical improvement: The unstable support of the isolation tube also influences beam distribution and induces incorrect signal. Strong and stable fixtures were designed to support the isolation tubes to prevent tube deformation and vibration.

(iii) PSD curves fitting: The four-quadrant detector is a combination of four independent detectors separated by 30 μm wide gaps. The indicating signal of the PSD is calculated by the detecting power of each of the four sub-sensors. The relationship between real position and indicating signal is a curve, shown in figure 4. For different beam sizes, the transfer function is also different. Therefore, eight groups of PSD transfer function, including both horizontal and vertical directions of four sets of PSD, have been introduced to the adjusting algorithm. The accumulating error of the PSD caused by laser beam drift can be removed.

3. Experimental result

Based on the laser linear characteristics, laser positions on PSD3 and PSD4 are predictable by signals of PSD1 and PSD2 and propagation distance. After introducing improvements, the difference between prediction value and real measurement is given in figure 5. The precision on PSD3 and PSD4 can reach 2 μm every 4 h at 9 and 13 m, respectively.

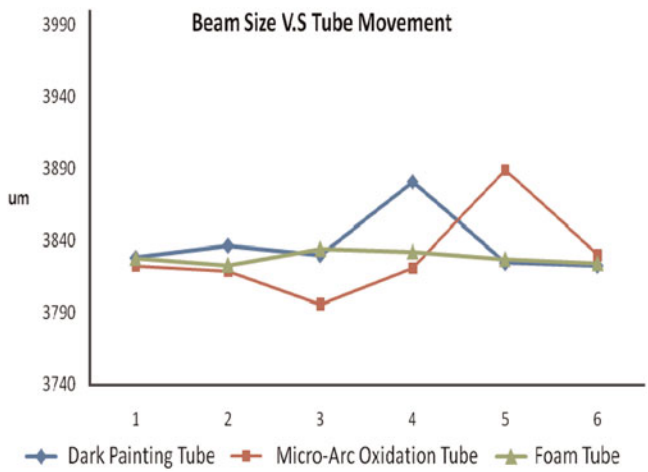

FIGURE 3. Beam size variation.

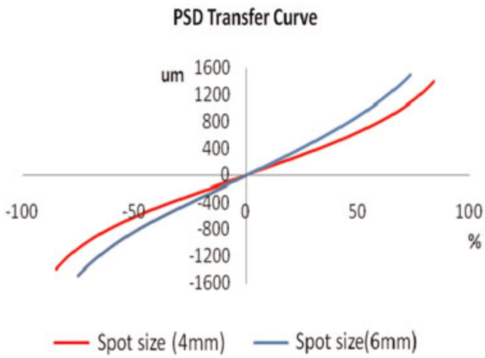

FIGURE 4. PSD transfer function.

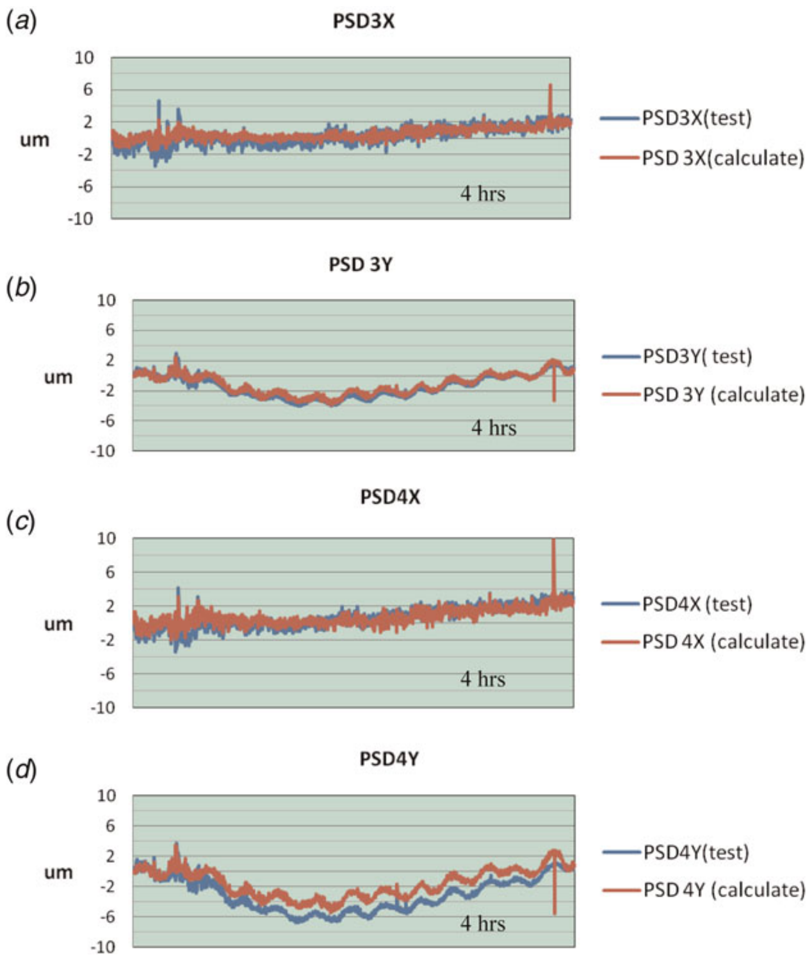

FIGURE 5. Comparison between PSD3 and PSD4 measurement data and the theoretical values calculated from PSD1 and PSD2: (*a*) horizontal data distribution of PSD3 during 4 h, (*b*) vertical data distribution of PSD3 during 4 h, (*c*) horizontal data distribution of PSD4 during 4 h, and (*d*) vertical data distribution of PSD4 during 4 h.

4. Conclusion

A high-precision and high-stability laser positioning system has been developed, and system unstable terms have also been eliminated. The precision can reach 2 μm every 4 h. This laser positioning system will be developed for 19 m long straight-section girders.

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