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DESIGN OF VERTICAL AND HORIZONTAL LINEAR FLEXURE STAGE FOR BEAM SIZE MONITOR SYSTEM

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Abstract

Taiwan photon source is a third-generation accelerator with low emittance and high brightness. The electric beam size is one of important parameters to indicate the stability and to measure the emittance and coupling of light source. The aperture size of beam slitter is a crucial part to calculate the value of beam size in the X-ray pine-hole system. In order to obtain the more precise result of beam size, the flexure mechanism on beam slitter is applied for the adjustment of the aperture. This paper shows that the design concept and the measurement of the beam size are obtained by the new adjustment system.

INTRODUCTION

The Taiwan Light Source (TPS) is a 3-GeV synchrotron radiation light facility. The construction started on February 2010 and after five years of construction and hardware developments, commissioning of the beam began on December 2014, and the 8 insertion devices were installed from April 2015 to now for user of beam line. Now the beam current of TPS storage ring can be up to 400mA for beam line used. TPS is a third-generation accelerator with the characters of low emittance and low coupling. Those beam parameters are routinely measured by the synchrotron radiation light produced from a dipole magnet, and the emittance can be measured indirectly by obtaining the transverse beam size. There is a dedicated beamline for photon diagnostics at the TPS storage ring utilized visible light and X-ray of the synchrotron radiation [1].

The structure of X-ray pine hole was oxidized seriously by the ozone resulted from reaction of ultraviolet in air after serval years. It made the measurement of beam size to be instable and unreliable, because of that there was some fluff on the aperture of X-ray pine hole generated by the oxidation of structure. The measurement of beam size is relating to the aperture of beam slitter sensitively and the energy peak of spectrum slightly [2]. Considering of that, the X-ray slitter at upstream is designed to be ability of scanning for obtaining the optimum aperture at different spectrum situation.

MECHANISM DESIGN

The previous measurement of the beam size at TPS was about 63μm and 40μm in the X and Y direction respectively. The result is large than the result of calculation [3]. In order to get the more precise beam size of TPS, the existing equipment need to be upgraded. To find the best aperture at the dedicated beam is the direction of promotion. Considering the purpose, an adjustable aperture mechanism with the ability of high resolution in a limited space was designed. The advantages of compliant structure are well known in no backlash motion and absence of lubrication and wear. Considering that the requirement of a stroke is also few and the requirement of space is limited, an adjustment system with vertical and horizontal linear flexure stage was designed at dedicated beam line as shown in Figure 1.

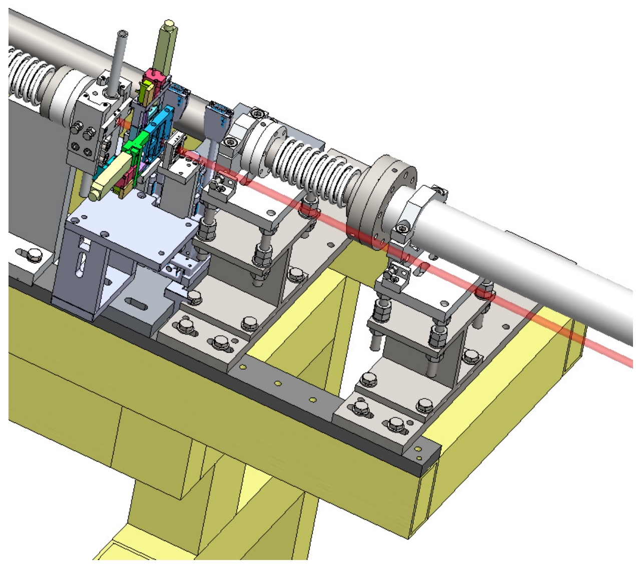

Figure 1: Layout of the adjustment system.

Introduction of Components

Figure 2 shows all the components of adjustment mechanism. The original structure of X-ray pine hole was set on commercial X, Y stages. The new adjustment system was set on the other X, Y stages. We can choose one those slitters by using those stages. Another function of stages is tuned for scanning the position of X-ray.

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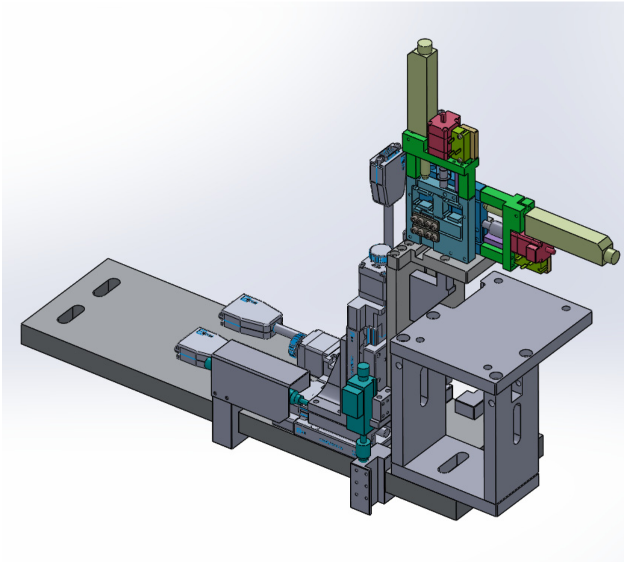

Figure 2: Components of the adjustment system.

The blue parts are the main structure of linear flexure stages in vertical and transverse direction. The flexure structure of leaf can provide a function of parallel motion. The main structure would be set on a two-axis stage. The 2-axis stage is used for searching the best position of X-ray. The black parts are the tungsten blade mounted on flexure mechanism for the function of slitter. The red parts are the two-phase stepper motor for adjusting the aperture of tungsten blade. The absolute length gauges are used for the feedback of aperture as shown in olive parts, and the purple parts are potentiometers for the function of limit switch and the alternate length gauges.

Result of Simulation

The material of flexure mechanism is aluminium, and the adjustment range was design form 1 mm to 0.005 mm. When displacement is 1mm and the thickness of leaf is 0.3 mm, the maximum stress is close to the yield stress of aluminium from the result of simulation as shown in Figure 3. Base on the simulation, the thickness of the leaf is designed at 0.3 mm to get the maximum stiffness and keep the required stroke.

According to the simulation, the mechanism is needed to be exerted a 17.26 N for 1mm displacement. Considering the convenience of system integration, the two-phase step-per motors are used for the actuators of the adjustment sys-tem. According to the torque transform formula as shown in Equation 1. The symbol F, T, η, and R is the meaning of the output force, input torque, efficiency parameter and the pitch of screw respectively. We used screws with 1.25 mm pitch and take the efficiency parameter to be 0.67. The mo-tors can produce 0.02 N·m torque and generate 67 N of load force on the flexure structure by the translation of a screw. That is three times of required force, so no more decelera-tor is needed in the adjustment mechanism.

$$F = \frac{2\pi\eta T}{R} \qquad (1)$$

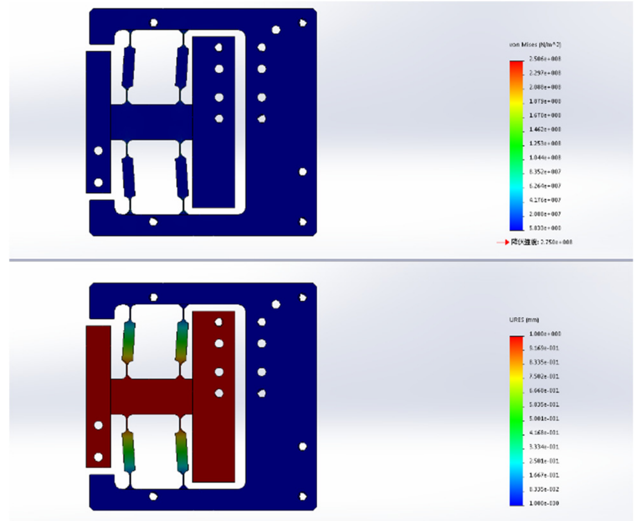

Figure 3: Simulation of a flexure mechanism.

MEASUREMENT AND RESULT

The adjustment system is used for finding the optimum aperture in the beam size monitor system. The difference in aperture can be vertified by absolute length gauge. Even if the the system is power off, the actual size of aperture can be obtained by the absolute legth gauge. In order to get the size of an aperture which corresbond with the reading of absolute length gauge, the adjustment mechansim will be assembled and measured in a laboratory. To confirm the aperture of tungsten blades, the system was measured by a microscope and compared with the absolute length gauges and potentiometers as shown in Figure 4.

The adjustment mechanism was set on the microscope, and we can confirm the parallelism between two blades by the optical observation. After the inspection, the aperture was tuned to achieve 5 µm observed by a microscope, and the reading of length gauge and potentiometer was rec-orded for a threshold at the same time. Afterwards, we ad-justed different aperture and compare with a microscope and a potentiometer as shown in Table 1.

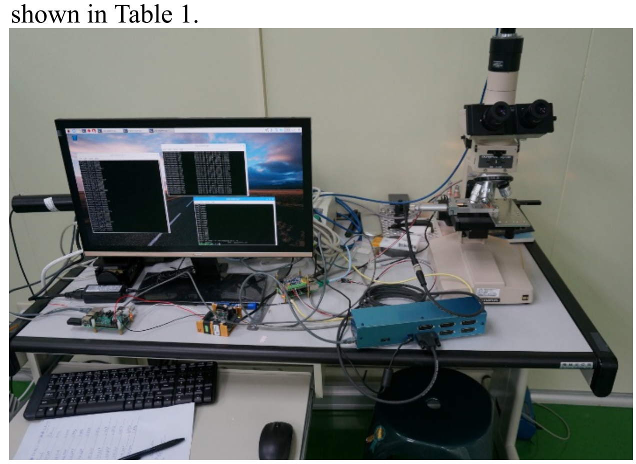

Figure 4: Measurement equipment.

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Table 1: Result of Measurement

Micro-scope (μm)	Absolute length gauges (mm)	Potentiome-ters (mm)
100	64.826	4.040
90	64.816	4.034
80	64.806	4.026
70	64.796	4.019
60	64.786	4.012
50	64.776	4.002
40	64.766	3.995
30	64.756	3.986
20	64.746	3.977
10	64.736	3.970
5	64.731	3.967

The microscope was used to reconfirm the parallelism at the different size of aperture, and the potentiometer was to set the boundary of limit switch and the alternate length gauges by those table. After those measurements, the vertical and horizontal flexure stages are installed on commercial X, Y stages. The commercial stages are used for scanning the position of X-ray. When the Y stage moved up to the edge, the X-ray can pass without obstruction, and the original function of pine holes structure can keep being used. The absolute length gauges are covered with 2mm thickness lead as radiation protection as shown in Figure 5.

Figure 6 show the relations of gaps of blades and the beam size. The result shows the optimum aperture is about 25 μm, and the result is similar to the calculation [3]. In the original intention, the adjustment system can be suitable in different spectrum situation. However, the system is not sa-ble in the beginning, the aperture was influenced with the change of temperature. According that, we measure the re-lation between temperature and the gaps of blades. We heated the mechanism and raised the temperature by 10 degrees. The aperture would increase 10 μm. According the result, cooling fans and temperature sensors were installed on the adjustable system.

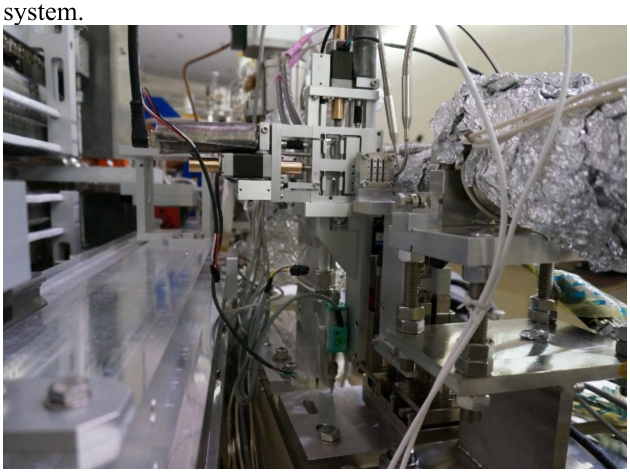

Figure 5: Adjustment system on front end.

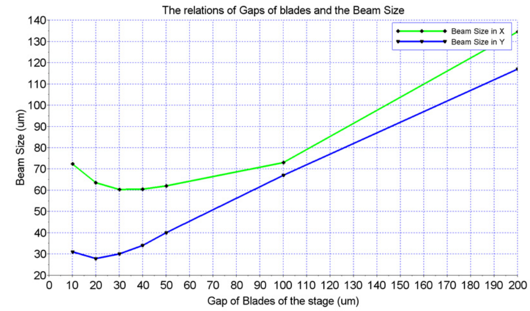

Figure 6: Graph of result.

After completing the installation of cooling fans, the amount of raising temperature decreased to 6 degree, and the temperature of system was stable within 1degree. The measurement of beam size is stable presently and the meas-ure of beam size is about 56 μm and 22.5 μm in the X and Y direction respectively.

SUMMARY

The X-ray of the synchrotron radiation is used for measurement of beam size routinely. The aperture of slitter is the critical parameter on this diagnostic system. The optimum aperture of slitter is also related to the peak of spectrum of light source. According to that, a linear flexure stage for the adjustable aperture was designed and applied on beam size monitor system. The result shows that the optimum aperture of slitter can be adjusted by this system easily and correctly. In the begging, the measurement of beam size is not very stable. After the cooling fans being installed, the measurement of beam size is stable. The measure of beam size is about 56 μm and 22.5 μm in the X and Y direction respectively.

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