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THE DETECTOR ADJUSTMENT SYSTEM OF TAIWAN PHOTON SOURCE 24A

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Abstract

The soft X-ray tomography endstation of TPS has the ability to provide 3D biological cell images by fluorescence structured-illumination microscopy (SIM) and soft x-ray tomography (SXT). The electron energy is design to be in the range of 200 eV to 3 keV. The detector system equipped with an Andor® iKon-L Series imaging CCD, X-Z-roll-pitch adjustment stage, and long stroke bellows system. The detector system can adjust the CCD about 10 mm in both X and Z direction, and +-5 degree of roll. Moreover, the long stroke bellows system gives the CCD an extra degree of freedom in the Y direction and its range is up to 2500 mm. That can locate the CCD close to the sample to get a larger field of view, and far from the sample to get higher image resolution. In this study, the design and commission status of the detector system is studied and the mechanical structures are also presented.

INTRODUCTIONS

The soft X-ray tomography endstation (TPS 24A) is one of the phase II beamlines of Taiwan Photon Source. The main function of this endstation is aimed for the transmission full-field imaging of biological samples, such as thick cells or tissues. Most of the bio-cell or tissues are composed of carbon, oxygen, and nitrogen, etc. That gives a good chance to adopt the water window, which is between the K edge of carbon (284 eV) and oxygen (543 eV), to get the high contrast between biological sample and water. Moreover, the image contrast can be further improved when the x-ray energy decrease to the range of 2000 ~ 3000 eV for phase contrast soft X-ray tomography [1-3].

BEAMLINE LAYOUT

The beamline layout of TPS 24A is shown in Fig. 1. The X-ray comes out from bending source and focused by the horizontal focused mirror (HFM) and vertical focused mirror (VFM). The x-ray is further pass through the plane grating mirror (PGM) and vertical refocusing mirror (VRFM). Finally, the x-ray is focused by the capillary condenser (CC) and shine on the biological sample. The fluorescence structured-illumination microscopy (SIM) is used to get the 3D biological cell images. Besides, the image can be projected by zone plate (ZP) and collected by the detector system, which is performed by Andor® iKon-L Series imaging CCD. The distance between detector system and the sample can be changed in a large range of 1390 mm to 3910 mm.

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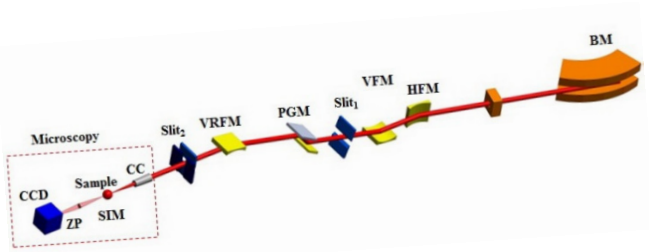

Figure 1: Beamline layout of TPS 24A.

DETECTOR SYSTEM

The image of soft X-ray beamline is collected by the detector system, which is at the very end of this endstation. The detector system has three major parts, which includes (1) foundation, (2) long linear guide way, and (3) adjustment part. The detail design concept and components are described in this section.

Design Target

The phase contrast or absorption contrast signal comes from the sample, which is shining by the soft X-ray, will be collected by structured-illumination microscopy and Andor® iKon-L Series imaging CCD. The design target of the detector system is shown in the following: (1) system stability: The pixel size of Andor iKon-L series imaging CCD is 13.5 μm x 13.5 μm, thus, the vibration of the detector system shall be less than 2.7 μm (20% of pixel size). (2) the position of detector: According to the optical design, the distance between detector and sample for different X-ray energy and magnification are in the range of 1390 mm to 3910 mm. (3) adjustment part: The resolution and travel range of the adjustment system is 1 μm and 10 mm, respectively. This alignment part is necessary for adjusting the position of the detector with x-ray.

Foundation of Detector System

The allowable peak to peak vibration level is 2.7 μm, this value is quite larger than the ground vibration, which is around 130 nm. But the foundation of the detector system still needs to design carefully, because the system has many degree of freedoms for adjustment. Therefore, stable and strong base is required.

Consider of the structure and thermal stability, the granite bases were adopted to form the reliable foundation of whole system. Each granite was placed on a 20 mm thick stainless steel, which is well aligned by laser tracker. The accuracy of vertical and horizontal position of both the stainless steel plate and granite is about several micro-meters. The foundation of detector system is shown in Fig. 2.

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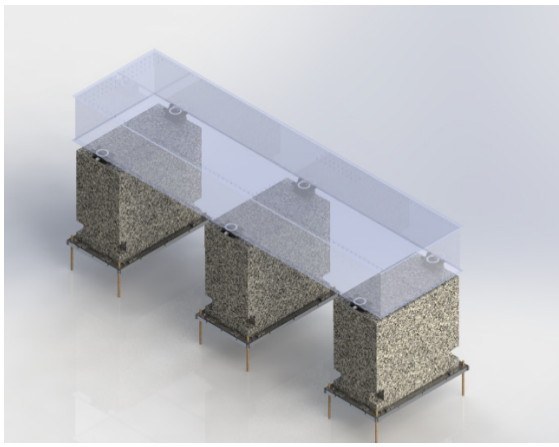

Figure 2: Foundation of detector system.

Long Linear Guide Way of Detector System

The long travel range of detector system is realized by a long linear guide way system. The long linear guide way system is based on thick optical table, which dimension is 3600 mm x 1000 mm x 400 mm (L x W x T). This optical table is support with six Hi-wedge® supports, each support can adjust the height level in the range of +- 6 mm. That support also provides the optical table a rotational range about 3 mrad. The long linear guide way od detector system is shown in Fig. 3.

The long bellows with 2500 mm stroke was connected in front of the detector, this bellows will be pumped down to the pressure lower than 10^{-4} torr to avoid the absorption of signal. The bellows is divided into two parts, one is used to axial compression and elongation in the range of 2500 mm, and the other is for the lateral movement in the range of +- 10 mm. The first part of the bellows is supported by seven pairs of frame, which is based on individual sliding block. The second part of the bellows is linked with the adjustment part. The THK® GSR-25T long linear guide way was adopted to transfer the bellows and the adjustment part. The rack teeth were made on the side of the linear guide, thus the alignment of the linear guide way and the teeth for the actuator gear is not necessary.

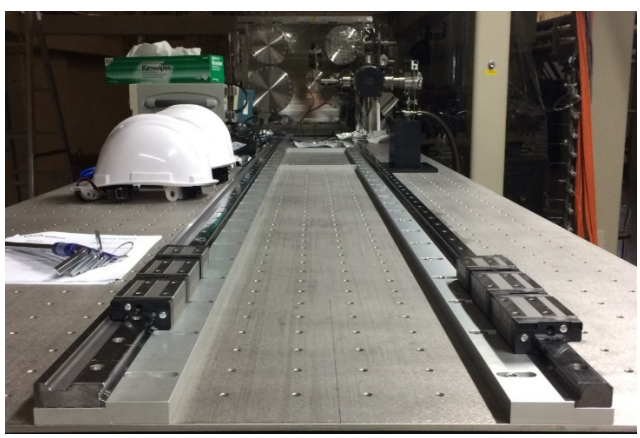

Figure 3: Long linear guide way of detector system.

Adjustment Part of Detector System

The main portion of the adjustment part is shown in Fig. 4. The heavy-duty Oriental motor® 5-phase motor combine with THK® GP6-25A pinion gear provide large push and pull force to the adjustment stage. The maximum pull and push force requirement of the system can be evaluated from the deformation of the bellows, the spring constant of bellows, cross-section of bellows, air pressure acting on the bellows, and the safety factor. Then the force shall be considered with the maximum torque and diameter of the pinion gear. The location of the adjustment stage in the Y direction is measured by Renishaw® optical encoder with the resolution better than 1 μm.

The second part of the bellows is used to cover the lateral movement of the detector during adjustment only, and no axial deformation is allowable. Therefore, this portion of bellows is located on the front of the adjustable stage, and fixed with the L-shaped frame.

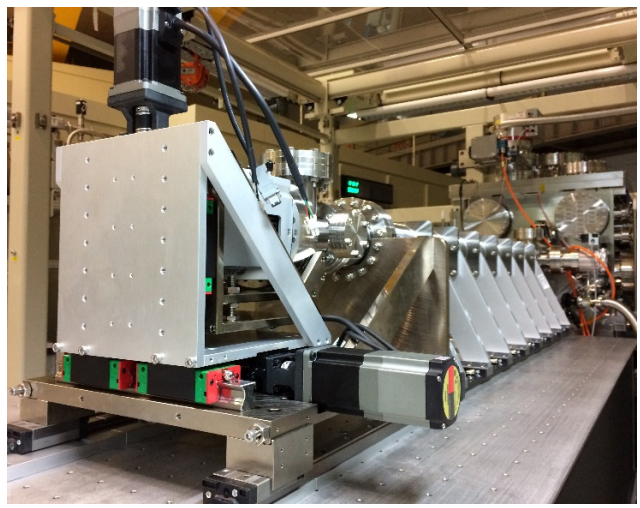

Figure 4: Adjustment part of detector system.

Two NSK® monocarriers combined with HIWIN® linear guide way and Oriental motor® are used to align the detector in the X and Z direction. The exact movement in these two directions is defined by the encoder, which is embedded in the 5-phase stepping motor. The total travel ranges in these two directions are both +- 10 mm.

In order to further align the oriental degree of freedoms, roll and pitch, there are four M10 screws, located on the bottom of the detector support plane, can manually adjust the detector during the pre-alignment process in the range of +- 5 degrees and +- 3 degrees for roll and pitch, respectively.

There is another six-way-crosses in front of the detector, which is used to mount the liquid nitrogen cryogenic pump and vacuum gauge, therefore the vacuum pressure at the end of the system can be monitored and maintained at the level of 10^{-4} torr.

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Connection with Main Chamber

The connection portion between the detector system and the main chamber is an individual six-way crosses, which is fixed on the stainless steel support. The support can be adjusted +- 5 mm in the x direction, moreover the upper part of the support can tune the horizontal level of the crosses, as shown in Fig. 5.

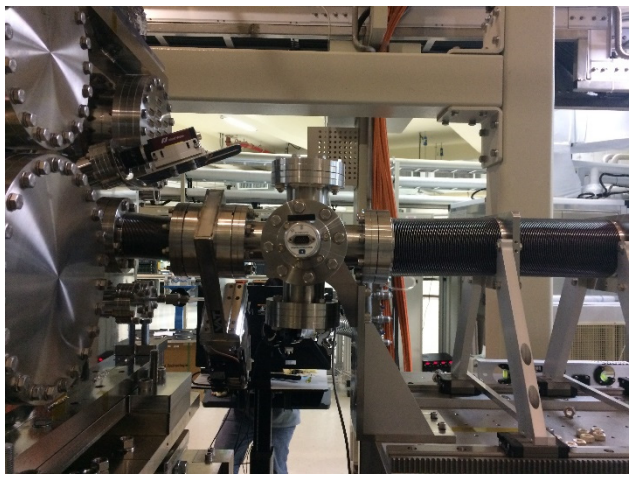

Figure 5: Six-way crosses for the connection portion.

CONCLUSION

The detector system of TPS 24A equipped with an imaging CCD, X-Z-roll-pitch adjustment stage, and long stroke bellows system was design and installed. The detector system can adjust the CCD about 10 mm in both X and Z direction, +-5 degree of roll, and +- 3 degree of pitch. Moreover, the long stroke bellows system gives the CCD an extra degree of freedom in Y direction and its range is up to 2500 mm. That can locate the CCD close to the sample to get larger field of view, and far from the sample to get higher image resolution. This system started commission in the early of 2018, and got the first image in April, 2018.

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