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DESIGN OF A LONG VERSATILE DETECTOR TUBE SYSTEM FOR PINK BEAM SMALL-ANGLE X-RAY SCATTERING (SAXS) BEAMLINE AT HEPS

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Abstract

The X-ray scattering experiment vacuum camera device is the first piping system of high-energy synchrotron radiation light source applied to pink small-angle scattering experiments, which has a variety of functions and can be used for WAXS, SAXS and USAXS experiments. This paper introduces the size, vacuum parameters, motion parameters and part of the radiation protection of the equipment, briefly summarizes how to solve the problem of the influence of uneven ground in the light source hall on the installation of the equipment, outlines how to solve the problem of maintaining good straightness of the track in a very long case, theoretically briefly analysis the influence of ground vibration on the stability of the detector, and outlines the radiation protection scheme of some vacuum cavities.

INTRODUCTION

This equipment is a small angle scattering experimental device applied to Huairou BB line station, which can perform SAXS/WAXS/USAXS, SAXS-CT and ASAXS combination experiments.

A 23m long versatile detector tube system is shown as Figure 1. Three Eiger2 detectors will be installed along the deciVe. The WAXS detector is suspended diagonally above the sample to collect about -5°~50° scattering signals. The SAXS detector, which is used to collect 0. 04°~6°, is installed in the front large tube with a diameter of 1.5 m and a length of 14 m. The detector can move freely within the tube according to experimental requirements. The distances between sample and SAXS [1] detector can be altered freely. The USAXS detector, which is used to collect 0.001°~0.1° signals, is placed at the end of tube. The vacuum degree of the tube is less than 1 Pa. The three detectors can work simultaneously to collect the whole larger angle range from 0.001°~50°. Two kinds of beamstop used for transmission mode and grazing incidence mode respectively, are installed in front of the SAXS and USAXS detectors.

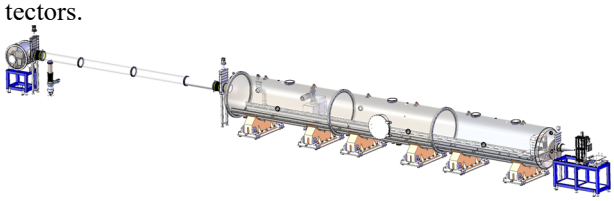

Figure 1: X-ray scattering experiment vacuum camera device.

STRCTURAL DESIGN

Figure 2 shows the overall overview of the equipment. The X-ray small-angle scattering experiment vacuum camera device consists of four parts: the device for WAXS experiment, the device for SAXS experiment, the device for WAXS experiment and the vacuum chamber.

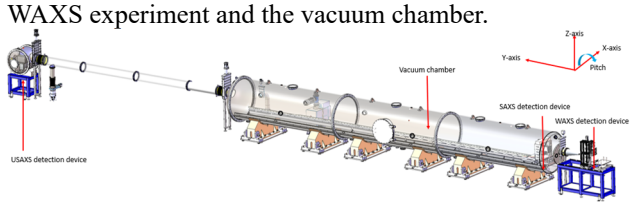

Figure 2: Overall device composition.

As shown as Figure 3, the WAXS device is located in the atmosphere and moves in a straight line in three directions of the detector. The probe's projection angle motion range is 55°. The lifting displacement table and the horizontal displacement table are spliced by processed aluminum alloy steel plates, and this structural design effectively reduces the weight of the device and effectively helps to improve the stability of the equipment structure. The base of the device is composed of square steel pipes. After the welding of the base is completed, it is treated with stress relief process, and then finished to effectively reduce the influence of welding deformation on the motion accuracy of the detector. In addition, the base is welded from Q235 square steel, which reduces the manufacturing cost. Similarly, the shelves used for the hoisting of the detectors are made of welded steel plates, which are subjected to a strain relief process of heat treatment after welding. Then drill the holes, which can ensure the concentricity of the two holes, and effectively reduce the error of detector installation.

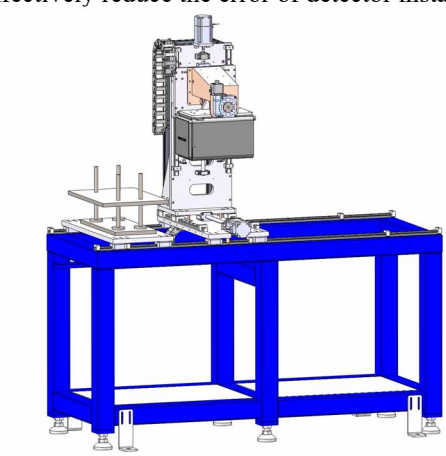

Figure 3: The device for WAXS experiment.

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Figure 4 shows that SAXS device is located in a vacuum environment, and although the cavity of the device is a low-vacuum environment, it has a lot of space. In order to reduce the pumping time and quickly achieve the vacuum specifications we require. Therefore, most of the parts are selected as special materials for vacuum. The SAXS device is composed of a track, a board for track support, a structure for track swing angle adjustment, a structure for track lifting adjustment, a trolley for the detector moving in the Y-axis direction, an electric slide table for the detector's displacement in the X-axis direction, an electric slide table for the detector to lift in the X-axis direction, and a support base. The SAXS device is capable of continuously moving the detector in the Y-axis direction for a travel of 12.5 meters. The motion straightness of the trolley in the direction of the beam line is guaranteed by the track of V-section and the track of rectangular section, and the adjustment mechanism of the lifting and swing angle of the track is increased, and the straightness error is less than 1mm by splicing. The device used for the lifting movement of the detector adopts a gantry-type steel plate splicing structure to ensure the stability of the detector's movement in the up and down and front and rear directions. In addition, the detector's lifting slide uses a single motor to drive two ball screws, which realizes the synchronization of the detector's lifting and lowering movements. The detector has a long distance of movement in the direction of the beam line, so the cable length of the motor, feedback element, BEAMSTOP and limit element will be very long, and its regularity will be very poor.

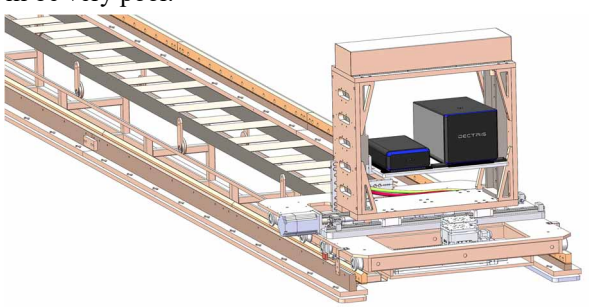

Figure 4: The device for SAXS experiment.

Figure 5 shows the structure of USAXS device. It only has two functions: lifting and lateral displacement. Its structure is relatively simple. Again, it is located in a vacuum and is used to do USAXS experiments.

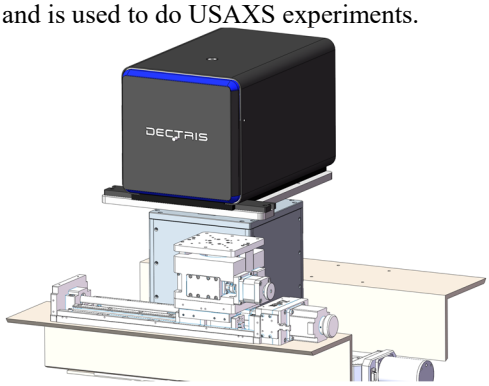

Figure 5: The device for USAXS experiment.

The vacuum chamber is the most basic component of the X-ray scattering experimental setup. Figure 6 shows an overview of its structure. Both the coarse and thin pipes are on the outside of the shed for radiation protection. In order to save the design cost, there are three types of radiation protection design for the cavity, namely the design of radiation protection shed, the design of thick pipe wall thickness, and the design of the lead layer wrapping structure of thin pipe. According to the calculations of the teachers of the relevant majors, the wall thickness of the thick pipe should not be less than 20 mm. The thick pipe consists of three sections, which allows the trolley of the SAXS unit to move in it according to the design specifications.

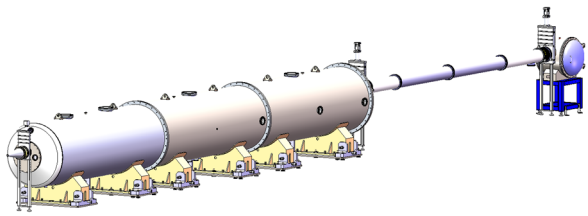

Figure 6: Vacuum chamber.

Figure 7 shows the support base of three thick pipes. The thick pipe has the characteristics of large mass and high center of the pipeline. There is a moving mechanism inside the pipeline, so the stability of the three-section thick pipe is required by higher requirements. Combining the above characteristics, the base of the pipe is designed as a saddle type.

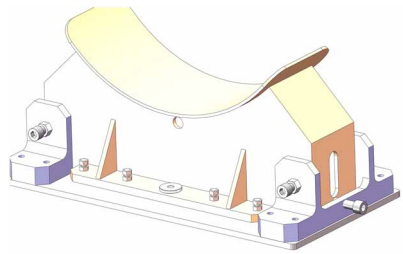

Figure 7: Support base of three thick pipes

Stability

When using this device for experiments, the stability [2] requirements for the detector are not very high, which is 30 % of the resolution, which belongs to the micron level. The ground vibration is about 10nm, and when the actual natural frequency of the system is 50 Hz, the amplification factor of the system is about 1.2 times, so when designing the structure, there is no need to simulate the natural frequency of the structure to more than 120 Hz.

PARAMETRIC INDICATORS

Detector Motion Parameters

As can be seen from Table 1, the Y-axis travel is very long, so it is very important to ensure the straightness of the track.

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Table 1: Detector Motion Parameters

	Resolution [μm]	Repeatability accuracy [μm]	Itinerary [mm]
WAXS-X	5	10	150
WAXS-Y	1000	1000	1210
WAXS-Z	2	5	230
WAXS-pitch	0.06°	0.06°	55°
SAXS-X	5	10	320
SAXS-Y	1000	1000	12500
SAXS-Z	5	10	260
USAXS-X	5	10	160
USAXS-Z	5	10	100

CONCLUSION

The X-ray scattering experiment vacuum camera device is a device that takes into account vacuum, radiation protection, ground profile, structural stability and functional design at the same time. If the requirements allow, more structural designs can be added for experiments. The design presented in this article leaves something to be desired in many areas and needs to be improved in the future.

REFERENCES

[1] https://www.xenocs.com/knowledge-base/saxs/

[2] W. F. Sheng, H. Liang, Y. S. Lu, and Z. Zhang, "Investigations on Stability Performance of Beamline Optics Supports at BSRF", in *Proc. MEDSI'20*, Chicago, USA, Jul. 2021, pp. 125. doi:10.18429/JACoW-MEDSI2020-TUPA04