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DESIGN AND TEST OF A NEW CRYSTAL ASSEMBLY FOR A DOUBLE CRYSTAL MONOCHROMATOR*

Yang Yang[1], Hao Liang† [1,2], Dashan Shen[1], Zekuan Liu[1],Yunsheng Zhang[1], Shan Zhang[1], Yuanshu Lu[1], Lu Zhang[1]
[1]Institute of High Energy Physics, Beijing, P. R. China,
[2]University of Chinese Academy of Sciences, School of Physics, Beijing, P. R. China

Abstract

A vertical diffraction double crystal monochromator is a typical optical component in synchrotron radiation beamlines, its main requirements and characteristics are high angular adjustment resolution and stability. Due to the development of the 4th generation light sources, those requirements get even more challenging. This paper mainly introduces the design and test of a new crystal assembly design in a vertical diffraction double crystal-monochromator. The designed scheme has been fabricated. The surface slope error of the first both crystals was measured and below 0.1 μ rad RMS. The motion adjustment test of the second crystal module has been carried out under atmosphere, vacuum and cryocooled conditions, and the results are much better than required ones. The stability of the monochomator was measured, and results below 10 nrad RMS were observed under cooling conditions.

INTRODUCTION

HEPS is a 4th generation light source which employs multi-bend achromat lattices and aims to reach emittance as low as 60 pm•rad with a circumference of about 1360 m [1]. The vertical diffracting double crystal monochromator (VDCM) described in this paper will be serving the X-ray microscopic imaging line station of HEPS. The monochromator hosts 2 Si(111) crystal, covers an energy range of 5 keV to 15 keV. It works in fixed exit mode. The maximum heat load is 435 W, thus the monochromator is liquid nitrogen cooled. The relative pitch stability requirement is 100 nrad RMS. This paper mainly introduces the design and test of the crystal assembly of the monochromator. The crystal assembly includes 2 main sub-components, the first crystal component and the second crystal component. The first crystal component mainly includes the first crystal cooling and clamping, using micro-channel side cooling and flat plate clamping schemes. The second crystal component provides gap, coarse pitch and roll, fine pitch and roll for the second crystal. At the same time, the Angle monitoring system is designed (Fig. 1).

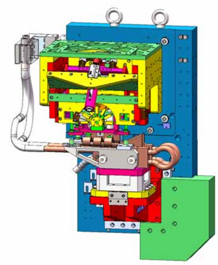

Figure 1: Crystal module design model.

The First Crystal Components

The first crystal component mainly includes the first crystal cooling and clamping component, crystal heat insulation component and crystal support structure.

Indirect cooling of the first crystal has been proven effective for high heat load monochromators around the world [2, 3]. Therefore, the crystal cooling in this scheme follows the microchannel edge cooling design, and the crystal clamping adopts the disc spring plate clamping mechanism. The two plates rely on the disc spring to provide compression force. Each disc spring is compressed by 0.2 mm, and six unilateral superpositions are used. The unilateral compression can be 1.2 mm, and the maximum force can be 814 N. The heat insulation of the crystal is designed with a machinable ceramic design, which is placed between the bottom of the crystal and the support structure. The heat leakage and mode analysis of the whole monocrystalline component are carried out. The overall heat leakage is 3.3 W, and the first-order angle direction mode is 312 Hz (Fig. 2).

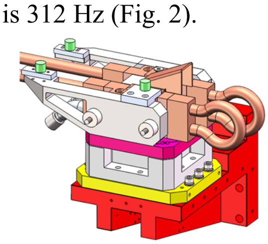

Figure 2: The first crystal components design model.

The design scheme was processed and assembled, and the crystal surface shape was measured (Fig. 3). The normal temperature result is less than 0.1 μrad, which meets the requirements of use.

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† yangyang@ihep.ac.cn and lianghao@ihep.ac.cn

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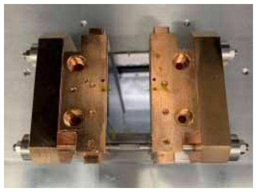


Figure 3: The first crystal clamping surface shape test.

The Second Crystal Components

The second crystal component mainly includes the clamping cooling structure of the second crystal and the angle adjustment mechanism of the second crystal (Fig. 4).

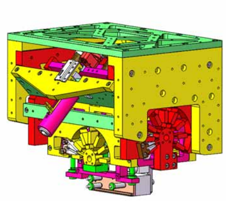


Figure 4: The second crystal components design model.

The cooling of the second crystal adopts mature copper foil cooling technology. The clamping of the second crystal mainly considers the deformation of the crystal under the action of gravity, using the Bessel point and the three-point support method. The finite element analysis results show that the surface shape of the central 30 mm area is 27.3 nrad RMS after removing the quadratic term. The scheme is processed and assembled, and the crystal surface shape is measured. The normal temperature result is less than 0.04 µrad, which meets the use requirements (Fig. 5).

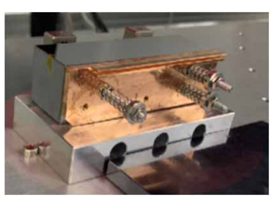
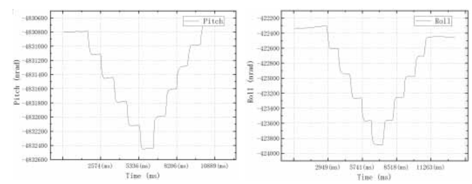


Figure 5: The second crystal clamping surface shape test.

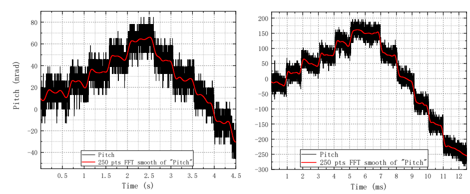
The angle adjustment mechanism of the second crystal can realize the pitch and roll angle adjustment of the second crystal. The flexible hinge structure design of double-layer drive is mainly adopted. Through the top of two actuators [4, 5], the coarse and fine two-step adjustment of the angle can be realized. The resolution of the coarse adjustment actuator is 30 nm, and the fine adjustment actuators is 0.6 nm. At the same time, the spring preload structure is designed to provide preload and recovery force for the whole system. Two sets of angle monitoring systems are designed, one of which is a grating scale monitoring system, which is directly arranged at the installation position of the hinge end drive, and can realize the monitoring of the pitch and roll angle respectively. The other set is an interferometer monitoring system. The relative position monitoring is realized by a 3-point laser head mounted on the second crystal load plate and a corner cube mirror mounted on the first crystal assembly, and then the angle monitoring is calculated.

The scheme was processed and assembled, and the angular resolution and stroke test were carried out under the three environments of atmosphere, vacuum and vacuum low temperature. The test results showed that the motion range of the pitch and roll angle was more than 0.5°, the coarse adjustment resolution of the pitch and roll angle was less than 485 nrad (Fig. 6), and the fine adjustment resolution was less than 50 nrad, which is better than the use requirements (Fig. 7).



(a) (b)

Figure 6: Coarse adjustment resolution, pitch (a), roll (b).



(a) (b)

Figure 7: Fine adjustment resolution, pitch (a), roll (b).

Global Stability Test

In the low temperature (17 Hz/2 L) vacuum environment, the overall stability test was carried out by using the interferometer angle monitoring system. The test results show that the pitch angle stability is about 10 nrad RMS, and the roll angle stability is about 28 nrad RMS (Fig. 8).

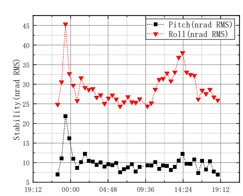


Figure 8: Angular stability result.

CONCLUSION

This paper mainly introduces the structure design and related test of a vertical diffraction monochromator crystal component. The test results show that the scheme has high stability and angle adjustment accuracy, has small crystal surface shape change, and the actual index is better than the parameter requirements. At the same time, the whole structure processing and assembly process is simple, easy to operate, and the vacuum adaptation degree is high. It can be identified as a preferred option and further tested in more detail.

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