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DESIGN AND IMPROVEMENTS OF A CRYO-COOLED HORIZONTAL DIFFRACTING DOUBLE CRYSTAL MONOCHROMATOR FOR HEPS

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Abstract

Horizontal diffracting double crystal monochromator (HDCM) are usually used in a 4th generation light source beamline due to the larger source size in the horizontal direction. This paper introduces the mechanical design and optimization of a HDCM for Low-dimension Structure Probe Beamline of HEPS. In order to achieve the high stability requirement of 50 nrad RMS, the structural design is optimized and modal improved through FEA. In order to meet the requirement of a total crystal slope error below 0.3 μrad, FEA optimizations of the clamping for first and second crystal are carried out. The vacuum chamber is optimized to become more compact, improving the maintainability. Fabrication of the HDCM is under way. The results show that the design is capable of guarantee the required surface slope error, stability, and adjustment requirements.

INTRODUCTION

HEPS is the first high energy beamline and the first 4th generation beamline in China. Thanks to the low emittance of the source, the beam source size could be as small as 10 microns. The low-dimension structure probe beamline (LODiSP) of HEPS is beamline dedicated on x-ray surface diffraction technique. The energy range of this beamline is the beamsize is in vertical and in horizontal. When a monochromator is used in horizontal diffraction mode, the tolerance of vibration in pitch direction for a double crystal monochromator could be as low as 50 nrad.

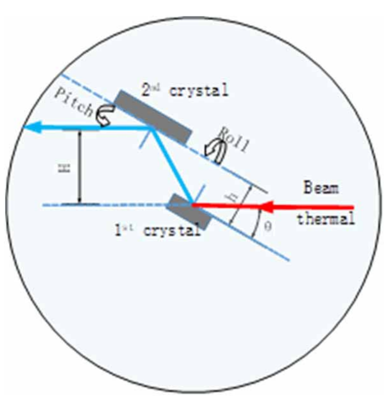

Figure 1: Beam path in a DCM.

The energy of the exit beam is a function of the Bragg angle θ (Fig. 1), and the resulting angular. and the resulting angular range with silicon crystals Si(111) is about 2.52°～24.32° (4.8～45 keV).

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According to Fig. 1, the spacing between reflected beam and Incident beam can be expressed as Eq. (1) [1]:

$$H = h \times 2cos\theta \quad (1)$$

A linear slide table under the second crystal enables high requirements to be fixed. Through the bellows (Fig. 2), the vibration of the cavity and the internal components is decoupled to achieve the purpose of improving stability.

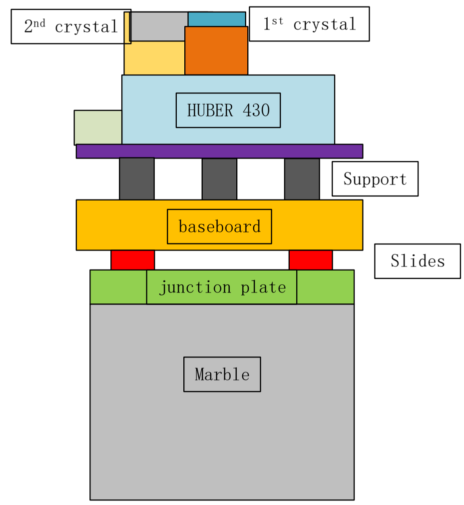

Figure 2: Monochromator construction.

DESIGN OF THE MONOCHROMATOR

The crystal slope error is an important parameter affecting the beam quality. The design of this monochromator (Fig. 3) uses a scheme in which copper blocks are clamped on both sides of the crystal [2, 3].

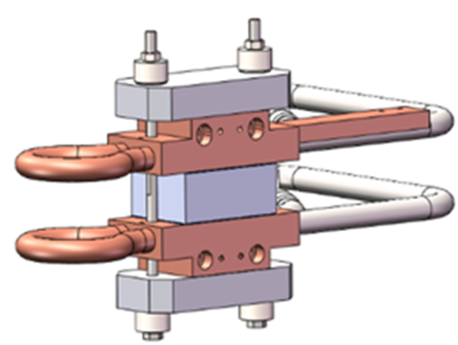

Figure 3: 1st crystal holder.

The FEA method was used to analyze the influence of different clamping positions and different thicknesses of pressure plate on it. Through multiple iterative optimizations, the clamping structure that meets the requirements of slope error is obtained, and the strain cloud diagram is shown (Fig. 4).

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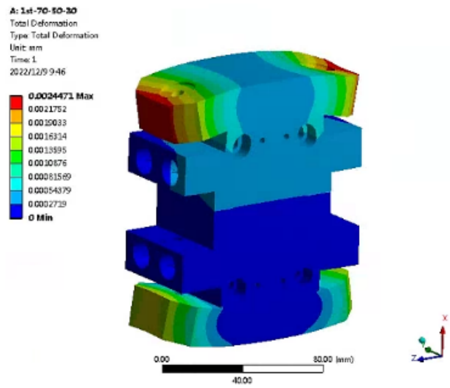

Figure 4: 1st crystal component strain analysis results.

The slope error affects the beam quality [4], Fig. 4 shows the FEA deformation analysis result as a contour map. The curve reflects the change in slope of the centerline of the crystal surface when stressed. The slope error is calculated as 0.1 μrad RMS (Fig. 5).

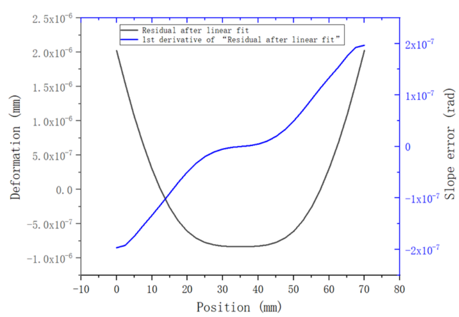

Figure 5: 1st crystal slope error

From the information given above, the device works by the position of the spot on the surface of a crystal is immovable. For this reason, in order to obtain more accurate results, it is more appropriate to use the data within a central range as the research object.

The result of 30 mm area in the center of the crystal plate was calculated as 0.006 μrad RMS with the slope error of removing the quadratic term (Fig. 6).

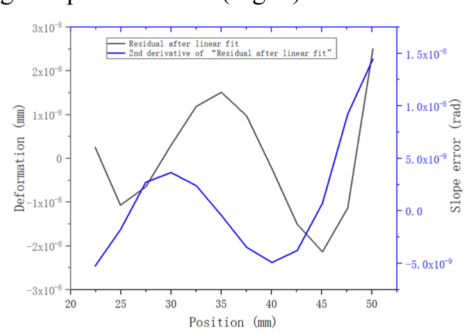

Figure 6: 1st crystal slope error (30 mm area).

Due to the long crystal, the position of the support point has a significant impact on the overall slope error result under the action of gravity.

The second crystal adopts the Bessel points clamping scheme, which is conducive to controlling the slope error of the crystal surface. Figure 7 shows the FEA deformation analysis result as a contour map.

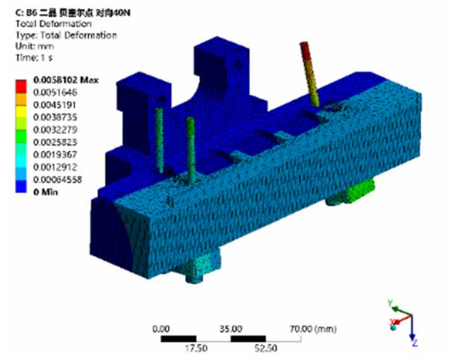

Figure 7: 2nd crystal component strain analysis results.

The overall surface shape of the two crystals in the arc vector direction of the photonic surface is 0.175 μrad (Fig. 8) after deducting quadratic term, the overall surface shape of the crystal in the full length range is 0.066 μrad (Fig. 9).

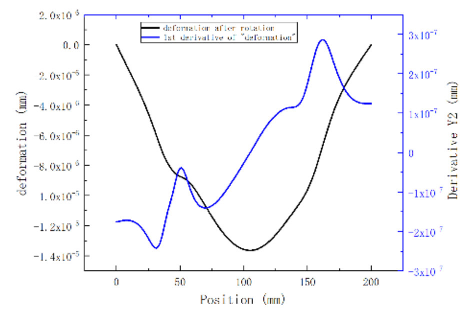

Figure 8: 2nd crystal slope error.

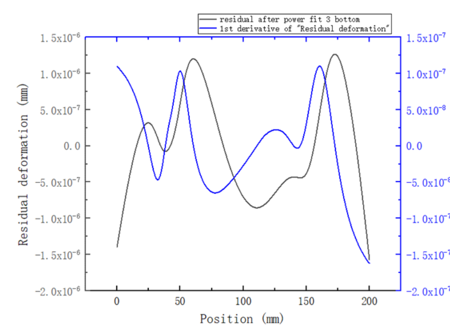

Figure 9: 2nd crystal slope error (deducting quadratic term).

VACUUM CHAMBER

The vacuum chamber was partially replaced with a square chamber. Improved compactness. The total weight of the cavity is about 645 kg. The FEA results show that the maximum stress is 55 MPa (Fig. 10) and the maximum strain of the chamber is 0.1 mm (Fig. 11). According to the yield strength, safety is calculated as 3.7.

The chamber is designed to be divided into two layers for easy access and maintenance. A cool-conducting copper column is added at the bottom plate. Reduce motor heat generation and temperature drift. The monochromator is equipped with 2 pneumatic insert valves along the inlet and outlet flanges in the direction of the beamline to isolate the vacuum and participate in the safety interlock; The

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molecular pump and ion pump port are equipped with manual insert valve, which is used to isolate the vacuum of the vacuum pump and the monochromator cavity; Equipped with metal angle valve, it can be used for pre-evacuation (Fig. 12).

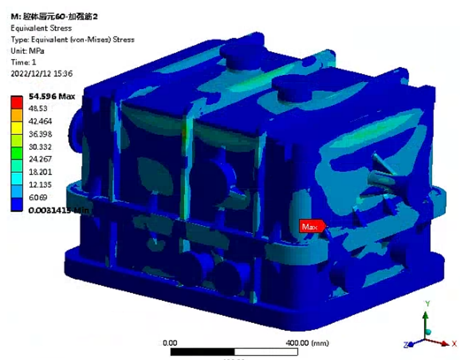

Figure 10: Crystal component strain analysis results.

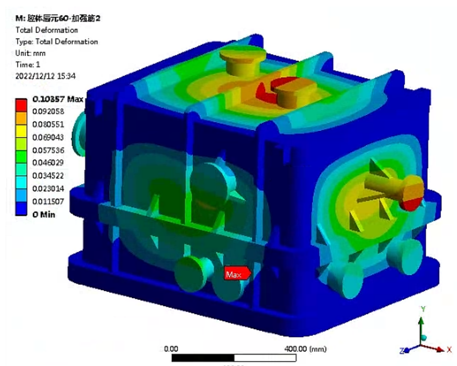

Figure 11: Crystal component strain analysis results.

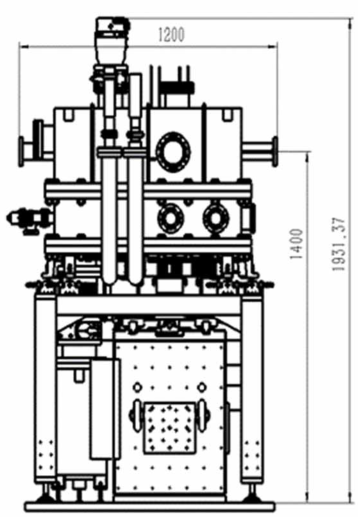

Figure 12: Crystal component strain analysis results.

CONCLUSION

The results show that the above analysis and calculation theoretically prove that the design can guarantee the required surface slope error, stability and adjustment requirements. The Fabrication of the equipment is underway.

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