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VIBRATIONAL STABILITY OF A CRYOCOOLED DOUBLE CRYSTAL MONOCHROMATOR AT SSRF *

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Abstract

There is an increasingly critical demand on the angular stability of double crystal monochromator (DCM). This work focuses on a method to measure angular vibration directly at the DCM crystals using a dual-frequency interferometer. This method was applied to the off-line test of a newly developed cryocooled DCM at Shanghai Synchrotron Radiation Facility (SSRF), which can obtain a resolution of 8 nrad. The DCM was then tested on the X-ray Test Line. Both off-line and on-line results were referenced for DCM structure optimizations. In this paper, the DCM angular stability measuring method is presented, and detailed information of the results are shown.

INTRODUCTION

In the Phase-II beamline project of Shanghai Synchrotron Radiation Facility (SSRF), a fast x-ray imaging beamline will be constructed. To ensure the imaging quality, the beam stability is supposed to achieve 0.25μrad/10min, thus the influence on the spatial resolution can be controlled within 1μm. A cryocooled double crystal monochromator (DCM) has been designed and manufactured for this new beamline, which is under optimization at present. Main specifications of DCM stability are shown in Table 1 [1]. To achieve this target, a series of tests has been carried out on DCM stability, so as to provide references on the structure optimization.

Table 1: Angular Stability Specifications of DCM

Imaging Mode	Spatial Resolution (μm/pixel)	Angular Stability (μrad)
Monochromatic /White beam	1	≤0.25/10min
	2	≤0.5/10min
	5	≤1.5/10min

EXPERIMENTAL DESIGN

Principle and Instrument

To obtain the frequency information of DCM vibration, an Agilent® 10719A differential interferometer was applied to angular measurement. As the interferometer is mounted with quarter-wave plates inside, direct measurement of a mirror or a polished crystal surface is available. Figure 1 shows the schematic of the interferometer [2,3].

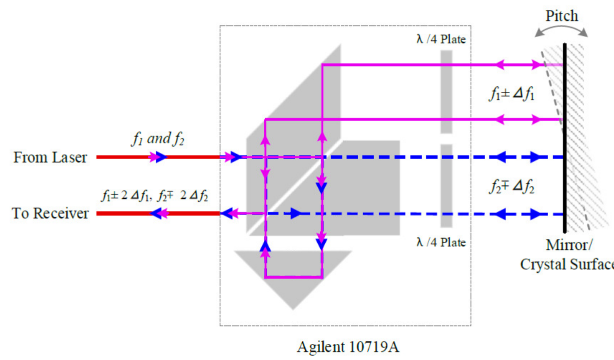

Figure 1: Schematic of 10719A.

According to Doppler effect, the angle can be worked out as:

$$\tan\theta = \frac{\lambda}{4D}\int_0^t \Delta f dt = \frac{N\lambda}{4D} \quad (1)$$

With an upgrade of the monitor board from E1735A to N1230A, the resolution of this measuring system can be increased from 50nrad to 8nrad [3,4]. The upgrade is now in progress.

Methodology and Experimental Setup

With a mirror located by the outlet flange, angular vibration of double-crystal could be measured directly, as shown in Figure 2. This method can also be applied to the vacuum condition. All the off-line tests were carried out in Lab 1042 at SSRF, shown as Figure3, where the floor is only 0.12m thick with no pile underground [5]. The sampling rate was set to be 500 Hz to obtain the frequency information within 200Hz. As the experimental environment was not satisfactory, more attention was paid on the frequency information.

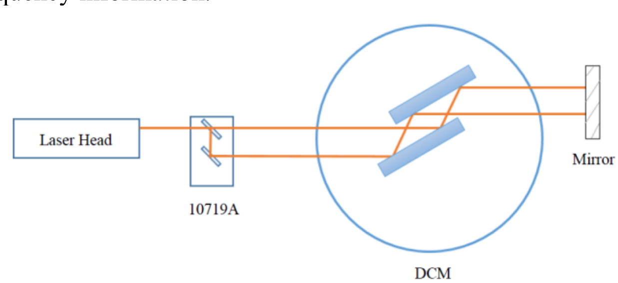

Figure 2: Direct measurement of double-crystal stability.

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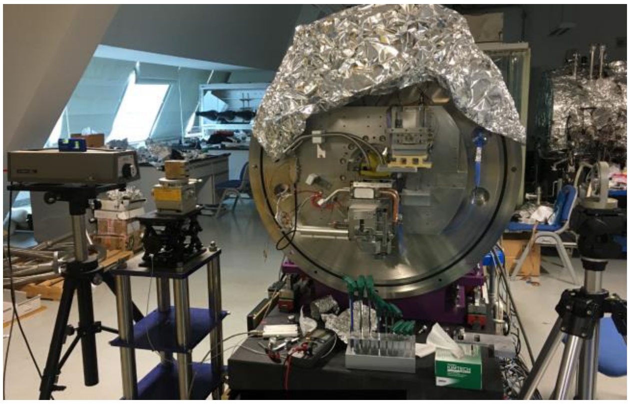

Figure 3: Off-line test of DCM angular stability.

RESULTS AND DISCUSSION

Off-line Test

To get rid of the influence of the measuring system itself, direct reflective signal from the mirror without passing through crystals was also acquired, working as the background information. The FFT results of both tests can be seen from Figure 4 and Figure 5.

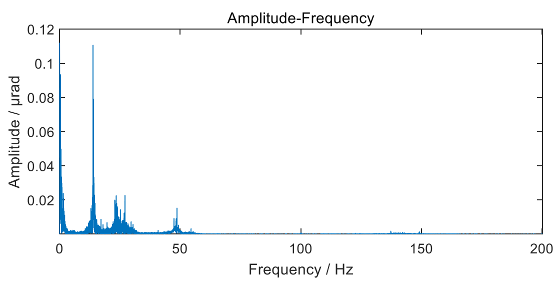

Figure 4: FFT of direct reflective signal.

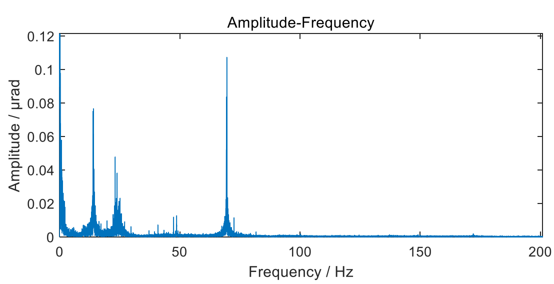

Figure 5: FFT of double-crystal pitch angle vibration.

RMS value of DCM vibration was about 200nrad. In consideration of the simplified facilities as well as the noisy experimental environment, more attention was paid on the frequency information rather than the amplitude. Comparing the two figures above, there is an apparent peak around 70Hz, which is believed to be the signal of double-crystal system. As laser has passed through the crystals back and forth, the actual amplitude should be half as shown. The off-line measurement could successfully obtain the frequency information of double-crystal vibration, which provided a useful reference on the structure optimization.

On-line Test

On-line tests of the DCM were carried out on the X-ray Test Beamline (09B) at SSRF. Altogether 3978 spots were acquired, with each image exposing for 1ms. Frequency analysis was done by picking up several line profiles and studying the rule of time-intensity, shown in Figure 6. FFT of the time domain data has been calculated and is shown in Figure 7. The main frequency distribution of vibration sources was around 30Hz, 40Hz, 50Hz, and 65Hz. Comparing Figure7 with Figure 5, we can see both results of off-line and on-line test matched well, the calculated frequency responses are similar.

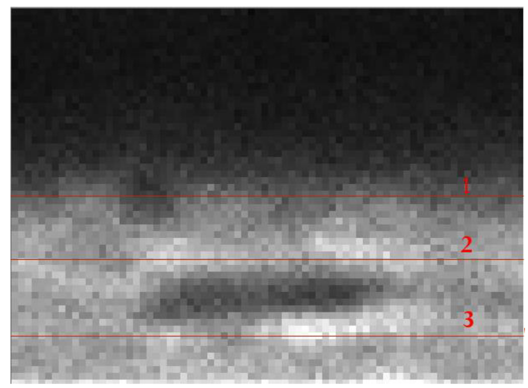

Figure 6: Picking up line profiles from spot.

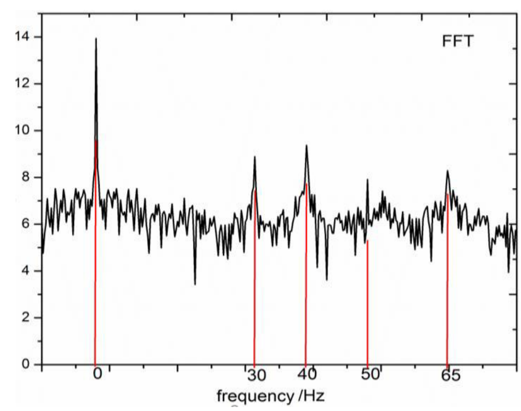

Figure 7: FFT analysis of spot vibration.

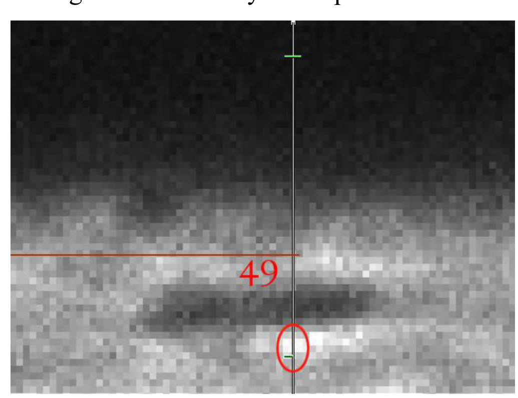

Figure 8: Picking up specific point from spot.

By picking up some specific points and observing their location change, shown in Figure 8, the amplitude analysis was done. To acquire more detailed data of the amplitude,

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subpixel digital image processing was applied. Through an interpolation of 1:0.05:2, the peak-to-valley amplitude was worked out to be about 8μm, shown in Figure 9. The DCM structure still needs optimization to improve the angular stability.

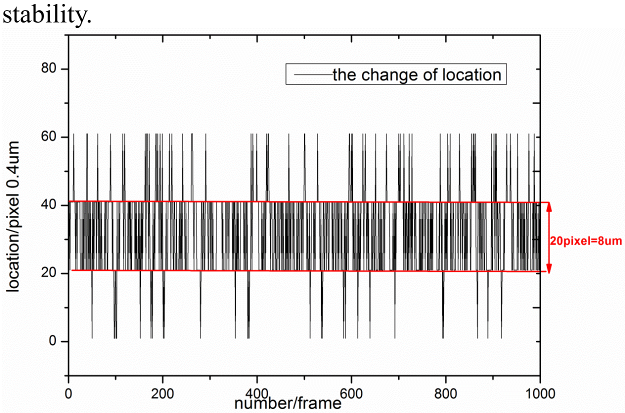

Figure 9: Amplitude analysis of spot vibration.

CONCLUSION

This paper represents a method to measure angular vibration directly at the DCM crystals using a dual-frequency interferometer, which can realize a resolution of 8 nrad. This method has been applied to the off-line test of a newly developed cryocooled DCM at SSRF, the results of which has been discussed. On-line test results have also been shown, and comparison between both measurements has been made. The DCM is currently under optimization to realize better angular stability, the tests can provide effective reference on the structure optimization.

ACKNOWLEDGEMENTS

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