Performance of A Double Crystal Monochromator Prototype for HEPS Under Water Cooling Condition at A Wiggler Beamline of BSRF

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Abstract

The performance of monochromator is crucial to the performance of a beamline, especially for a 4th generation synchrotron light source. To find out the performance of the monochromator prototype built for the HEPS project, it was tested at a wiggler beamline of BSRF with water cooling. The short term stability was tested with synchrotron beam under various cooling condition, and the result between 4.4 nrad to around 500 nrad were observed. The energy drift in 9 hours since the beam hit the beamline was 0.4 eV at the Cu K edge. The repeatability in 1 hour was about 0.1 eV. The cooling of the crystals was measured by rocking curve broadening at different energy and no alarming result was observed. Also the temperature stability in the optical hutch was measured for a long term. In conclusion, some performance are satisfying, but further improvements should be carried out in the future.

Introduction

A double crystal monochromator prototype was built for the HEPS project, it went through a series of offline and online test with LN2 cooling during 2016~2019, and some key results were obtained. The prototype has a stability of 40 nrad RMS with a LN2 flow rate of about 4.5 L/min. The LN2 cooling works fine under 800 watts of heat load provided by a heater. Other performances such as mechanical resolution, repeatability, vacuum, motion functions are all up to design requirements. Details can be found in [2].

However, we still need to know if it is really works for demanding experiments such as XAFS. In order to test that, it was then installed in 3W1 of BSRF, a wiggler beamline. However, it was tested only under water cooling condition, since we don't have dedicated LN2 distribution lines.

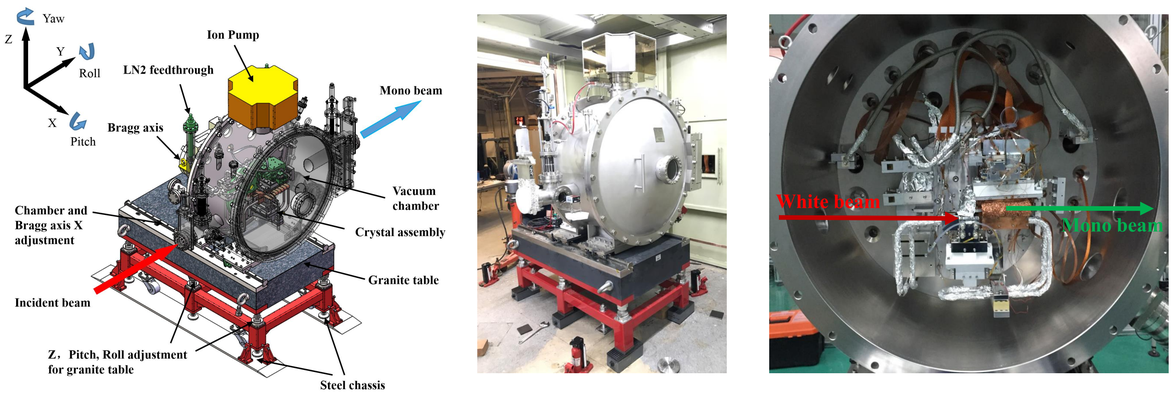

Figure 1 design model and protype of high heat load DCM

Test conditions

3W1 is a wiggler beamline, the DCM is 20.8m from the source, before the DCM is a collimating mirror, which will also reduce the heat load onto the monochromator. The reduced heat load is about 35W. After the DCM is a toroidal mirror at 23m. The focal point is 32m from the source. Cooling of the monochromator was done by a water chiller made in China, LX series from Coolium Instruments.

Most of the tests and experiments were done under XAFS mode. 2 ion chambers and diamond XBPM were used. Also an ADC were used to measure vibration at high frequency.

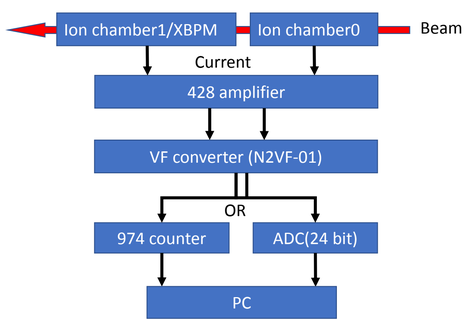

Figure 2 Schematic view of XAFS mode and vibration measurement mode

Figure 3 LX-1000 chiller

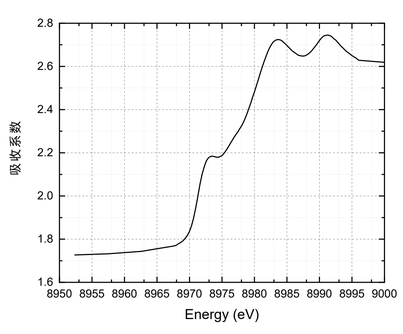

Figure 4 Cu K edge scan

Short term repeatability

The short term repeatability was done by non stop Cu K edge scans. It is about 0.1 eV for a period of 1 hour.

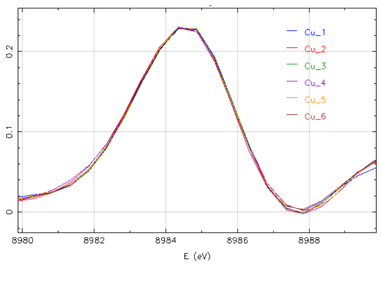

Figure 5 Short term repeatability

References

1. Jiao, Y., et al., The HEPS project. Journal of Synchrotron Radiation, 2018. 25(6): p. 1611-1618.
2. Hao Liang, Gang Cao, Lidan Gao et al, A High Heat Load Double Crystal Monochromator And its Cryo Cooling System for HEPS, in Proc. MEDSI'18, Paris, France, June. 2018, paper FROAMA05, pp. 430-434.
3. Chumakov, A.I., et al., Performance of a silicon monochromator under high heat load. Journal of Synchrotron Radiation, 2014. 21: p. 315-324.
4. Sergueev, I., et al., Angular vibrations of cryogenically cooled double-crystal monochromators. Journal of Synchrotron Radiation, 2016. 23(5): p. 1097-1103.
5. MCC DAQ website, https://www.mccdaq.com/sound-vibration-daq
6. Coolium Instruments website, http://www.ykky.com/

Cooling performance

The cooling performance was measured by rocking curves. It shows that intensity drops when flow rate drops, indicating insufficient cooling of crystals. Comparing all results with theory calculation, we come to conclusion that the thermal contact resistance of indium foils is too high for water cooling.

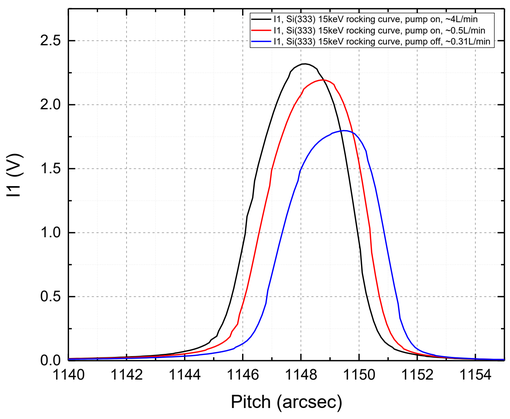

Figure 6 Rocking curve results

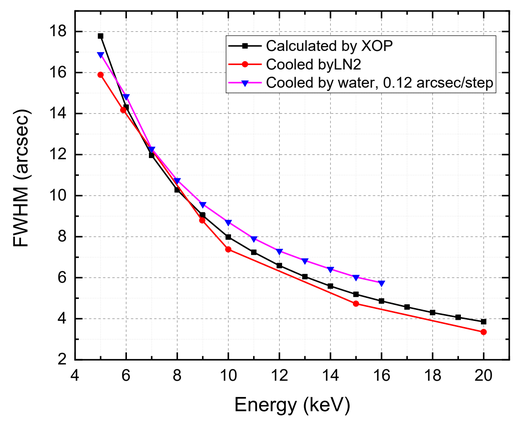

Figure 7 Water cooling results comparing to LN2 cooling and calculation results

Long term stability

The long term stability is important for XAFS application. By using 2 ion chambers we can easily get the absorption ratio for Cu foils under different energy. Fix the energy at one point where we know the relationship between absorption ratio and energy, we can get the energy drift by measuring the abortion ratio. Test results show that a 0.4eV drift from a "cold state" beamline to 9 hours after beam on. Temperature variation during this period is about 0.1℃ in the hutch. At the final stage the drift speed is less than 0.013eV/hour.

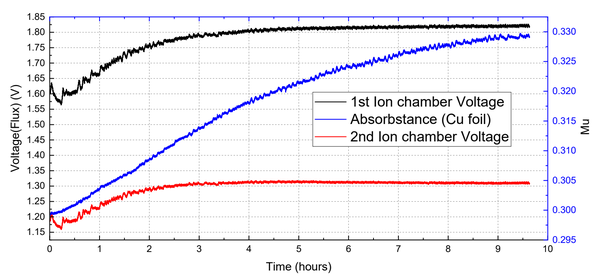

Figure 8 Ion chambers readings and absorption ratio from no beam to beam on

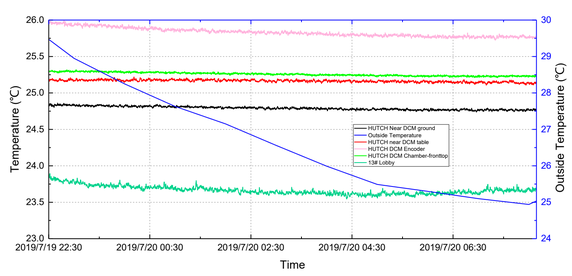

Figure 9 temperature log during long term stability test

Short term stability

The short term stability is crucial to position sensitive experiments. Flux data was acquired by an ADC with a sampling rate of 2kHz, then converted to rocking angle of the second crystal. With gravity cooling, best results is about 4 nrad. With chiller, stability can go up to 500 nrad. Main cause is the vibration from the chiller's motor and flow induced vibration.

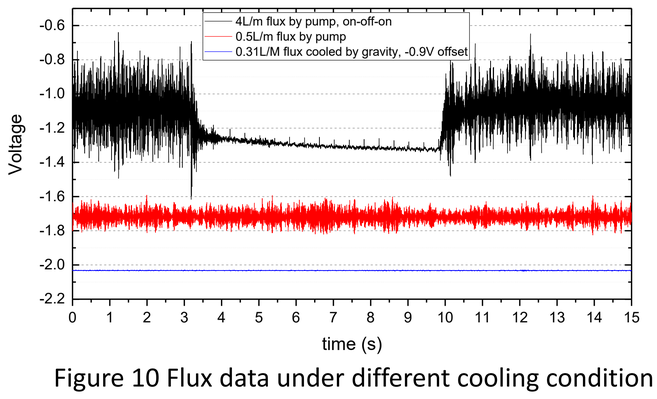

Figure 10 Flux data under different cooling condition

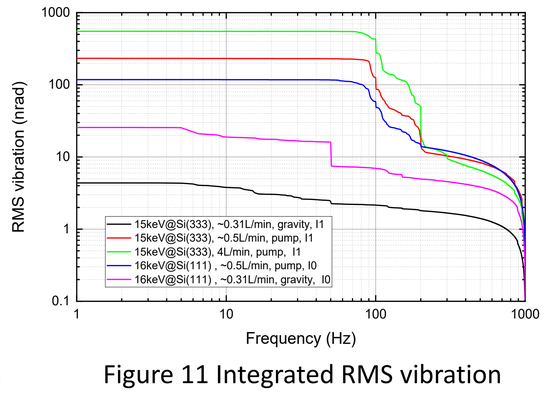

Figure 11 Integrated RMS vibration

Conclusion

A series of tests were carried out for the DCM, all results seems to satisfy XAFS requirements. Gravity cooling turns out to have great benefit for stability, however its cooling capability is not suitable for high heat load condition. These tests provided useful information for future development.