MECHANICAL VIBRATION MEASUREMENT SYSTEM AT THE CANADIAN LIGHT SOURCE

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Abstract

In recent decades, synchrotron radiation has developed into a valuable scientific tool around the world. At synchrotron radiation facilities, the mechanical vibrations in the optics hutch and experimental hutch, especially in the vertical direction, enlarges the beam size and changes intensity of the monochromatic X-ray beam. To investigate mechanical vibrations at the Canadian Light Source (CLS), a vibration measurement system was developed. This paper presents our investigations on mechanical vibrations at four beamlines and endstations at the CLS.

INTRODUCTION

At synchrotron radiation facilities, the vibration of the electron and/or photon beam, especially in the vertical direction, enlarges the size and changes its intensity. This degrades the performance of the beamline. It is reported that the amplitude of floor vibrations at the ATF2 project is approximately 50 µm, which is even larger than the vertical beam spot size expected at ATF2 [1]. In another report related to synchrotron radiation lithography, the quality of micro structures fabricated by the lithography beamline is greatly affected when the amplitude of the vibration is bigger than a quarter of the minimum feature size [2].

Many other factors that are responsible for vibrations at synchrotron radiation facilities were reported in the literature, such as traffic, human activities, strong wind and/or ocean waves, water pipes, and moving mechanical components. Thus, careful investigations of vibrations at synchrotron radiation facilities are crucial, especially if the photon beam size is within a few micrometers.

Studies of vibrations have been conducted at synchrotron radiation facilities worldwide and a brief review can be found in [3]. Although the CLS floor was carefully designed, we found that beamline developments still necessitate carrying out vibration studies. In this study, we investigated vibrations in the experimental and optics hutches at four beamlines and endstations at the CLS: CMCF 08ID-1 beamline, HXMA 06ID-1 beamline, REIXS 10ID-2 beamline, and the STXM endstation at SM 10ID-1 beamline. This work identified key vibration sources.

INSTRUMENTATIONS

The Canadian Light Source Vibration Data Acquisition system includes a Vector Signal Analyzer (VSA) (Model: Hp Agilent 89410A; Manufacturer: HP) and accelerometers (Model: 393B31; Manufacturer: PCB PIEZOTRONICS). Accelerometers produce a voltage proportional to the acceleration of their connected object. The VSA converts the output voltage of the accelerometers into a voltage power spectral density (S_v). Acceleration power spectral density (S_a, unit: $(m/s^2)^2/Hz$) is obtained from S_v by the following equation [4]:

$$S_a = \frac{S_v}{a^2} \tag{1}$$

where a is the sensitivity of the accelerometers. Displacement PSD (S_d, unit: $\mu m^2/Hz$) is calculated using S_a by the following equation [4]:

$$S_d = \frac{S_a \times 10^{12}}{(2\pi f)^4} \tag{2}$$

The RMS displacement over a given frequency band (f_1, f_2) can be calculated using the following equation [4]:

$$Z = \sqrt{\int_{f_1}^{f_2} S_d(f)df} \tag{3}$$

The sensitivity of the accelerometer a=1.02 v/(m/s^2). The frequency range of the measurement is 0.1 Hz to 300 Hz. The frequency resolution of the accelerometer is better than 0.1 Hz. In this study, we used two indexes for vibration evaluation--the displacement power spectral density (PSD) and the root mean square (RMS) displacement. The displacement PSD shows the strength of the displacement variation as a function of frequency. The RMS displacement represents the amplitude of displacement variations within a specific frequency range.

IDENTIFICATION OF VIBRATION SOURCES

The experimental set-up is discussed in [3].

Fan coil unit

The fan coil unit is hung on the ceiling in the CMCF 08ID-1 experimental hutch (SOE). Figure 1 shows that the fan coil unit induced vibrations have frequencies of 25.5 Hz (RMS displacement: 2.0×10^{-4} µm), 26.5 Hz (RMS displacement: 3.1×10^{-4} µm), and 53 Hz (RMS displacement: 4.0×10^{-5} µm) which is the harmonics of 26.5 Hz.

Detector cooling system

The equipment is used for cooling the detector of the MicroProbe endstation and it is approximately 0.5 m away from the microprobe endstation in the HXMA 06ID-1 experimental hutch. The microprobe endstation is very sensitive to vibrations since a very small beam spot

(3 µm × 5 µm) is required. Thus, three dimensional vibrations of the microprobe endstation were investigated--particularly, the effects of the detector cooling system on the endstation were studied. In this paper, however, only vibrations in vertical direction are presented. Figure 2 shows the displacement PSD of the microprobe endstation in the z-direction (vertical). RMS displacements in three dimensions are calculated. We found that when the detector cooling system is turned off, the total RMS displacements are 0.001 µm in the *x*-direction, 0.0013 µm in the *y*-direction, and 0.0032 µm in the *z*-direction. When the detector's cooling system is turned on, the total RMS displacements increase to 0.0130 µm in the *x*-direction, 0.0054 µm in the *y*-direction, and 0.0109 µm in the *z*-direction. This suggests that the operation of the detector's cooling system will significantly increase the vibration of the microprobe endstation by 1200% in the *x*-direction, more than 300% in *y*-direction and approximately 240% in the *z*-direction.

Vacuum pump

The Varian TriScroll pumps are widely used as rough vacuum pumps on many beamlines at the CLS. Figure 3 shows the displacement PSD of the floor vibrations in the CMCF 08ID-1 SOE experimental hutch when the Varian TriScroll pump is turned on (red line) and off (blue line), respectively. Figure 3 shows that the TriScroll pump induced vibrations with a frequency of 29.7 Hz (RMS displacement: 1.5×10^{-3} µm) and with harmonics of 59.4 Hz (RMS displacement: 1.2×10^{-4} µm) and 89.1 Hz (RMS displacement: 4.7×10^{-5} µm). Figure 3 shows that the Varian TriScroll pump produces the most significant vibrations (in terms of RMS displacement) on the CMCF 08ID-1 beamline.

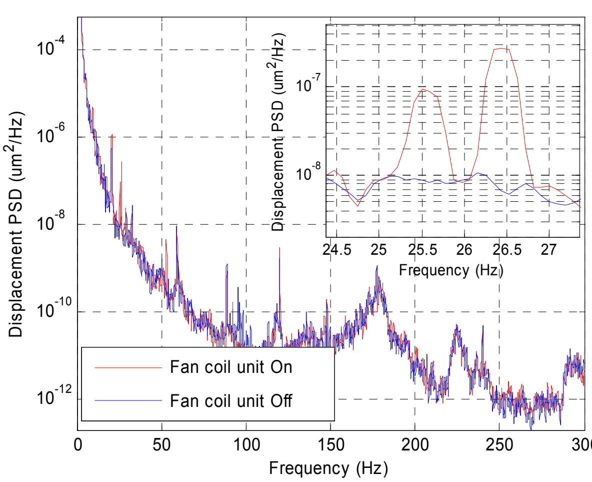

Figure 1: Floor vibrations when the fan coil unit is turned on/off.

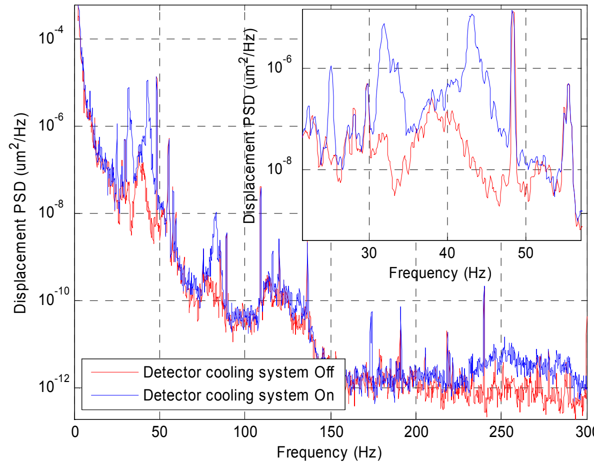

Figure 2: *z*-direction vibrations.

Chiller

The chiller is used for water cooling system and it is approximately 3 meters away from the monochromator outside the optics hutch at the HXMA 06ID-1 beamline. Figure 4 shows that when the chiller is turned on and the damping material is removed, both floor and monochromator vibrations at a frequency of 27.2 Hz dramatically increase, compared to the vibrations when the chiller is turned off. This means when the chiller is in normal operation it causes vibration with frequency of 27.2 Hz and the vibration propagates from the floor to the monochromator. Figure 4 also shows that when the damping material is used, the vibration of 27.2 Hz disappeared from the monochromator and floor. This implies that the used damping material can effectively isolate the chiller induced vibration.

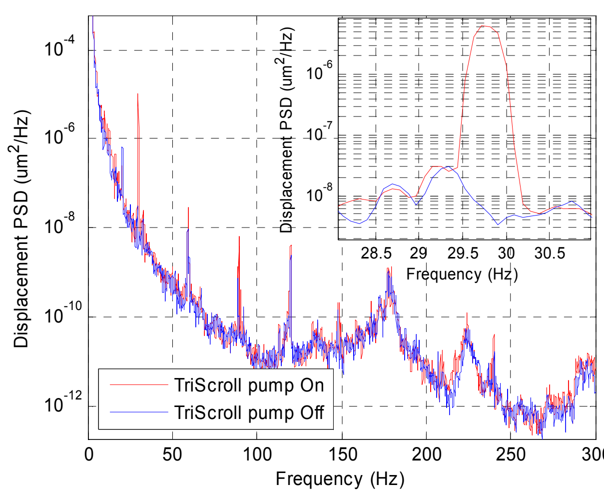

Figure 3: Floor vibrations when the Varian TriScroll pump in SOE is turned on/off.

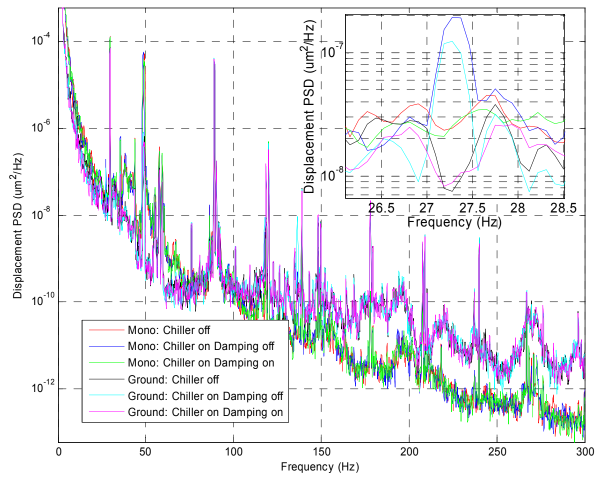

Figure 4: Vibration identification and isolation.

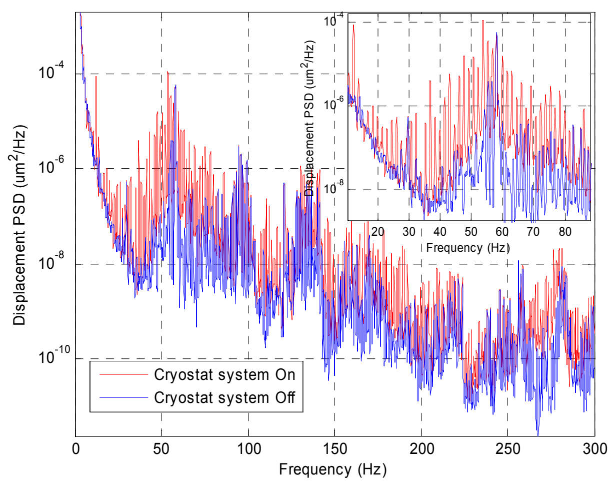

Figure 5: Cryostat system induced vibrations (in vertical direction).

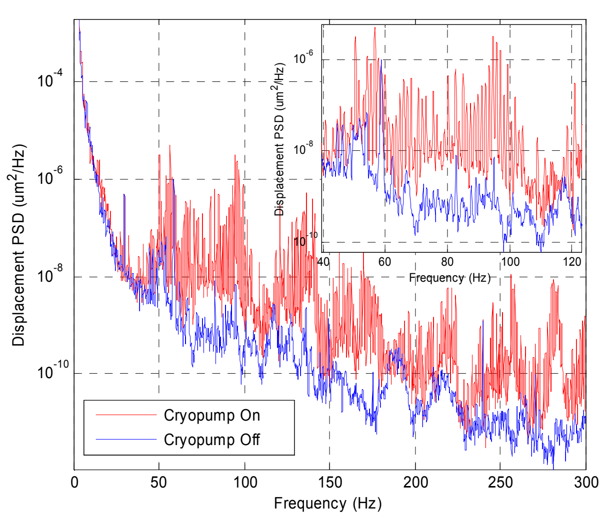

Figure 6: Cryopump induced vibration (in the vertical direction).

Cryostat system

The cryostat compressor is placed outside of the REIXS 10ID-2 experimental hutch and is approximately 1.5 meters away from the endstation The cryostat system includes the cryostat compressor and a cold head inside endstation chamber. The cold head and the cryostat compressor always work simultaneously and thus they are considered as one unit called cryostat system here. Figure 5 shows that the cryostat system produces vibrations with very broad frequency range from approximately 20 Hz to 80 Hz and many of these vibrations have fairly large displacement PSD (over 10^{-6} $\mu m^2/Hz$). Similar observations were found in the horizontal direction, which are not shown in this paper. The cryostat system does not affect the REIXS 10ID-2 beamline so far due to the relatively large beam spot (200µm × 200µm). However, it has been found that its operation significantly affects its neighbour SM 10ID-1 STXM endstation, which is discussed in [3].

Cryopump

The Helix Cryo Torr 8F cryopump compressor is located outside of the REIXS 10ID-2 experimental hutch and just beside the cryostat compressor. Figure 6 shows that the cryopump produces vibrations with very broad frequency range from approximately 40 Hz to 120 Hz, but most of these vibrations have relatively small displacement PSD (below 10^{-6} $\mu m^2/Hz$). Similar observations can be found from vibrations in the horizontal direction, which is not shown in this paper. So far no evidence has been found that the cryopump induced vibrations cause problems for operations of either the REIXS 10ID-2 beamline or the STXM endstation.

CONCLUSIONS

The results demonstrate that mechanical movable equipment in optics hutch and experimental hutch can cause significant vibrations. The information provided in this paper is important to understand and control vibrations not only for beamlines at the CLS but also for other synchrotron radiation facilities worldwide.

REFERENCES

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