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NSLS-II SITE VIBRATION STUDIES TO CHARACTERIZE BEAMLINE STABILITY

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Abstract

High performance goals of NSLS-II require stringent mechanical stability of its instruments such as BPMs, slits, mirrors, monochromators, and detectors. Mechanical stability of these components can be compromised by site-wide as well as local vibration sources (pumps, compressors, etc.). Several vibration studies have been performed at NSLS-II at the request of beamline users. This paper presents the results of these studies highlighting sources of vibration and mitigation strategies.

INTRODUCTION

Modern light sources, such as the NSLS-II at Brookhaven National Laboratory are designed to generate an electron beam with very low emittance and small beam size which requires a high degree of mechanical stability of the girder assembly and a low ground vibration level. The ground motion below 4 Hz is assumed to be correlated over the length of the storage ring cell (25m), and motion above 50 Hz is expected to be negligible.

MOTIVATION FOR MEASUREMENTS

Be it long (DC) or short term (AC), stability directly affects the operation and performance of NSLS-II. The beamlines also require precision mechanical and optical stability in order to meet their specifications and performance goals. At the request of the beamline users, a number of vibration studies were carried out to determine the sources of vibration instabilities that were affecting their operations.

SOURCES OF INSTABILITIES

Vibration sources can be broken down into four categories: natural, cultural, electrical and mechanical. Examples of natural sources are lunar tides, solar tides , earthquakes, wind, barometric pressure, and seasonal changes.

Heavy truck and traffic on the local expressway contribute greatly to the cultural instabilities. Mechanical vibration sources include AC handlers, water flow, liquid helium induced vibrations, and vacuum pumps. Electrical sources include power supply ripple as well as 60 Hz noise from power supplies, etc.

FLOOR MOTION OVER TIME

In October of 2012 vibration data was taken on the NSLS-II floor 2-ID SIX beamline every thirty minutes over a number of days. Measurements of the ground motion in the NSLS-II ring were made on a grouted floor plate as well as on a girder flange in cell 7 inside the tunnel. The results of the integrated displacement vs time from 2-100 Hz can be seen in Figure 1 below.

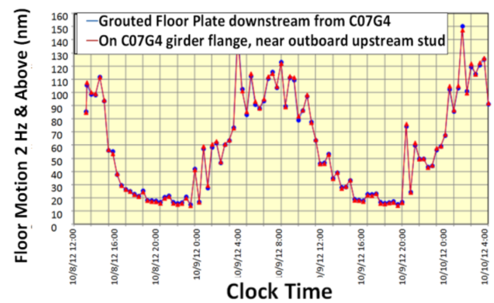

Figure 1: Vertical RMS Displacement vs Time.

The integrated displacement is periodic over a twenty-four hour period. The maximum day-time amplitude was about five times that of the night time amplitude. This was quite a surprise. The day time vertical RMS displacement from 2-100 Hz were upwards of 120 nm at mid-day while the night amplitudes dropped to 15-20 nm. Vibration measurements were taken over the next few months and were found to be very repeatable, though the weekend displacements measurements were slightly lower than the weekday and were also repeatable. The periodic nature of the vibration levels suggested the nearby Long Island Expressway which was later confirmed with measurements as the source of the vibrations.

11-BM VIBRATION MEASUREMENTS

Vibration studies have been performed over the last several years at bequest of the beamline users. The 11-BM (Bending Magnet beamline) was seeing a 200 µm fluctuation in beam position at a rate of 1 Hz during opera-tions. Below is Figure 2 that shows the layout of the beamline consisting of a number of optical benches, a sample chamber, two crys-tals and a single monochromator.

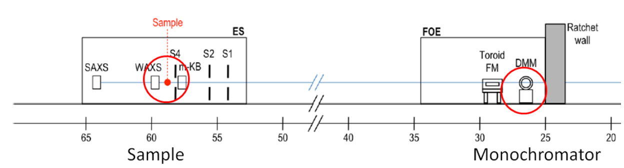

Figure 2: 11-BM layout

Vibration measurements on the floor as well as along the entire beamline on the granite tables at beam height did not find the source of the 1 Hz signal. After a thorough inspection of the beamline, it was found that the spring-loaded screws for the kinematic mount for the 1st crystal were loose. [1] Tightening of these screws resulted in the dampening of the vertical motion as shown in Figure 3.

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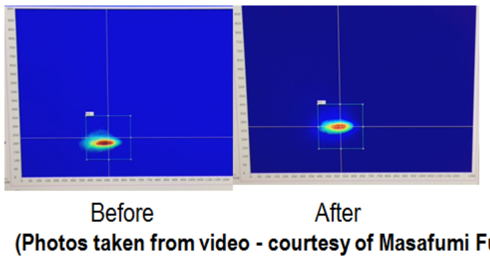

Figure 3: 200 μm position error and result of tightening spring-loaded screws.

2-ID SIX BEAMLINE

Prior to installation of the beamline, the SIX (Soft Inelastic X-ray Scattering) group requested a continuous study of the vertical signatures of the future detector and sample locations for a period of two weeks. Seismometers were placed 14 M apart and vibration data was taken over the two week period. Below is a graph of the displacement vs Time of the sample and detector locations. The periodic nature of the vibrations from the nearby LIE can be seen as well as a few large spikes due to the freight train activity in the early morning hours.

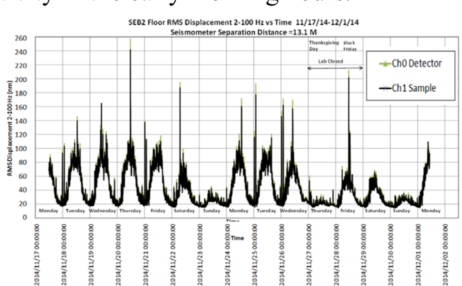

Figure 4: Vertical Displacement vs Time.

The vertical displacement varied from 15 to 100 nm (not counting vibration spikes) (Figure 4).The tight (400 nm) vertical stability tolerance across the 2.5 M vertical motion range to track energy led to a complete re-design of the experiment.(Figure 5).

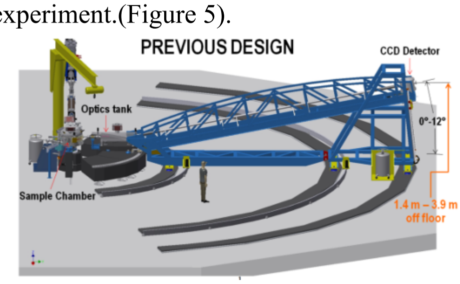

Figure 5: Previous Design.

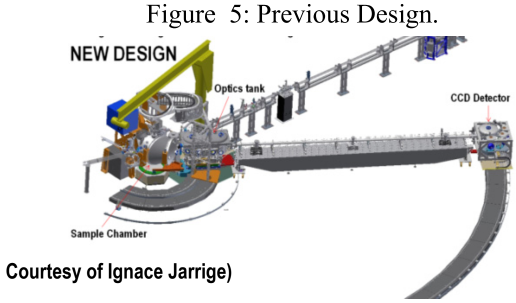

Figure 6: Re-design.

In this new design (Figure 6), a vertically reflecting mirror was added in the spectrometer optics tank to produce a constant output at all energies with the new detector height being only 1 M off the floor. [2]

3-ID HXN BEAMLINE

A vibration study was carried out in the satellite building that houses the HXN 3-ID beamline. The HXN Satellite Building (Figure 7) is a state of the art building designed to meet stringent technical requirements for vibration isolation and temperature stability, which are critical to operating the Hard X-ray Nanoprobe Beamline. [3]

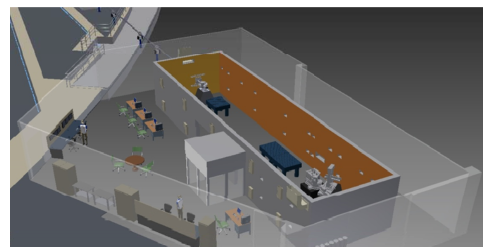

Figure 7: HXN Satellite building.

To that end, the hutch was built with a 1 M thick concrete floor as opposed to the 27” floor of the storage ring and the 15” thick experimental floor. To characterize the hutch and experimental floors, a series of correlation measurements were made as well as a vibration study over a number of days. Correlation measurements were made by measuring the vibration levels with two seismometers side by side, then increasing the distance between them after each measurement. These were done up to 11 M separation.

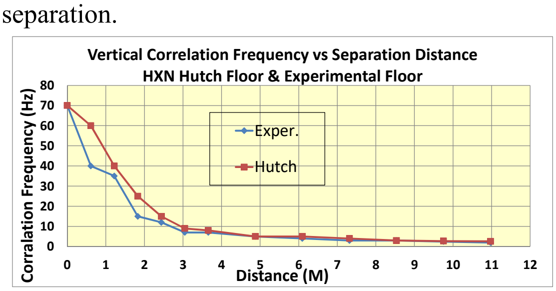

Figure 8: Correlation frequency vs separation distance.

The correlation study (see Fig. 8) shows that for short distances – up to 4.8 M, vertical correlation is slightly better on the hutch floor than the experimental floor. From 4.8 M to 11 M, the frequencies at which the correlation remains ‘good’ (> 90%), are about the same. The ratio of the relative displacement/absolute displacement vs separation distance (Figure 9) shows a better relative displacement for the hutch floor up to 8.53 M due to the flatter response of the hutch floor above the correlation frequency. At 11 M, the responses of the floors are about the same (figure 10).

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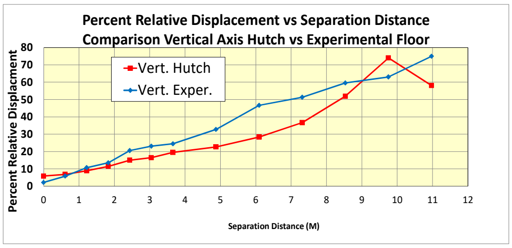

Figure 9: Ratio Rel./Abs. vertical displacement vs separation distance.

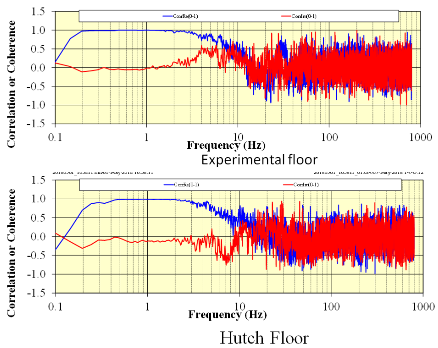

Figure 10: Vertical Correlation at a 8.53 M separation.

The horizontal correlation study shows that for all separation distances, the horizontal correlation is slightly better on the hutch floor than the experimental floor. (Figure 11).

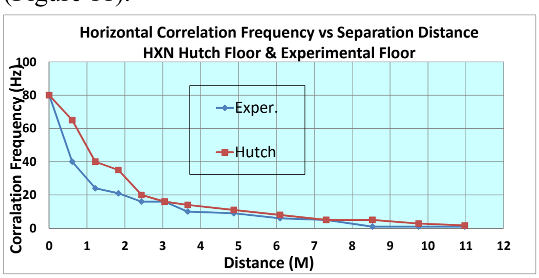

Figure 11: Correlation frequency vs separation distance

Looking at the relative displacement ratio (Figure 12), the hutch floor is better at the longer distances. At a distance of 8.53M, (Figure 13), the correlation for the hutch floor is still good at 5 Hz while that of the experimental floor falls below 1 Hz which is the lower bandwidth of the seismometer.

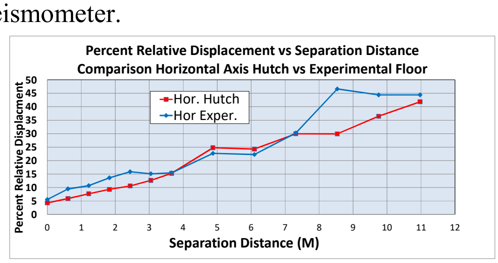

Figure 12: Ratio Relative/Absolute horizontal displacement vs separation distance.

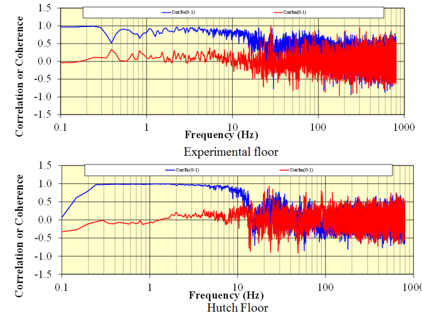

Figure 13: Horizontal correlation at 8.53 M separation.

The absolute RMS displacement maximums are slightly better on the hutch floor than the experimental floor , 55 vs 80 nm horizontally and 70 vs 90 vertically. See figures 14 & 15 below. The experimental floor minimums are slightly different for horizontal and vertical but for the hutch floor they are about the same.

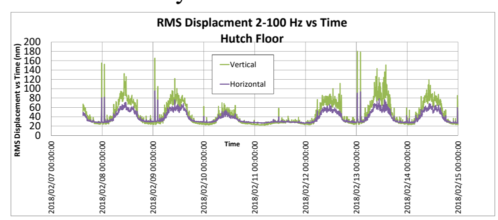

Figure 14: Hutch Floor Displacement vs Time.

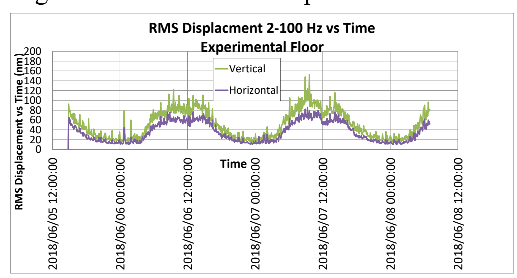

Figure 15: Experimental floor displacement vs time.

SUMMARY

Vibration studies have been used successfully to investigate the various sources of instabilities in the operation of the NSLS-II beamlines and to find the cause of these instabilities. In the one case, the vibration study led to a re-design of the experiment prior to installation, thereby saving both time and money in a costly redesign after the fact. The comparison of the experimental floor and the thickened HXN floor show that the absolute displacements are slightly less for the HXN floor. Measurements show that the vertical response of the floors are about the same while HXN floor shows a much better horizontal response at longer distances than the experimental floor.

REFERENCES

[1] Private communication with M. Fukumo

[2] Private communication with I. Jarrige

[3] Preliminary Design Report for Hard X-Ray Nanoprobe (HXN) Beamline, LT-C-XFD-HXN-PDR-001, June 2011.