# Ambient Vibration Measurement for APS 32-ID-C Floor, Table, and Sample Stages

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## 1 Introduction

One imaging technique used in beamline 32-ID-C at the Advanced Photon Source (APS) is x-ray microscopy. A new full-field transmission x-ray microscope has spatial resolution as high as 20nm and in situ imaging capability [1]. With such high resolution it is very important to minimize the ambient vibration levels present at critical components of the x-ray microscope.

This report summarizes ambient vibration measurements taken in beamline 32ID-C throughout 2015. At each location measurements were taken in the vertical direction and horizontal direction perpendicular to the beamline. These two directions are the most important for the x-ray microscope.

## 2 Objectives

- Compare vibration levels at the sample position with the current positioning stages stack to the previous stages stack.
- Compare vibration levels on the current granite zone plate platform to the previous invar platform.
- Show the effect of coolant water on the ambient vibration levels at the sample position.
- Measure and report the vertical vibration levels present at the top of the interferometer platform.

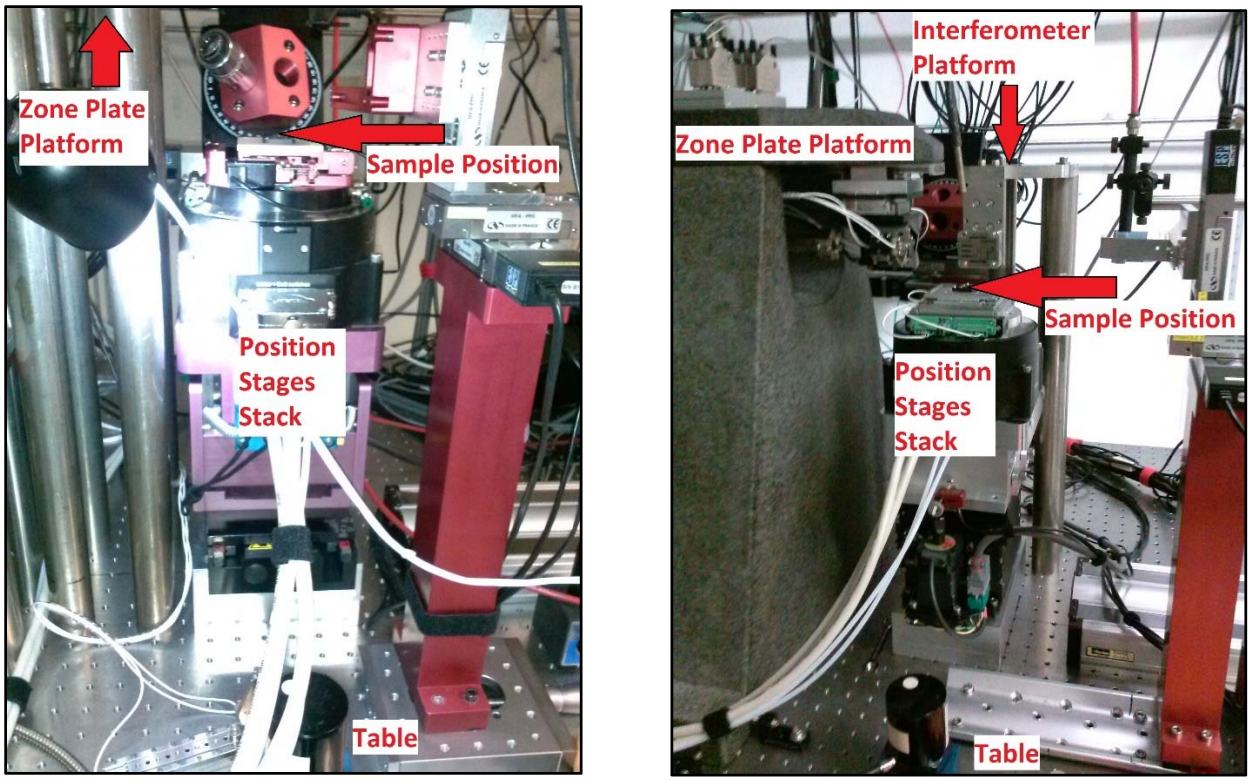
## 3 Ambient vibration level measurement

### 3.1 Methodology

Three models of piezo based accelerometers were placed in multiple locations in beamline 32-ID-C (see Fig. 1). For the measurements at the floor, table, and granite zone plate platform the high sensitivity, low-frequency accelerometer, VibraMetric Model 1030, was used. At the sample position, invar zone plate platform, and interferometer platform two lower mass PCB Piezotronics accelerometers were used. The PCB models used were 353B44 and 356B18.

The accelerometers along with a Hewlett Packard (HP) E1432A 16 Channel 1.2 kSa/s Digitizer plus Digital Signal Processor and Data Physics Corporation's Signal Calc 620 Dynamic Signal Analyzer measured the acceleration in the vertical and perpendicular to beamline directions. The acceleration

data was then converted into rms displacement and plotted using Microsoft Excel software. Displaying data in displacement is consistent with previous reporting on ambient vibration levels at APS [2].




(a) (b)

Figure 1: (a) Previous microscope configuration (b) Current microscope configuration

## 3.2 Results

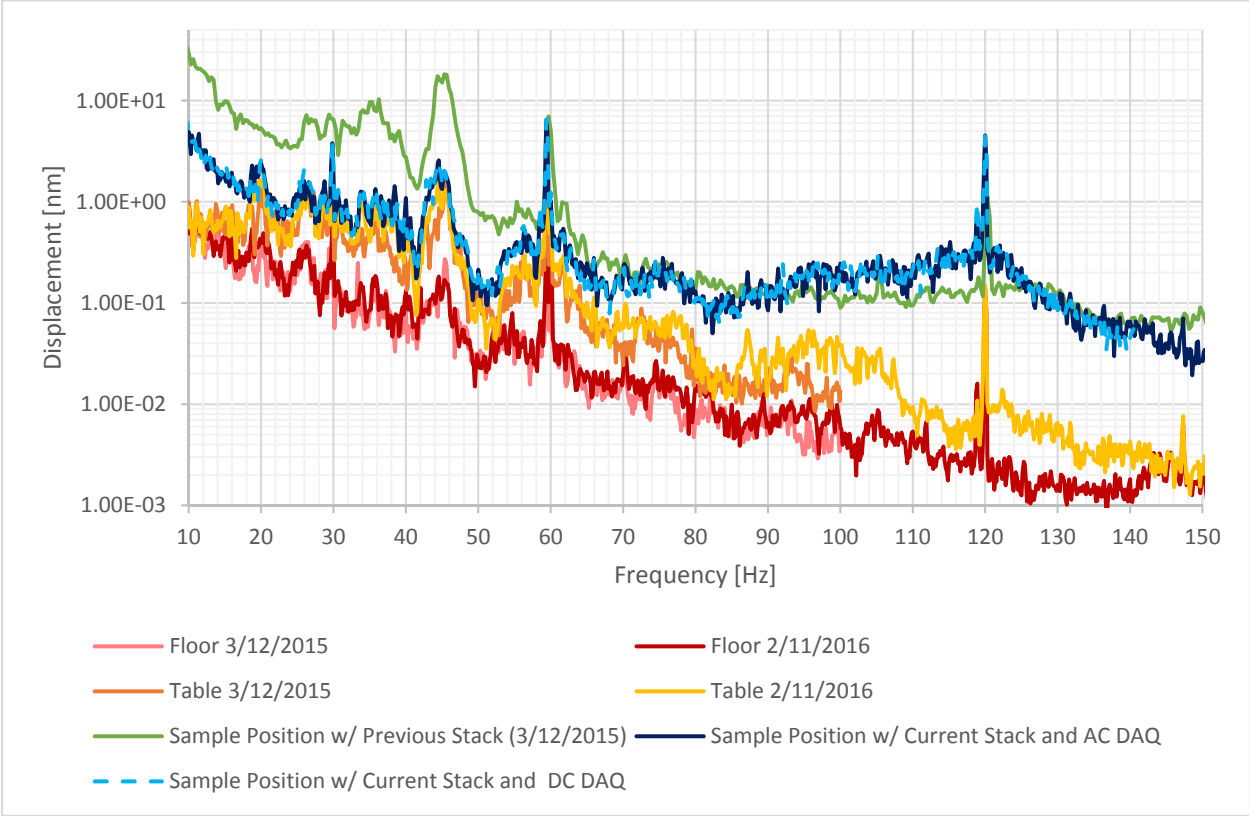



Figure 2: Perpendicular to Beam-Line Displacement Spectra 10-150Hz

| Location | Date | Acc. | DAQ PS | Freq. [Hz] | Mag. [$nm_{rms}$] | Freq. [Hz] | Mag. [$nm_{rms}$] | Freq. [Hz] | Mag. [$nm_{rms}$] | Freq. [Hz] | Mag. [$nm_{rms}$] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Floor** | 3/12/15 | 1030 | AC | 29.4 | 0.35 | 45.4 | 0.27 | 59.4 | 0.55 | --- | --- |
| **Floor** | 2/11/16 | 1030 | AC | 29.8 | 0.57 | 44.5 | 0.18 | 60.0 | 0.35 | 120.0 | 0.14 |
| **Table** | 3/12/15 | 1030 | AC | 29.9 | 1.08 | 45.4 | 1.72 | 59.4 | 2.66 | --- | --- |
| **Table** | 2/11/16 | 1030 | AC | 29.8 | 2.87 | 44.5 | 1.63 | 59.4 | 3.37 | 120.0 | 0.15 |
| **Sample** Previous Stack | 3/12/15 | 353B44 | AC | 35.9 | 10.30 | 45.1 | 13.21 | 59.4 | 6.53 | 119.9 | 1.14 |
| **Sample** Current Stack | 2/11/16 | 356B18 | AC | 29.8 | 3.78 | 44.5 | 2.57 | 59.4 | 6.13 | 120.0 | 4.51 |
| **Sample** Current Stack | 2/11/16 | 356B18 | DC | 29.8 | 3.79 | 44.5 | 2.47 | 59.4 | 6.53 | 120.0 | 4.43 |

Table 1: Peak Perpendicular Displacements for Vertical Stage Comparison

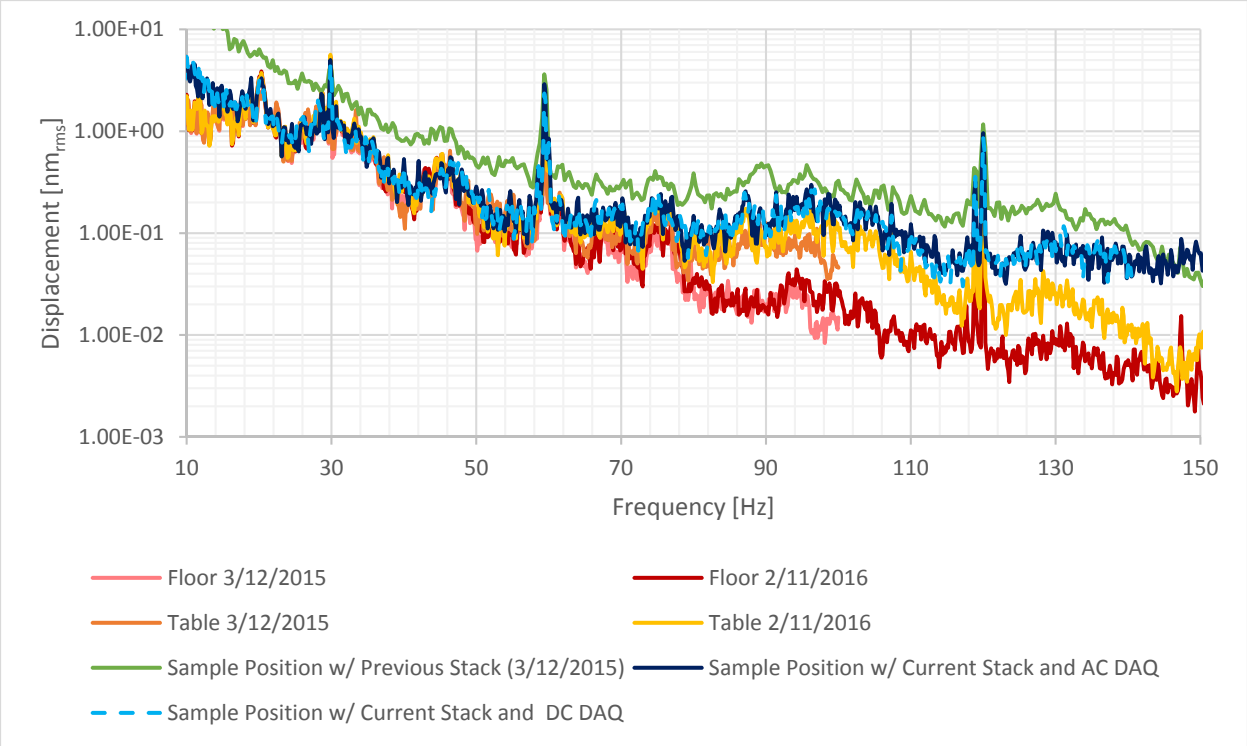



Figure 3: Vertical Displacement Spectra 10-150Hz

| Location | Date | Acc. | DAQ PS | Freq. [Hz] | Mag. [$nm_{rms}$] | Freq. [Hz] | Mag. [$nm_{rms}$] | Freq. [Hz] | Mag. [$nm_{rms}$] |
|---|---|---|---|---|---|---|---|---|---|
| **Floor** | 3/12/15 | 1030 | AC | 29.9 | 3.04 | 59.4 | 2.38 | --- | --- |
| **Floor** | 2/11/16 | 1030 | AC | 29.9 | 5.23 | 59.5 | 2.69 | 120.0 | 0.18 |
| **Table** | 3/12/15 | 1030 | AC | 29.9 | 3.16 | 59.4 | 3.12 | --- | --- |
| **Table** | 2/11/16 | 1030 | AC | 29.9 | 5.46 | 59.5 | 3.07 | 120.0 | 0.39 |
| **Sample** Previous Stack | 3/12/15 | 353B44 | AC | 29.9 | 3.44 | 59.4 | 3.44 | 120.0 | 1.17 |
| **Sample** Current Stack | 2/11/16 | 356B18 | AC | 29.8 | 4.99 | 59.4 | 2.89 | 120.0 | 0.96 |
| **Sample** Current Stack | 2/11/16 | 356B18 | DC | 29.8 | 4.52 | 59.4 | 2.35 | 120.0 | 0.86 |

Table 2: Peak Vertical Displacement for Stages Stack Comparison

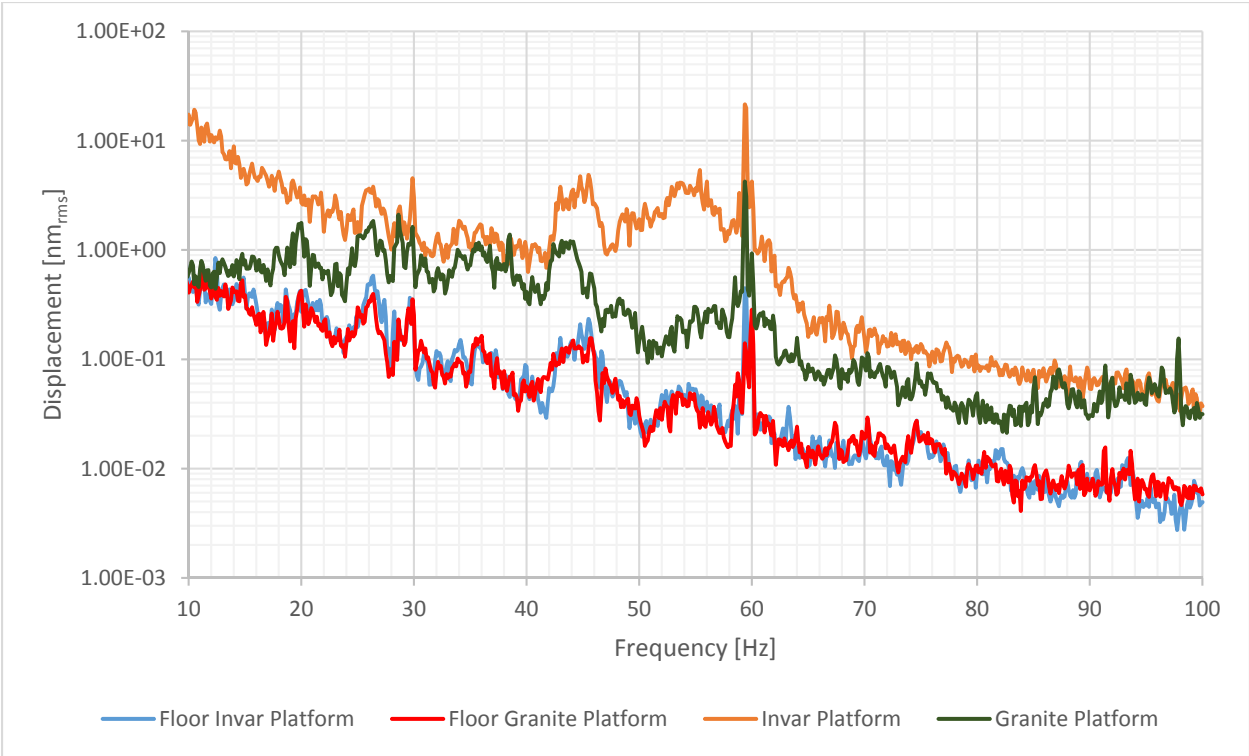



Figure 4: Invar Platform vs Granite Platform for Zone Plate.
Perpendicular to Beam-Line Spectra 10-100Hz

| Location | **Freq. [Hz]** | **Mag. [$nm_{rms}$]** | **Freq. [Hz]** | **Mag. [$nm_{rms}$]** | **Freq. [Hz]** | **Mag. [$nm_{rms}$]** |
|---|---|---|---|---|---|---|
| **Floor (Invar Platform)** | 26.38 | 0.58 | 45.50 | 0.23 | 59.38 | 0.45 |
| **Floor (Granite Platform)** | 26.38 | 0.40 | 45.63 | 0.16 | 60.00 | 0.28 |
| **Invar Platform** | 29.88 | 4.52 | 45.50 | 4.87 | 59.38 | 21.48 |
| **Granite Platform** | 28.63 | 2.10 | 43.13 | 1.21 | 59.38 | 4.23 |

Table 3: Peak Perpendicular Displacement for Zone Plate Platform Measurements

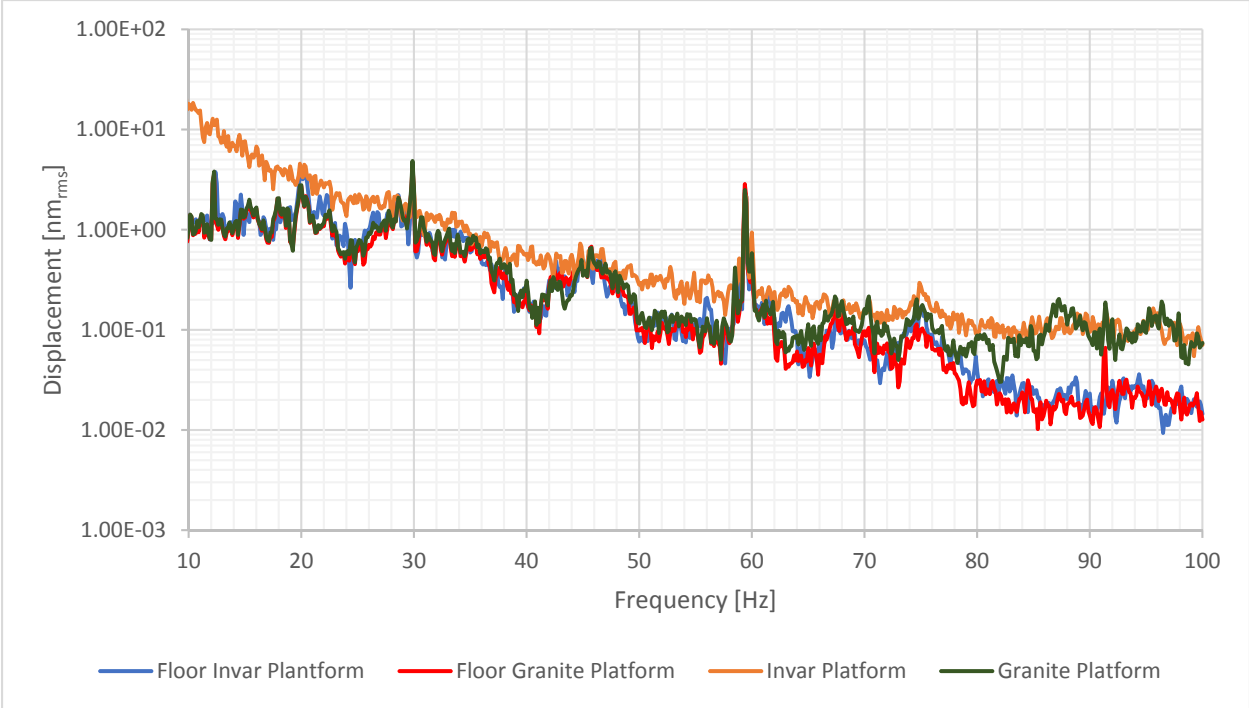



*Figure 5: Invar Platform vs Granite Platform for Zone Plate Vertical Displacement Spectra 10-100Hz*

| Location | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** |
|---|---|---|---|---|---|---|
| **Floor (Invar Platform)** | 29.88 | 3.53 | 44.75 | 0.64 | 59.38 | 2.33 |
| **Floor (Granite Platform)** | 29.88 | 4.40 | 45.75 | 0.68 | 59.38 | 2.85 |
| **Invar Platform** | 29.88 | 3.43 | 44.75 | 0.73 | 59.38 | 2.31 |
| **Granite Platform** | 29.88 | 4.84 | 45.75 | 0.66 | 59.38 | 2.49 |

Table 4: Peak Vertical Displacement for Zone Plate Platform Measurements

Figure 6: Coolant Water On vs Coolant Water Off
Perpendicular to Beam-Line Spectra 10-100Hz

| Location | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** |
|---|---|---|---|---|---|---|
| **Sample Position (Water On)** | 28.63 | 2.41 | 44.13 | 2.18 | 59.38 | 17.00 |
| **Sample Position (Water Off)** | 29.88 | 3.10 | 43.88 | 1.70 | 59.38 | 17.81 |

Table 5: Peak Perpendicular Displacement for Coolant water comparison

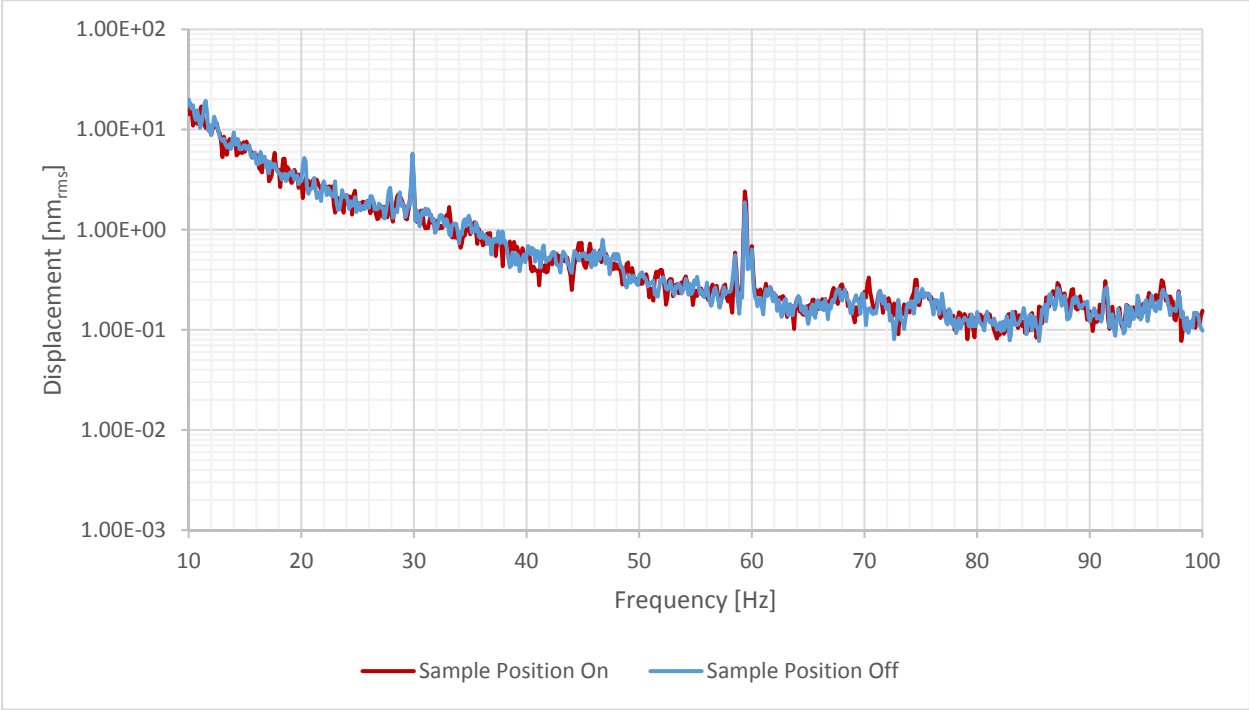



Figure 7: Coolant Water On vs Coolant Water Off
Vertical Displacement Spectra 0-100Hz

| Location | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** | **Freq. [Hz]** | **Mag. [nm$_{rms}$]** |
|---|---|---|---|---|---|---|
| **Sample Position (Water On)** | 29.88 | 4.56 | 44.88 | 0.74 | 59.38 | 2.40 |
| **Sample Position (Water Off)** | 29.88 | 5.74 | 46.75 | 0.79 | 59.38 | 1.88 |

Table 6: Peak Vertical Displacement for Coolant Water Comparison

Figure 8: Interferometer Platform Vertical Displacement Spectra 0-100Hz

| Location | Freq. [Hz] | Mag. [nm$_{rms}$] | Freq. [Hz] | Mag. [nm$_{rms}$] | Freq. [Hz] | Mag. [nm$_{rms}$] | Freq. [Hz] | Mag. [nm$_{rms}$] |
|---|---|---|---|---|---|---|---|---|
| **Floor** | 20.38 | 2.91 | 29.88 | 5.23 | 45.13 | 0.62 | 59.50 | 2.69 |
| **Table** | 20.38 | 2.83 | 29.88 | 5.46 | 45.13 | 0.64 | 59.50 | 3.07 |
| **Interferometer Platform** | 20.38 | 2.77 | 29.88 | 4.78 | 40.38 | 2.13 | 59.50 | 1.32 |

Table 7: Peak Vertical Displacement for Interferometer Platform Measurements

# 4 Discussion

## 4.1 Comparison of positioning stages stack

Figure 2 and Table 1 show displacements in the perpendicular to beam line direction. From the figure it can be seen that the current stack has lower vibration amplitudes at the sample position between about 25Hz and 50Hz. This is seen using 356B18 accelerometer with higher sensitivity for current stack.

In the frequency range of 50 to 90Hz similar vibration levels in the perpendicular to beam line direction are observed for either stack.

Above 100Hz Figure 2 shows higher vibration levels for measurements taken at the sample position with current stack. The fundamental frequency of the current stack seems to be higher than that of the previous stack. Thus there is a reduction in vibration levels in the low frequencies, but an amplification of vibration levels in higher frequencies at the sample position with the new stack.

Figure 3 shows an overall reduction in vibration from the previous positioning stages stack to the current stack in the vertical direction. But the reduction is not very much. Furthermore, Table 2 doesn't show a clear reduction in vibrations levels at the peak values.

To verify the results, measurements were taken with the Hewlett Packard data acquisition system, which has an AC power source, and a data acquisition system using a DC power source. Figure 2 and 3 and Table 1 and 2 show nearly identical results using each system. This gives confidence to the results that are seen. Especially at 60Hz where electrical interference could have made vibration levels seem higher than actually present.

### 4.2 Comparison of Zone Plate Platforms

Figure 4 and Table 3 show that in the perpendicular-to-beam-line direction the granite zone-plate platform has much lower displacement values pretty much throughout the entire frequency range compared to the invar platform.

In the vertical direction, figure 5 and Table 4, show not much difference in vibration levels between the old invar platform and the new granite one. The only exception is seen in the 10-30Hz range. This is most likely because of the higher noise floor of the 353B44 accelerometer versus the 1030 accelerometer.

Floor vibrations were compared in Figure 4 and 5 and Table 3 and 4. No real difference is seen between the two sets of measurements. Therefore, one can conclude that the difference in performance between the two zone plate platforms is due to their own performance not a significant change in environmental conditions at the measurement dates.

### 4.3 Effect of Coolant Water at the Sample Position

Figures 6 and 7 and Tables 5 and 6 show that the coolant water does not change the vibration levels at the sample position in either the vertical or the perpendicular-to-beam-line directions.

### 4.4 What is the vertical vibrational noise present at the top of the interferometer platform?

Figure 8 and Table 7 show that interferometer platform has higher vibration levels in the frequency range of 35-45Hz compared to the table and floor. But, the vibration levels are low overall.

## 5 Conclusion

At the sample position significantly lower levels of displacement were measured when the current positioning stages stack was installed compared to the previous stack. With the current stack, peak displacements are below 10 $nm_{rms}$ from 10 to 150 Hz in the perpendicular to beam line and vertical directions

The current zone plate platform has much lower levels of displacement throughout a broad range of frequencies compared to the previous invar platform.

Coolant water has a negligible effect of vibration levels at the sample position

The vertical displacement observed on the interferometer platform is less than 5 $nm_{rms}$ throughout the frequency range of 10 to 100 Hz.

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## References

[1] Vincent De Andrade, and et al., “Nanoscale 3D imaging at the Advanced Photon Source,” SPIE (2016) 10.1117/2.1201604.006461.

[2] Royston, T. J. "Vibration characteristics of an APS lab facility in building 401," *ANL Report APS/LS Note* 263 (1996).