LCLS-II Technical Note

LCLS-II TN
Vibration measurements across the SLAC site

LCLS-II TN-15-35

9/25/2015

Georg Gassner

Septe

1 Introduction

This document collects 4 reports into one technical note. The attached sections cover vibration measurements in the Linac, beam switch yard (BSY), linac to undulator (LTU) and the undulator hall.

1.1 Memo: Transfer function for CQ32 (2/28/2013)

To crosscheck vibration simulations, measurements on a typical quadrupole stand (CQ32 in the LTU) were taken.

1.2 Memo: Vibration measurements BSY – Effect of cooling water on magnet vibration (4/11/2013)

This memo covers measurements which were taken to determine the effect on magnet vibration from cooling water running though the magnets in the BSY.

1.3 Memo: Vibration measurements UH – Quad on Girder #9 and floor at Girder #9 (4/24/2013)

This memo covers measurements which were taken on the undulator quadrupole #9, on the floor between girders #9 and #10 and on the floor below girder #9

1.4 Memo: Vibration measurements LCLS-I Linac (6/30/2014)

To check for any vibration change since new LCW components have been installed, multiple quad locations in the LCLS Linac were observed with seismometers.

Metrology Department
Alignment Engineering Group
MEMORANDUM

Date: **2/28/2013**

To: Alev Ibrahimov, Rick Iverson

From: Georg Gassner

Subject: Transfer function for CQ32

To crosscheck vibration simulations, measurements on a typical quadrupole stand (CQ32 in the LTU) were taken.

1 Measurements

we installed four seismometers at the location of CQ32 (see Figure 1). One vertical and one horizontal sensor (along x-axis) on the top and on the bottom of the stand. The sensors were aligned with the coordinate axes of LCLS. All measurements were taken with Sercel L4C sensors (sensitivity: 276.8 Volts / meter / second; Natural Freq.: 1.0 Hz). One dataset consists of 30 seconds of data sampled at 2560Hz. The data acquisition unit used was a National Instruments Model 9234 (24 Bit).
The vibration device used was a ButtKicker BK-LFE (12lbs; 400-1500Watt) operated with a function generator (sinus wave) and a Boss amplifier.
To check the seismometer measurements, an interferometer (Etalon Laser Tracer) was used. The laser interferometer was also used to check x-axis vibrations at the center of the quadrupole and at the top of the support stand.

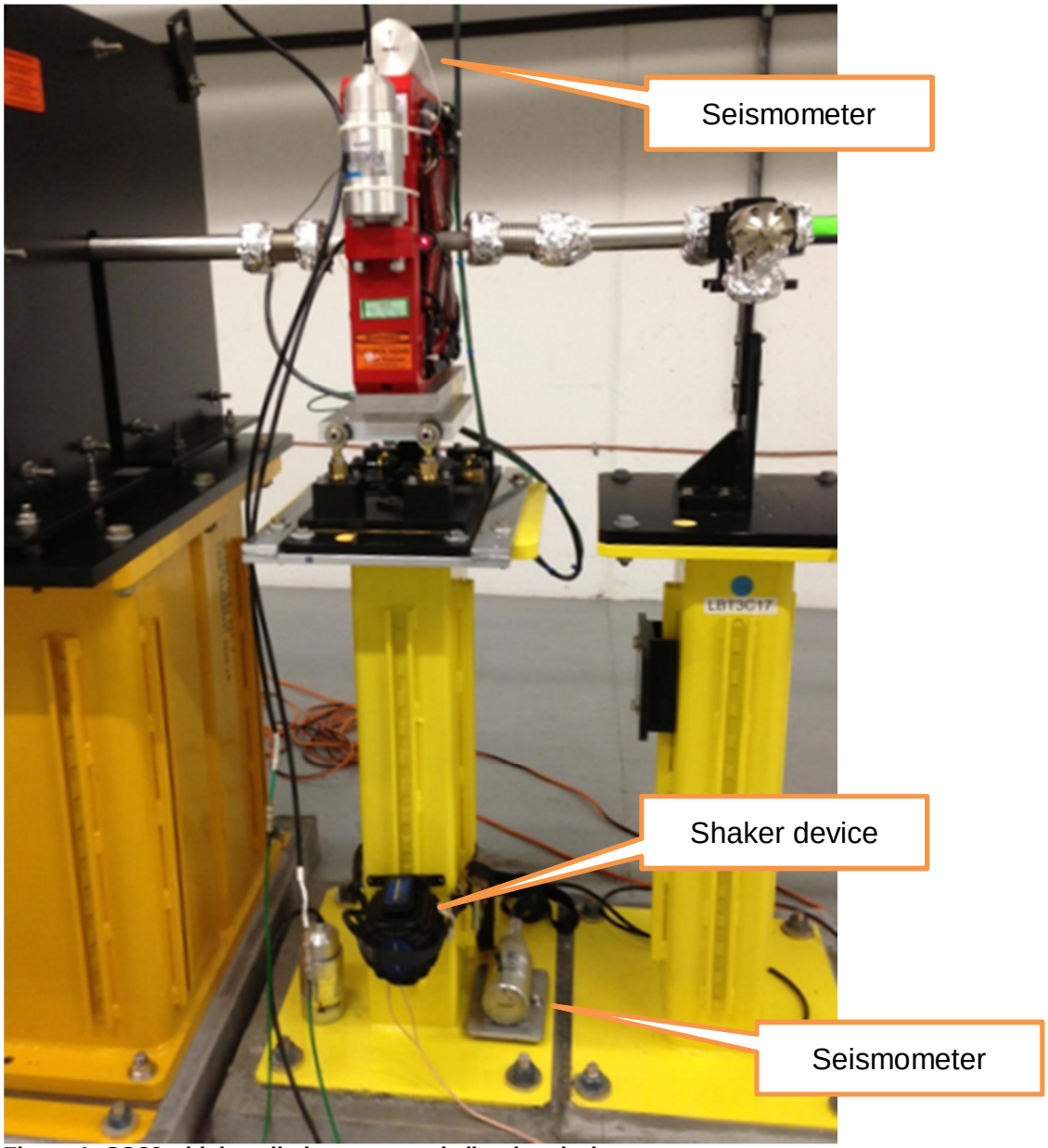


Figure 1: CQ32 with installed sensors and vibration device.

2 Results

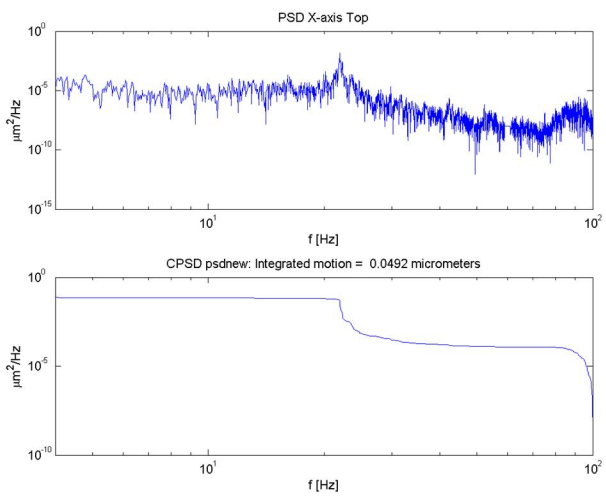
2.1 Background noise

As results, the integrated motion for a sensor between 4 and 100Hz is given, see Table 1. A Graphical representation of the Power Spectrum density is given in Figure 2 and Figure 3. The vibration along the vertical seems to be transmitted without gain. The integrated motion along the horizontal x-axis direction was amplified by a factor of 4.5. The PSD on the top sensors had a peak around 22Hz.

Table 1 Background noise, integrated motion at sensor locations.

Top Sensors		Bottom Sensors	
X [nm]	Y [nm]	X [nm]	Y [nm]
50	17	11	13

X-axis Top



X-axis Bottom

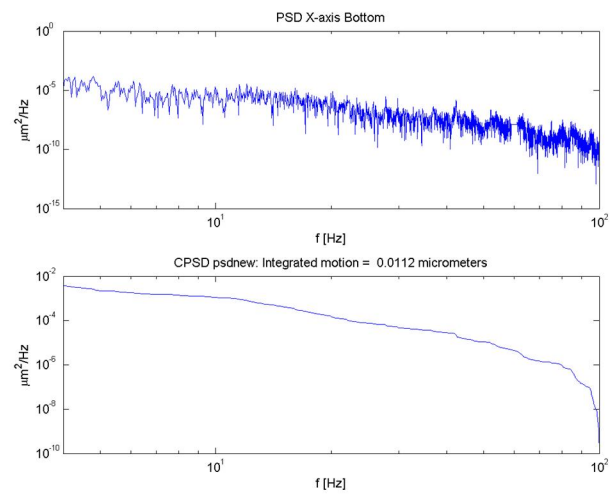
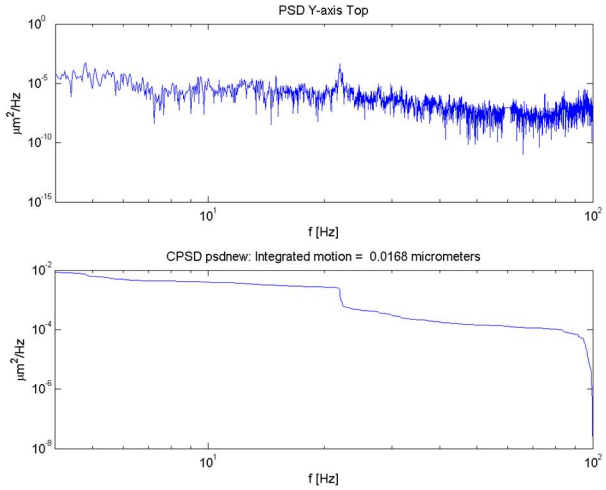


Figure 2: PSD x-axis, top vs. bottom sensor readings.

Y-axis Top



Y-axis Bottom

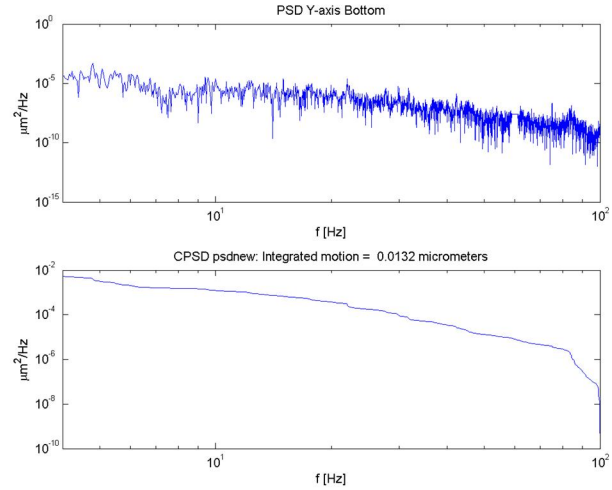


Figure 3: PSD y-axis, top vs. bottom sensor readings.

2.2 Artificially induced vibration

To establish a transfer function between floor vibrations and quadrupole vibrations we artificially shook the stand as close to the bottom as possible. We then measured the integrated motion at +/- 3Hz of the induced frequency (see Table 2) and compared the results (see Figure 4 and Figure 5). The natural frequency of the assembly is at 21.5Hz, this is where the highest amplification of about 110 occurs. The vertical measurements on top of the quadrupole where taken off center of the magnet. A coupling between x- and y- motion occurred which could explain the amplification along the y-axis.

Table 2: Integrated motion values at +/- 3Hz of the induced vibration.

Frequency	Amplitude Top x-axis	Amplitude Top y-axis	Amplitude Bottom x-axis	Amplitude Bottom y-axis	Amplification x-axis	Amplification y-axis
[Hz]	[μm]	[μm]	[μm]	[μm]		
5.0	0.433	0.090	0.119	0.085	4	1
10.0	1.037	0.177	0.095	0.082	11	2
15.0	1.932	0.332	0.076	0.082	26	4
20.0	5.546	1.040	0.093	0.107	60	10
21.5	44.033	8.688	0.419	0.566	105	15
22.5	13.481	2.710	0.125	0.328	108	8
25.0	2.682	0.584	0.052	0.083	52	7
30.0	1.091	0.248	0.053	0.078	20	3
35.0	0.529	0.142	0.054	0.078	10	2
40.0	0.330	0.113	0.051	0.083	7	1
45.0	0.275	0.101	0.056	0.082	5	1
50.0	0.188	0.070	0.050	0.074	4	1
55.0	0.164	0.072	0.056	0.075	3	1
60.0	0.161	0.079	0.063	0.084	3	1
65.0	0.136	0.068	0.062	0.075	2	1

70.0	0.132	0.080	0.063	0.085	2	1
80.0	0.154	0.075	0.046	0.074	3	1
90.0	0.176	0.129	0.054	0.072	3	2
100.0	0.083	0.061	0.057	0.075	1	1

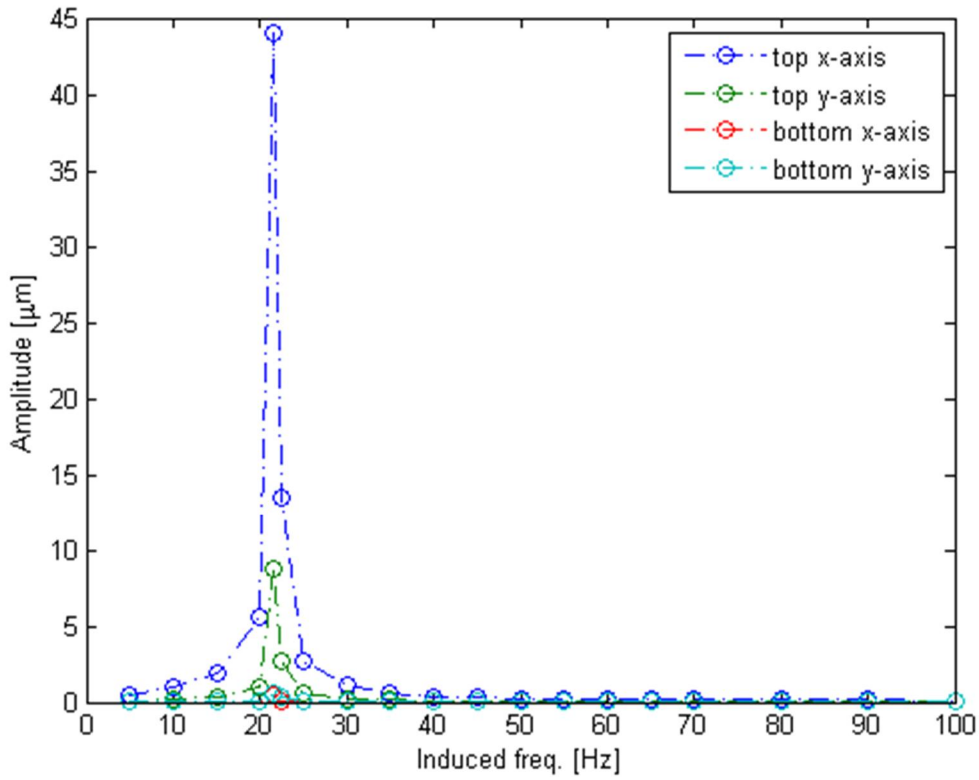


Figure 4: Integrated motion at induced frequency.

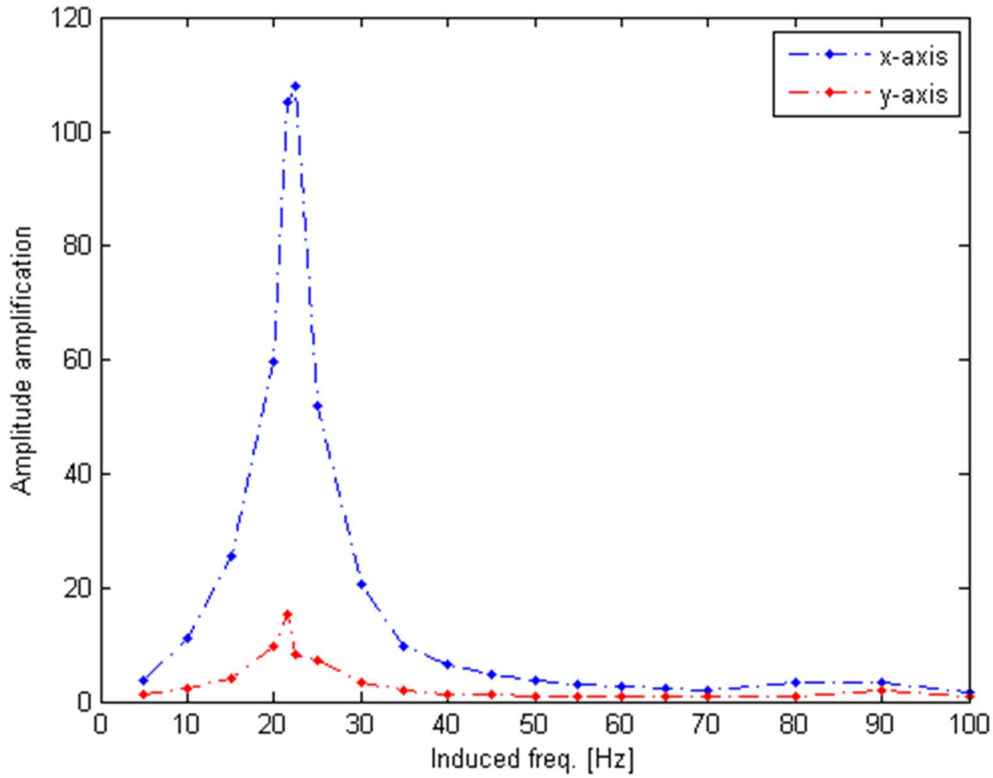


Figure 5: Amplitude amplification at induced frequencies

2.3 Correlation of induced vibration

As mentioned above, the measurements of the y-motion were taken off axis of the quadrupole, the motion measured between the y- and x- motion is highly correlated (correlation coefficient: 0.9995). The movement on the top and the bottom is also highly correlated (correlation coefficient along x axis: 0.95; along y axis 0.67).
The x-motion on top has its main vibration at 21.5Hz, the bottom plate has a sideband at 322.5Hz as well, see Figure 8.

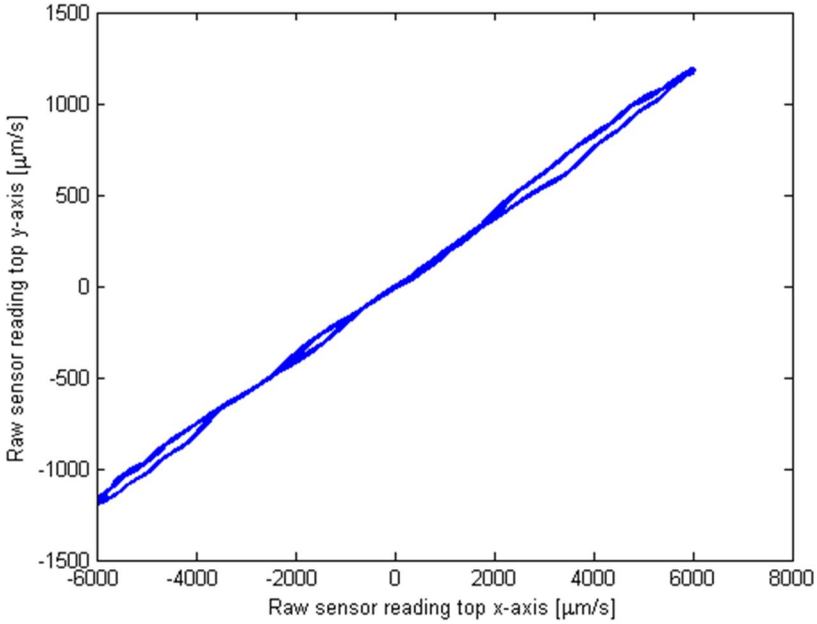


Figure 6: Correlation plot between x- and y-axis sensor readings on top of CQ32, with induced vibration at 21.5Hz.

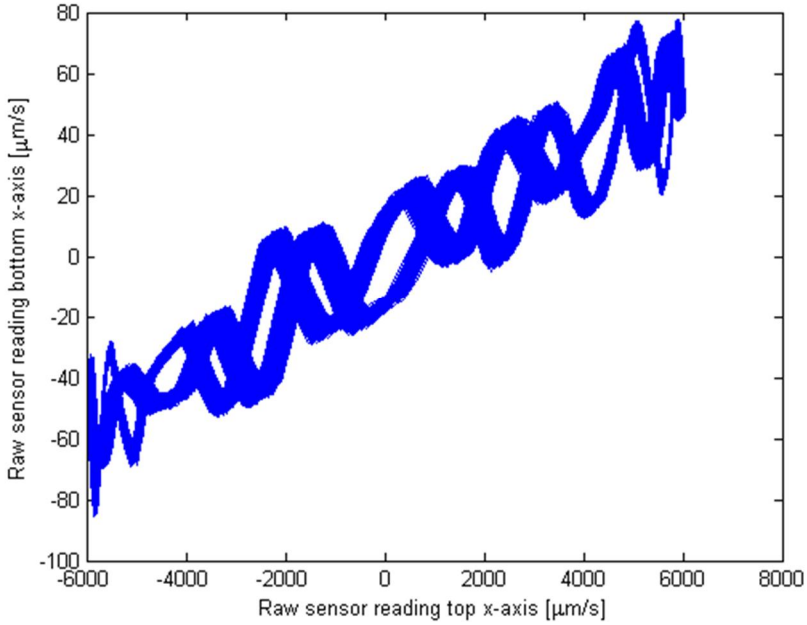


Figure 7: Correlation plot between x-sensor readings on top and bottom of CQ32, with induced vibration at 21.5Hz.

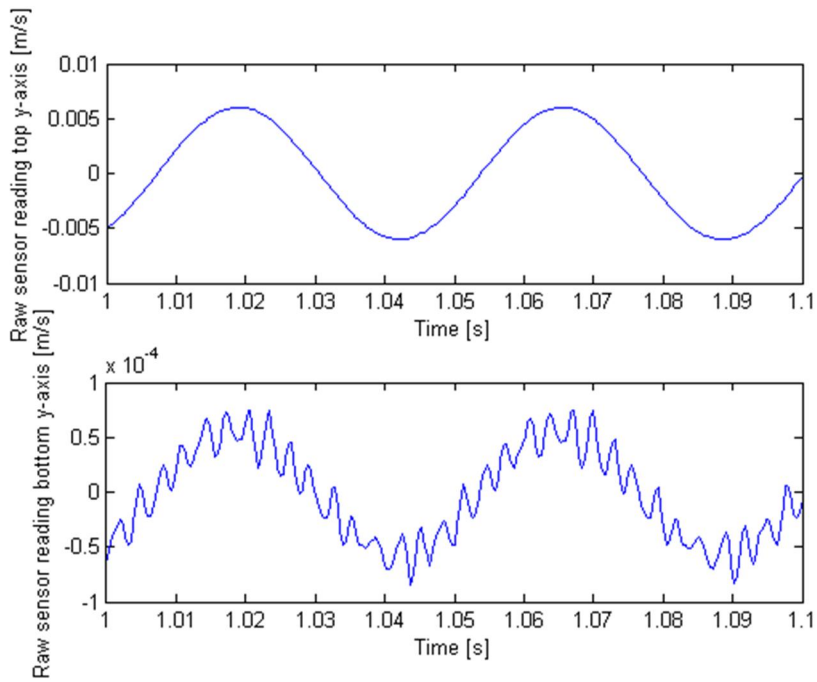


Figure 8: Comparison between x-sensor readings on top and bottom of CQ32, with induced vibration at 21.5Hz. The bottom sensor has not only a signal at 21.5Hz but also a sideband at the 15 fold multiple of 322.5Hz.

2.4 Vibration at the top plate compared to the quadrupole.

The quadrupole itself is supported by alignment struts on top of the stand. To compare the top of the stand and the quadrupole vibration itself, we measured the vibration at these points with an interferometer. The vibration at the plate (0.9m from floor) and at the quadrupole center (1.35m) increases linearly with the distance from the floor, see Figure 9.

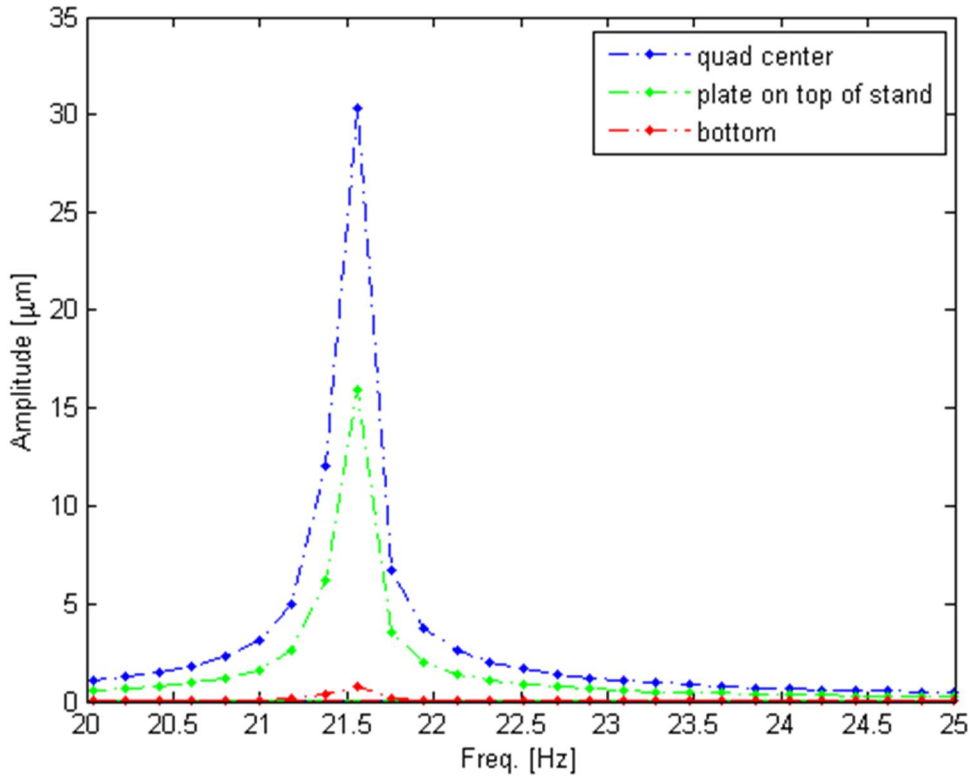


Figure 9: Amplitudes measured at different spots of the quad stand assembly.

3 Summary

The measurements show a natural frequency of 21.5Hz for the stand and quadrupole. The measurements at various spots on the quadrupole and stand assembly are all highly correlated increasing in amplitude with the distance to the floor.

Metrology Department
Alignment Engineering Group
MEMORANDUM

Date: **4/11/2013**

To: Alev Ibrahimov, Rick Iverson

From: Georg Gassner

Subject: Vibration measurements BSY – Affect of cooling water on magnet vibration

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To determine the effect on magnet vibration from cooling water running though the magnet we installed seismometer on the magnet and the supporting plate.

1. Measurements

The tests were performed on QA11 and the supporting plate, see Figure 1. The sensors were aligned with the coordinate axes of LCLS. On top of the magnet the measurements were taken along one axis at a time to due space constraints. All measurements were taken with Sercel L4C sensors (sensitivity: 276.8 Volts / meter / second; Natural Freq.: 1.0 Hz). One dataset consists of 120 seconds of data sampled at 4096Hz. The data acquisition unit used was a National Instruments Model SCC-68 (16 Bits).

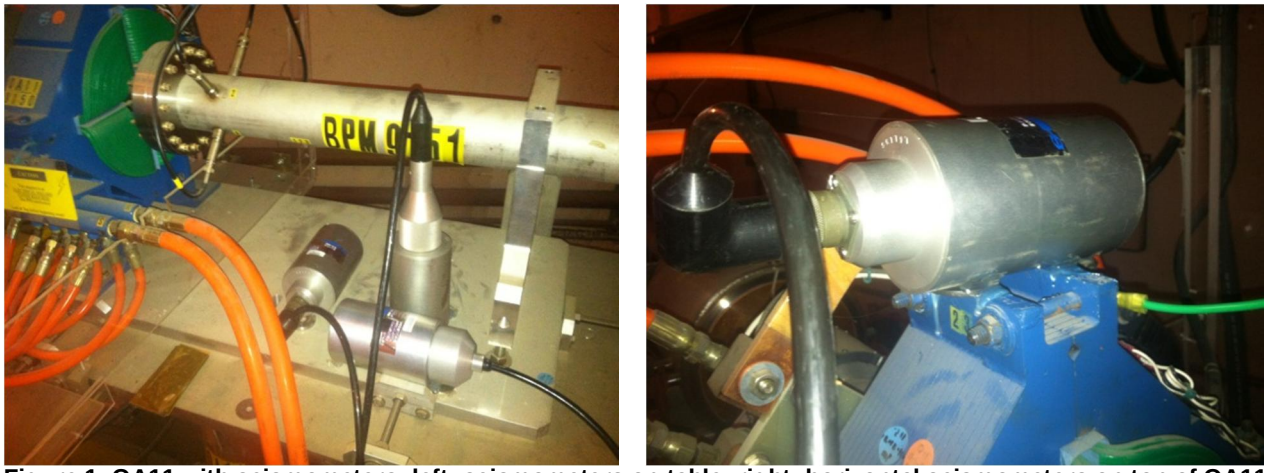

Figure 1: QA11 with seismometers; left: seismometers on table; right: horizontal seismometers on top of QA11.

2. Results

As results, the RMS for a sensor between 4 and 200Hz is given. At different locations large 60Hz signals were picked up by the sensors which indicate electromagnetic interference on the sensors instead of an actual vibration. All measurements were taken once with the cooling water running through the magnet and without. Graphical results are given in Appendix A.
The support of the table is directly under the QA11, the sensors on the table is cantilevered out which explains the higher vibrations in the Y direction on the table.

Table 1: Vibration RMS at quad locations for LCLS-II in the BSY.

Location	Z [nm]	X [nm]	Y [nm]
QA11 Top without water flow	53	174	34
QA11 Top with water flow	329	339	94
Table without water flow	11	12	72
Table with water flow	164	89	115

Appendix A:

a. Power Spectral Density and Integrated Motion Plots at QA11 without water flowing.

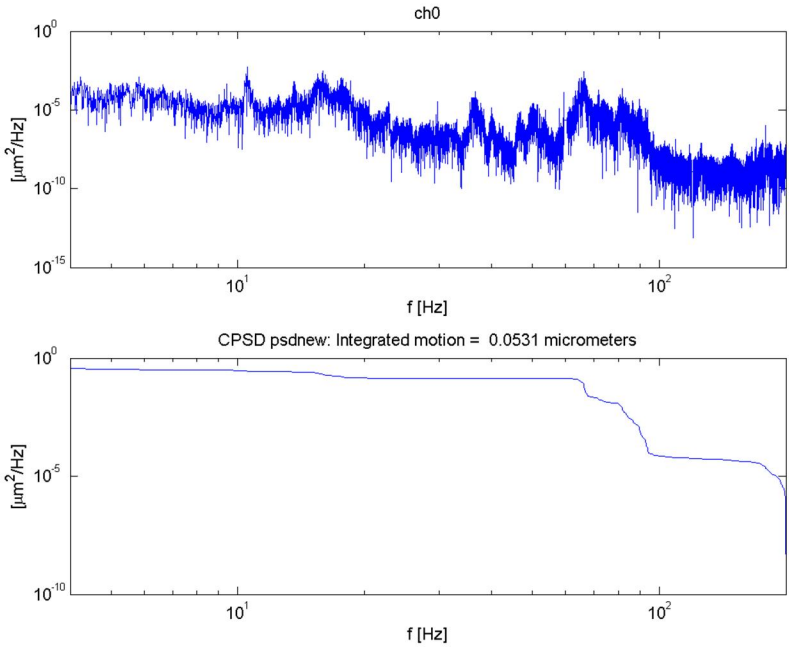

Figure 2: PSD, QA11 top no water flowing, z-axis.

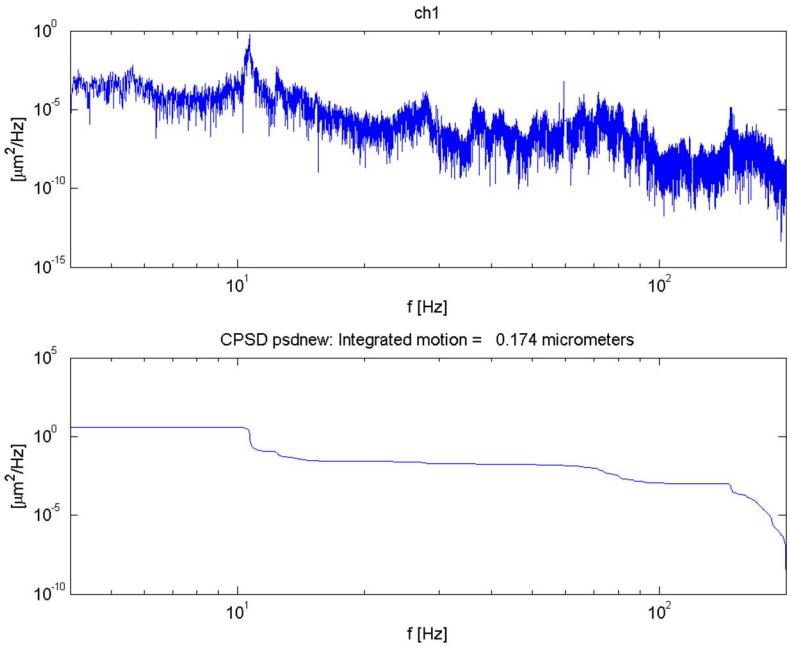

Figure 3: PSD, QA11 top no water flowing, x-axis.

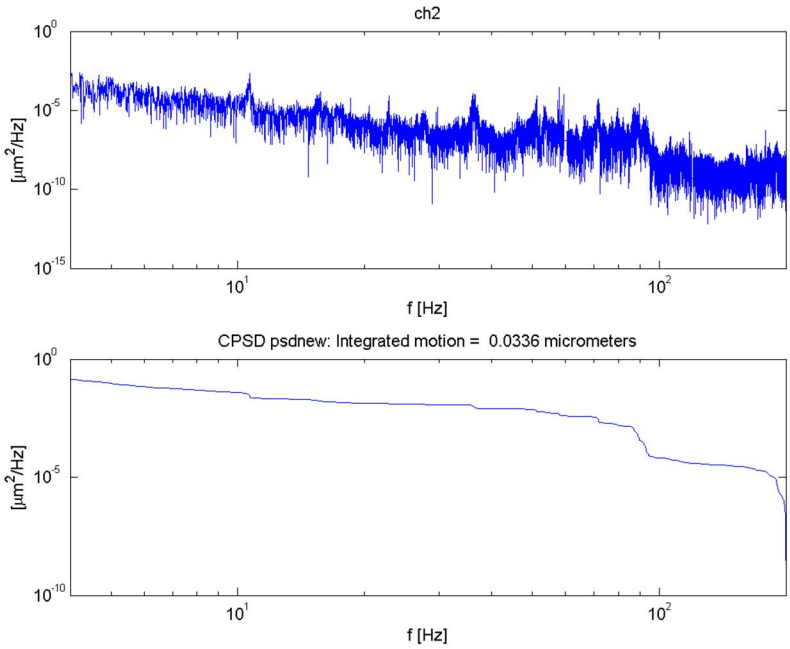

Figure 4: PSD, QA11 top no water flowing, y-axis.

b. Power Spectral Density and Integrated Motion Plots at QA11 with water flowing.

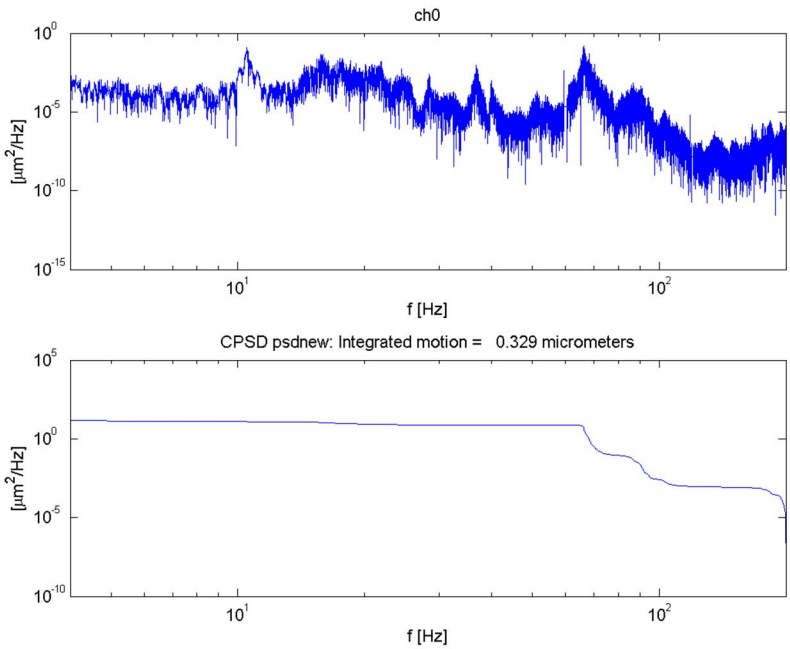

Figure 5: PSD, QA11 top water flowing, z-axis.

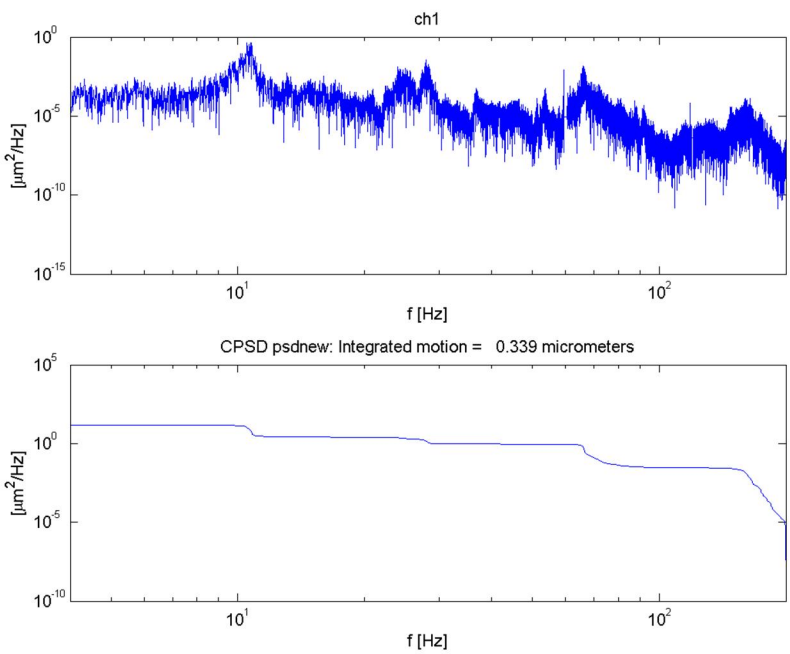

Figure 6: PSD, QA11 top water flowing, x-axis.

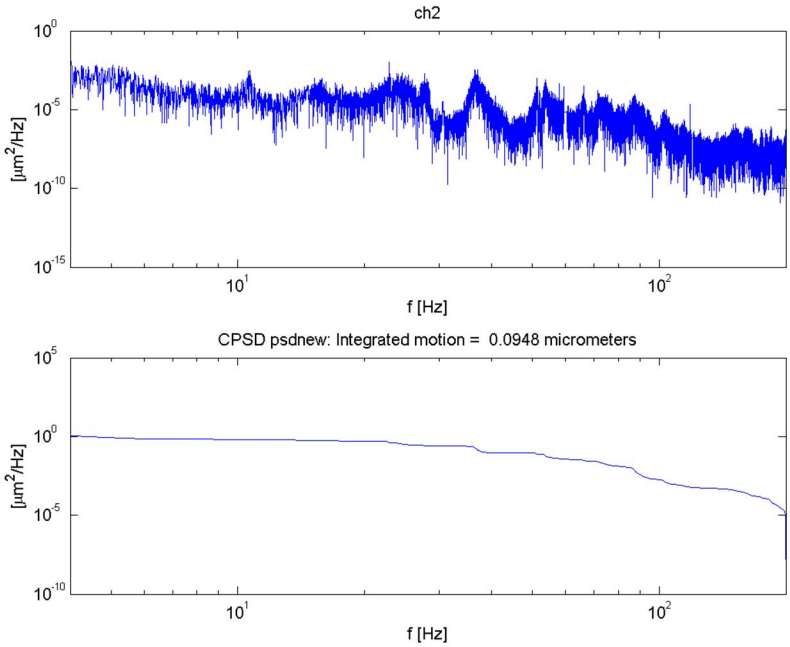

Figure 7: PSD, QA11 top water flowing, y-axis.

c. Power Spectral Density and Integrated Motion Plots at table of QA11 without water flowing.

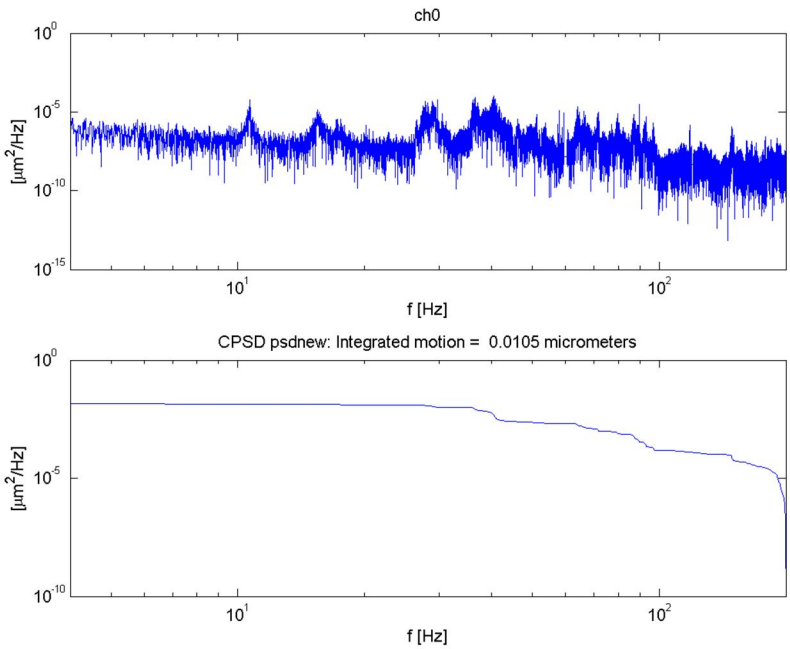

Figure 8: PSD, table of QA11 without water flowing, z-axis.

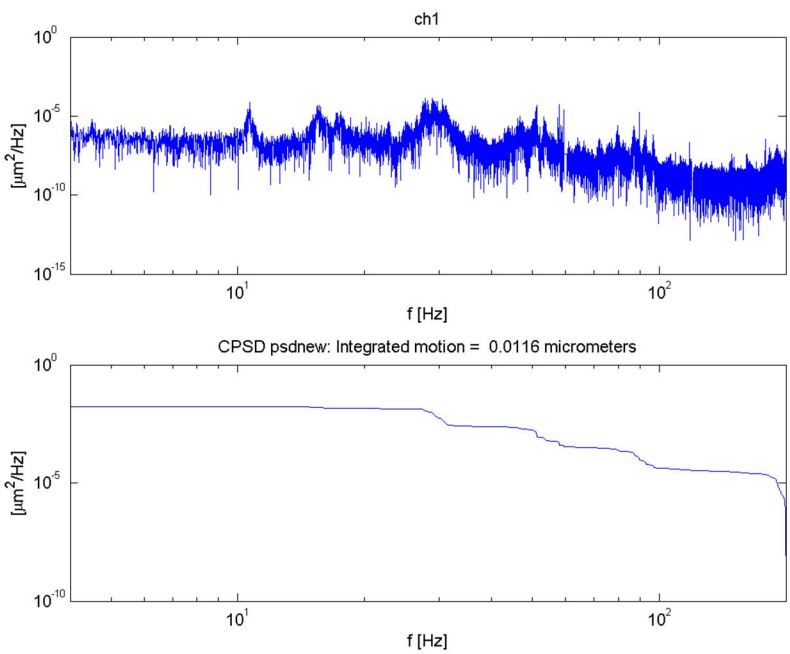

Figure 9: PSD, table of QA11 without water flowing, x-axis.

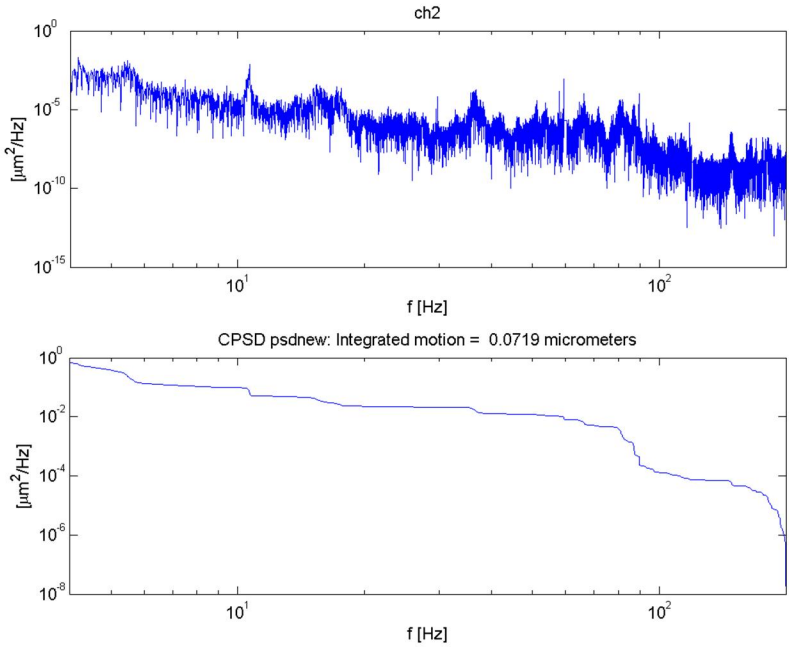

Figure 10: PSD, table of QA11 without water flowing, y-axis.

d. Power Spectral Density and Integrated Motion Plots at table of QA11 with water flowing.

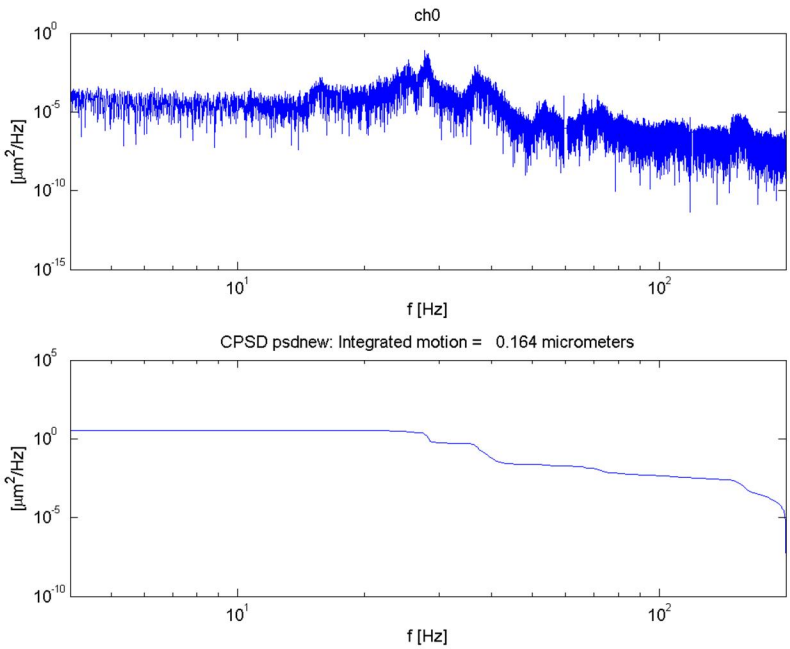

Figure 11: PSD, table of QA11 water flowing, z-axis.

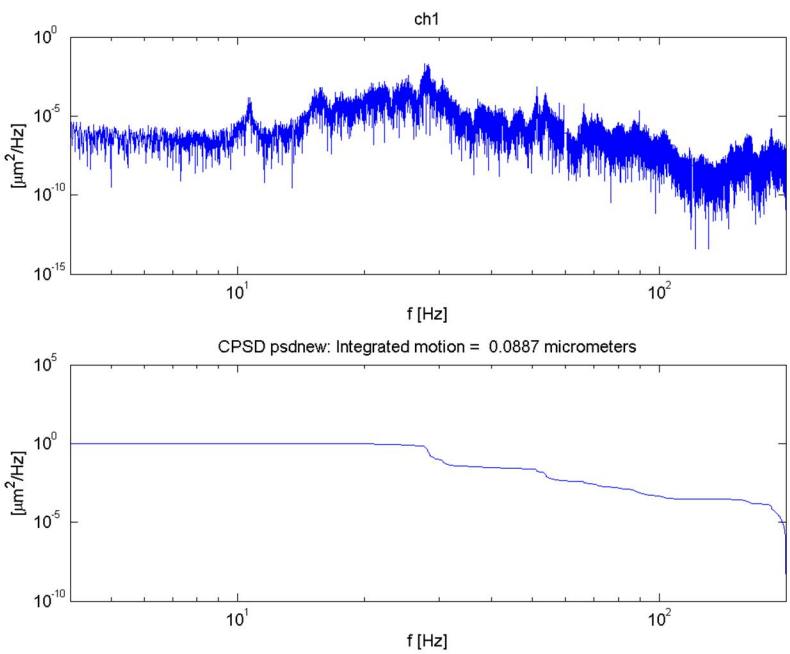

Figure 12: PSD, table of QA11 water flowing, x-axis.

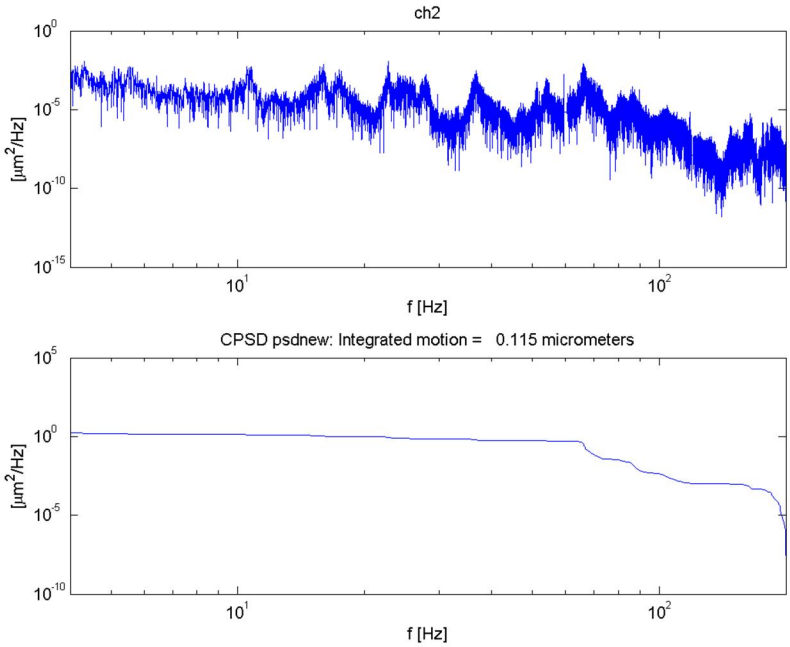

Figure 13: PSD, table of QA11 water flowing y-axis.

Metrology Department
Alignment Engineering Group
MEMORANDUM

Date: **4/24/2013**

To: Daniel Bruch

From: Georg Gassner

Subject: Vibration measurements UH – Quad on Girder #9 and floor at Girder #9

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1. Measurements

The measurements were taken on the undulator quadrupole #9, on the floor between girders #9 and #10 and on the floor below girder #9, see Figure 1. The sensors were aligned with the coordinate axes of LCLS. On top of the magnet the measurements were taken along one axis at a time due to space constraints. All measurements were taken with Sercel L4C sensors (sensitivity: 276.8 Volts / meter / second; Natural Freq.: 1.0 Hz). One dataset consists of 120 seconds of data sampled at 4096Hz. The data acquisition unit used was a National Instruments Model SCC-68 (16 Bits).

Figure 1: Girder #9; left: seismometers on quad; right: triplet of sensors on floor.

2. Results

As results, the RMS for a sensor between 4 and 200Hz is given. Graphical results are given in Appendix A.

Table 1: Vibration RMS at quad locations for LCLS-II in the BSY.

Location	Z [nm]	X [nm]	Y [nm]
On top of quadrupole	8	14	21
Floor under Girder #9	5	5	8
Floor between Girder #9 & #10	7	5	11

Appendix A:

a. Power Spectral Density and Cumulative PSD Plots on top of undulator quadrupole 9.

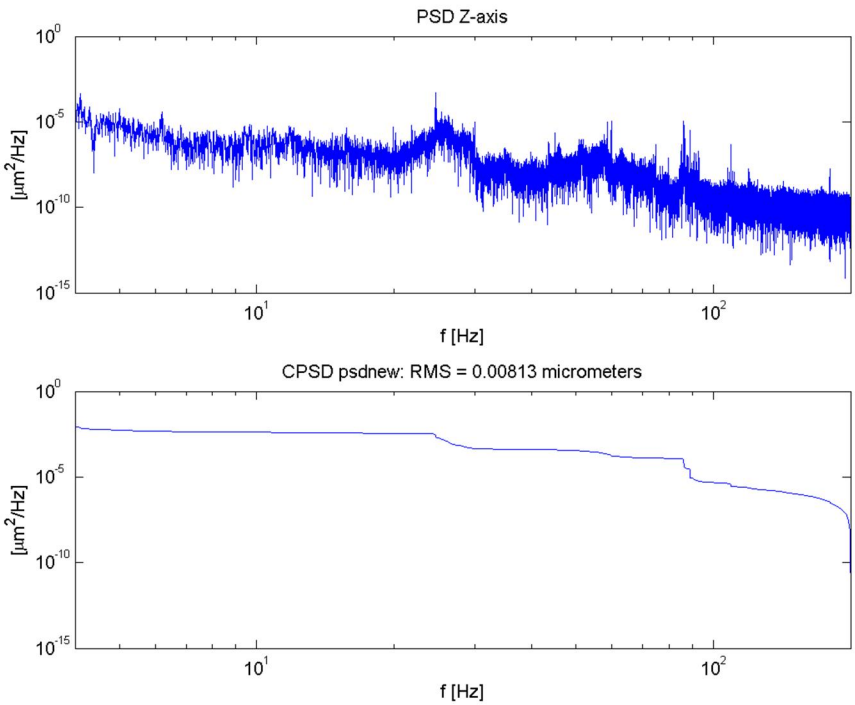

Figure 2: PSD, Undulator Quad 9, z-axis.

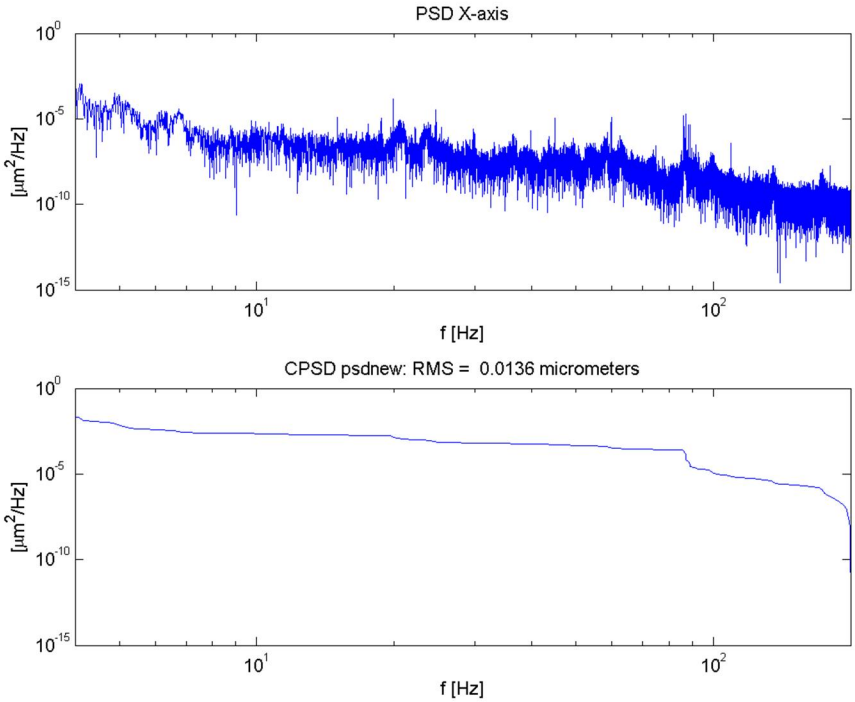

Figure 3: PSD, Undulator Quad 9, x-axis.

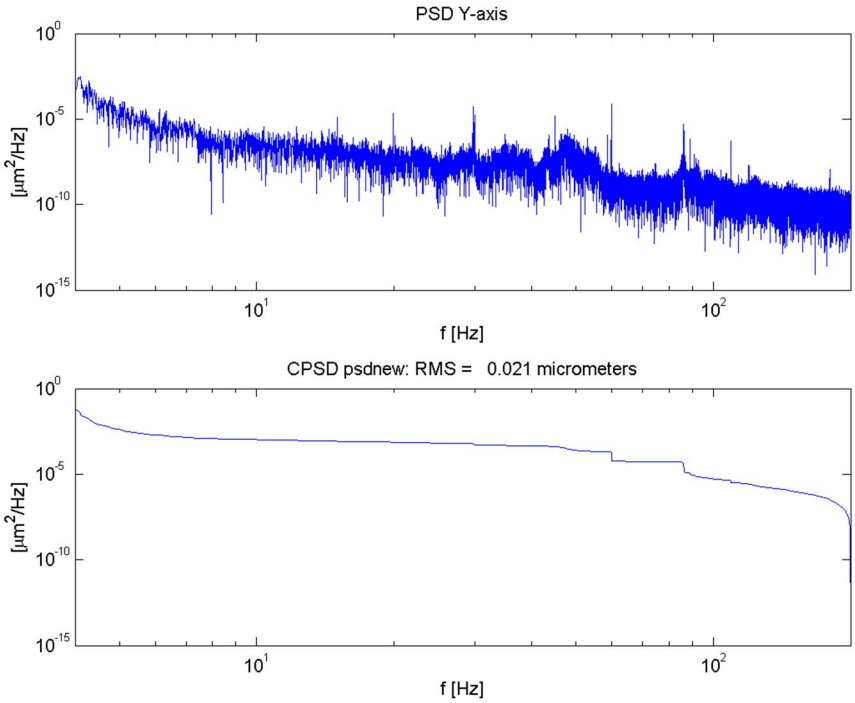

Figure 4: PSD, Undulator Quad 9, y-axis.

b. Power Spectral Density and Cumulative PSD Plots, floor between girder #9 and girder #10.

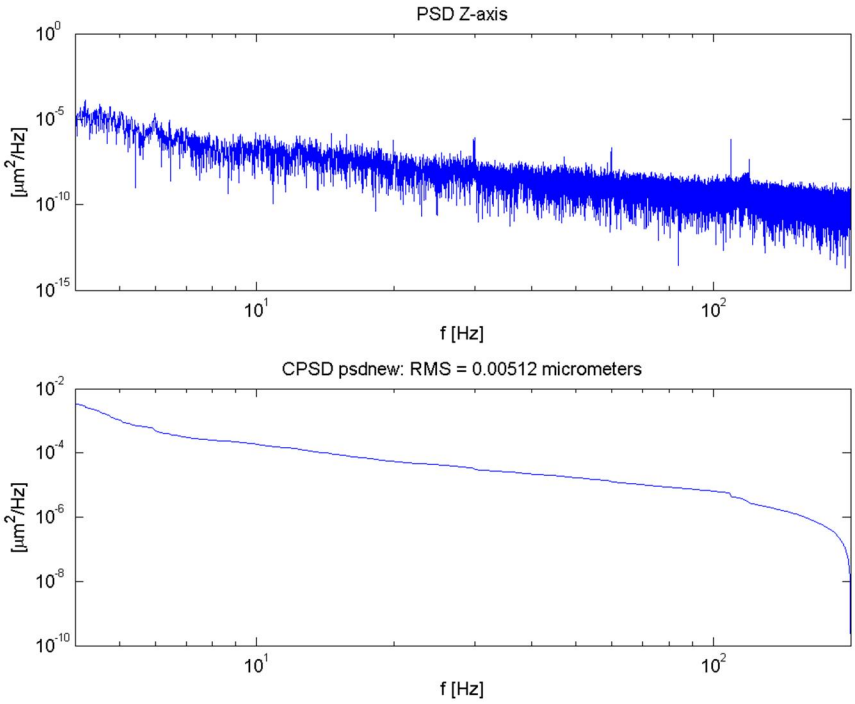

Figure 5: PSD, floor between girder #9 and girder #10, z-axis.

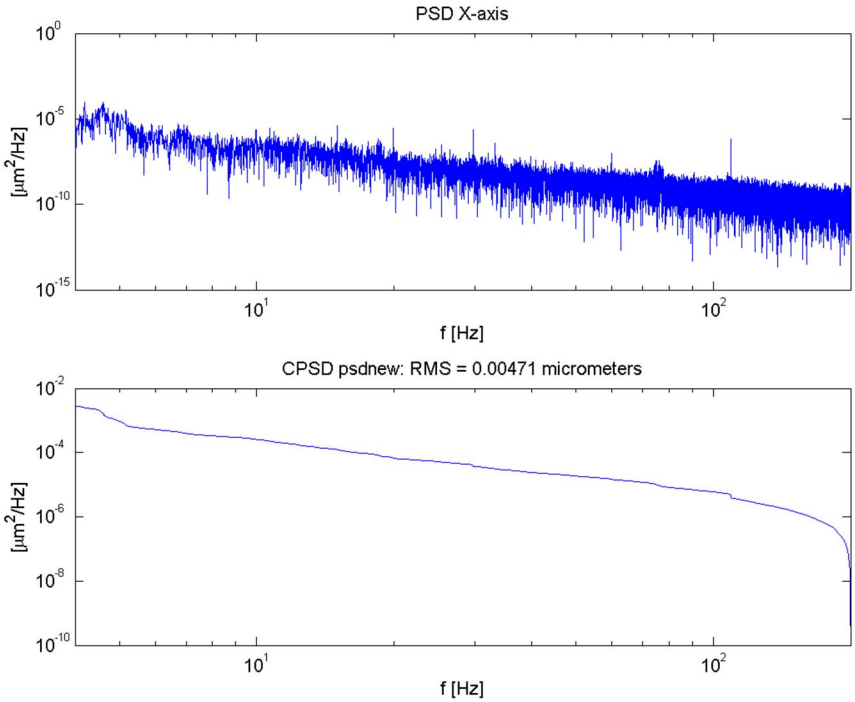

Figure 6: PSD, floor between girder #9 and girder #10, x-axis.

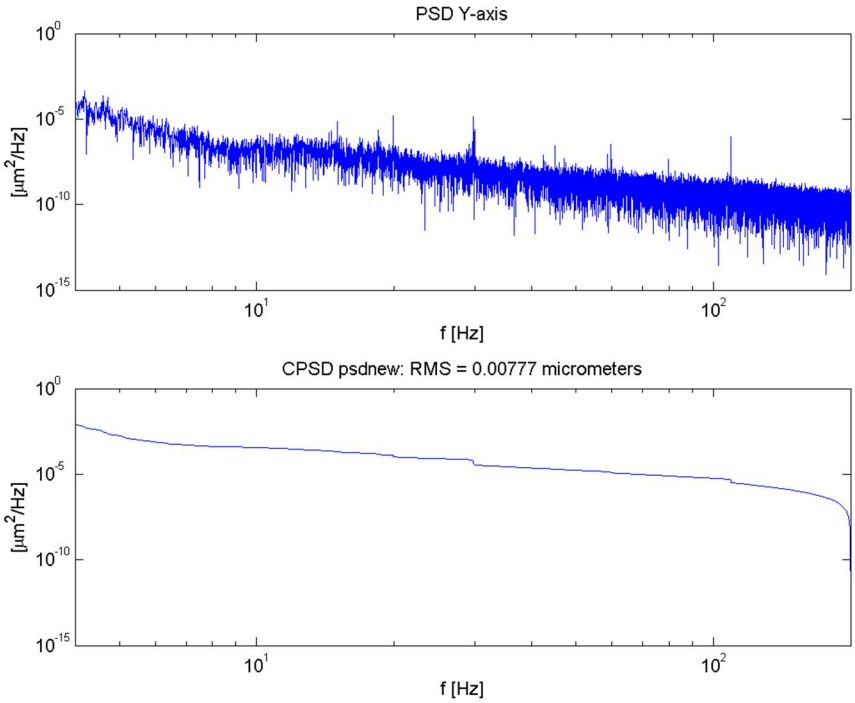

Figure 7: PSD, floor between girder #9 and girder #10, y-axis.

c. Power Spectral Density and Cumulative PSD Plots on floor under #9.

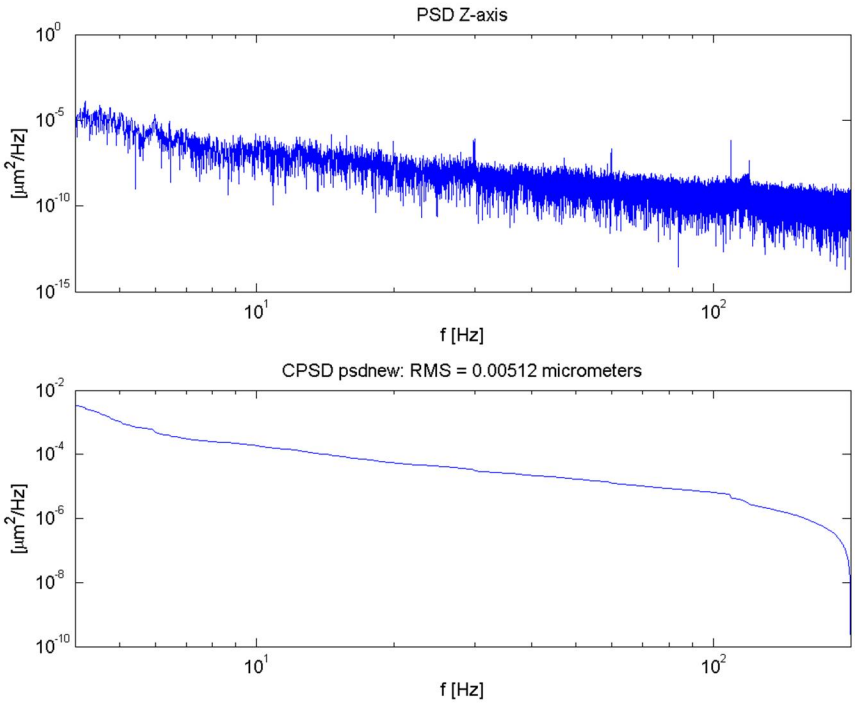

Figure 8: PSD, floor under girder #9, z-axis.

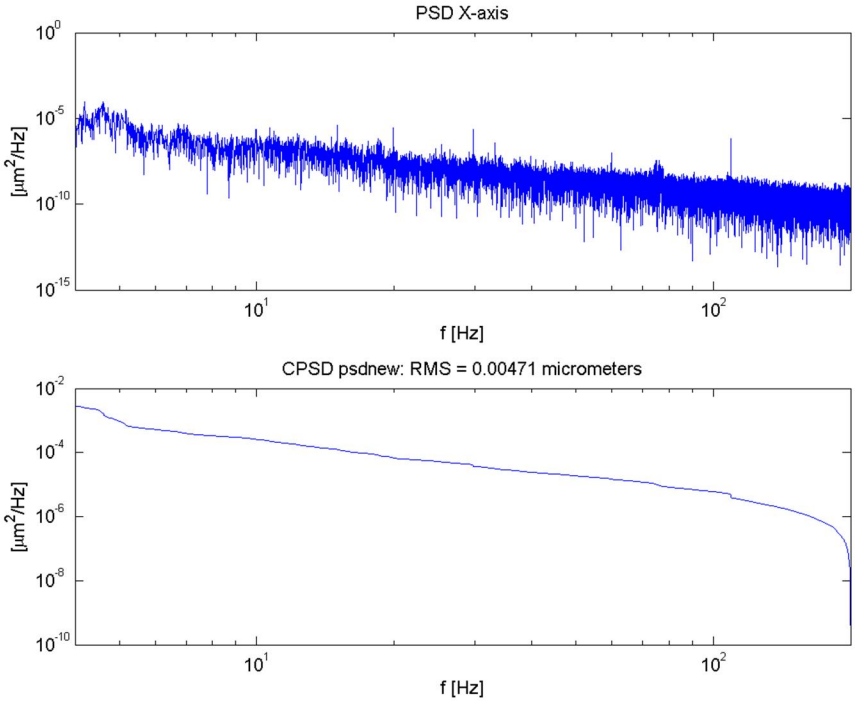

Figure 9: PSD, floor under girder #9, x-axis.

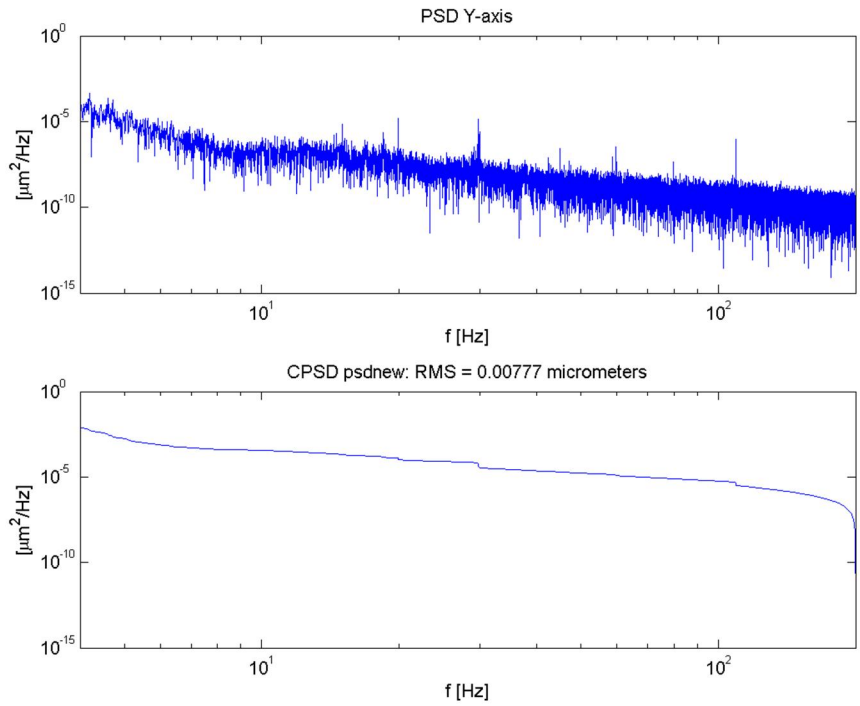

Figure 10: PSD, floor under girder #9, y-axis.

Metrology Department
Alignment Engineering Group
MEMORANDUM

Date: **6/30/2014**

To: Jim Turner

From: Georg Gassner

Subject: Vibration measurements LCLS-I Linac

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1. Measurements

To check for any vibration change since new LCW components have been installed, multiple quad locations in the LCLS Linac were observed with seismometers. All measurements were taken on top of the quadrupoles, see Figure 1, with Sercel L4C sensors (sensitivity: 276.8 Volts / meter / second; Natural Freq.: 1.0 Hz). One dataset consists of 120 seconds of data sampled at 5120Hz. The data acquisition unit used was a National Instruments Model Ni9234 (24 Bits).

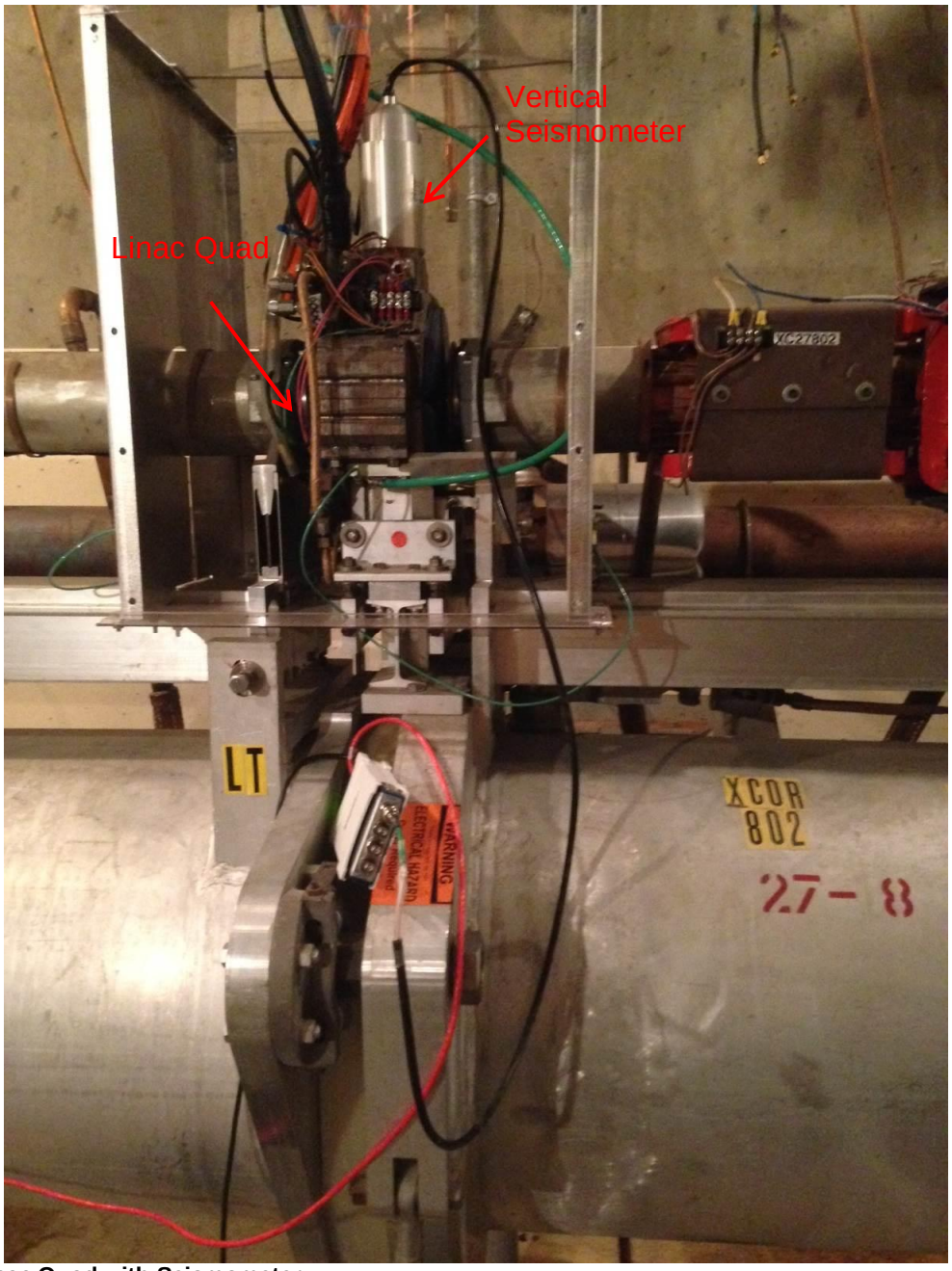


Figure 1: Linac Quad with Seismometer.

2. Results

As results, the RMS for a sensor between 4 and 200Hz are given in Table 1. Graphical results are given in Appendix A.

Table 1: List with RMS between 4-200Hz on top of Linac quads.

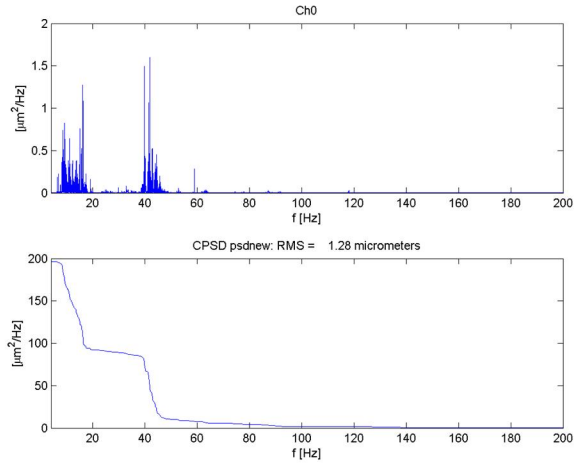
Location	Z	X	Y
	[nm]	[nm]	[nm]
Li23-301	1280	385	241
Li23-501	1800	267	348
Li23-801	2860	205	243
Li25-301	1110	181	258
Li25-501	1680	266	217
Li25-801	1830	395	353
Li27-301	1800	260	202
Li27-501	1440	218	223
Li27-801	1410	354	229

3. Summary

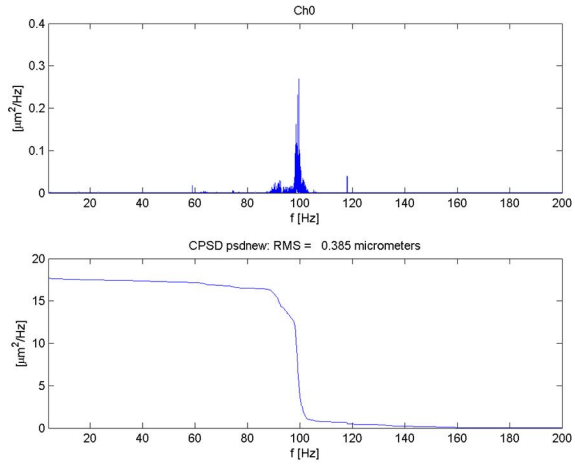
According to Jim Turner the numbers are similar to before the LCW hardware change.

Appendix A: Power Spectral Density and Cumulative PSD Plots

Z-Axis



X-Axis



Y-Axis

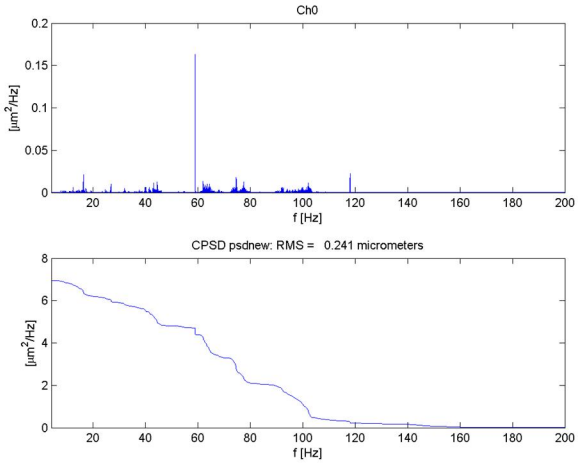
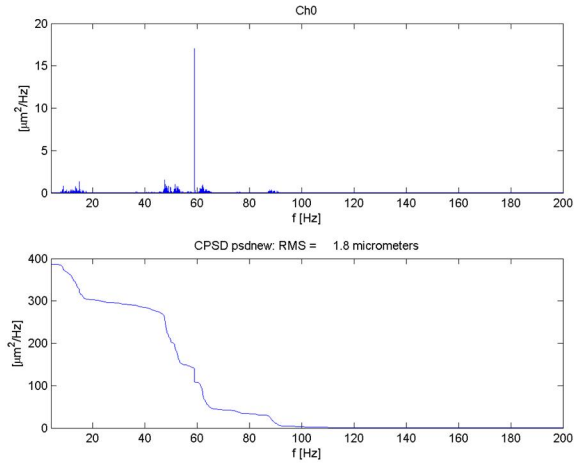
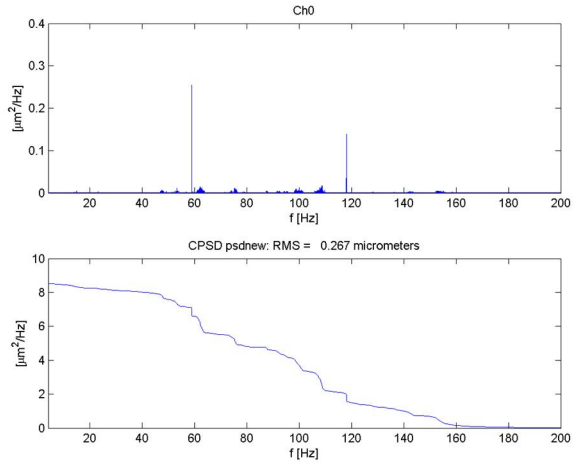


Figure 2: PSD, Top of Quad Li23-301

Z-Axis



X-Axis



Y-Axis

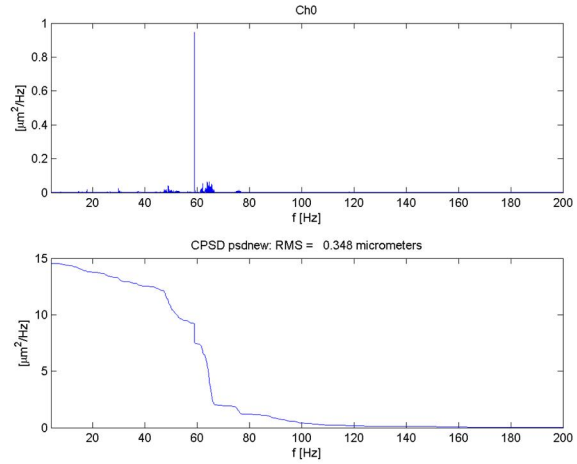
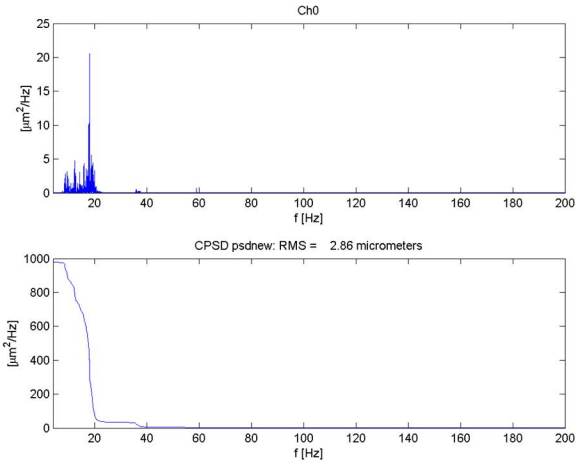
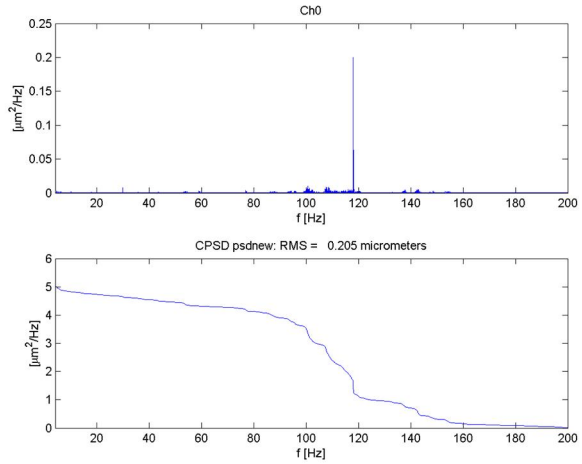


Figure 3: PSD, Top of Quad Li23-501

Z-Axis



X-Axis



Y-Axis

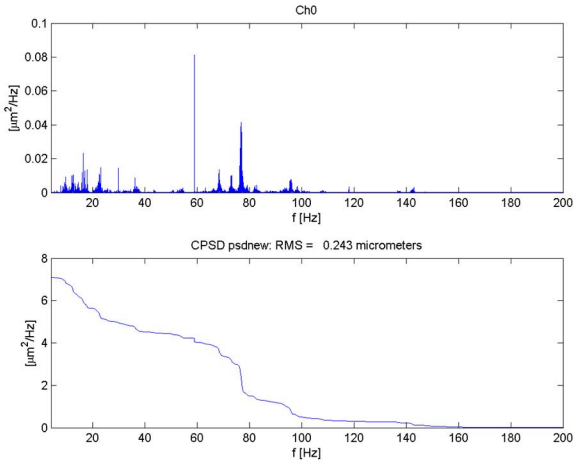
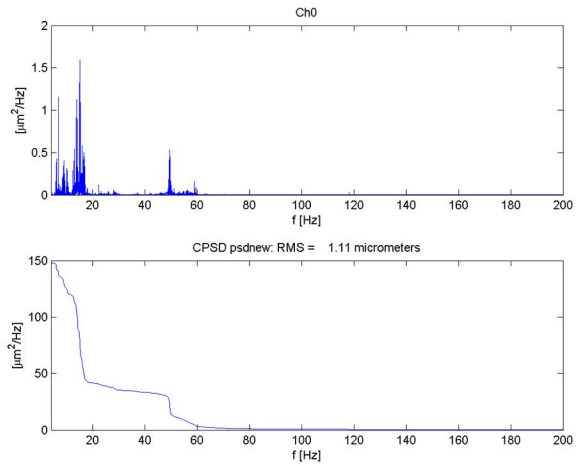
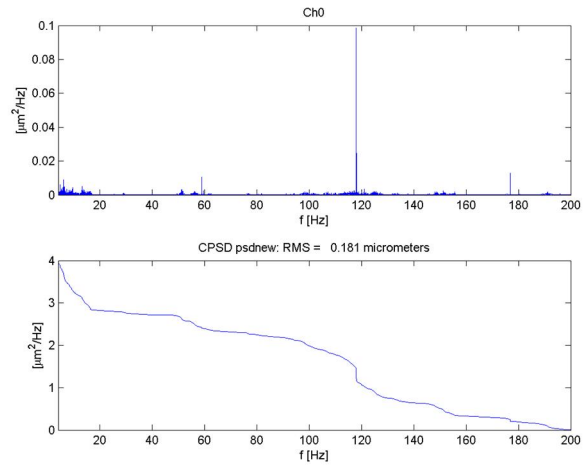


Figure 4: PSD, Top of Quad Li23-801

Z-Axis



X-Axis



Y-Axis

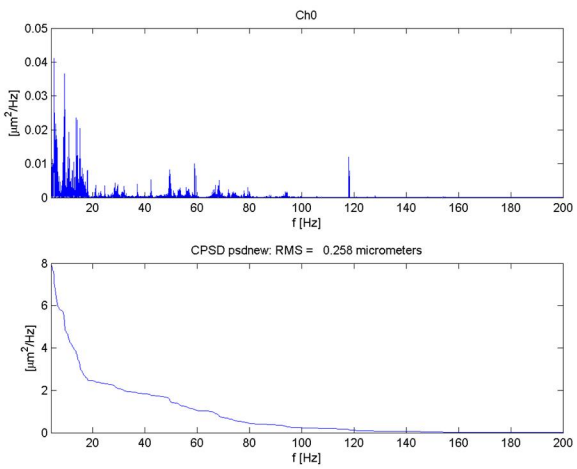
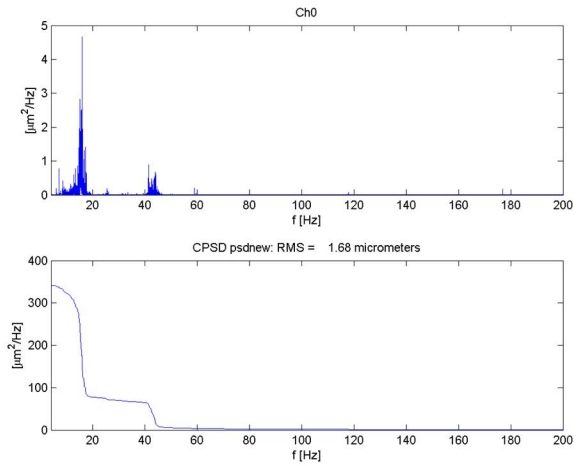
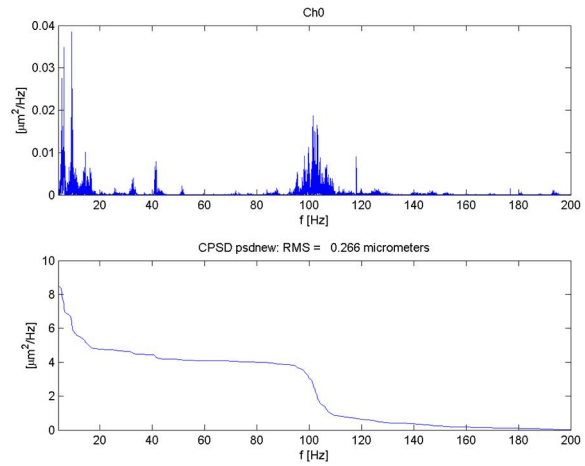


Figure 5: PSD, Top of Quad Li25-301

Z-Axis



X-Axis



Y-Axis

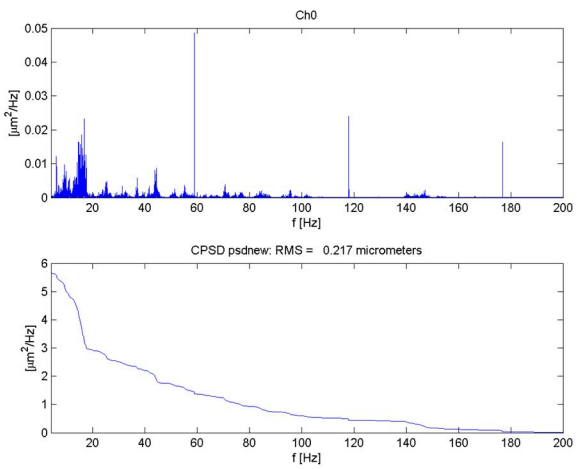
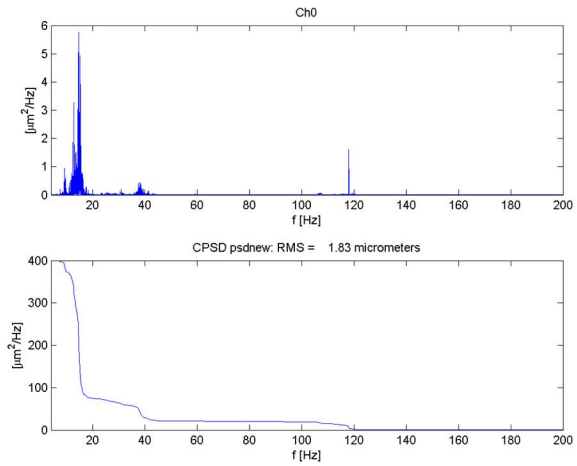
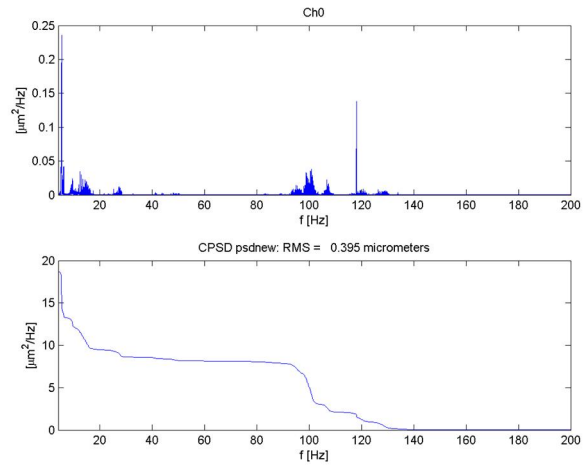


Figure 6: PSD, Top of Quad Li25-501

Z-Axis



X-Axis



Y-Axis

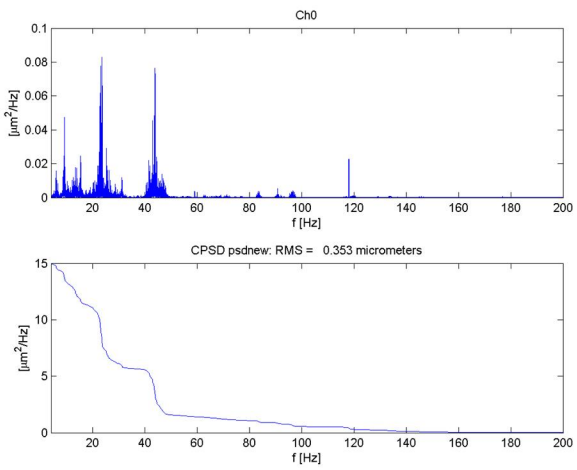
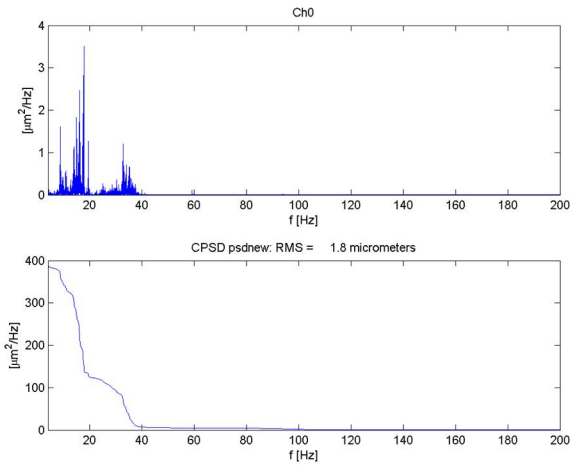
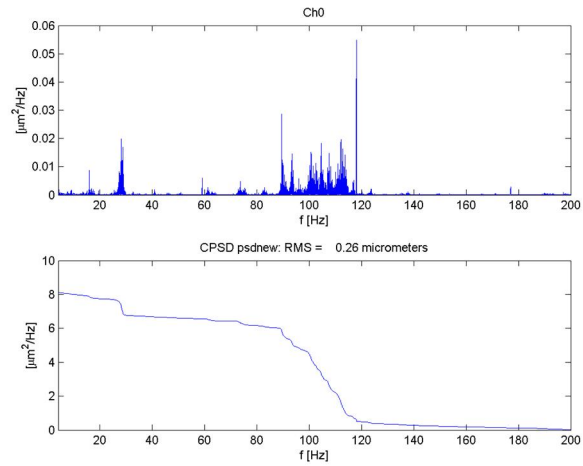


Figure 7: PSD, Top of Quad Li25-801

Z-Axis



X-Axis



Y-Axis

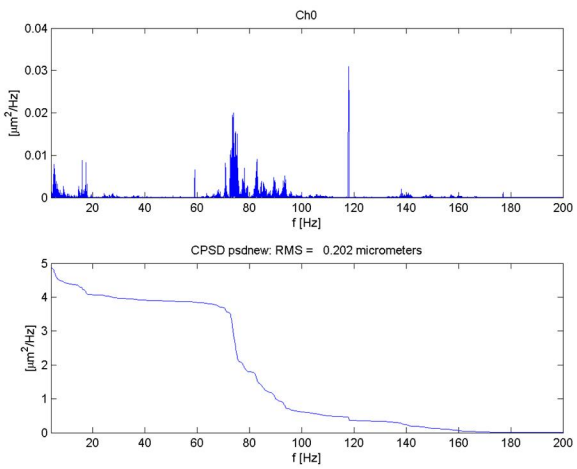
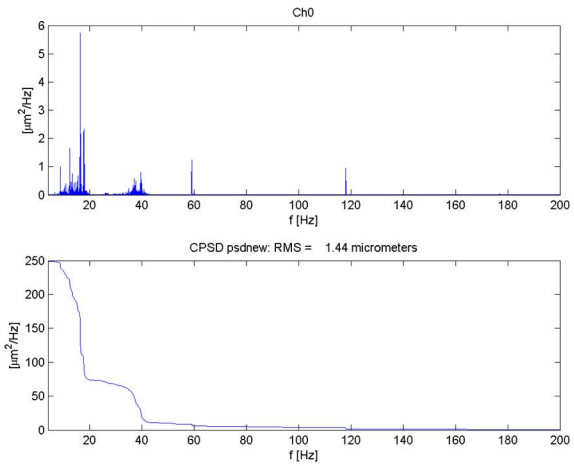
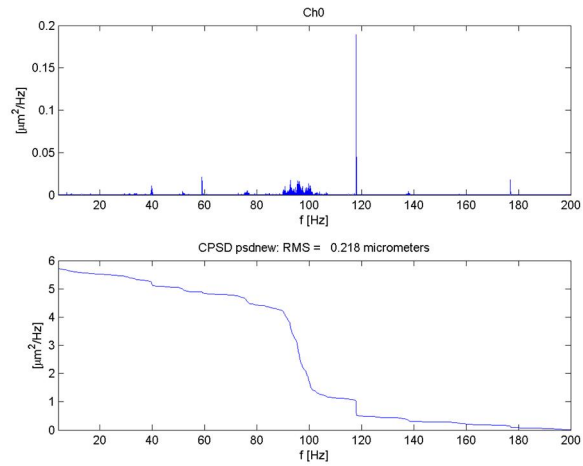


Figure 8: PSD, Top of Quad Li27-301

Z-Axis



X-Axis



Y-Axis

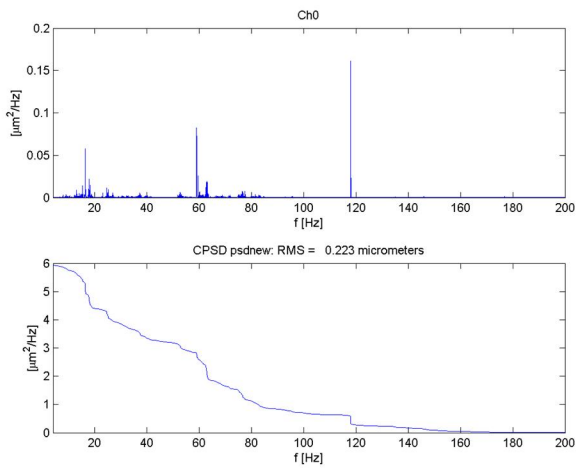
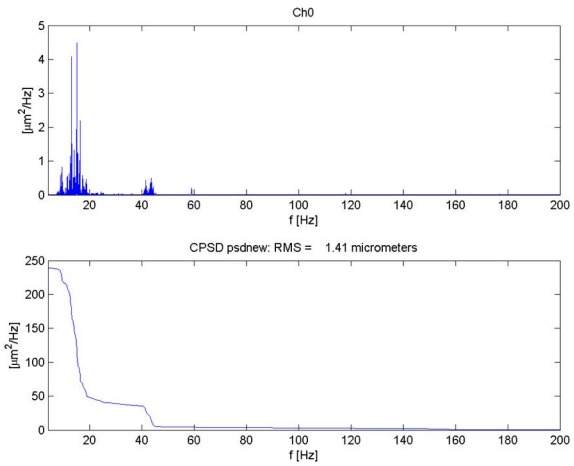
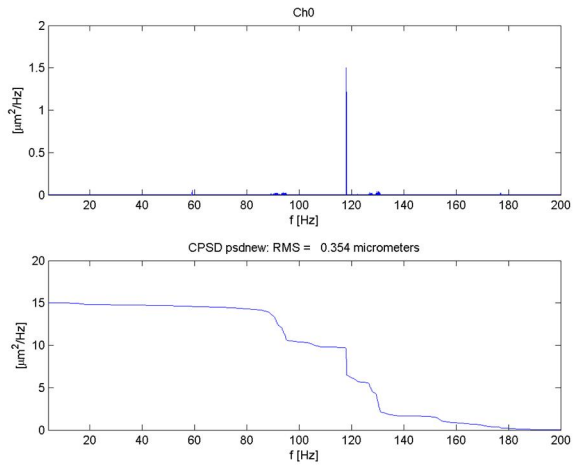


Figure 9: PSD, Top of Quad Li27-501

Z-Axis



X-Axis



Y-Axis

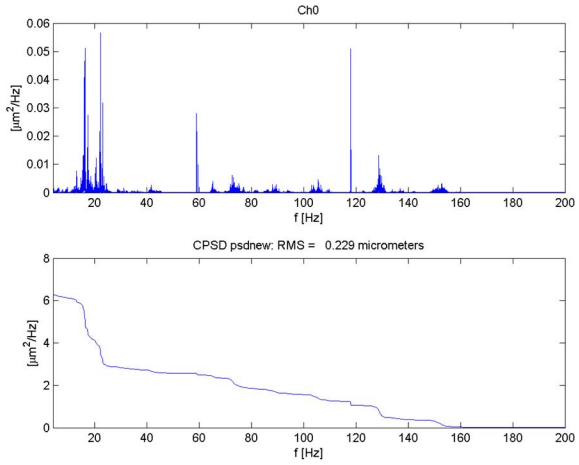


Figure 10: PSD, Top of Quad Li27-801