Vibration Stability Studies of a Superconducting XFEL/ILC Accelerating Module at Room Temperature and at 4.5K

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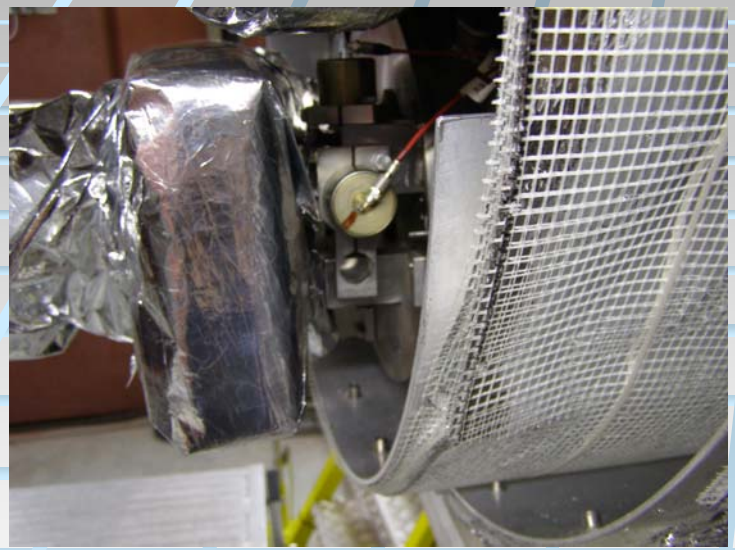
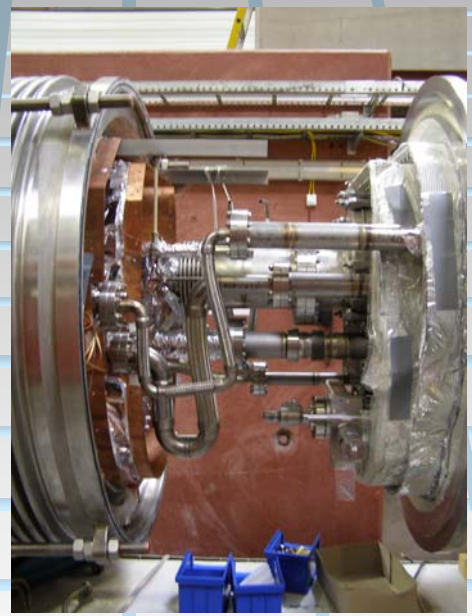


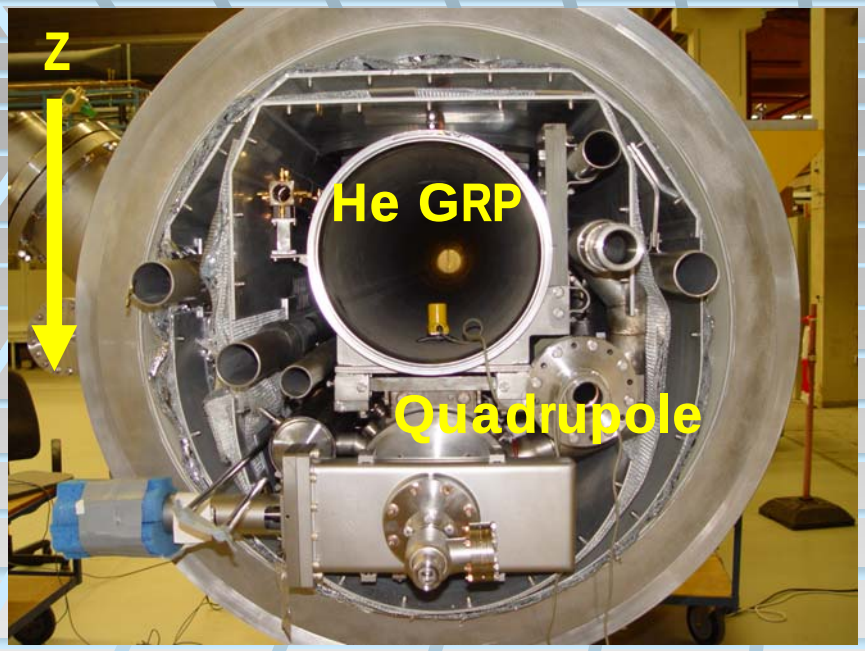


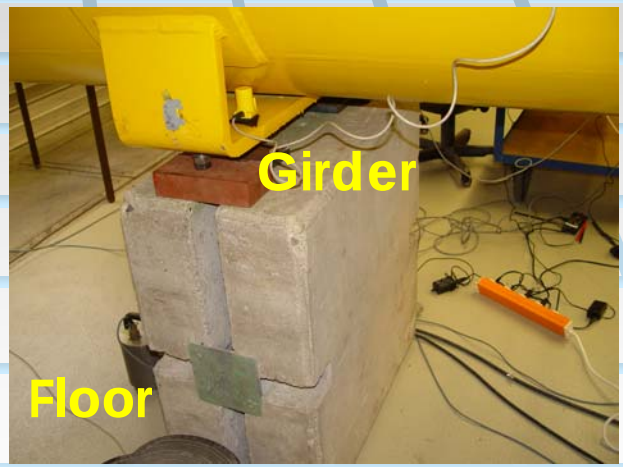
DESY

Methodology

- Systematic approach: from room temperature to 2K measurements in order to facilitate comparison between ´warm´ vs. ´cold´ on the same cryomodule.
- Repeated measurements on more than one cryomodule (eg. Superstruktur, Module 6 etc.) to gain a better understanding of a cryomodule stability as a whole.
- Repeated measurements on each cryomodule and in more than one site (eg. Hall III, #70, FLASH) to check for reproducibility of data.
- Study the influence of the cryomodule support (tunnel ceiling or floor).
- Study the behavior of a string of cryomodules in FLASH.

Room Temperature Measurements, Module 6 in Hall III (2006)

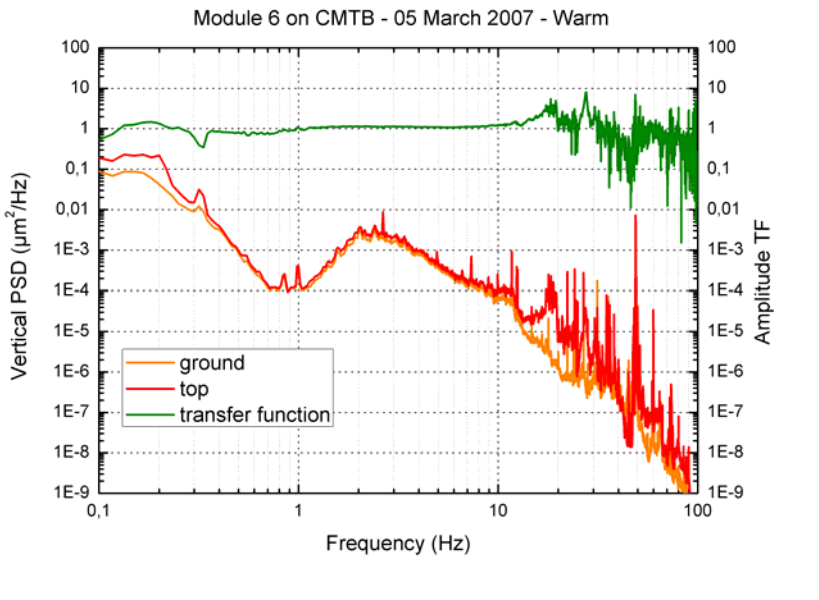




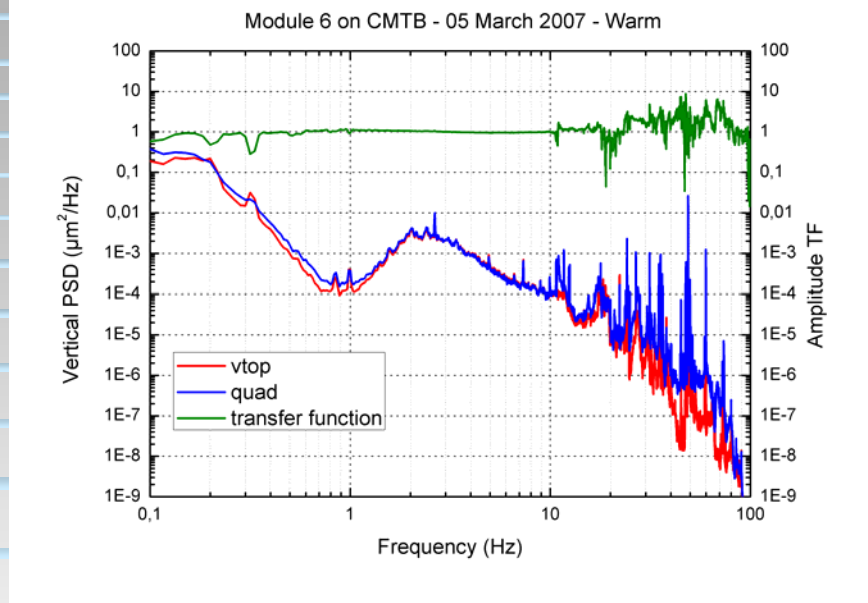
Sensor positions (in vertical + Horizontal transverse directions):

- Vessel Top vs. He GRP
- He GRP vs. Quadrupole
- Vessel Top vs. Quadrupole
- Reference measurement on the girder/floor

Room Temperature Measurements, Module 6 in #70 (2007)



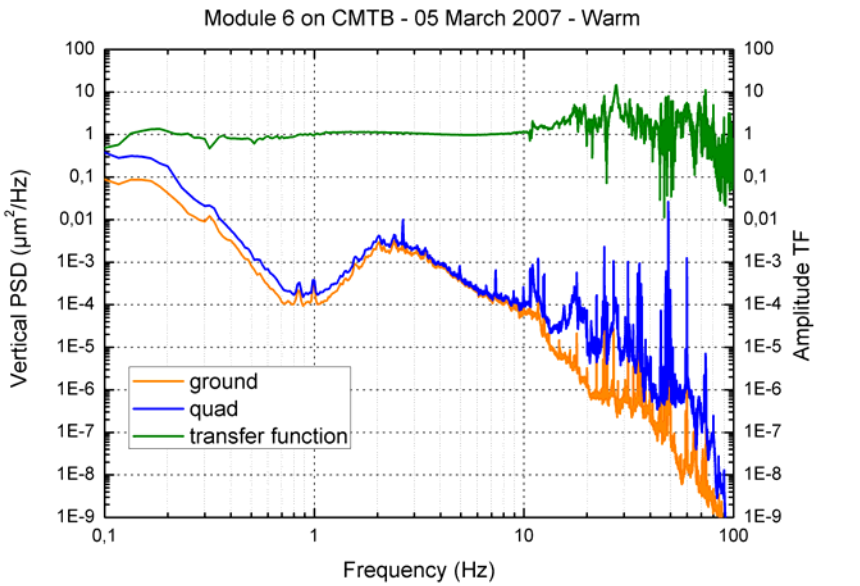
Displacement PSDs, vertical, vessel top & ground on 5 March 2007, and their corresponding transfer function.

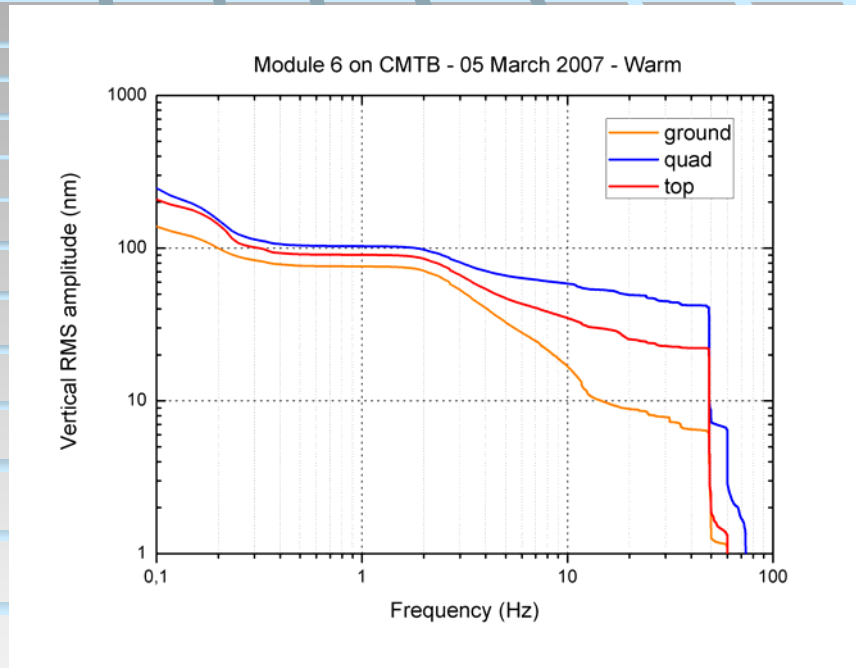


Displacement PSDs, vertical, vessel top & quadrupole on 5 March 2007, and their corresponding transfer function.

Typical DESY site spectrum at low frequencies. Technical noise dominating @ f > 20 Hz; strongest peak from the insulation vacuum pump at 48 Hz. Module vertical resonance at 26 Hz; quad vs. top transfer function almost flat below 40 Hz.

Room Temperature Measurements, Module 6 in #70 (2007)



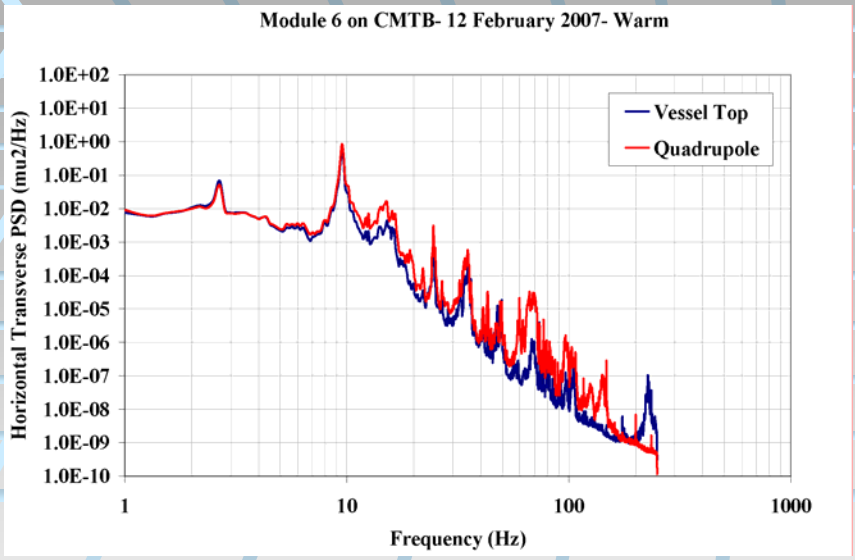


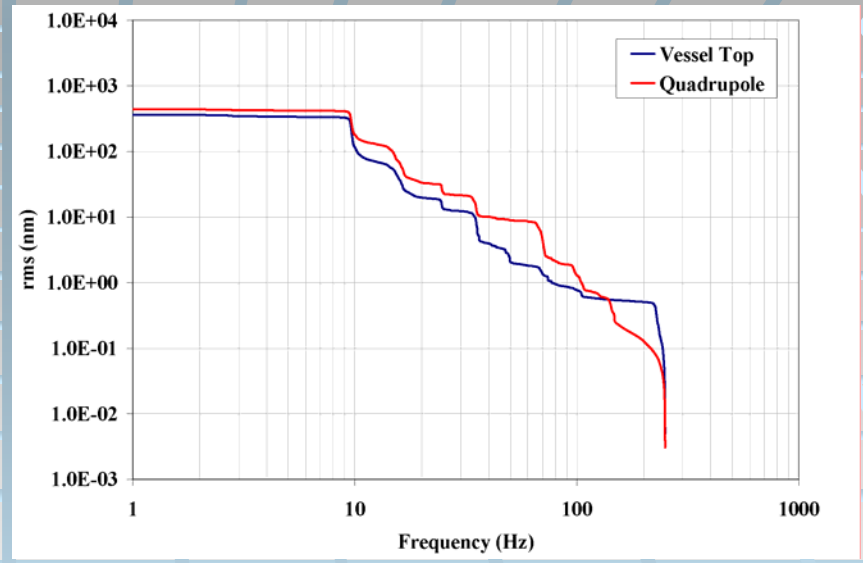
Displacement PSDs, left (vertical, quad & ground) and the corresponding integrated rms, at f > 1 Hz, on 5 March 2007 (shown together with the vessel top, right).

Displacement rms values @ 1 Hz:

Ground:	**76 nm**
Vessel Top:	**90 nm**
Quadrupole:	**103 nm**

Room Temperature Measurements, Module 6 in #70 (2007)





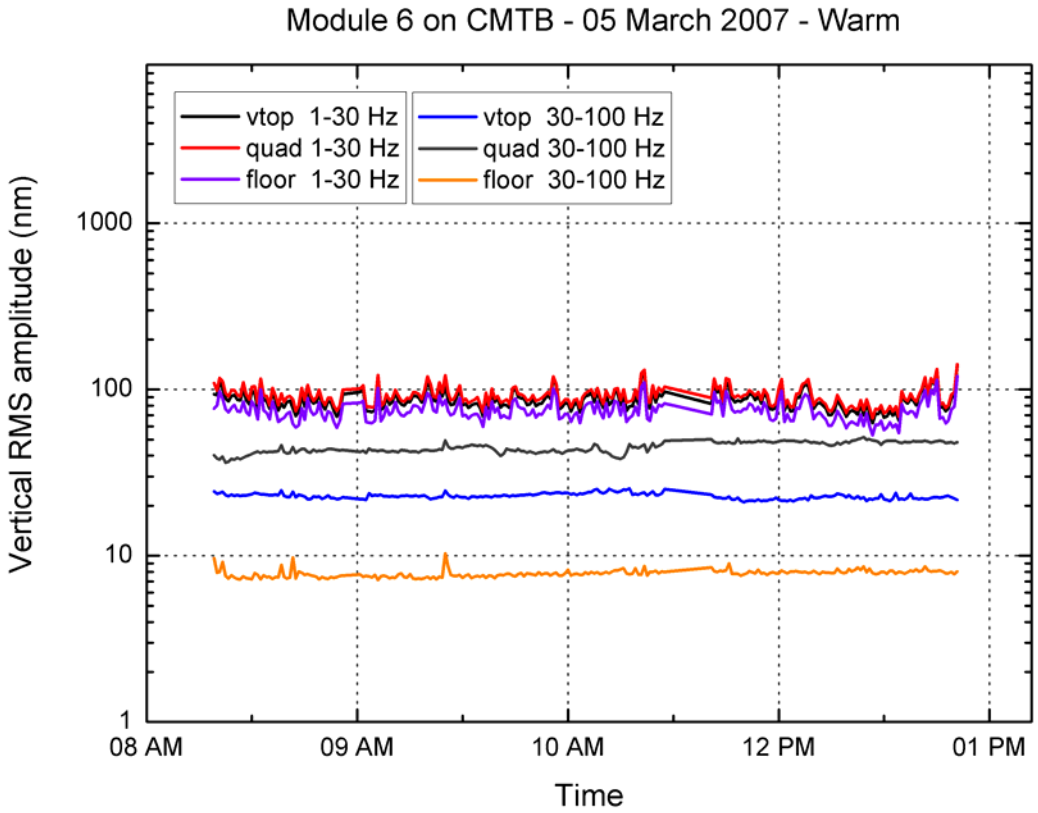
Displacement PSD (horizontal transverse) and the integrated rms at f > 1 Hz of vessel top vs. quadrupole on 12 February 2007.

Displacement rms values @ 1 Hz:

Ground: 104 nm
Vessel top: 370 nm
Quadrupole: 448 nm

Room Temperature Measurements, Module 6 in #70 (2007)

In the low frequency band, the quadrupole motion tracks the ground vibration level. Slight amplitude differences are related mainly to the mechanical transfer function of the module on its support system.



rms analysis of quad and vessel top vibrations vs. time, 5 March 2007 (morning).

Summary

- Throughout our measurement program, stability within the module (quad vs. He GRP, quad vs. vessel top) is consistently observed within a 20% window, maximum.
- The support system used for a machine such as XFEL/ILC may play a crucial role in the stability and hence, the quality of its beam/s. A careful design of such girders/support systems should be implemented such that the overall system does not contain resonances below 10 Hz, at least.
- Our measurements within a cryomodule (quad vs. He GRP and quad vs. vessel top) are reproducible at room temperature conditions.
- We aim to produce a database of cryomodule vibration measurements and to make it available via our homepage.
- Our results at room temperature are being used for mechanical design of the ILC cryomodule type IV at Fermilab.
- A EuroTeV report and a subsequent PAC'07 paper are being prepared (R. Amirikas).

Quadrupole Vibration Measurements at 4.5K

- Test geophone behavior at 4K inside a fully operating cryomodule.

- On-board seismic sensor with adequate noise level down to below 1 Hz.

- Behavior unknown, never been tested by the manufacturer in these extreme conditions; the company recommends use of the device down to -40°C; only one cryogenic application cited in the literature.

- The very robust and mature (~30 years) design was encouraging and the test has been successful.

- Chance to give a first quantitative (from 1 Hz) evaluation of the impact of cryogenic plant and high gradient RF on the quadrupole vibration level, not possible so far because of the lack of sensitivity of piezo accelerometers below ~10 Hz.

Quadrupole Vibration Measurements at 4.5K

Test amplifier

Cold/warm Geophone

20 m cable

$$\frac{\omega_0^2 - \omega^2 + i\frac{\omega\omega_0}{Q_l}}{\omega_1^2 - \omega^2 + i\frac{\omega\omega_1}{Q_l}}$$

preamp Inverse filter

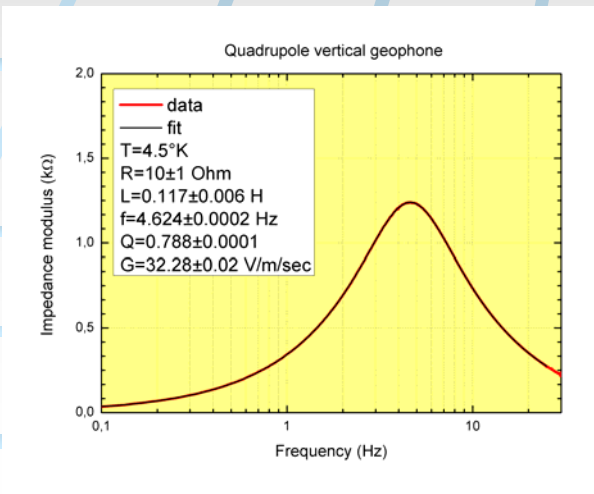
24 bit Güralp digitizer

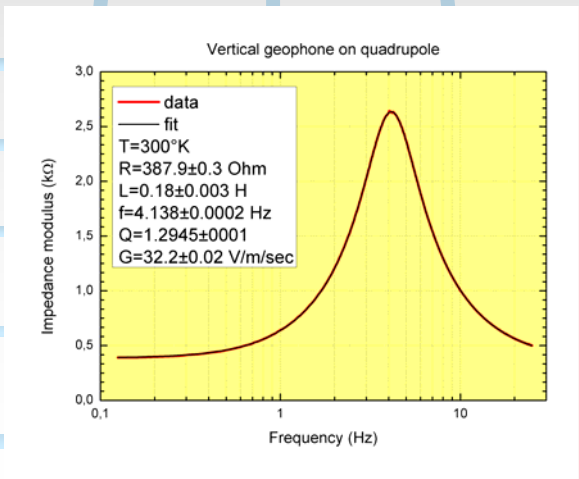
200 S/s

Laptop for Data logging, Spectral analysis (FFT, PSD, Coherence, RMS,Transfer function,etc.)

Inverse filtering provides equalization of the geophone response down to 0.35 Hz

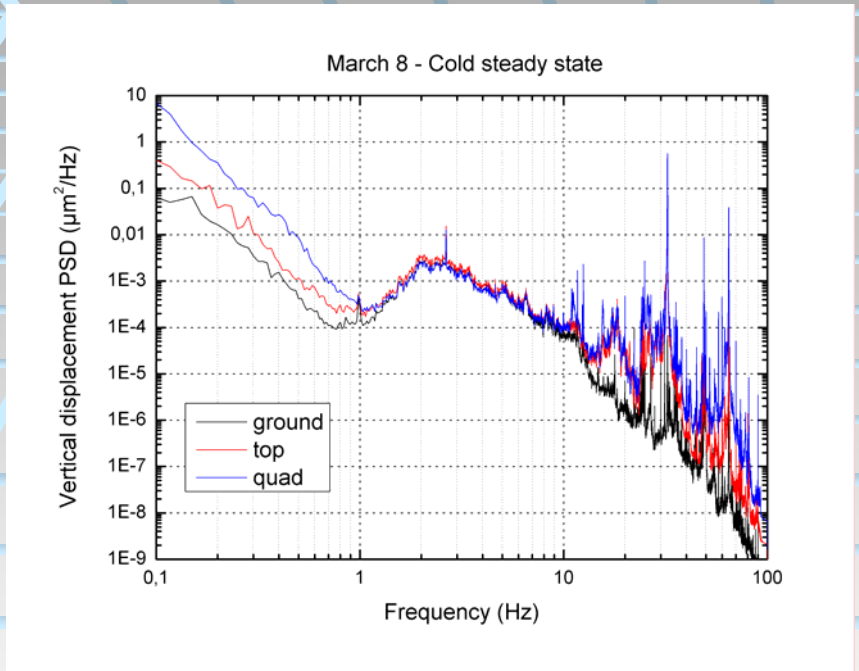
Two new seismic sensors (geophones) were installed aboard the Module 6 quadrupole for the 10/11th thermal cycles, from February 21st to March the 8th.

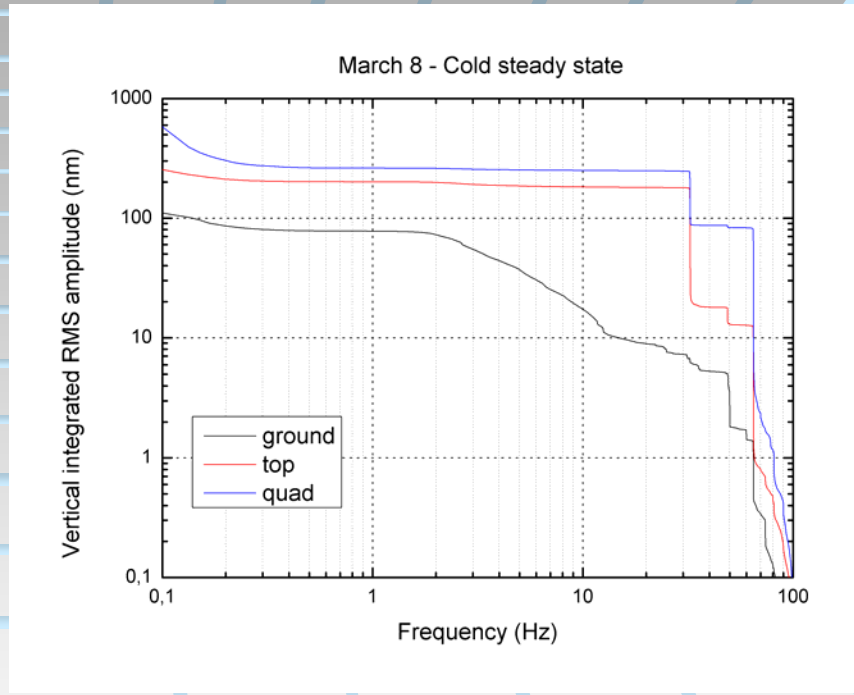




In-situ calibration of the geophones during cool-down was tested.

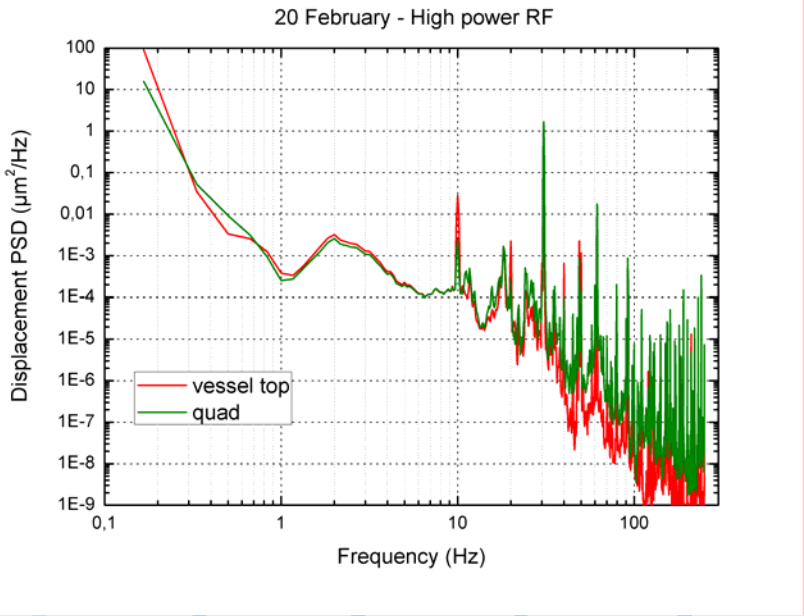
Quadrupole Vibration Measurements at 4.5K, Cold Steady State-No RF

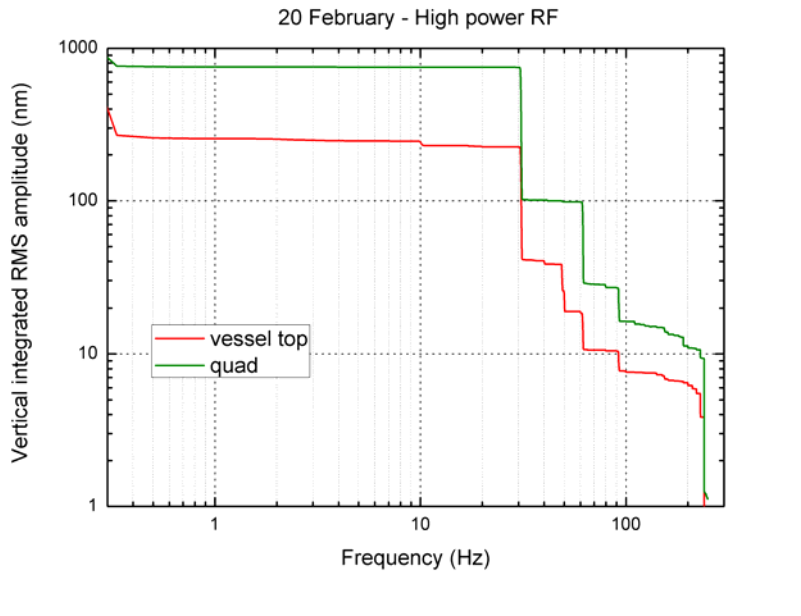




Peak frequency ~ 32Hz in this case. The integrated rms @1 Hz values are 78 nm (ground), 206 nm (vessel top), 260 nm (quad). This peak is also visible in the ground spectrum and is believed to be originating from the cryogenic operation conditions (preliminary conclusion).

Quadrupole Vibration Measurements at 4.5K, High Power RF Operation





Large vibrations due to the build up of a strong peak ~30Hz. The frequency of the peak changes from 30.1Hz up to 32Hz. The amplitude can vary from 200 nm up to > 1 μm. Not a mechanical resonance of the cryomodule; not visible at all in the quad vs. top transfer function.

The large step at ~30 Hz, is most probably due to the cryogenic operation conditions in #70 (preliminary conclusion) and needs further investigation.

Preliminary Conclusions & Future Plans

- A classic 4.5 Hz industrial geophone can operate at 4K without any loss of sensitivity.
- In-situ high accuracy calibration procedure has been demonstrated.
- Geophones are a new tool for low frequency vibration investigations at cryogenic temperatures.
- Low frequency (1-100 Hz) quadrupole vertical stability is not affected by high gradient RF operation (preliminary conclusion).
- Quadrupole vertical stability is not affected by the refrigeration system at frequencies up to 30 Hz (preliminary conclusion). Results are not conclusive at higher frequencies at this stage.
- Comparison with operation in the FLASH linac may be insightful.
- Quad @ 2K vs. 4.5K?
- A EuroTeV report and a subsequent PAC'07 paper are currently under preparation (A. Bertolini)

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