Vibration studies on TTF-like cryomodules

A summary of the work done so far

Serena Barbanotti
Second Cryomodule Microphonics and Resonance Control Workshop
New York City, 25 October 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Outlook

01 Vibration measurements at the Tesla Test Facility (now FLASH accelerator)

- Ground motion measurements
- Measurements on cryomodules: FLASH, CMTB
- Measurements with Wire Position Monitors

02 Measurements in the XFEL tunnel

- Validation of the module support system and alignment principle

03 XFEL cryomodules

- Measurements at AMTF
- Using piezo as vibration sensors

04 Future plans for CW XFEL Modules

- Characterization of an XFEL cryomodule
- Possible optimization of the module design

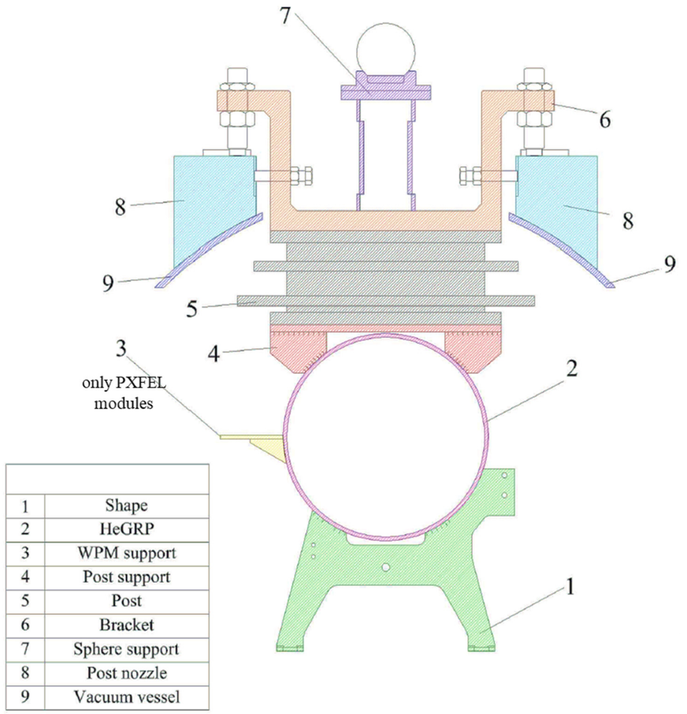
Vibration measurements at TTF-FLASH

Vibration studies at FLASH and CMTB

2004-2007 – DESY vibration group and INFN Milano LASA

Tools developed to perform and compare vibration measurements

- DESY: using geophones, piezo and seismometers to measure PSD / RMS
- INFN-Mi-LASA: using the Wire Position Monitors as vibration sensors



1	Shape
2	HeGRP
3	WPM support
4	Post support
5	Post
6	Bracket
7	Sphere support
8	Post nozzle
9	Vacuum vessel

Different studies performed

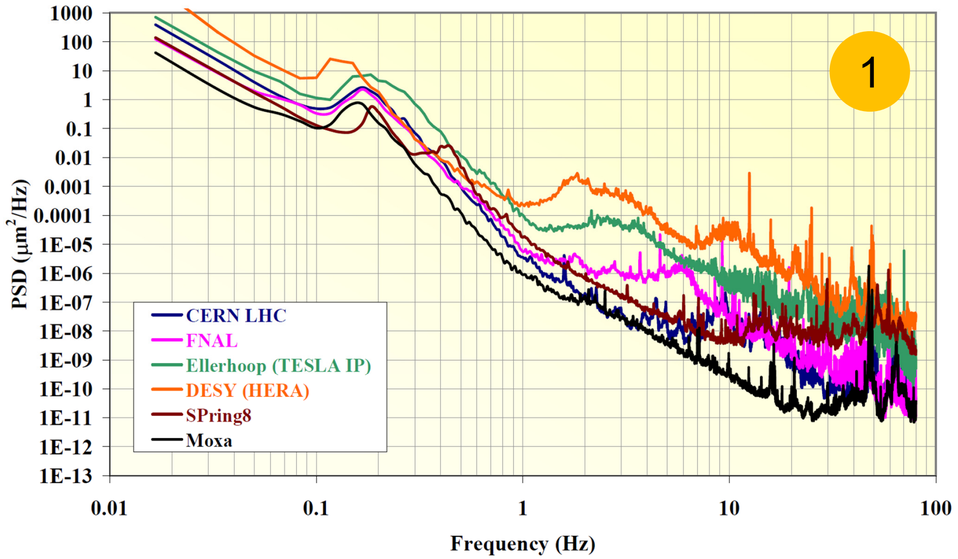
- Ground motion at DESY and in the world
- Vibration at the quadrupole at different cryogenic conditions
- Vibration at the cavities
- Vibration transfer functions between vessel, GRP, quadrupole

Vibration studies at FLASH and CMTB

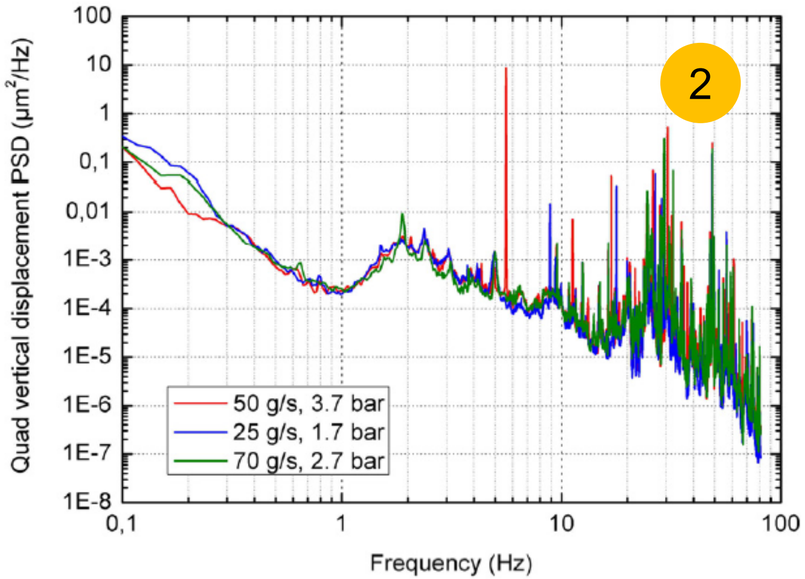
2004-2007 – DESY vibration group and INFN Milano LASA

Some significant results (my personal opinion)

- Ground motion studies at different DESY sites 1
- Almost no effect of cryogenic operation conditions on vibrations at the quadrupole 2



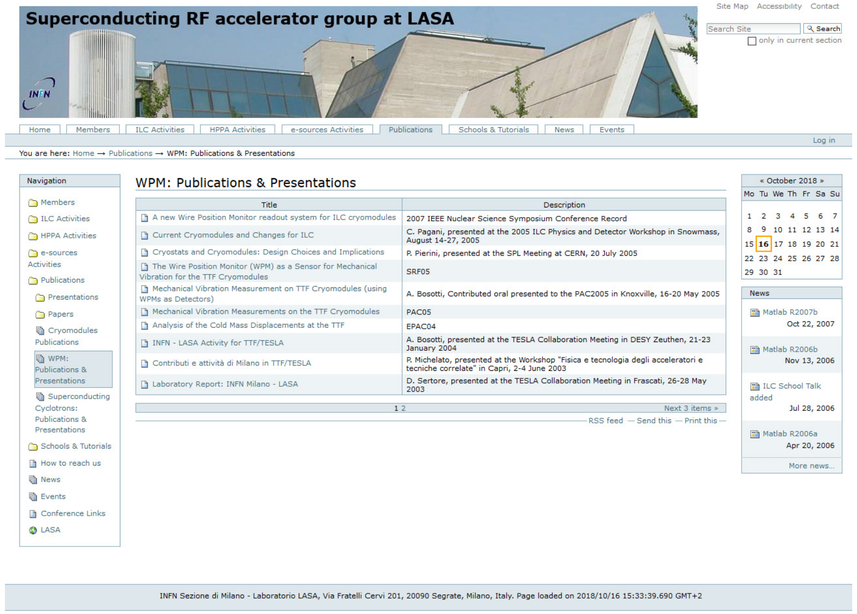
- Study of quadrupole stability at CMTB
  - Low freq. (1-30 Hz) vertical stability not affected by refrigeration system
  - Low freq. (1-100 Hz) vertical stability not affected by high gradient RF operation
- Study of the transfer functions between vessel, GRP and quadrupole
  - Amplitudes of the vibrations in the hundreds of nm
  - Motion is transmitted almost completely from vessel to quadrupole (at low freq.)
- WPM study
  - Comparison of vibrations at different positions along the GRP
    → quieter at the middle?

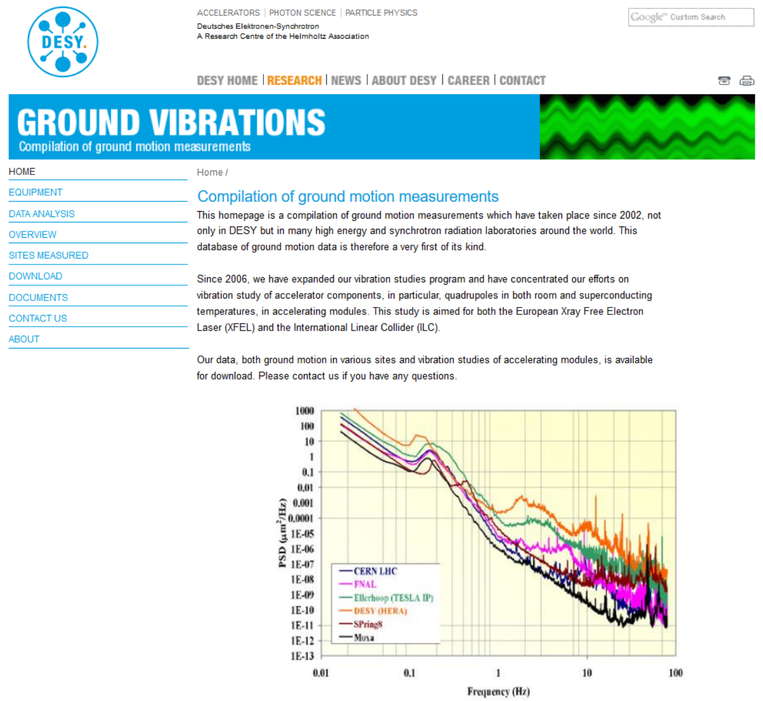


Further information

https://vibration.desy.de/

http://wwwsrf.mi.infn.it/publications/topic.2006-05-02.3276868848





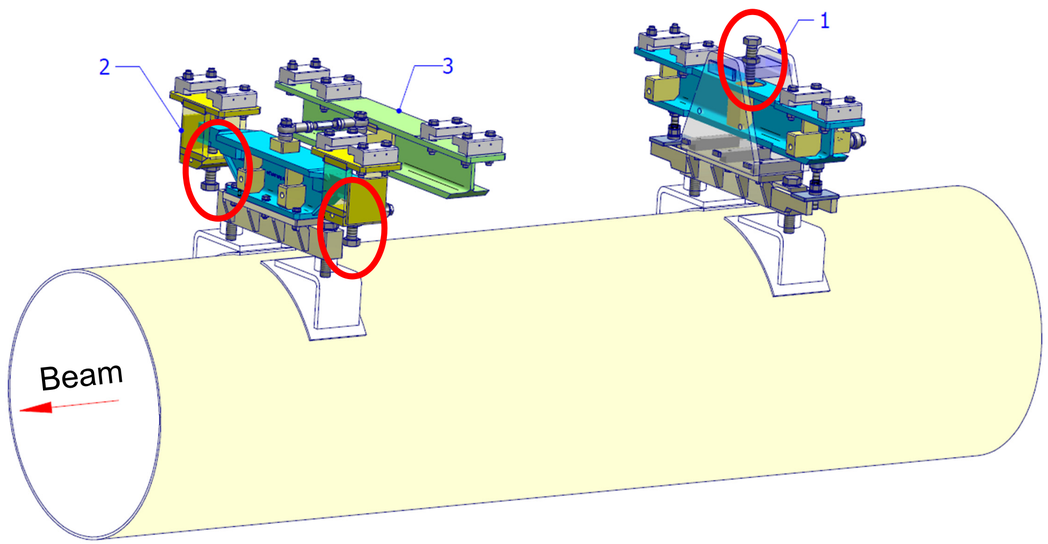
Vibration measurements in the XFEL tunnel

Measurements in the XFEL tunnel

2015 - DESY MEA Group (further information: N. Meyners)

Case study

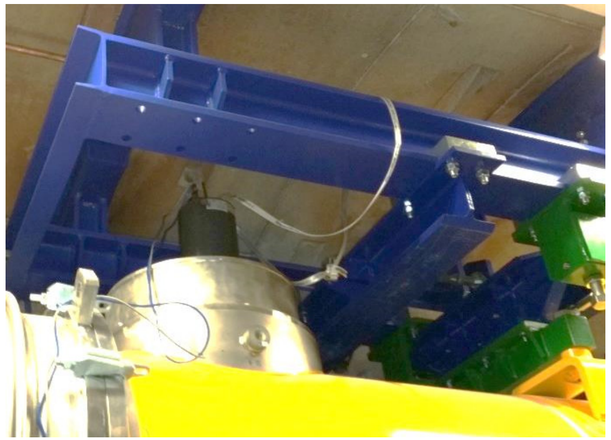
- XFEL cryomodules hang from the ceiling



- Position is adjusted with bolts -> influence of the bolt length on the cryomodule vibration spectrum?

Measurement campaign

- Measurement performed on a single hanging cryomodule with seismometers (Guralp CMG-6TD, bandwidth 30s – 100 Hz) on the tunnel ground and on the post cover
- Vertical position of the support bolts changed and measurement repeated

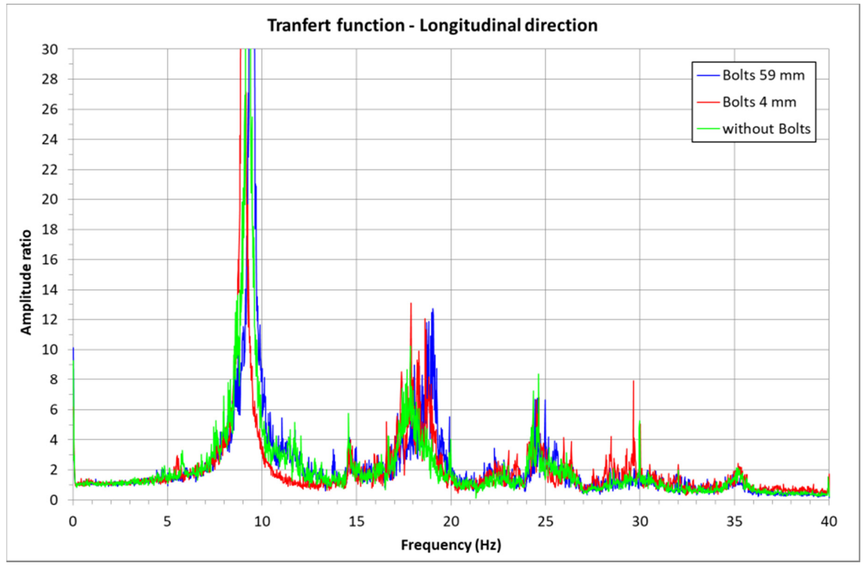


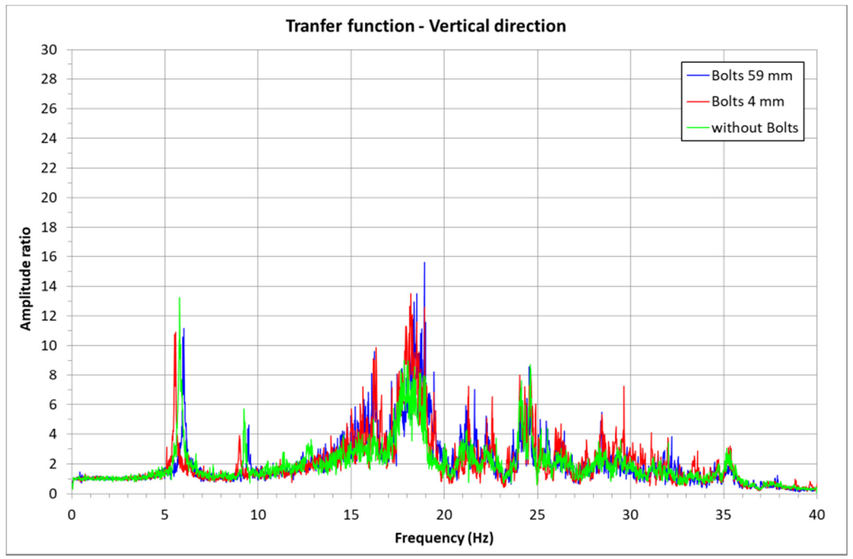
Measurements in the XFEL tunnel

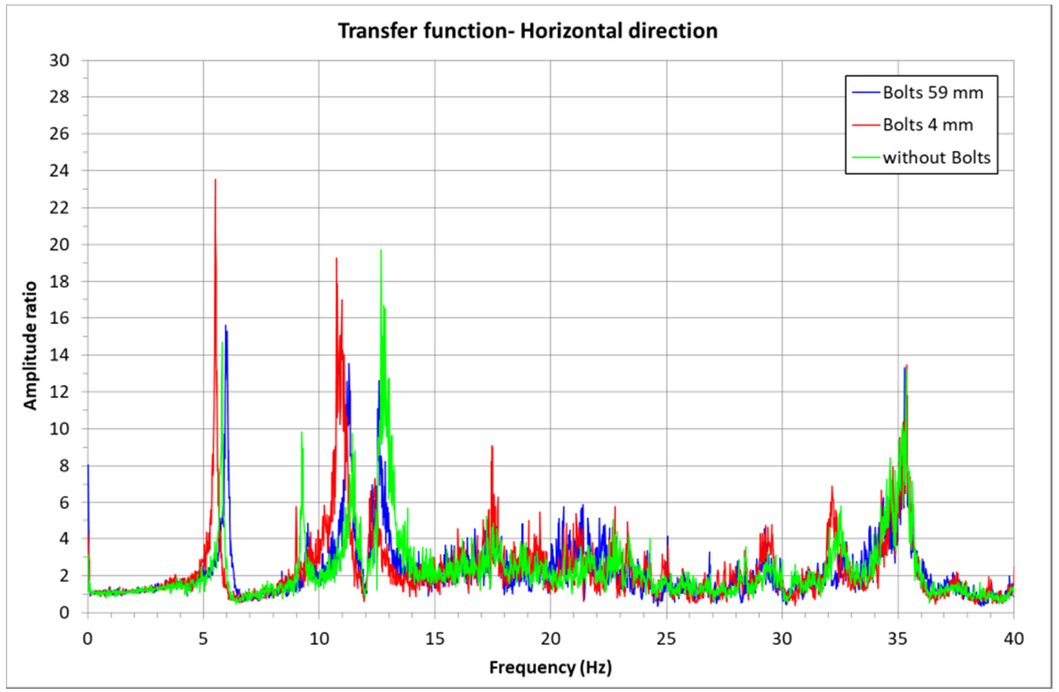
2015 - DESY MEA Group (further information: N. Meyners)

Results

- No real changes at different bolt positions
  → validation of the support system
- Measurement of the vibration spectrum
  → can be used as comparison for further studies







Vibration measurements on XFEL cryomodules

Vibration measurements on cryomodules in the AMTF hall

2014 - Internship M. Ajerrar, MSK Group (further information: J. Branlard)

Test plan

- Cryomodules installed on the horizontal test stand XATB3
- Measurement with geophones at one position on the vessel, longitudinal and vertical direction
- Parallel measurement with the piezo sensors
- Measurement with and without RF
- Cold measurements
- Equipment used:
  Endevco 7703A-1000
  DeltaShear Uni-Gain Type 4379

Vibration measurements on cryomodules in the AMTF hall

2014 - Internship M. Ajerrar, MSK Group (further information: J. Branlard)

Results and conclusions

- Measurements on the cryomodule XM5 in the test stand 3 showed:

  Higher sensitivity to vibration in **the longitudinal direction** (maybe depending on the test stand set up)

  Main vibration contribution comes from 10 Hz **RF repetition rate** (Klystron farther away than in the tunnel).

  Observed **frequencies at 10.5 Hz and 15 Hz,** might come from **modes of the vacuum vessel** on its support system.

- Measurements on XM8 confirm the **vacuum pumps** as source of **vibration around 50 Hz**.
- Some measurements on the cavities (piezo), but difficult to compare
- Fluctuations at the cooling system of the klystron (modulator + klystron) might also affect the module

→ **Further studies recommended**

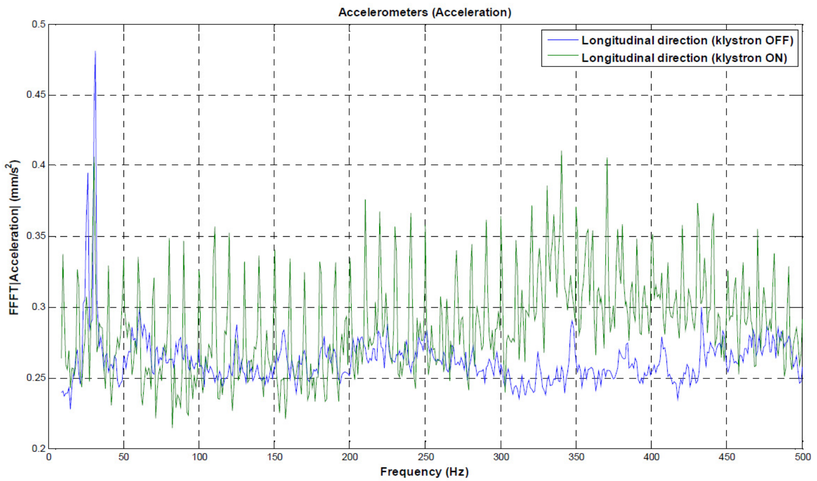
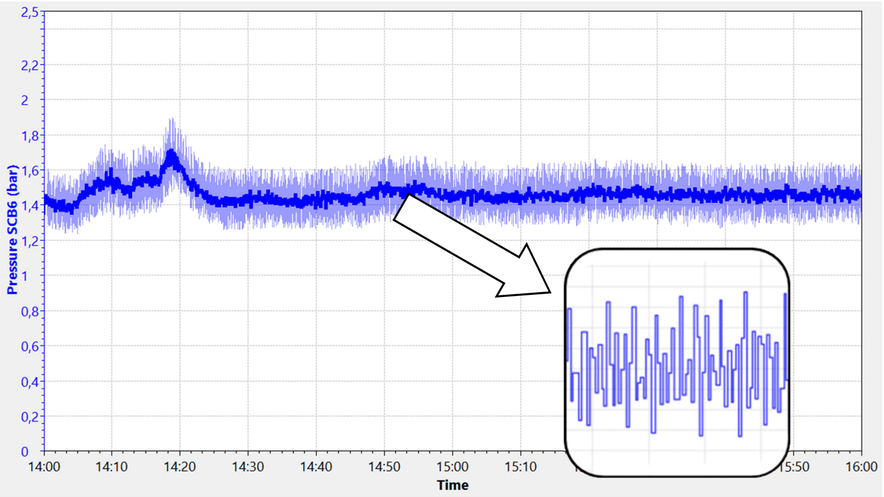


Figure 6.6- FFT of vibration (klystron ON) vs FFT of vibration (klystron OFF) in the longitudinal direction.

Using piezo to measure vibrations on XFEL modules

The cryogenic look into microphonics

Pressure fluctuation in the SCB6 2.2 K F pipe



Why did we come to this idea?

- In 2017 we noticed pressure fluctuations in the 2.2 K forward pipe at the XFEL tunnel

  Frequency ~ 0.2 Hz

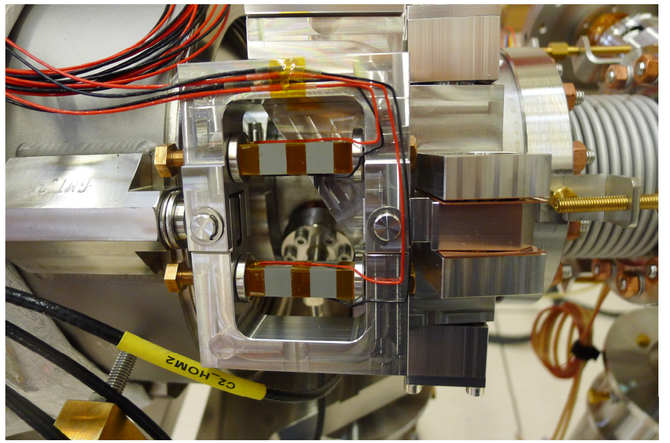
  The pressure sensors are at the feed / end / string connection boxes

    only 12 positions along the tunnel

    not representative of the cavity status

  The pressure values are not constantly recorded with high resolution -> FFT data difficult to obtain

- To better understand the situation and look closer to the cavities, we decided to try to use the piezo sensors at the cavities to look for this vibration



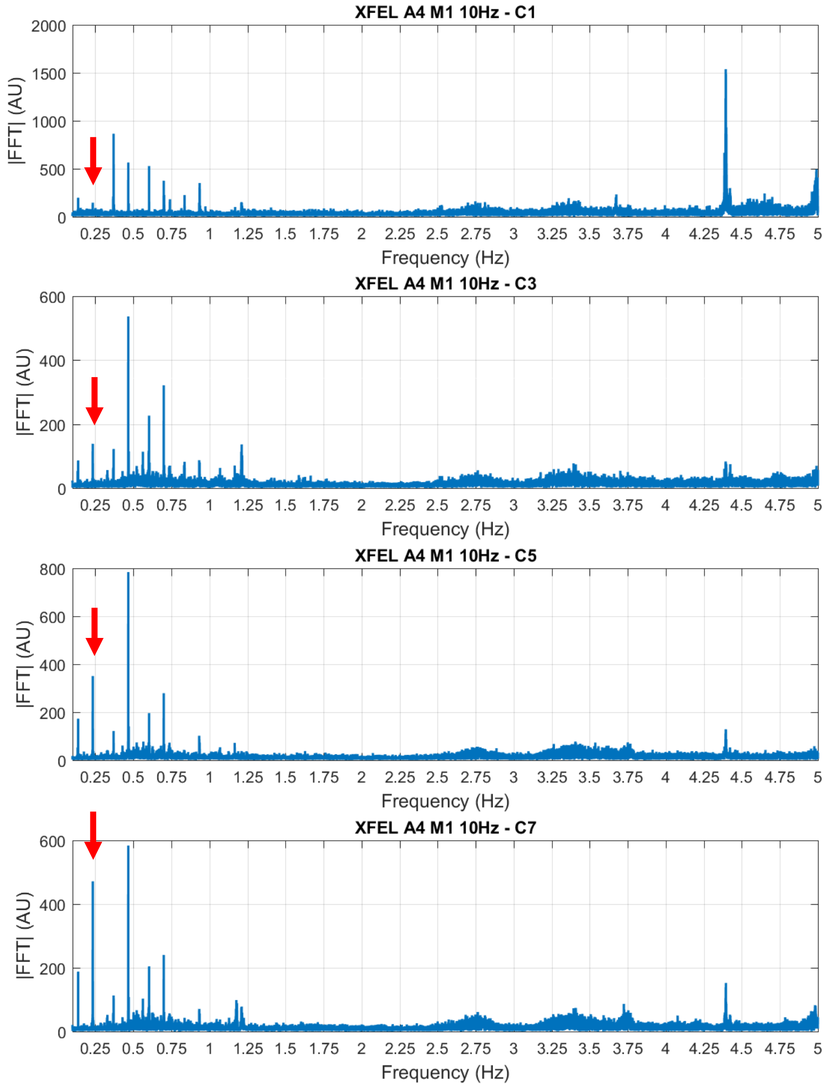
Using piezo to measure vibrations on XFEL modules

The cryogenic look into microphonics

How do we use the piezo?

- Measure the piezo voltage with a frequency of 10 Hz
- Data analysis in Matlab: FFT and, to be refined, PSD
- 3 RF stations investigated without RF
  (12 modules, 96 cavities)

- Results: ~0.2 Hz frequency well visible at almost all cavities
- Measurement repeated at different cryogenic status



Using piezo to measure vibrations on XFEL modules

Comparing different cryogenic systems

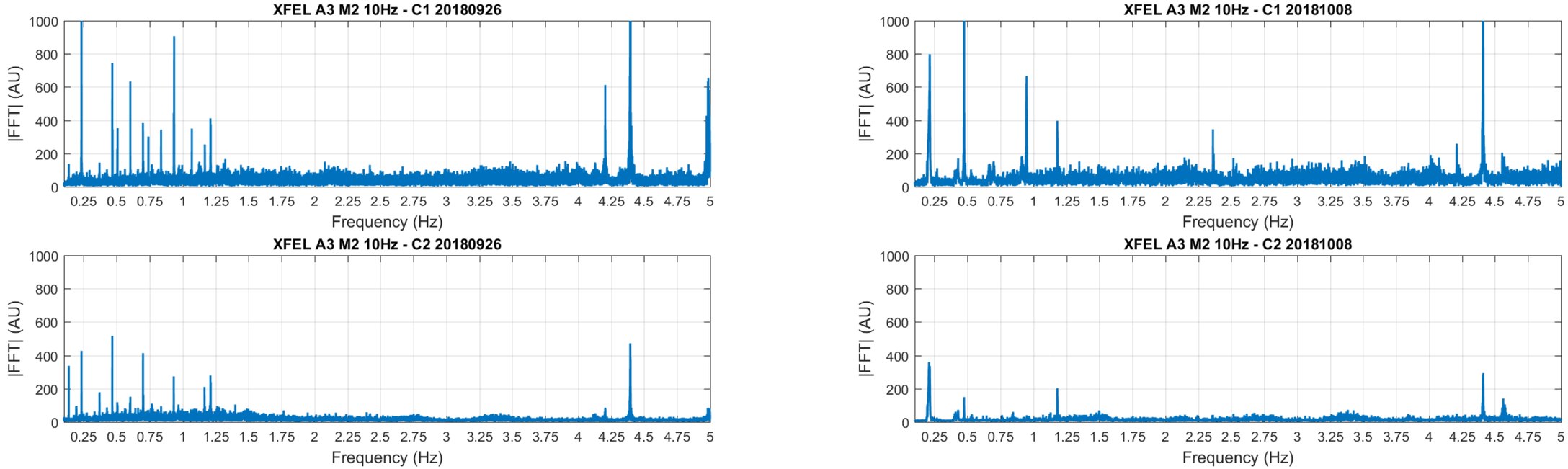
Left: **Cold Compressors**

- Direct pumping at the 2K level
- In the same building

Right: **Warm Compressors**

- Pumping of the warm gas
- In the AMTF building

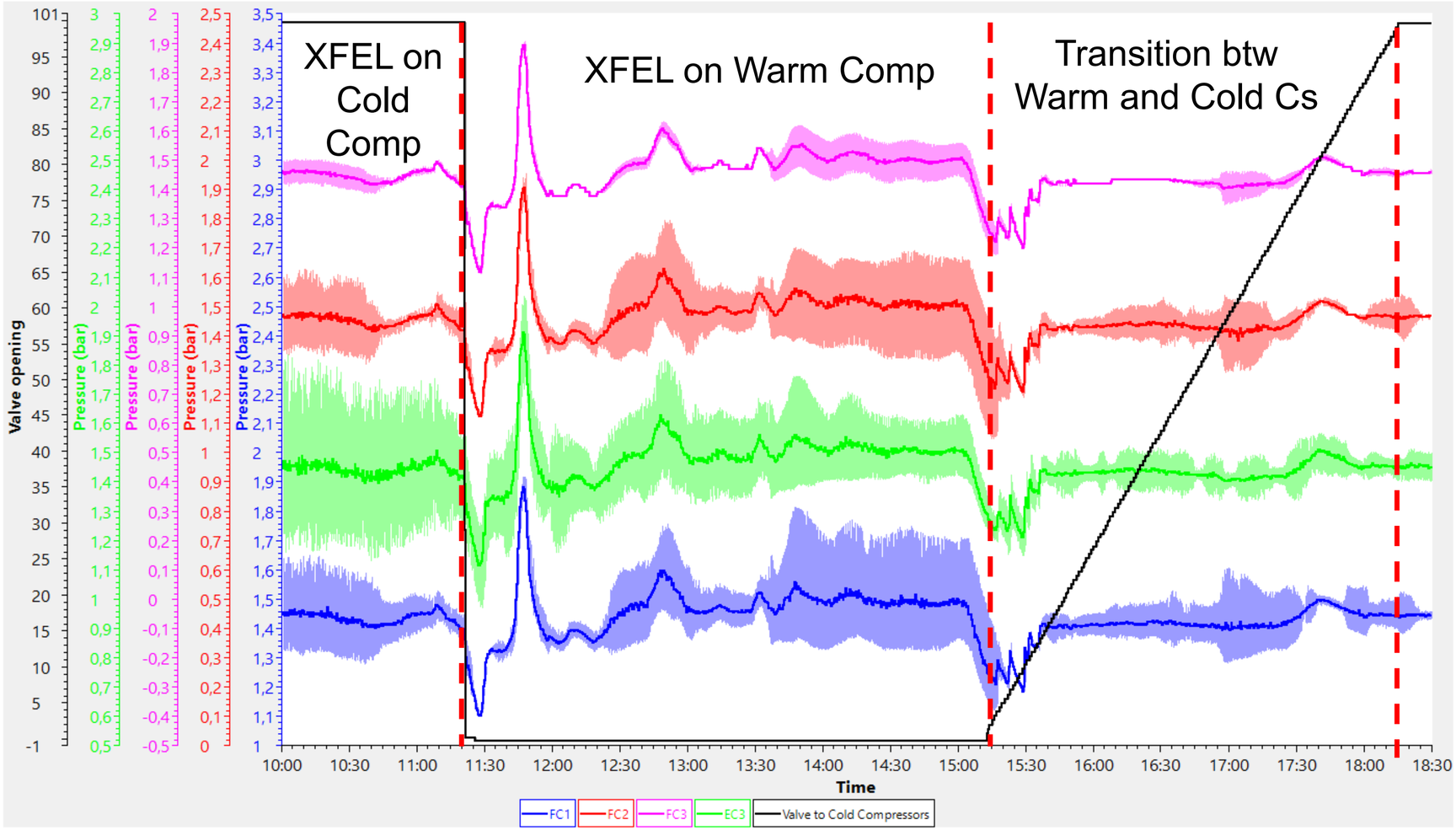
Data in the frequency domain - XFEL A3 M2



Using piezo to measure vibrations on XFEL modules

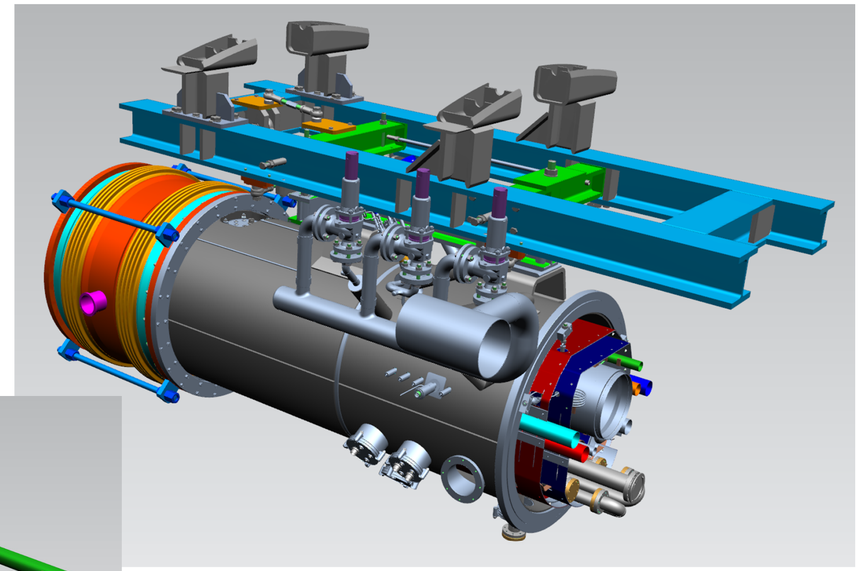
Comparing different cryogenic systems

Actually, it is much more complicated…



Using piezo to measure vibrations on XFEL modules

The cryogenic look into microphonics

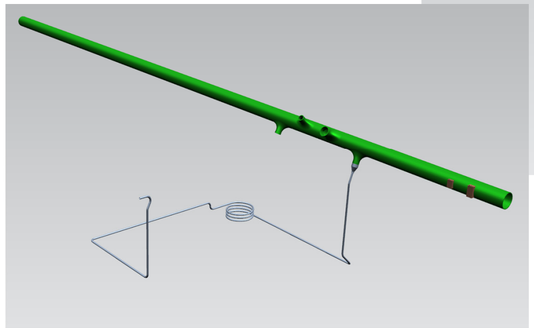


Where are we now

- We have a probable interpretation:

  Travelling wave propagating along the 2.2 K He pipe with sound velocity

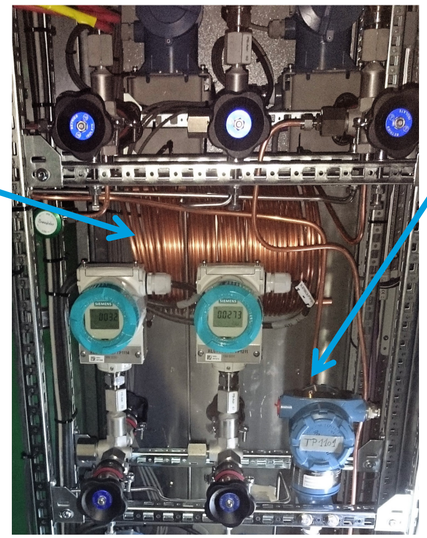
  - difficult to demonstrate
  - still missing the source



- We have an idea for the mitigation:

  Add ~20m long capillaries at the pressure sensor locations to damp the oscillations in the pipe

  - But… are we damping the oscillations in the whole pipe or only at the measuring point?



Using piezo to measure vibrations on XFEL modules

The cryogenic look into microphonics

Next steps

- Further extend the capillaries at the SCB and monitor in parallel with the nearby piezo

- Expand the use of piezo to all the XFEL RF stations as soon as the piezo drivers are available

  More systematic work: compare different module positions in a string or cavity positions in a module

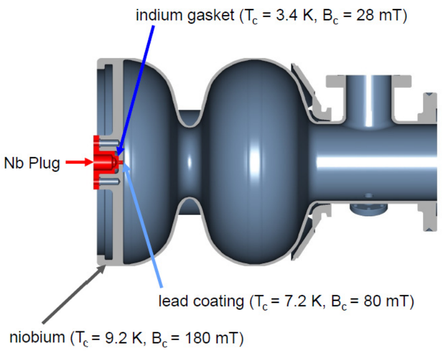
  Compare different locations along the linac -> is there a way to recognize a travelling wave?

Additional options

- Compare different cryogenic systems → CMTB - FLASH cryoplant, AMTF - XFEL cryoplant
- Compare different working conditions → AMTF - single module test stand, warm compressors
  XFEL - whole linac, cold compressors

Plans for the XFEL CW cryomodules

Plans for the XFEL CW upgrade



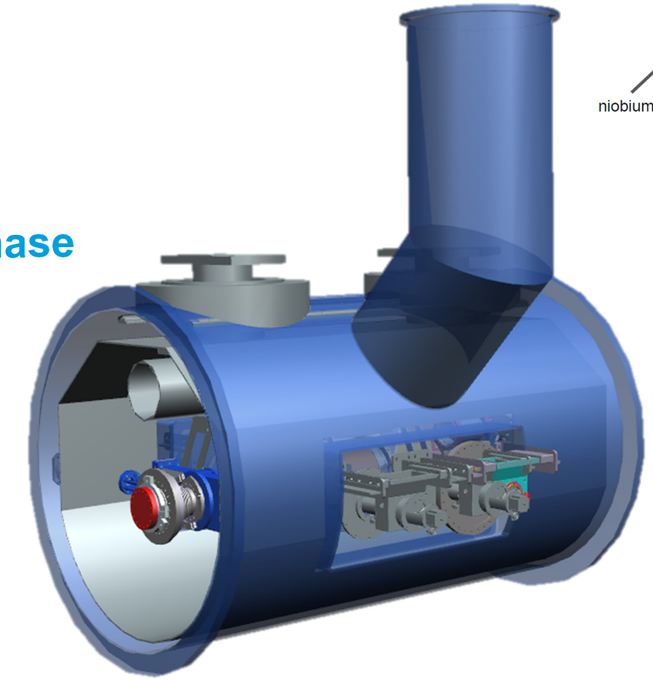
CW R&D program at DESY for the XFEL CW upgrade

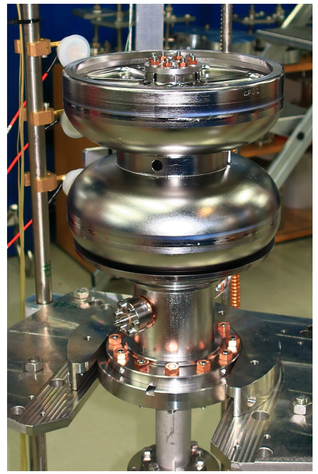
- CW-SRF Gun being developed at DESY

  new cryomodule design needed

  reduction of microphonics as parameter during the design phase

  test cryomodule → can be used for optimization





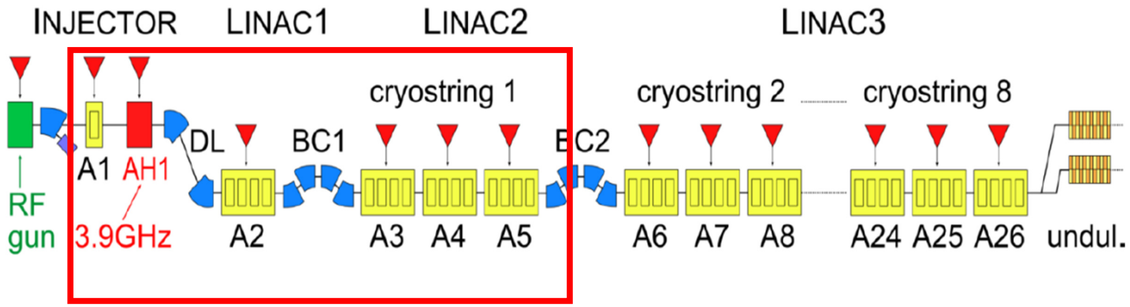
- Design of CW 1.3 GHz cryomodules

  Need of design changes at the cavity tank level (at least)

  Possibility of design modifications on the whole cryomodule

  Implement lessons learnt at LCLSII

  Implement lessons learnt from vibration studies



Replace with CW components

Plans for the XFEL CW upgrade

In the near future

- Fully characterize a 1.3 GHz XFEL cryomodule

  AMTF test stand available -> warm and cold, with and without RF

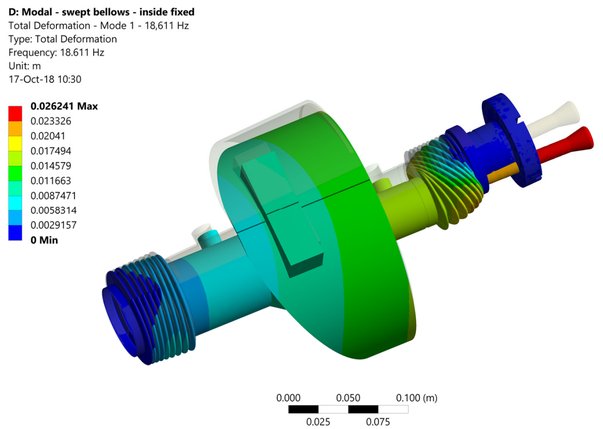
  Module available

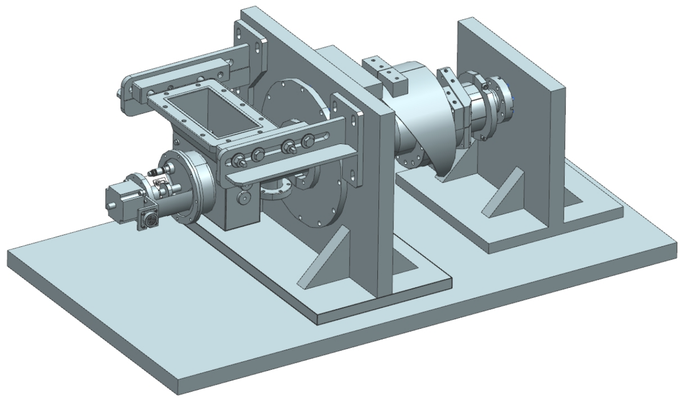
  Sensors available (piezo and geophones), acquisition system and data analysis need to be improved

- Compare results with calculations / simulations / …

  Look for possible design optimization

  Detailed analysis of subcomponents (couplers →)





Conclusions

What did I learnt so far

Lot of work done at DESY on vibration measurements

- At different facilities
- From different groups
- With different scopes

What's missing

- A comprehensive look on the microphonics issue at the cryomodule level
  - Separate contributions from the cryomodule itself or the environment
  - Design optimization
- Coordination between RF / control requirements and mechanical aspects

Thank you

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Serena Barbanotti
MKS Group
serena.barbanotti@desy.de
+49 40 8998 5628