Characterization of the dynamic performance of DCMs at Alba

Josep Nicolas
Juan Carlos Martínez
Jordi Juanhuix
Marta Llonch
Jon Ladrera
Carles Colldelram

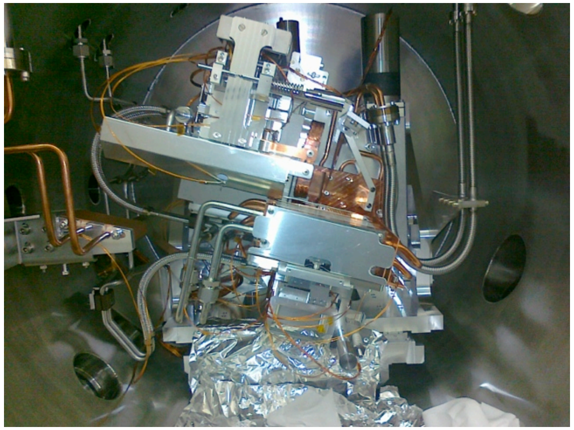
Characterization of the dynamic performance of DCMs at Alba

Josep Nicolas
Juan Carlos Martínez
Jordi Juanhuix
Marta Llonch
Jon Ladrera
Carles Colldelram

1. DCMs at Alba, standard motion performances
2. Vibration measurements
- *Instruments*
- *Applications*

3. A case of mechanical noise

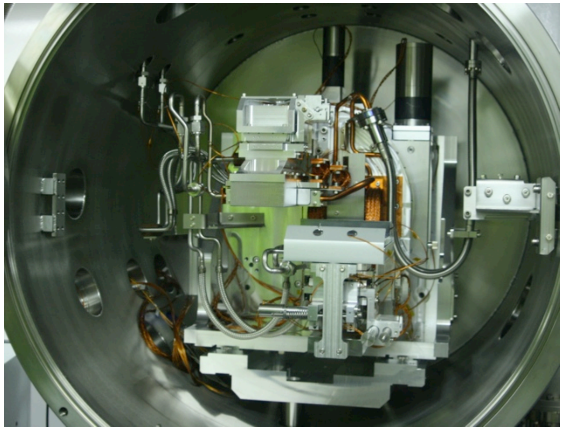
DCMs at Alba



BL04-MSPD

Powder diffraction BL
Super conducting wiggler
Si(111)
8-50 keV
Cryogenically cooled

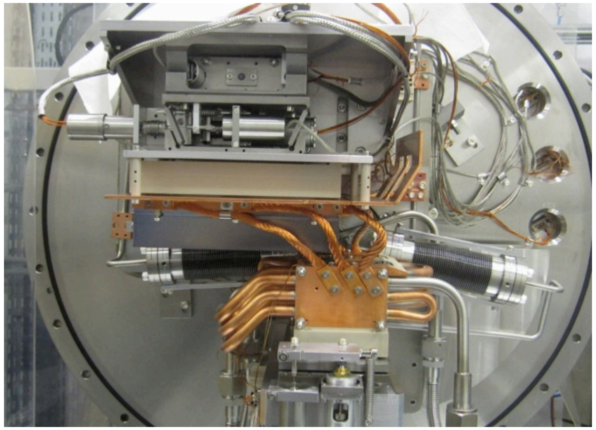
Bragg axis: Stepper
Piezo for fine X2 pitch



BL11-NCD

SAXS/WAXS beamline
In vacuum undulator
Si(111)
6-15 keV
Cryogenically cooled

Bragg axis: Stepper
Piezo for fine X2 pitch



BL22-CLAESS

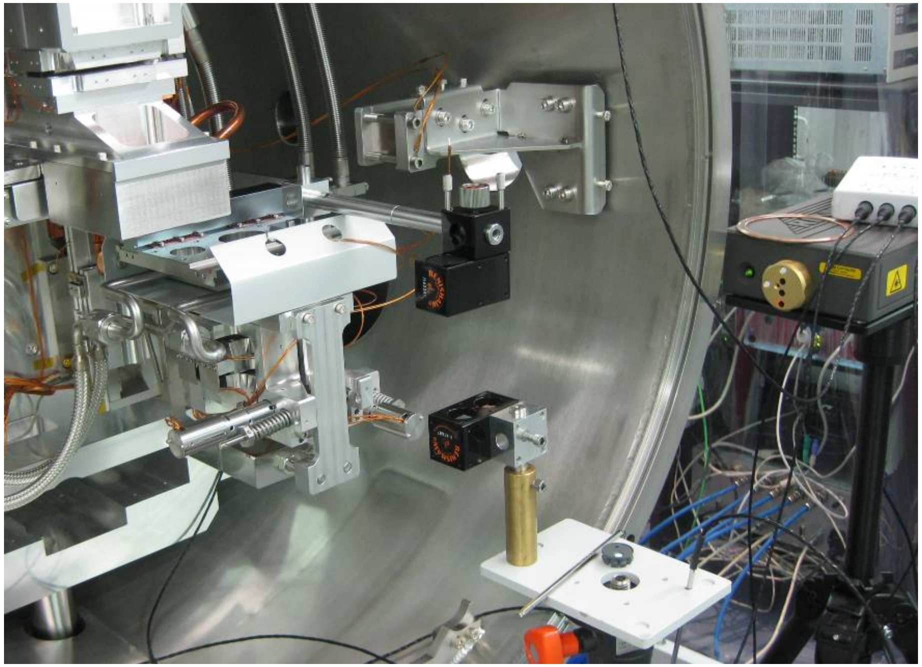
Absorption Spectroscopy
Wiggler
Si(111) Si(311)
6-50 keV
Cryogenically cooled

Bragg axis: Servo, Direct drive
Piezo for fine X2 pitch

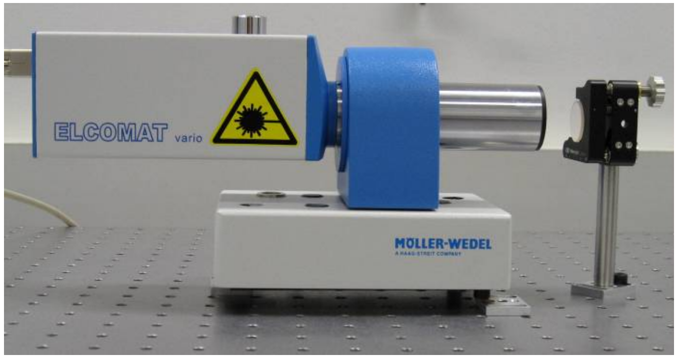
Metrology

As for other BL components, we perform motion metrology tests of DCMs as part of the acceptance process.

- Standard instruments: Differential interferometer, Autocollimator
- We use standard metrology routines (several full stroke cycles) as well as specific ones.
- We develop and use specific data analysis routines.



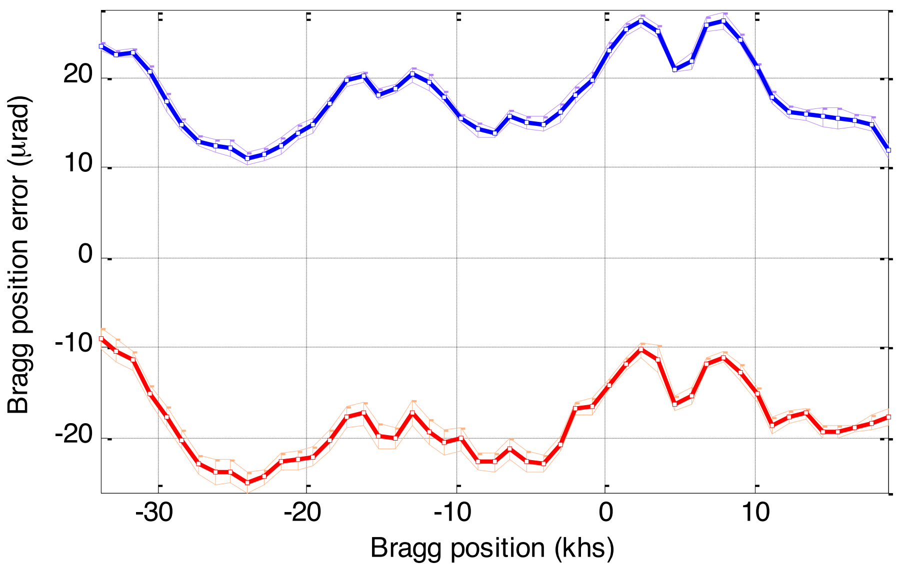
We aim for:
Resolution,
Repeatability,
Backlash,
Linearity of motions,
Stability,
Crosstalk between motions
… Vibrations



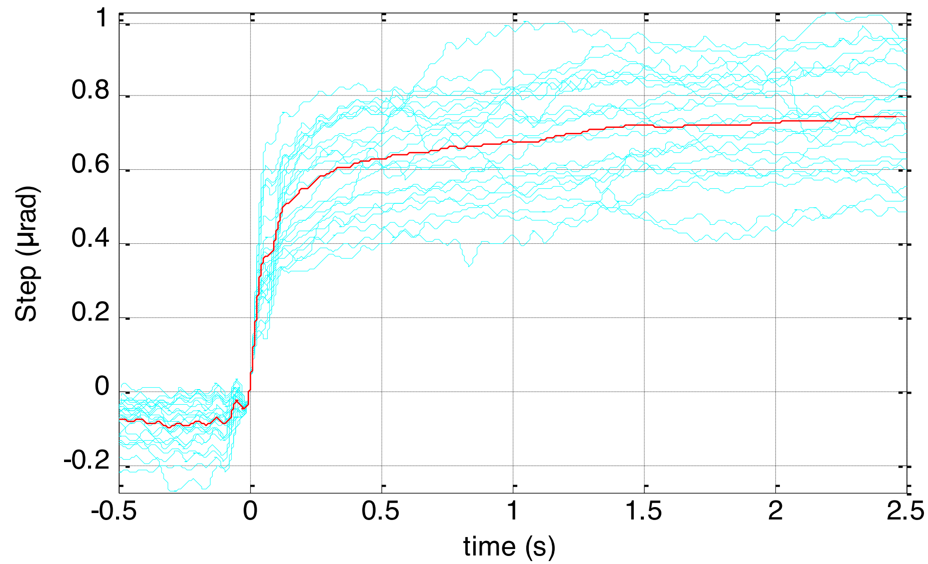
Motion performance

In general, the systems respect specifications and have good mechanical performances:

Position error, MSPD, Bragg axis



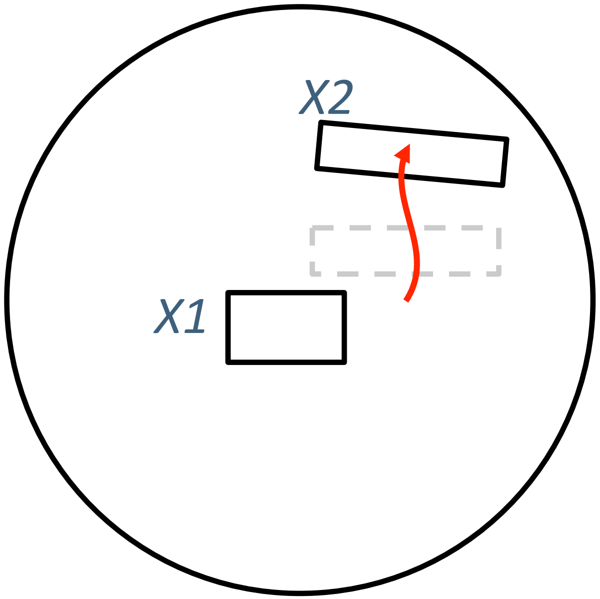
Step profile, MSPD, Bragg axis



Parameter	Unit	Motor	Encoder
Average resolution	µrad/ct	0.870	0.24
Backlash/Hysteresis	µrad	36.11	3.14
Repeatability	µrad	0.91	0.68
Linearity	µrad	15.93	9.17

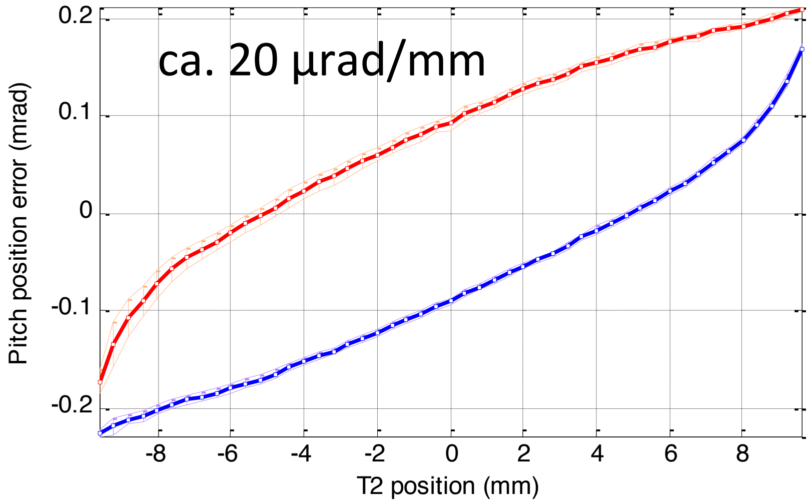
Motion performance

… but crosstalk between motions is not so good.

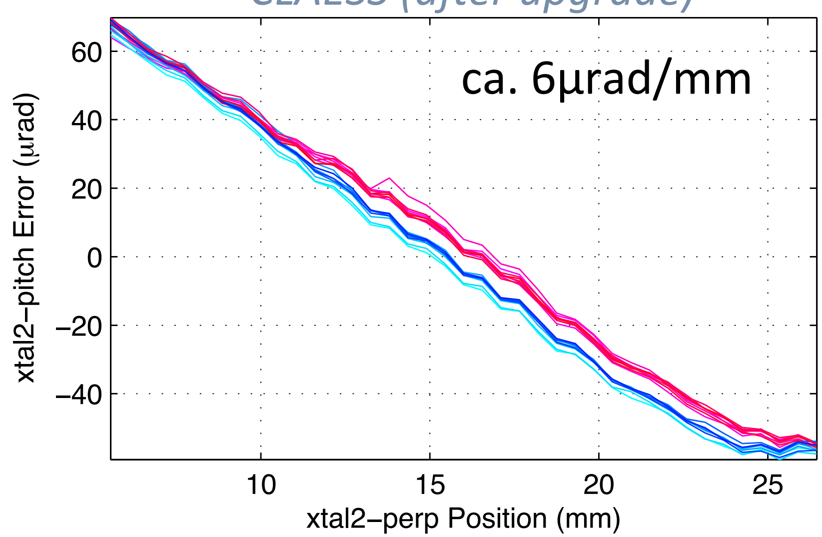


Usually, parallelism between crystals is lost when changing the gap between them.

MSPD

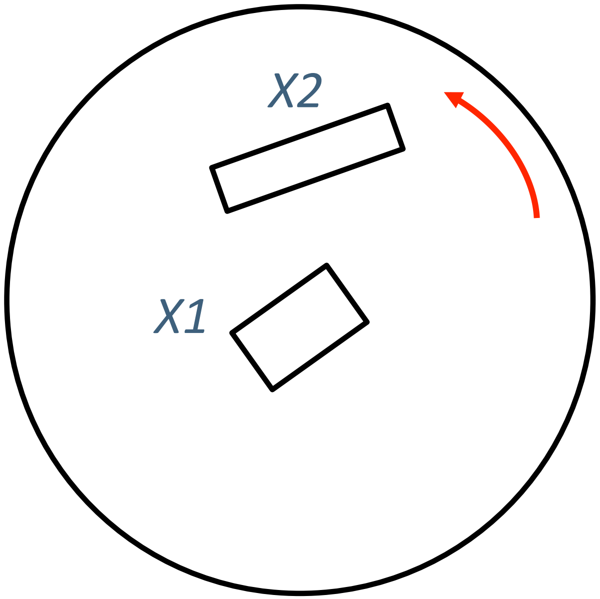


CLAESS (after upgrade)

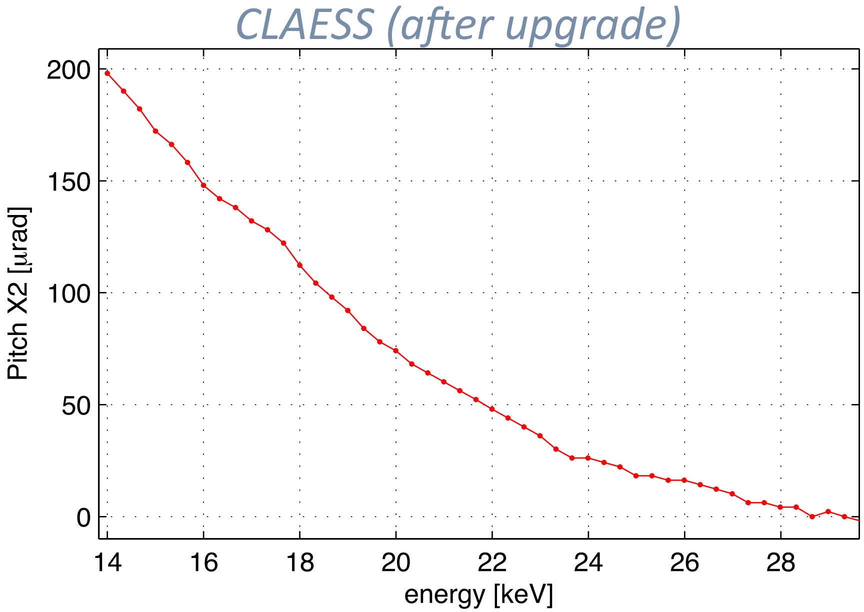


Motion performance

… but crosstalk between motions is not so good.



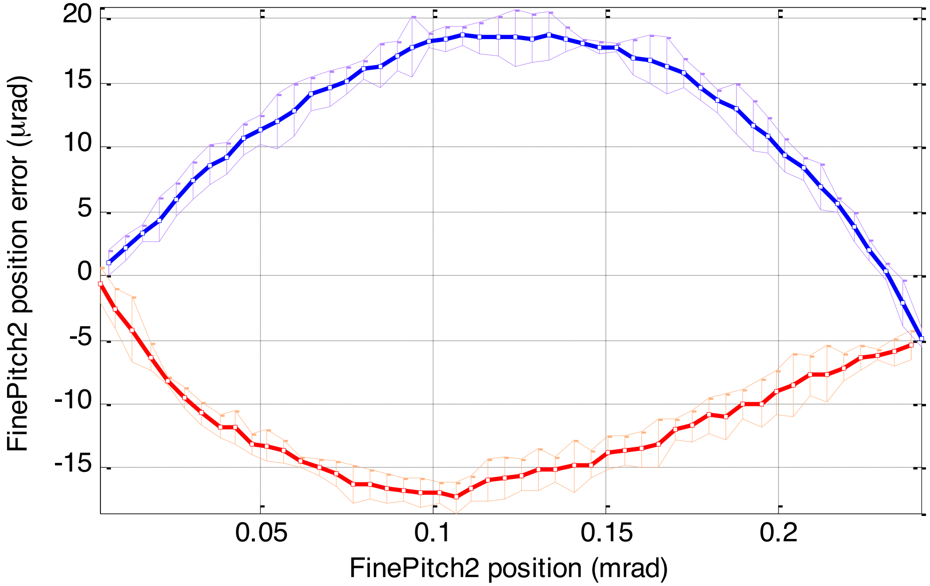
Parallelism between crystals is also lost when scanning the Bragg angle

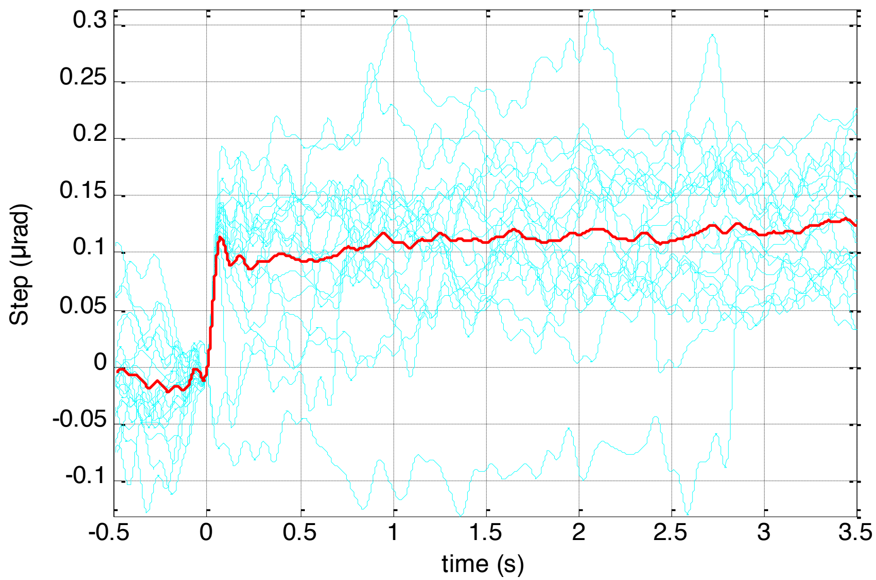


Position of the peak of the rocking curve vs photon Energy

Motion performance

In some cases, this can be compensated by a piezo-actuated fine pitch

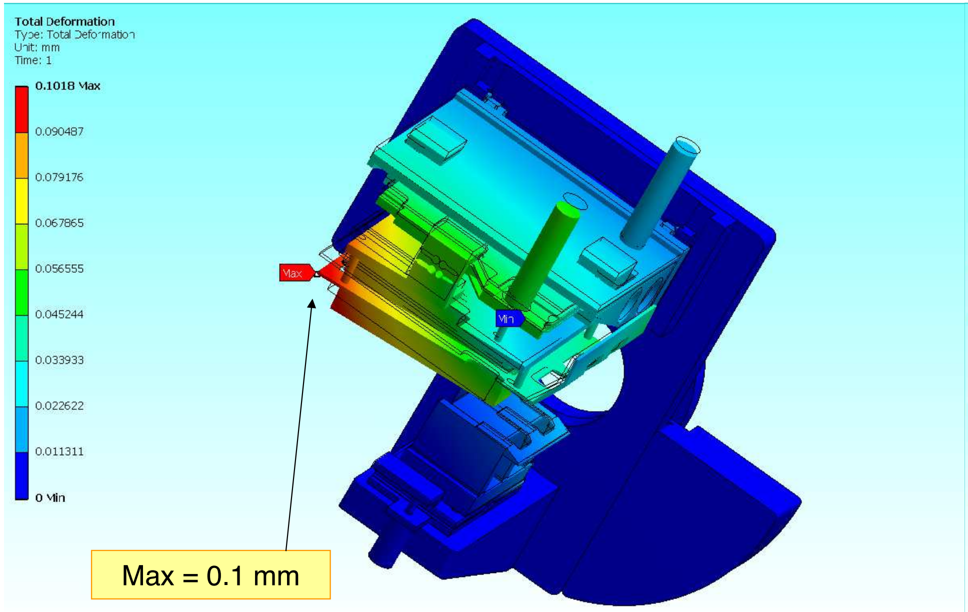




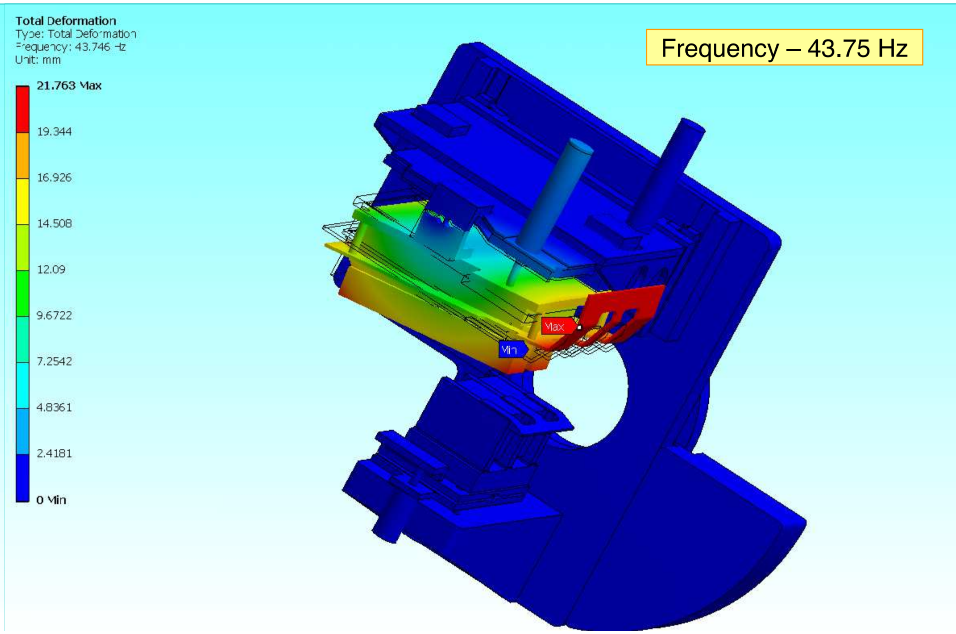
Parameter	Unit	Motor
Explored length	µrad	230
Average resolution	µrad/mV	0.01225
Backlash/Hysteresis	µrad	23.57
Repeatability	µrad	1.37
Linearity	µrad	23.61

Stiffness problem

- The presence of angle adjustment tables limits the stiffness of the crystal cages.
- This is detrimental also for the vibration stability of the monochromator.
- Systems are sensitive to mechanical noise coming from: ground, cooling, motion.
- Resonances at about 40 Hz are usual.

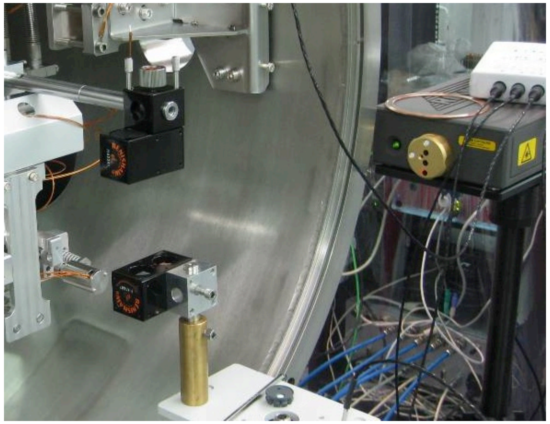


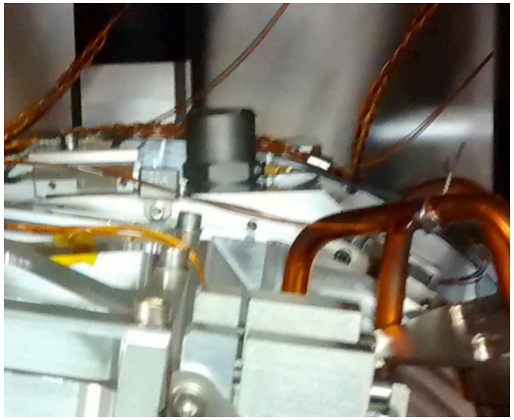
CLAESS
Static deformation of the second crystal cage (gravity)

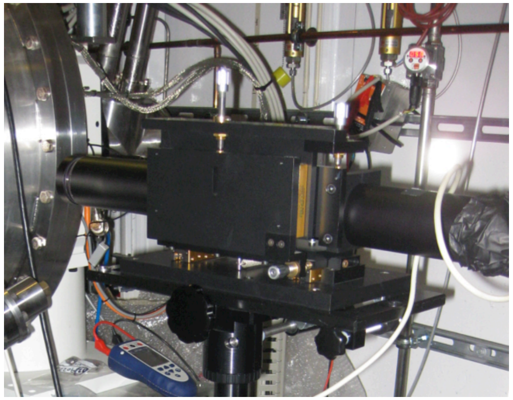


CLAESS
First resonance frequency (pitch of X2)

Vibration metrology







Differential interferometer

- ☺ High sensitivity
- ☺ Clean spectrum
- ☺ Amplitude
- ☹ One axis only
- ☹ In-air only
- ☹ Weight of target

➔ ***Following error***

Accelerometers

- ☺ Easy setup
- ☺ Several axes
- ☹ Acceleration
- ☹ In-air only
- ☹ Weight of sensor

➔***Diagnostics***

Fast Deflectometer

- ☺ In air or in vacuum
- ☺ No weight on optics
- ☹ One axis only
- ☹ Trace on spectrum

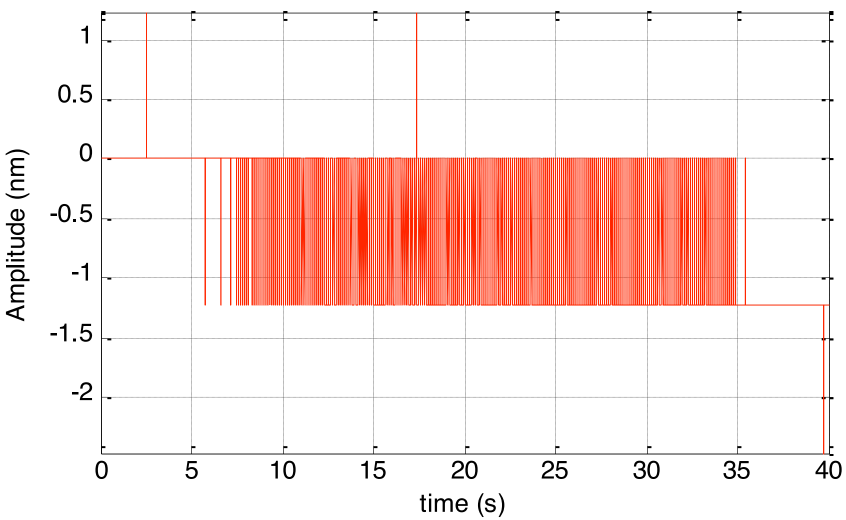
➔ ***Cooling-induced vibrations***

Interferometer

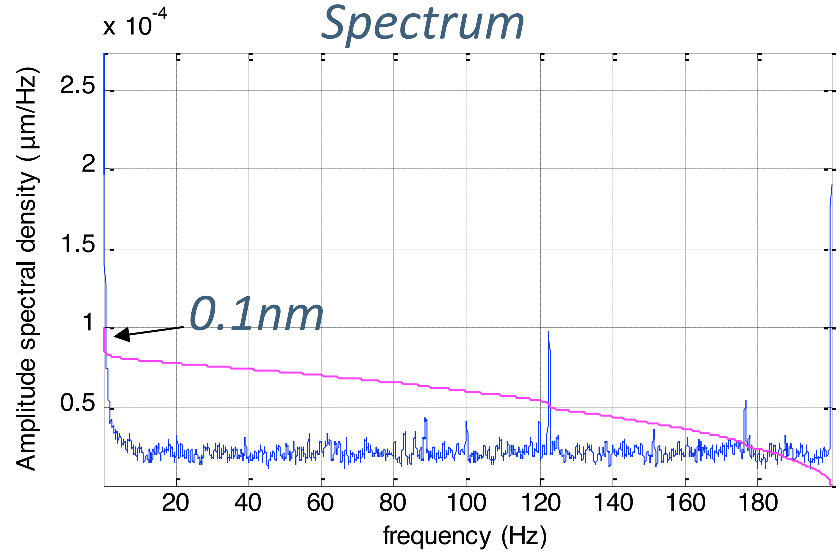
The differential interferometer provides a high resolution and high sampling rate measure of the position (or angle) variation.

Parameter	Value
Resolution	1 nm
Noise	<0.1 nm
Sampling rate	5 kHz

Stability test of the interferometer



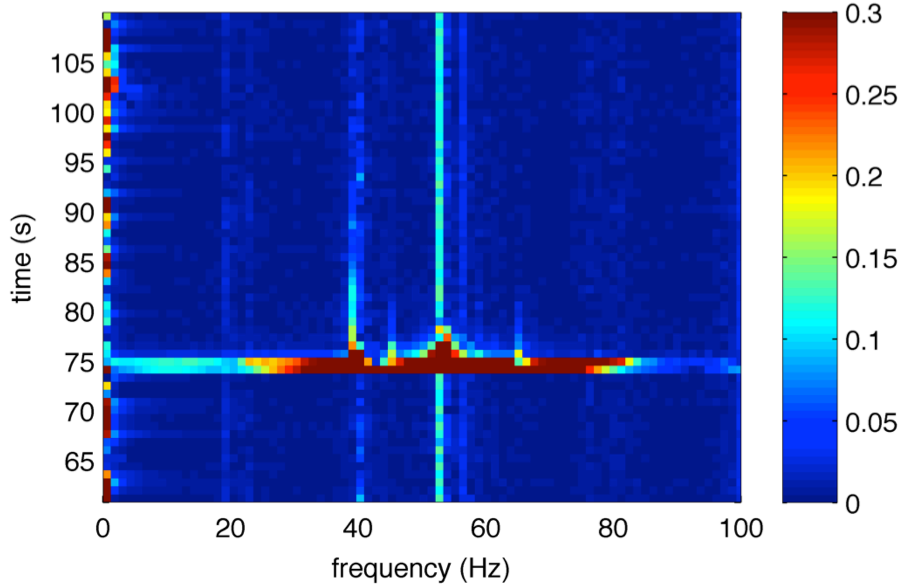
Spectrum

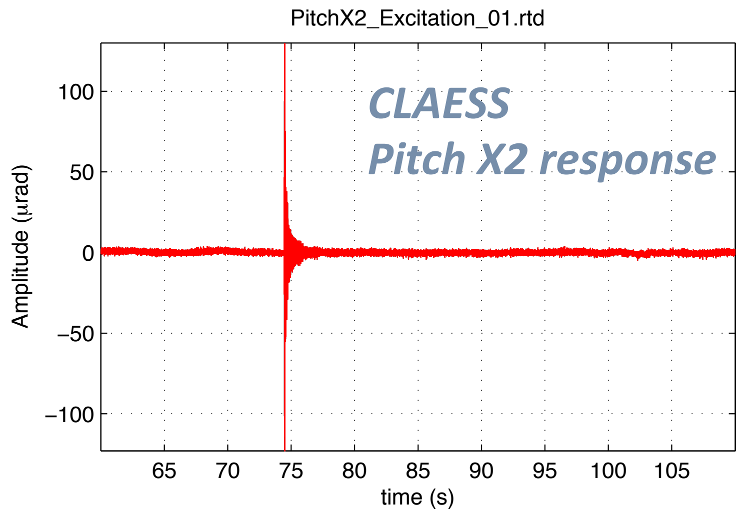


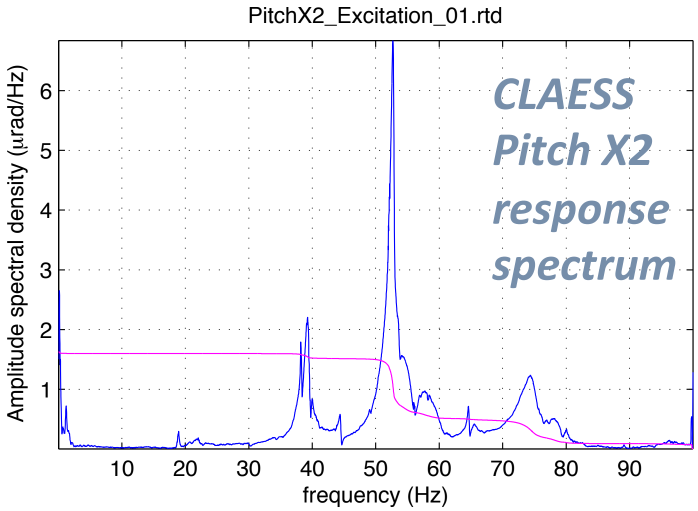
Interferometer

Resonance frequencies are easy to find by exciting the hardware with a hammer, and measuring the spectrum of the response.

Other frequencies that may be present, are normally too weak in comparison

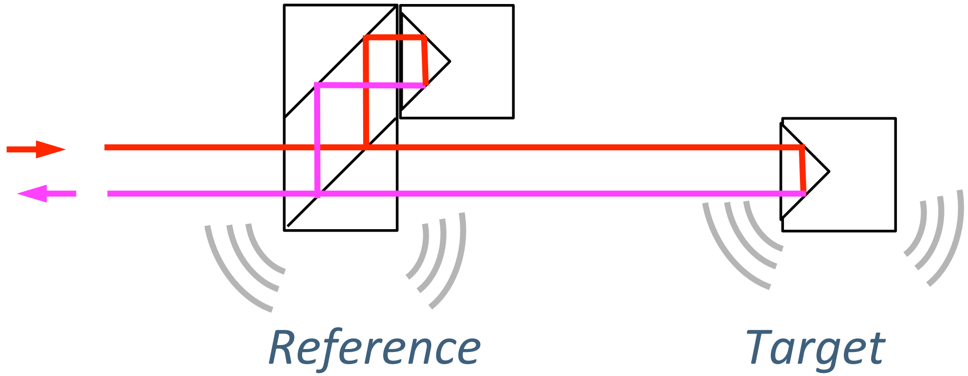


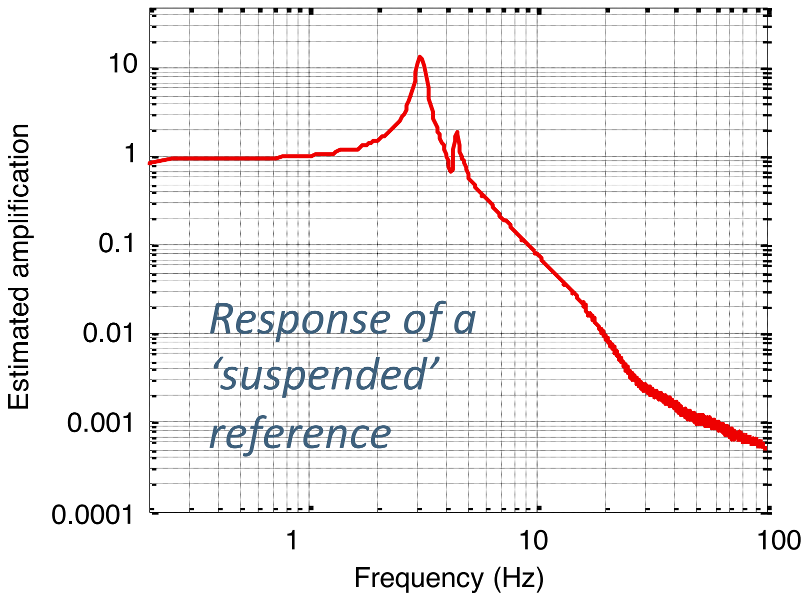




Measuring amplitudes

The interferometer measures motion relative between reference and target. The contribution to the noise by the reference must be identified/filtered, before amplitudes can be measured.



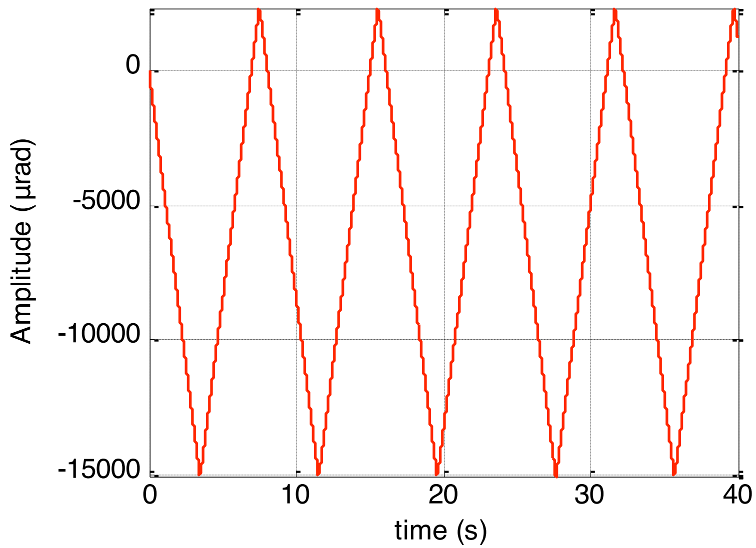


By suspending the reference on weak springs one gets clean spectrum for mid-high frequencies, so one can measure amplitudes of vibrations.

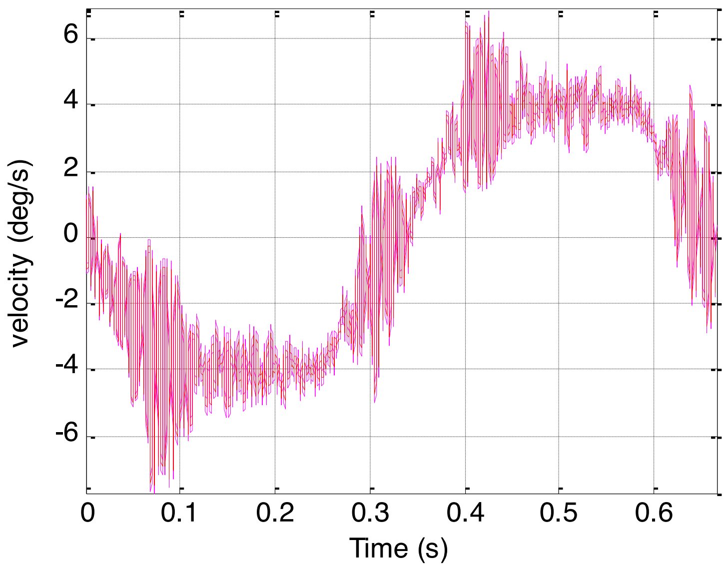
$$Z(u_C) = \sqrt{2\Delta u^2 \sum_{u=u_C}^{u_{Max}} \left|FT[f](u)\right|^2}$$

Following errors

The interferometer allows measuring following error as well as obtaining the amplitudes of the corresponding position errors.



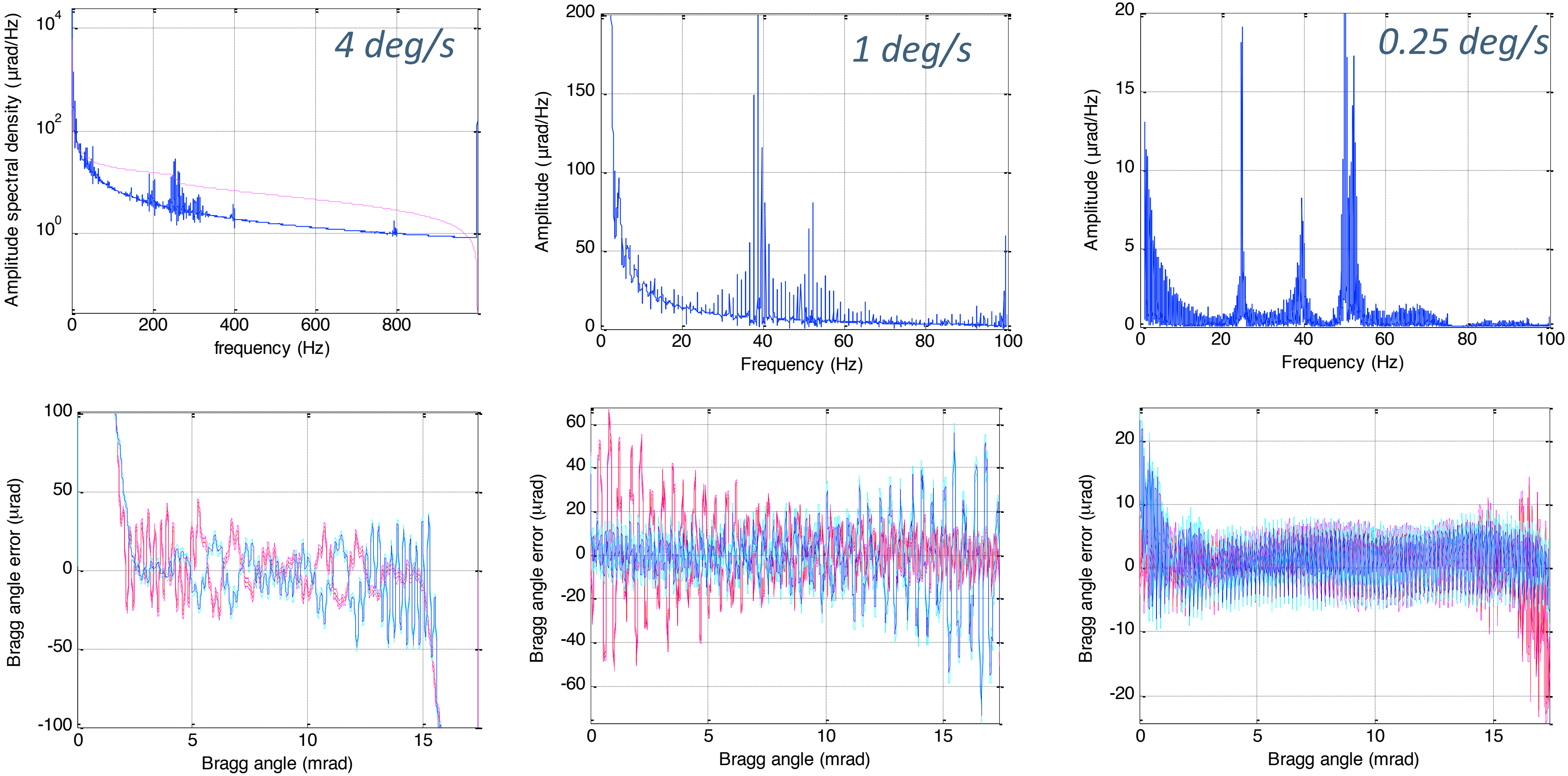
Motion sequence programmed at the CLAESS monochromator to quantify the following error



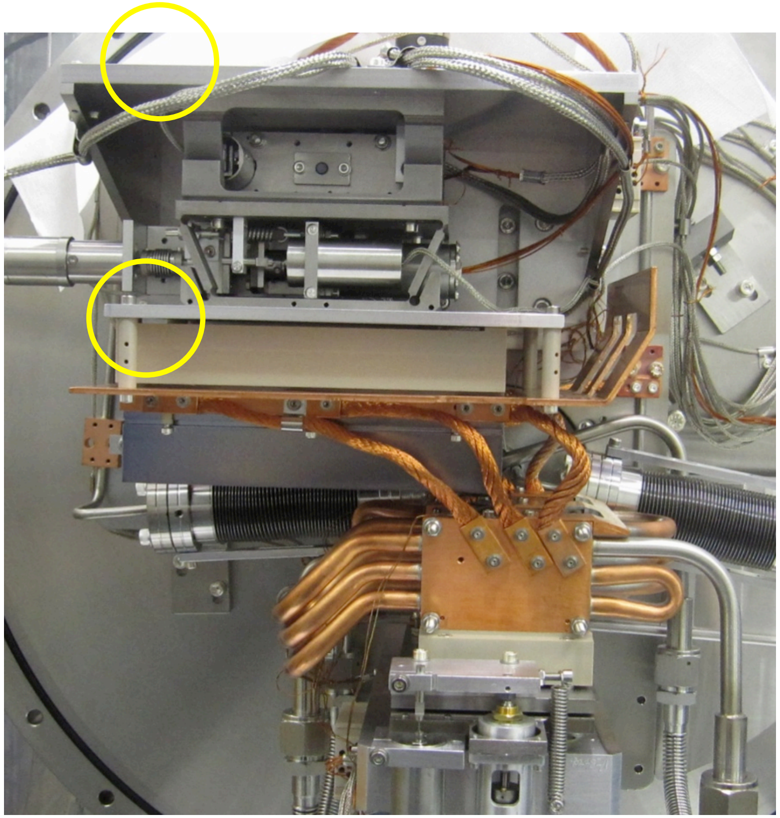
From the velocity pattern one can already see that there are some resonances being excited

Following error

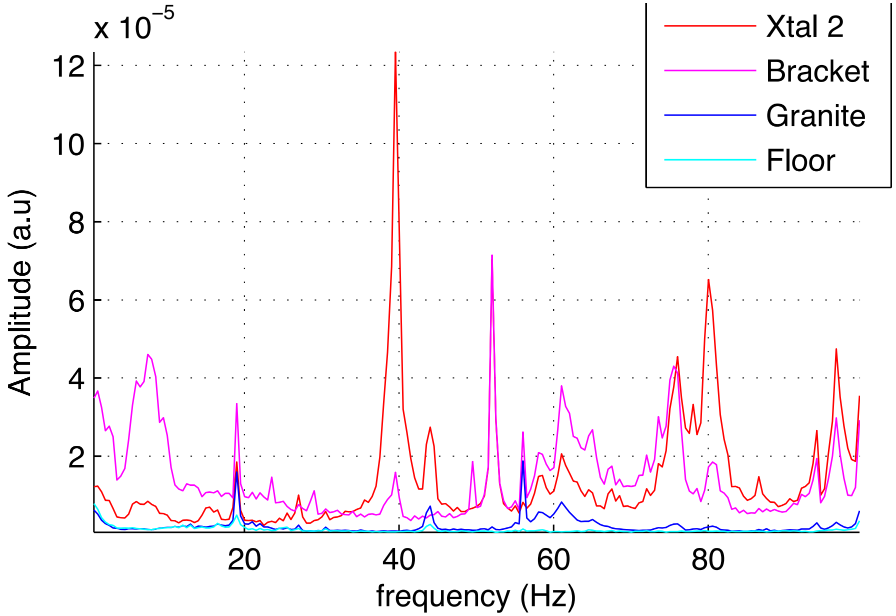
The CLAESS monochromator requires high speed, to do Quick EXAFS scans. At 1 deg/s, resonances of the second crystal cage are excited.



Accelerometers



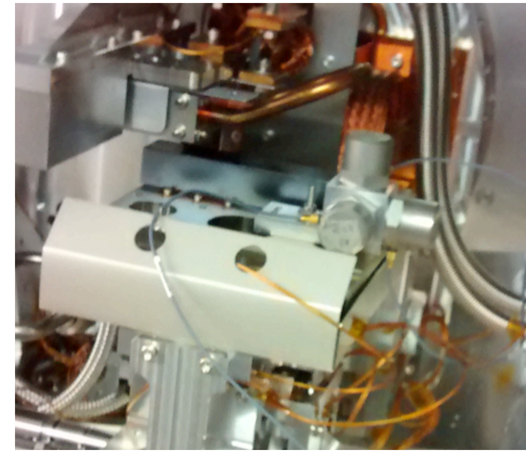
Accelerometers do not allow obtaining amplitude, but they can be easily installed and allow comparing the spectra at different positions.

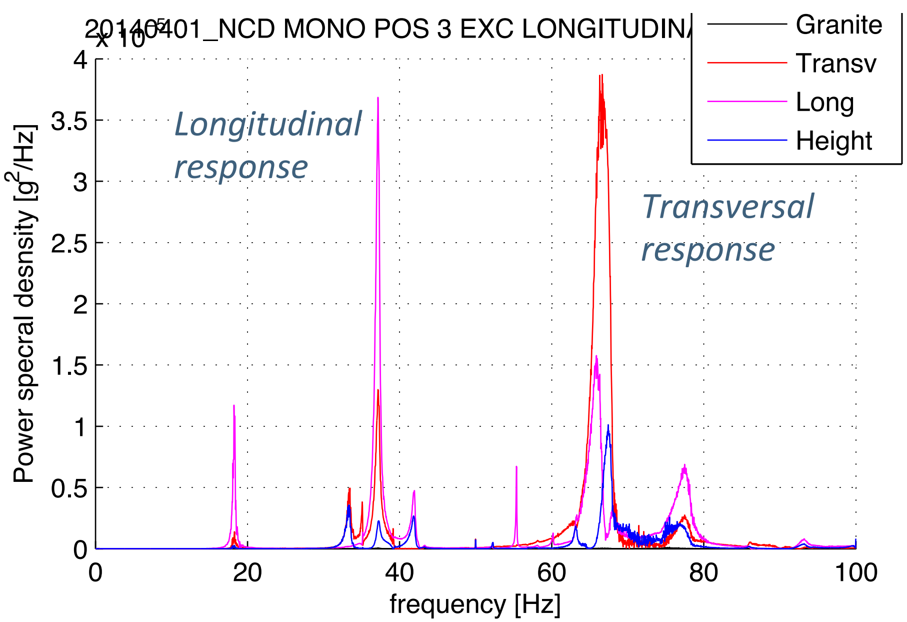


Resonance at 40 Hz is on Xtal 2 only,
Resonance at 55 Hz present at the bracket

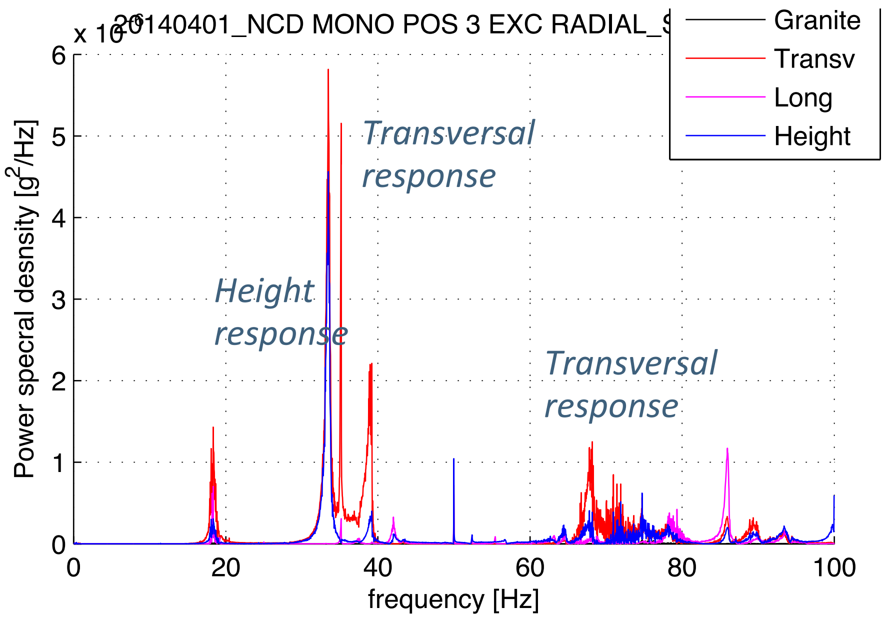
Accelerometers

They can be placed also in different directions





Response to a Longitudinal excitation

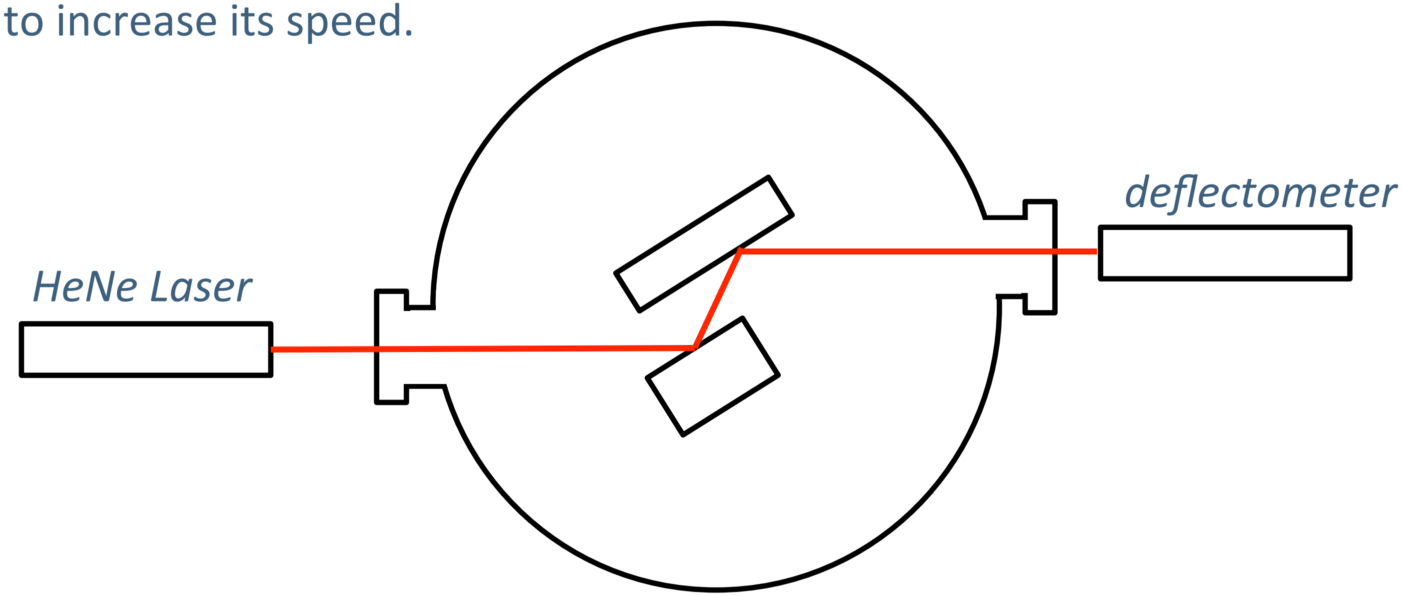


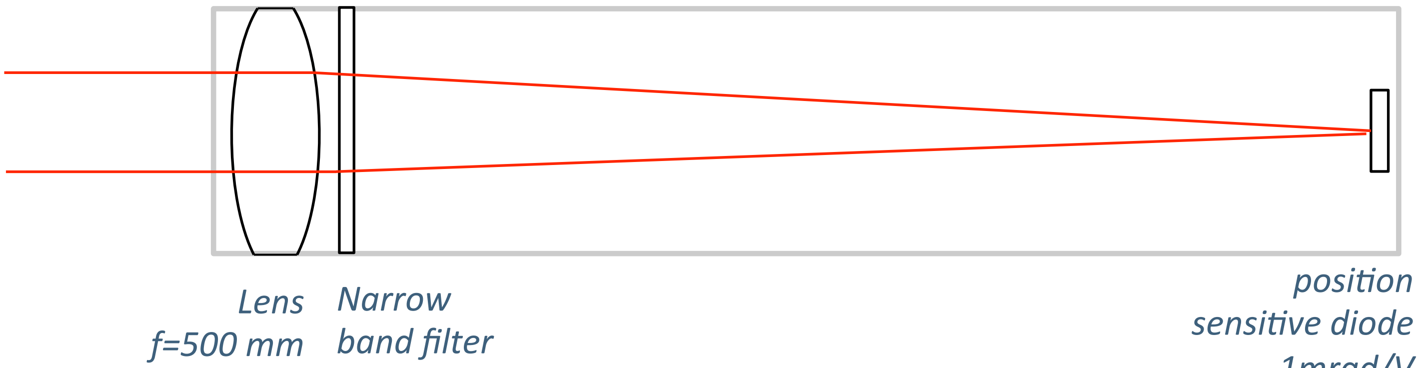
Response to a Transversal excitation

In-vacuum measurements

To allow measuring the response to vibrations induced by the cryogenics, we have built a fast deflectometer, which allows us measuring in-vacuum.

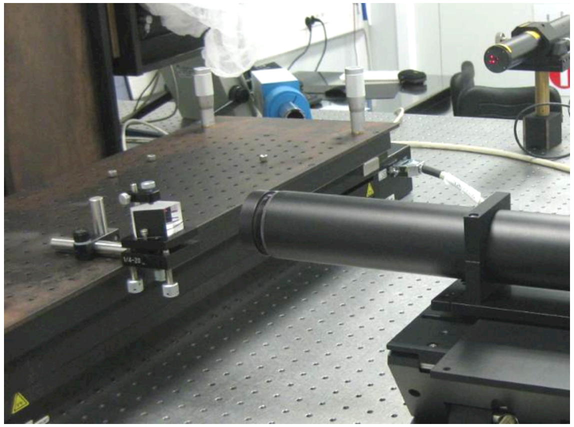
The system follows the same concept as an autocollimator, but it uses a PSD instead of a camera to increase its speed.

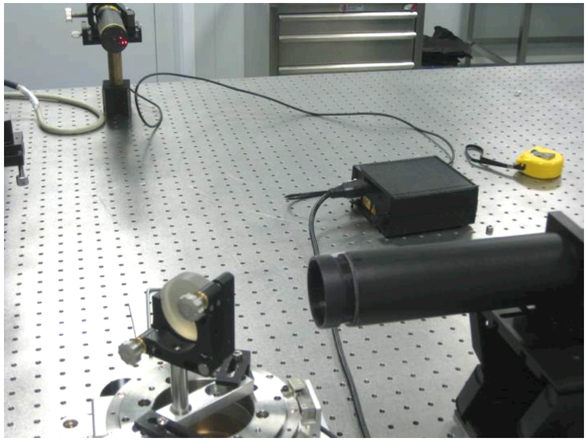




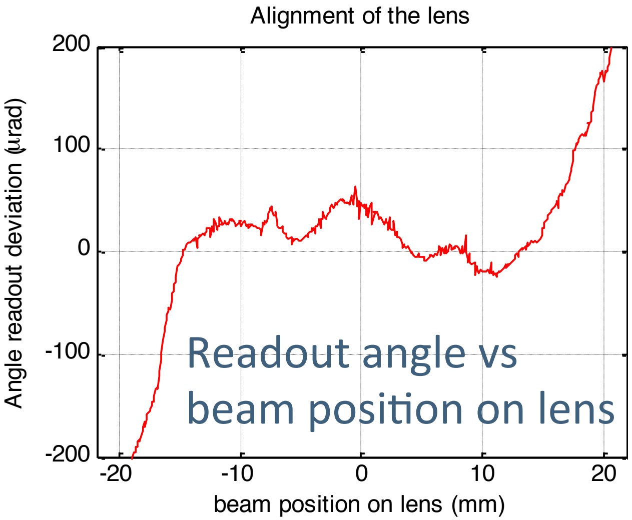
Fast Deflectometer

The deflectometer was aligned and calibrated in the optics lab against a goniometer.

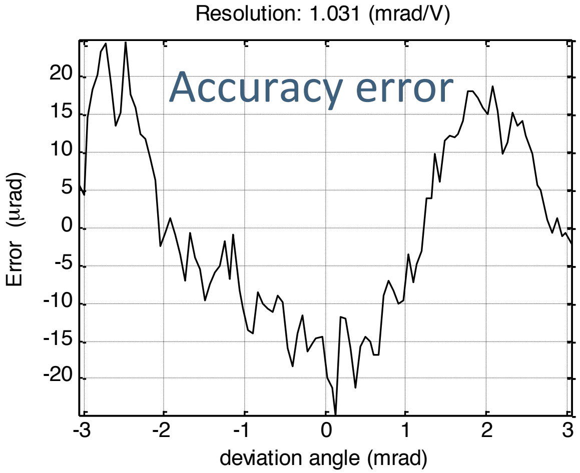




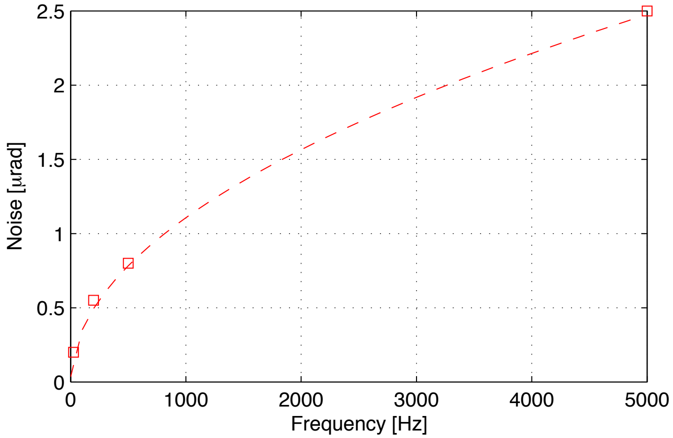
It can detect amplitudes of 1 μrad to frequencies below 800 Hz



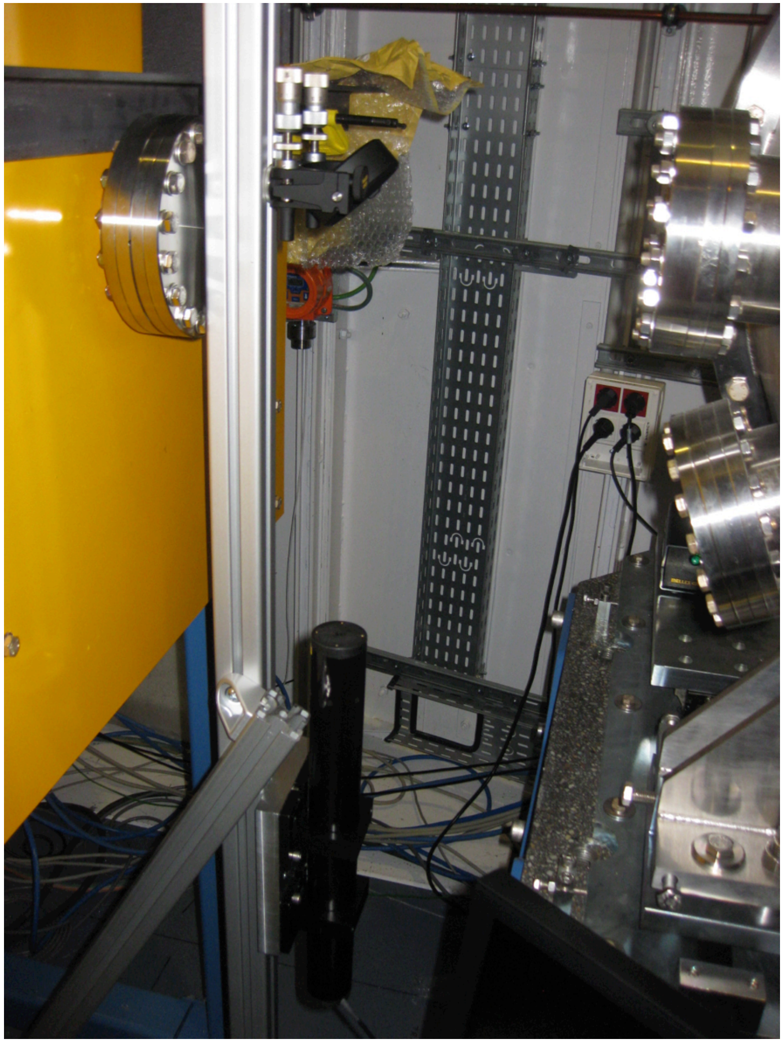
Readout angle vs beam position on lens

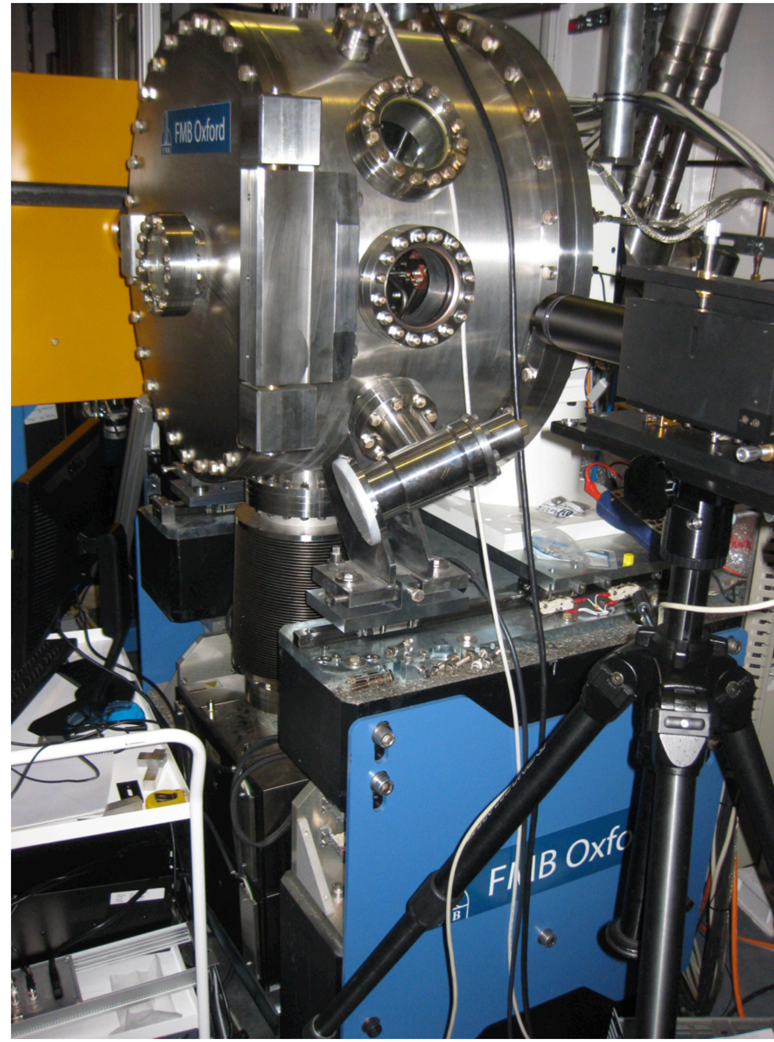


Accuracy error



In-vacuum measurements

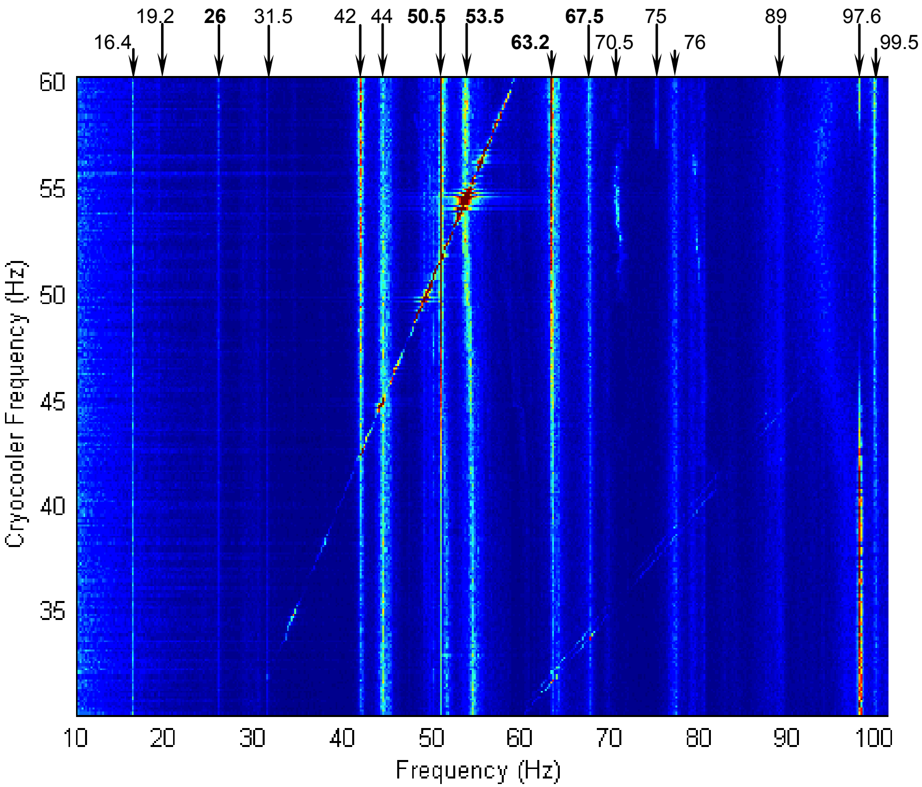




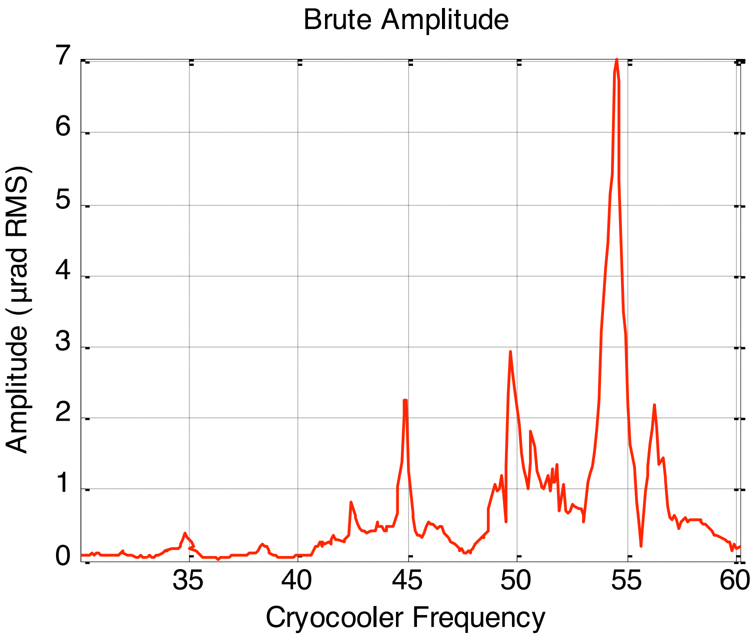
In-situ measurements

With the system in vacuum, we can measure the response of the mono (in terms of parallelism of the crystals) to the different cryocooler pump frequencies.

CLAESS monochromator

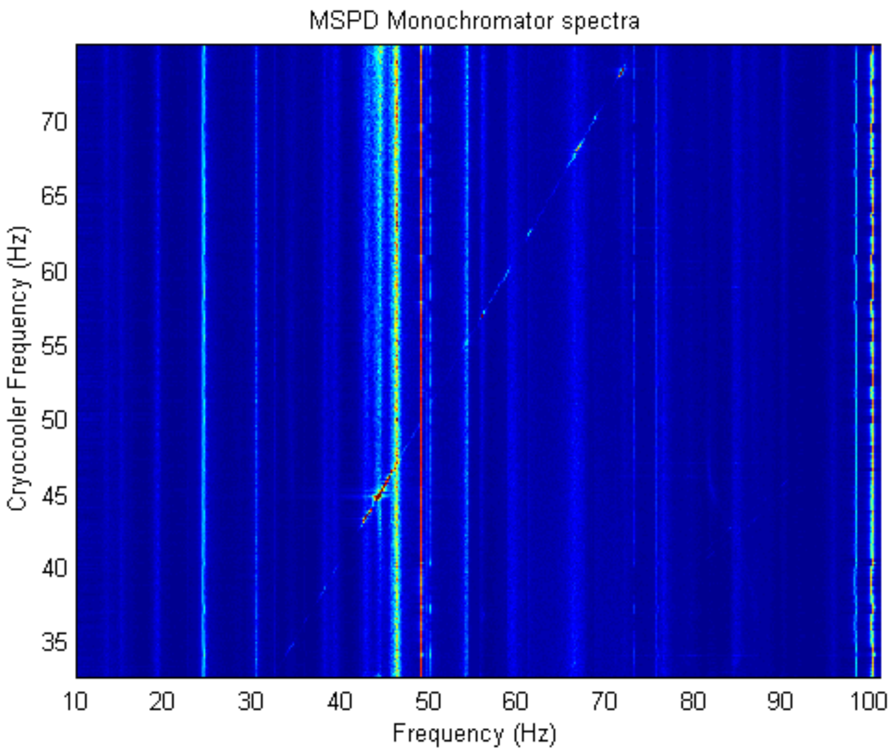


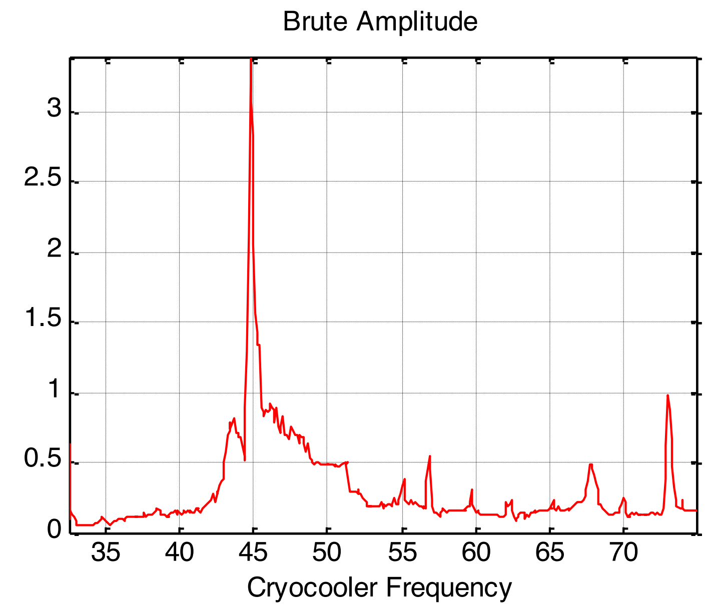
The amplitude of the system is very high when the 53 Hz resonance is excited.



Cryocooler scans

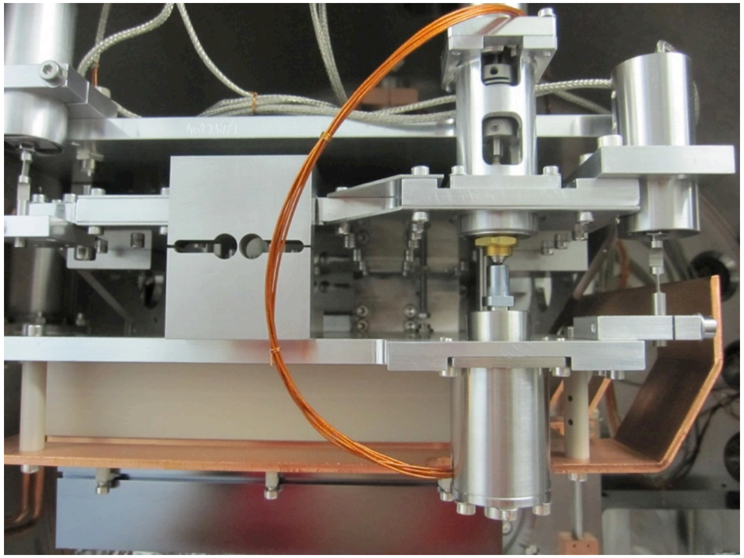
The MSPD monochromator is more robust to mechanical noise induced by the cryocooler



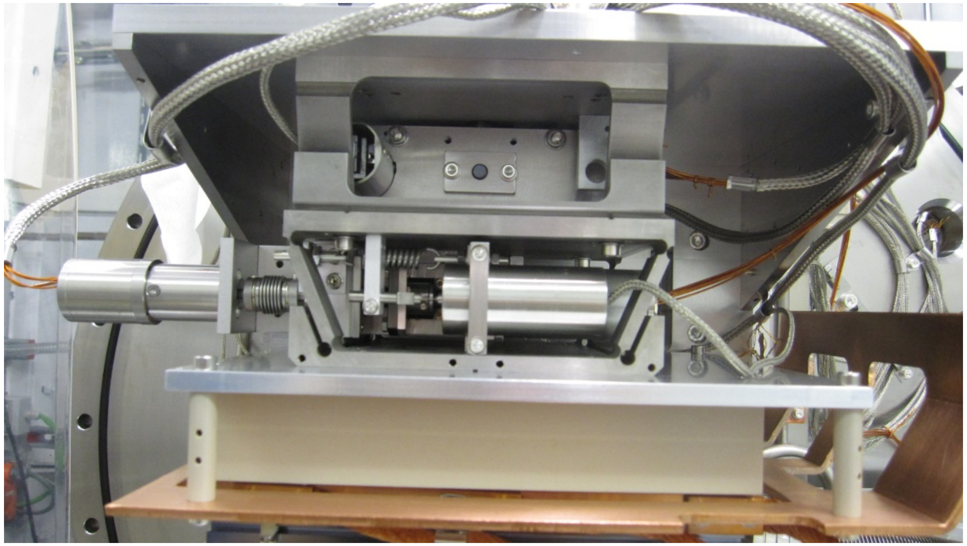


Crystal cage upgrade

The 2nd crystal cage of the CLAESS monochromator was upgraded in 2012



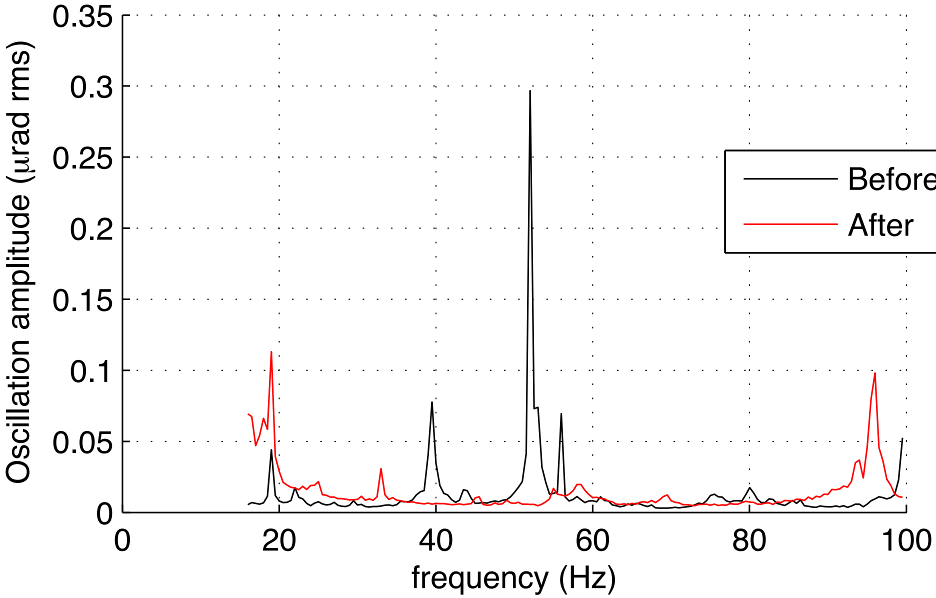
Old system, with single flexure hinges.

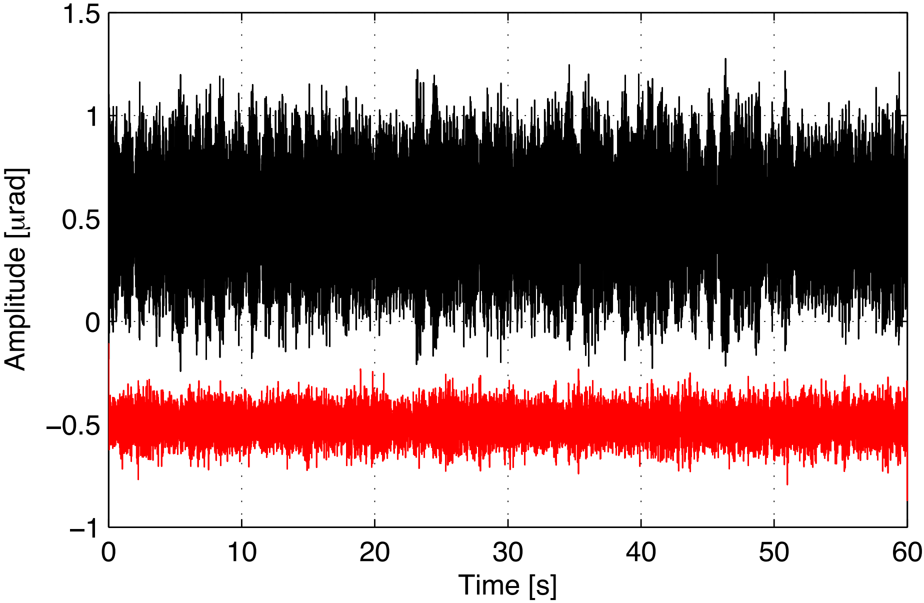


Upgraded system, with double flexure hinges.

Crystal cage upgrade

The 2nd crystal cage of the CLAESS monochromator was upgraded in 2012, to improve the response to mechanical noise





The new cage is stiffer, and does not have a resonance at 53 Hz.
The amplitude of the mechanical noise is reduced from 0.25 μrad rms to 0.06 μrad rms.

Conclusions

- *Although usual mechanical specifications, like resolution and repeatability are usually met. Complicated crystal cages have limited stiffness, and present resonances at relative low frequencies.*

- *Several instruments have been used to investigate the response of the system to the different sources of mechanical noise.*
  - *Differential interferometer provides a direct measure of amplitudes and can measure following error*
  - *Accelerometers are easy to install and provide several channels simultaneously, this is useful to look for weak points.*
  - *A fast deflectometer has been built to perform in-vacuum measurements. To measure the response to excitation induced by the cooling system.*

- *The 2nd crystal cage of the CLAESS monochromator had to be upgraded to improve its dynamic response*

Acknowledgements

Vera Cuartero
Gemma Guilera
Konstantin Klementiev
Michael Knapp
Inma Peral
Claude Ruget
Fabien Rey
Liudmila Nikitina
Marcos Quispe
Guifré Cuní
Zbigniew Reszela
Sergi Blanch