

Investigation of the vibrational stability of synchrotron X-Ray optics using a differential interferometer

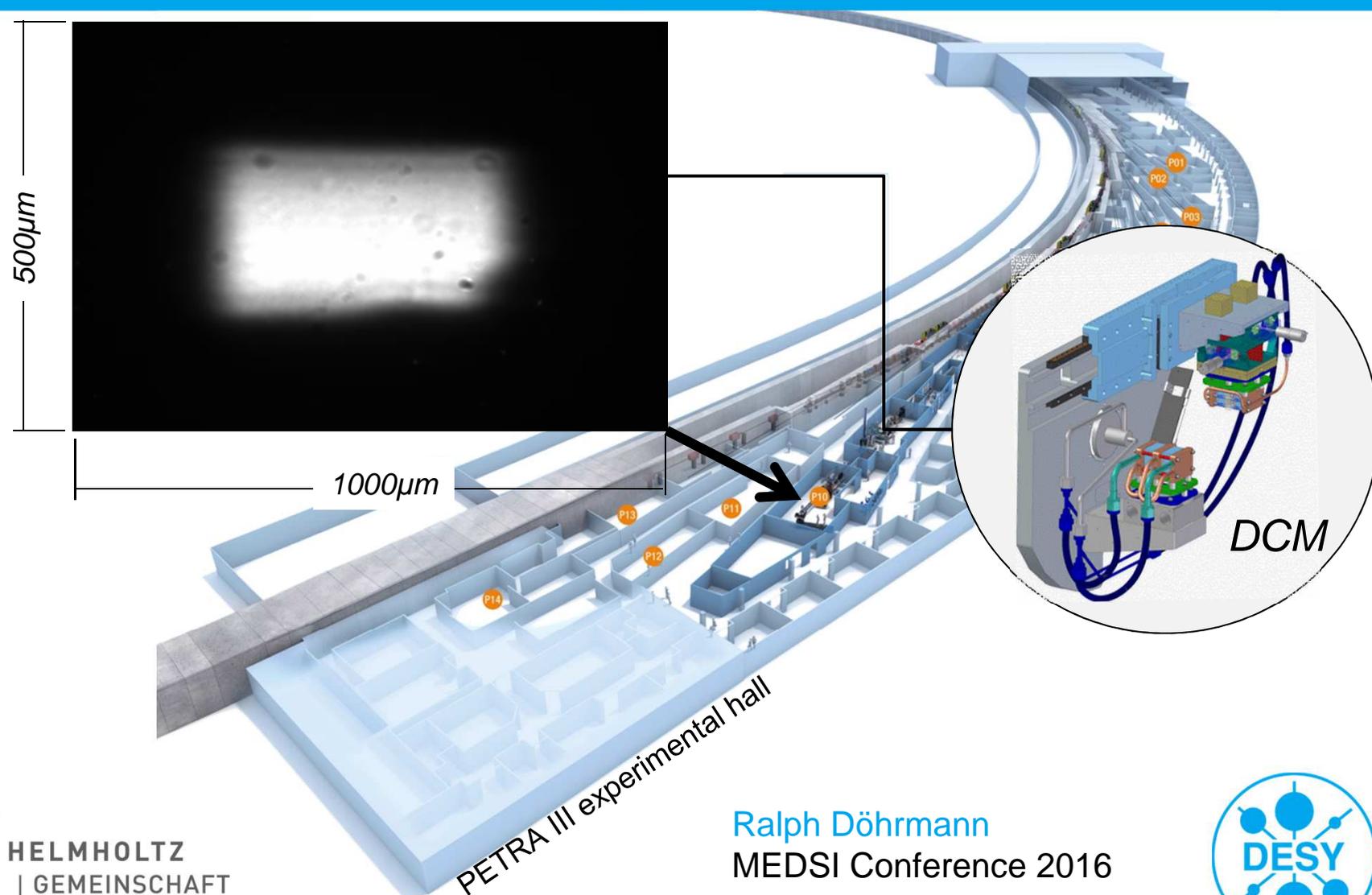
Ralph Döhrmann

Ilya Sergeev, Joachim Heuer, Jan Horbach
and Horst Schulte-Schrepping

HASYLAB at DESY, Notkestr. 85, D-22607 Hamburg, Germany



Investigation of the vibrational stability of synchrotron X-Ray optics using a differential interferometer

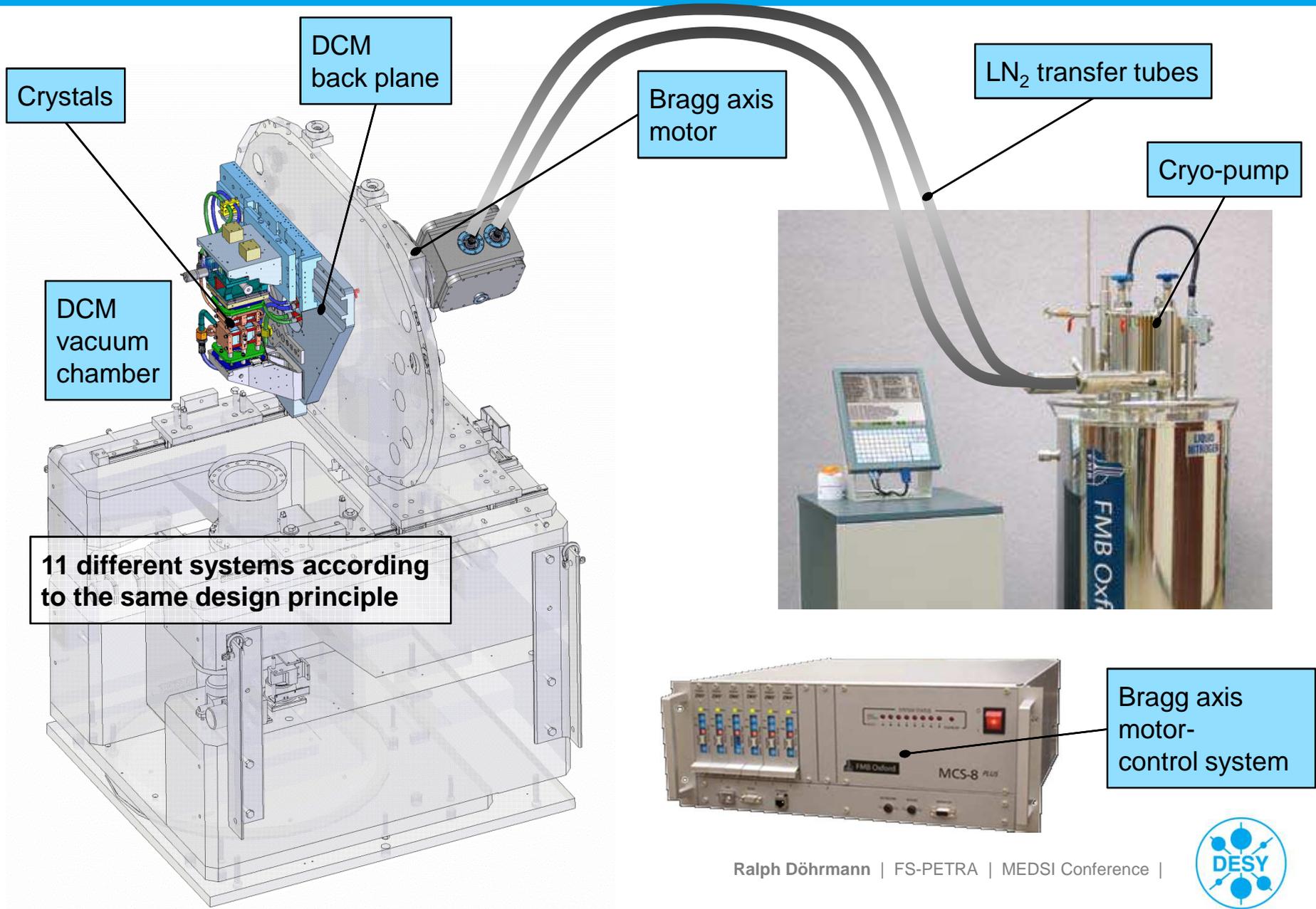


Outlook

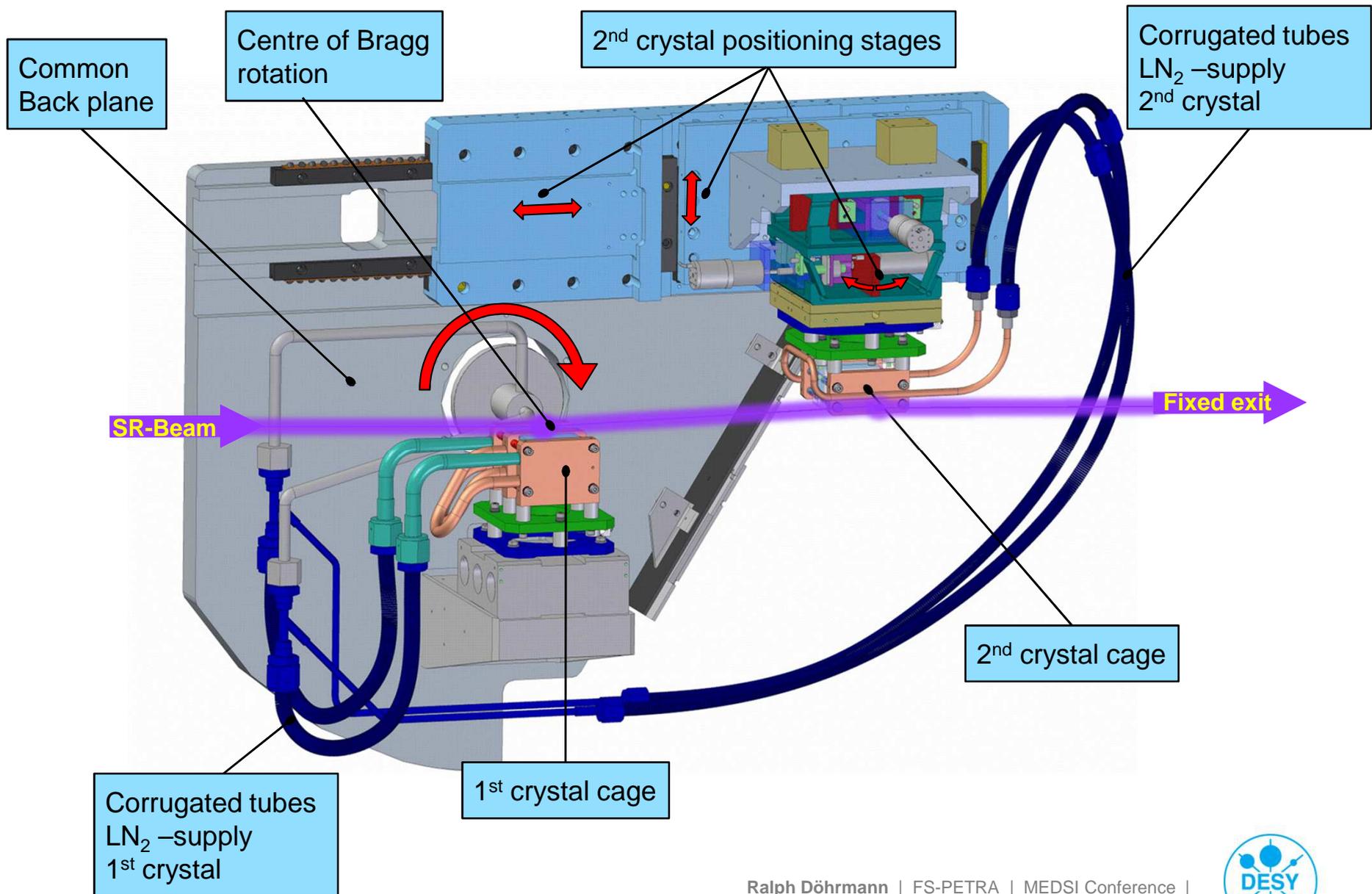
- PETRA III Cryo –cooled double crystal monochromators (DCM)
- What kind of vibrations do we have and why are they bad?
- How to measure and assess the vibrations
- Systematic investigations at the DCMs
- Results and design improvements



PETRA III cryo-cooled Double Crystal Monochromator (DCM)

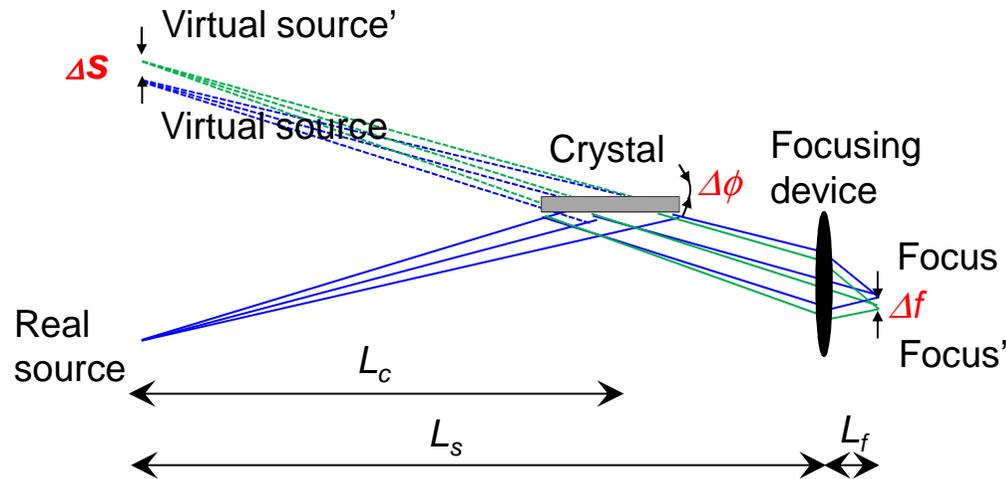


Initial state of the DCM



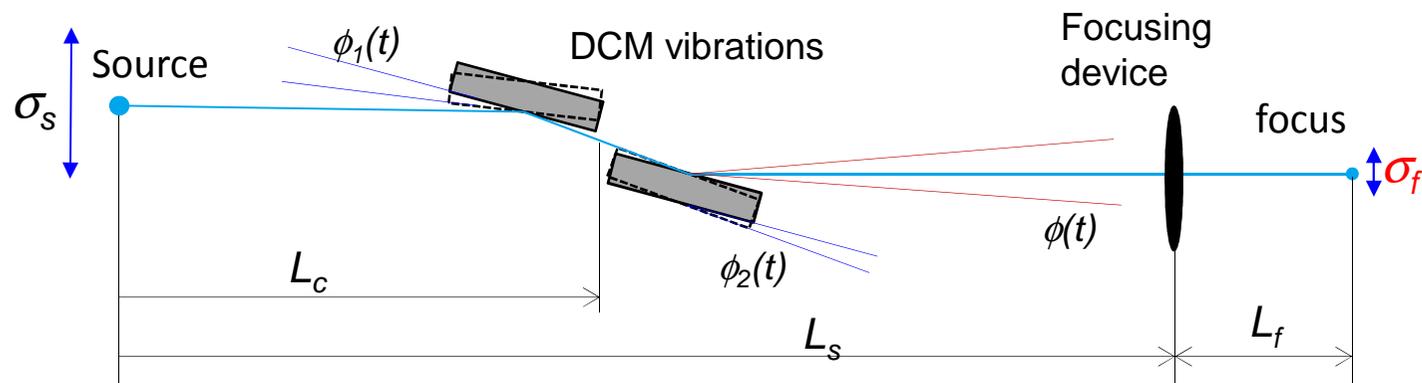
Vibrations and the effect on the beam quality

Effect of crystal vibrations



Leads to broadening due to the movement of the virtual source (ΔS)

Effect of relative movements of beamline optics

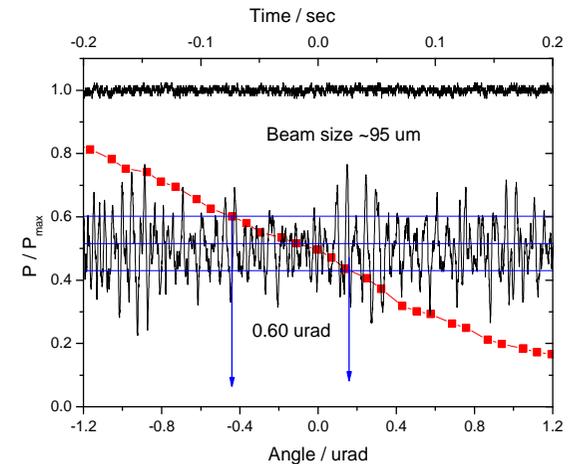
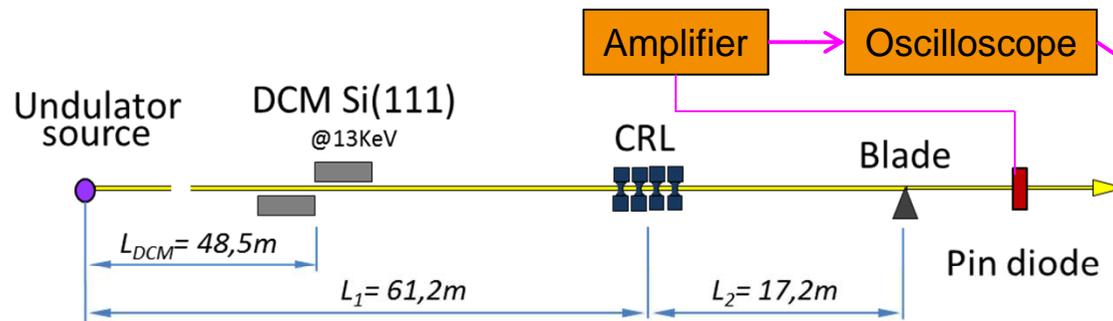


Leads to broadening due to movement of beam and focus position (σ_f)

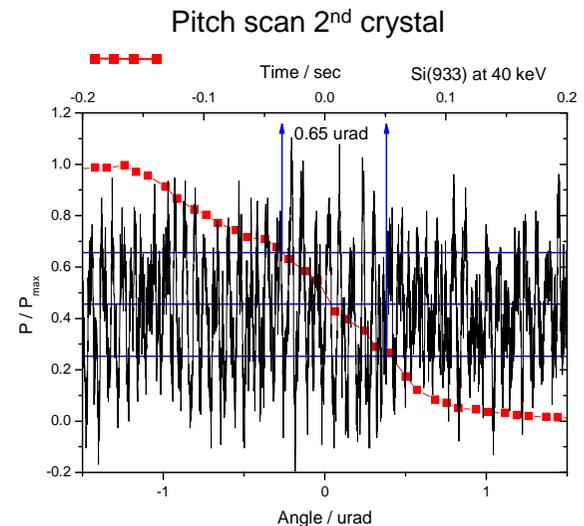
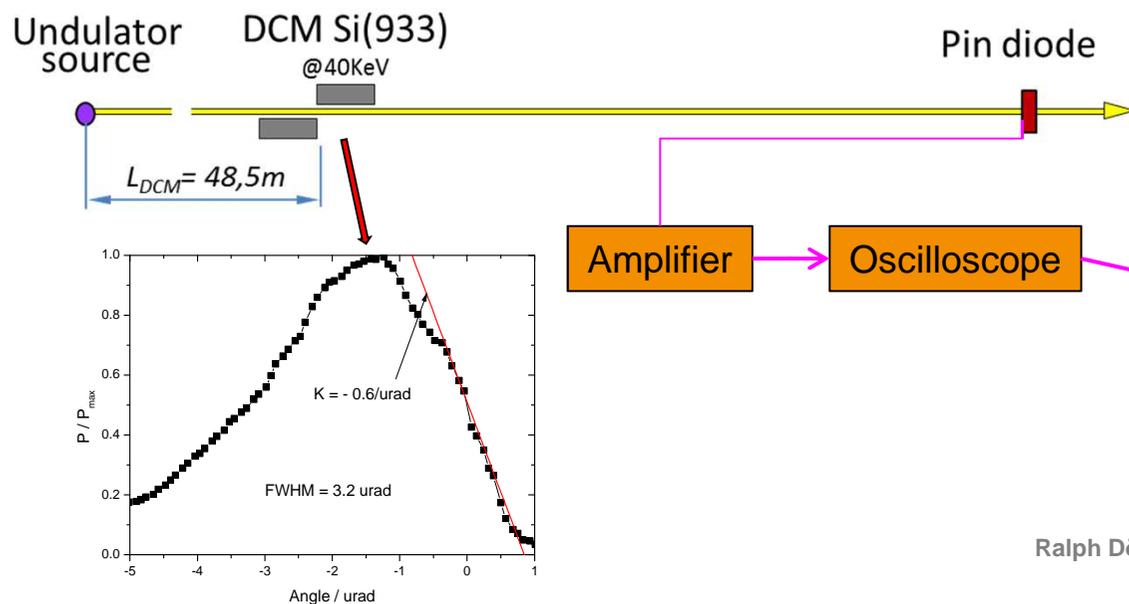
Vibrations measurements using the x-ray beam

- How can we measure and analyze the beam vibrations
- Reproducible methods are required

Focused beam at knife edge

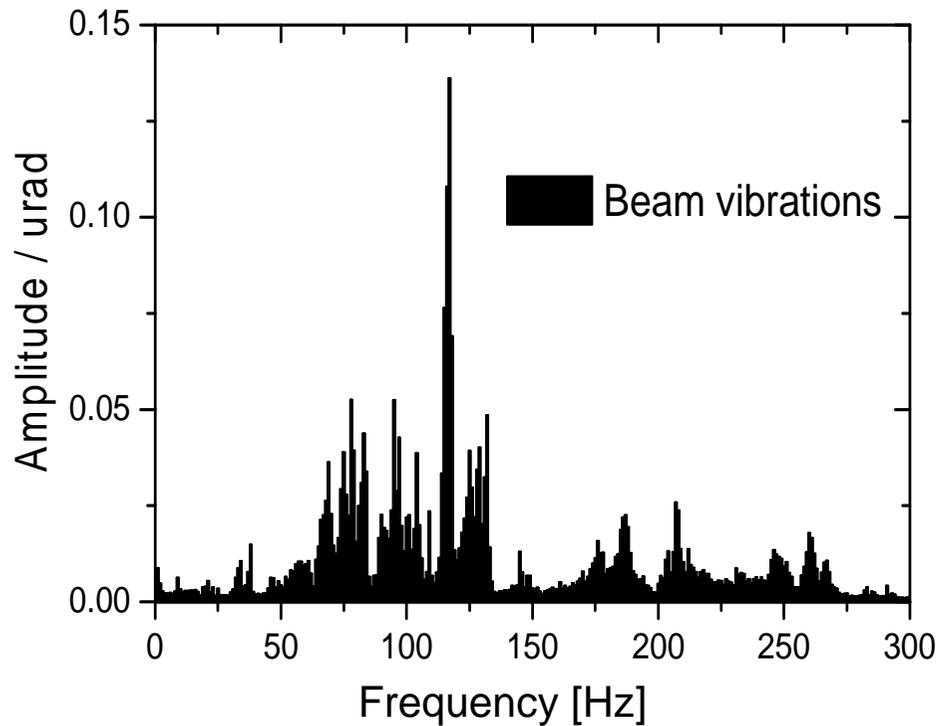


Full beam at slope of rocking curve

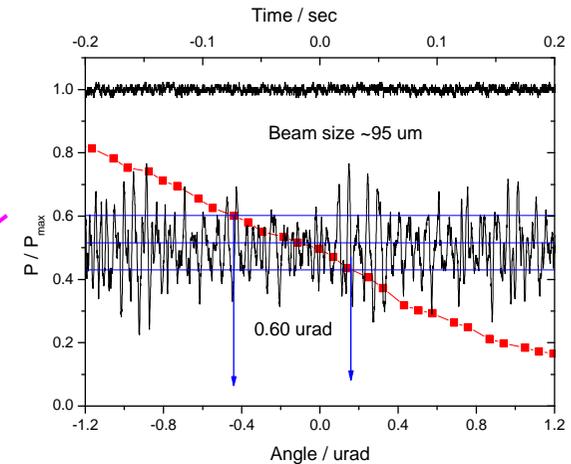


Vibrations measurements using the x-ray beam

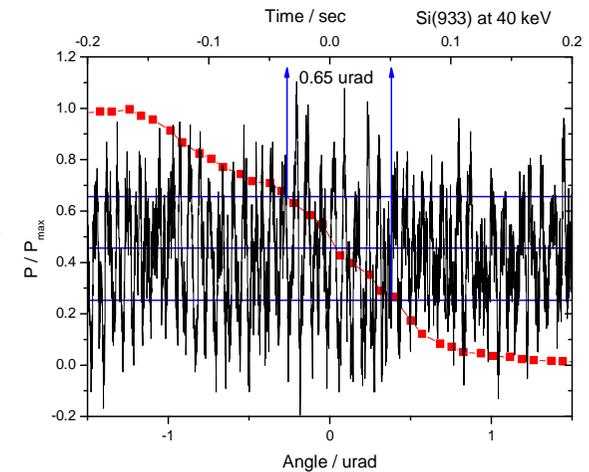
- Fourier transformation to separate the vibration contributions



$$\sigma^2 = \sum_{i=1}^N c_i^2$$



--- Pitch scan 2nd crystal



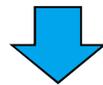
- Both methods produced comparable results.



Vibrations measurements using the x-ray beam

Methods working well to define vibration behavior of the beam

Only limited access to the installed DCM during the measurement periods.



Perform vibration measurements, without synchrotron beam



Requires new methods to measure the DCM vibrations

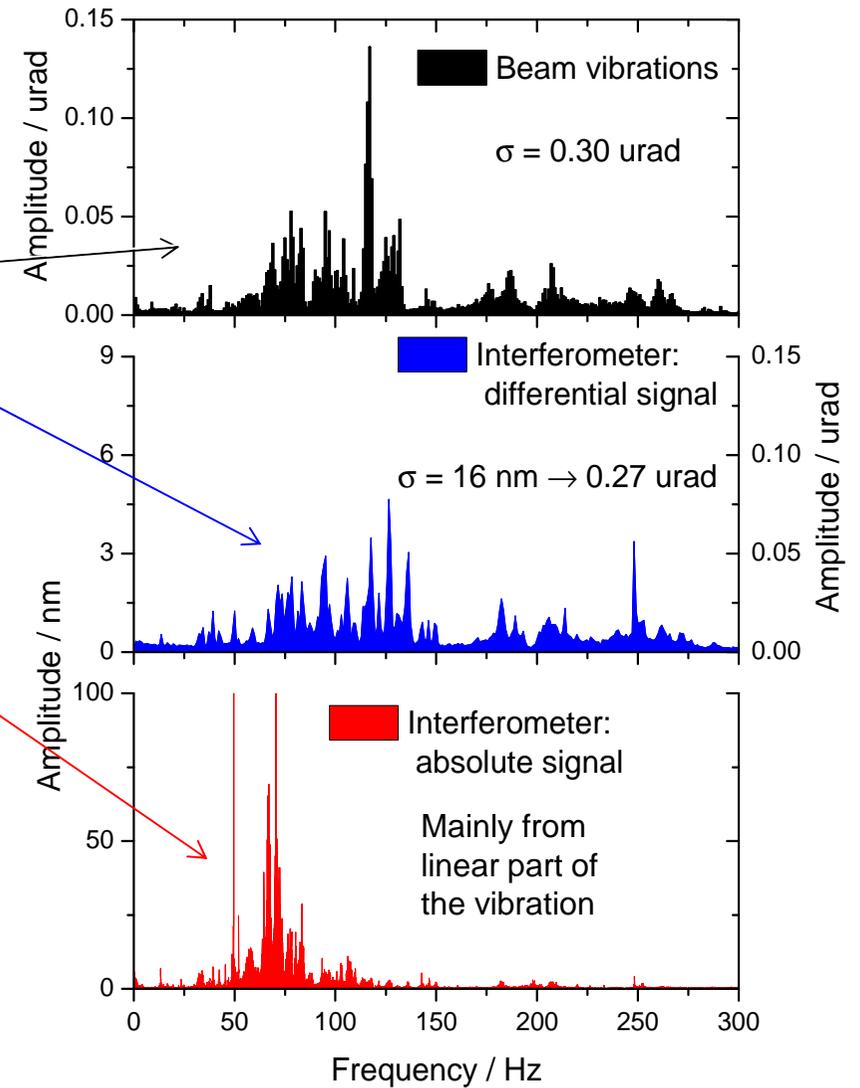
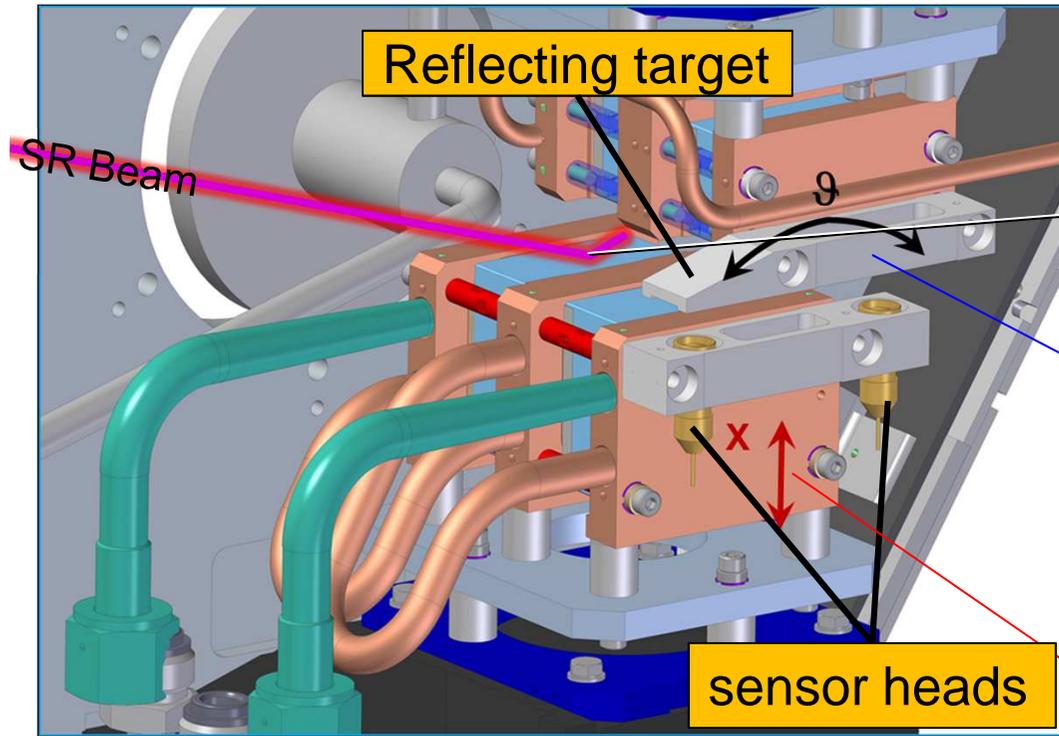


Perform test- experiments under operating conditions



Comparability of DCM vibration and beam vibration is necessary.

Vibrations measurements using a differential interferometer



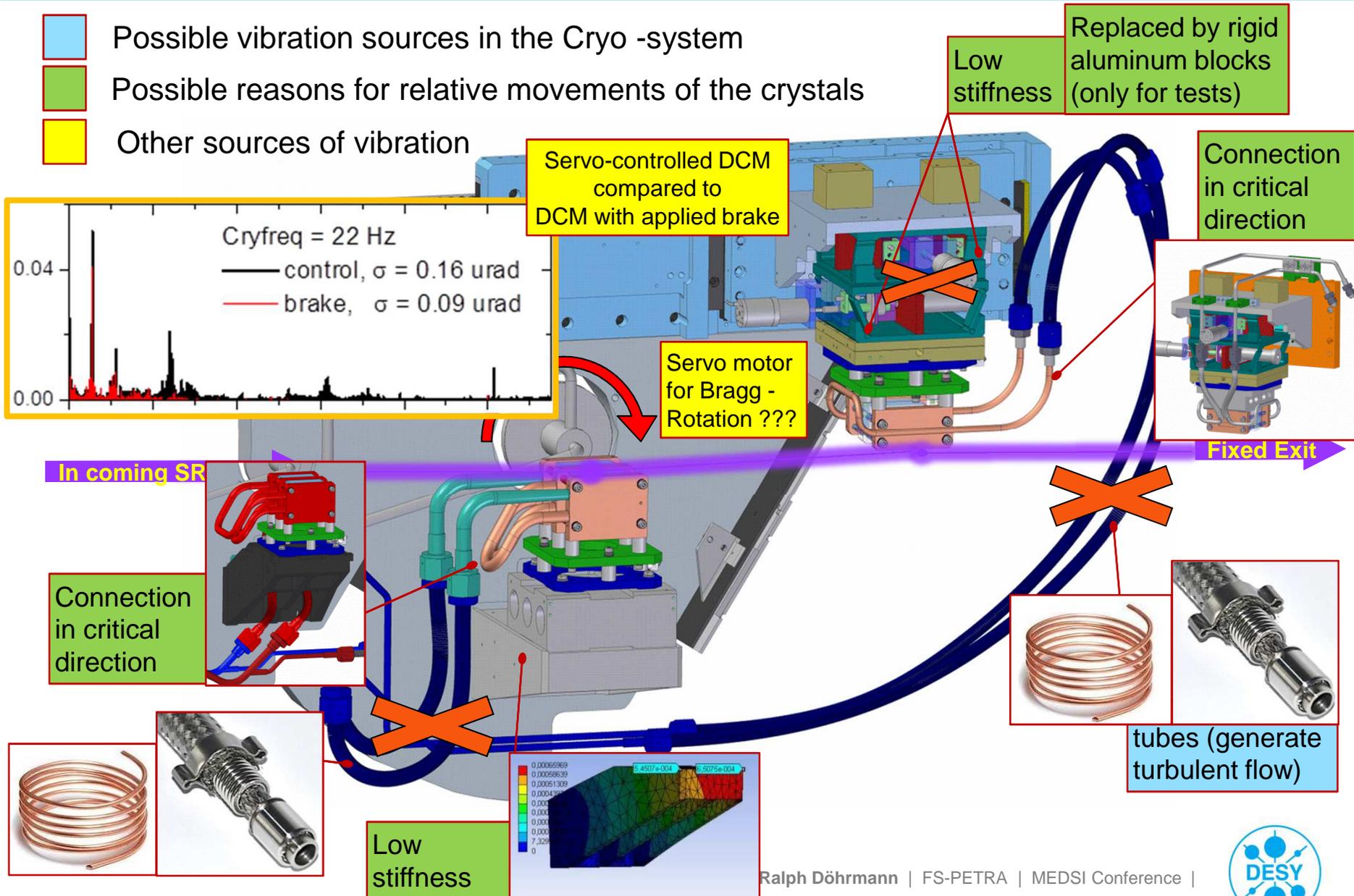
Laser
interferometer

Working distance 0-400 mm
Sensitivity 25 pm
Repeatability 2 nm
Bandwidth 10 MHz

Real Time Interferometric Sensor

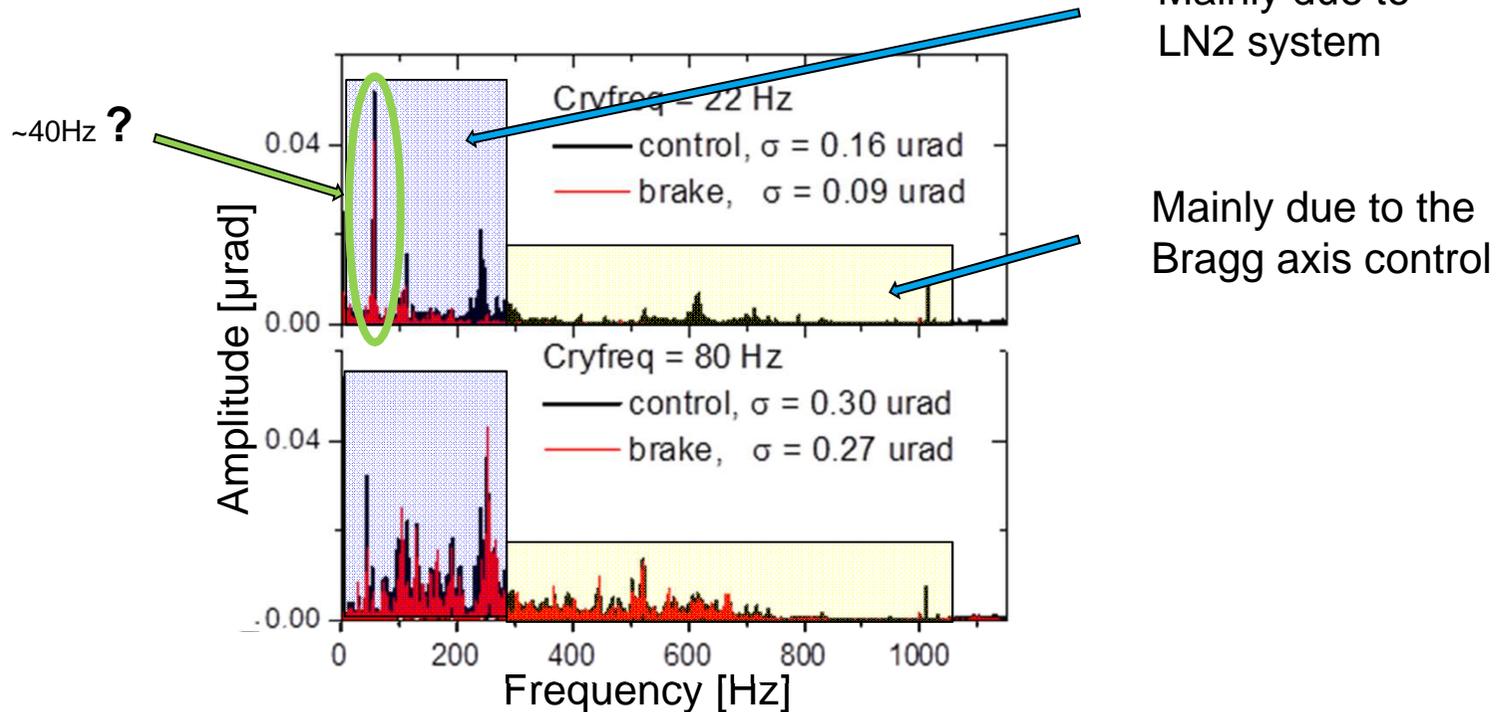
Performed modifications in the DCM

- Possible vibration sources in the Cryo -system
- Possible reasons for relative movements of the crystals
- Other sources of vibration



What we learned from these investigations

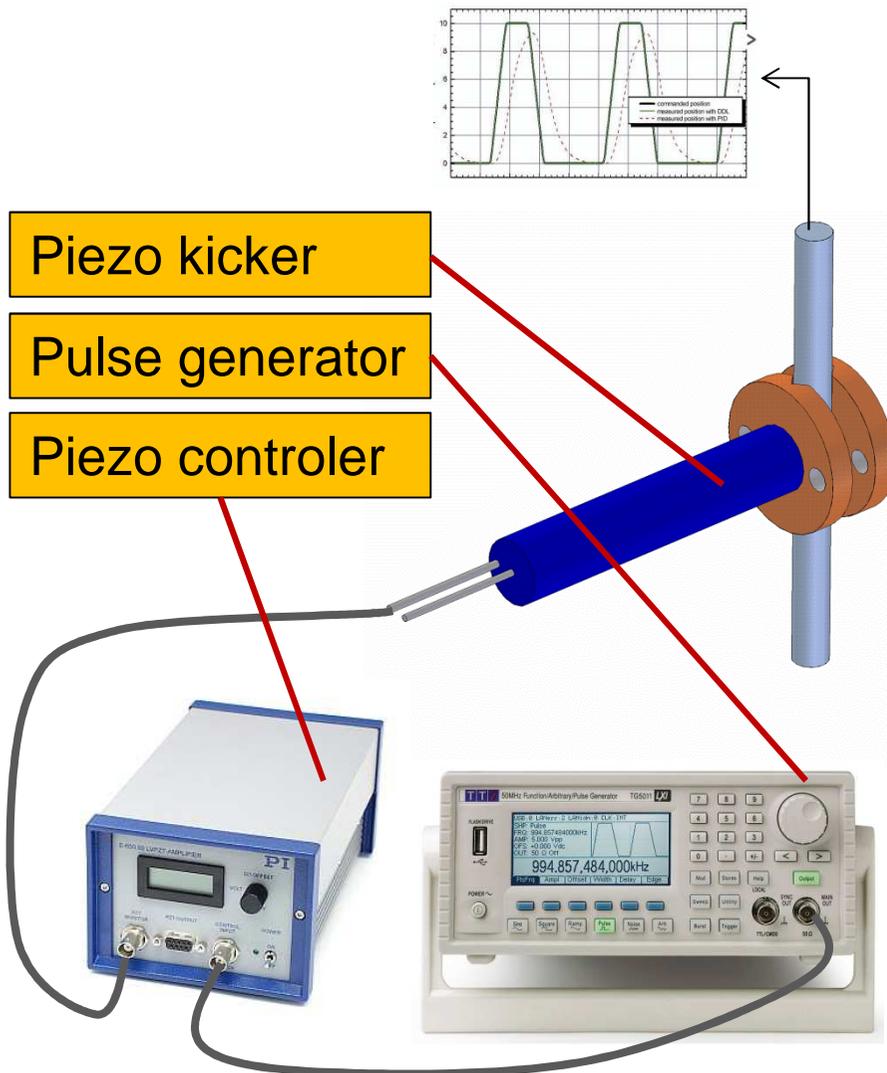
- > Many small improvements but no real breakthrough.
- > One source of vibration could be identified



- > The actual cause of the vibrations due to LN₂ system was still unclear.
→ So we had to find further investigation methods

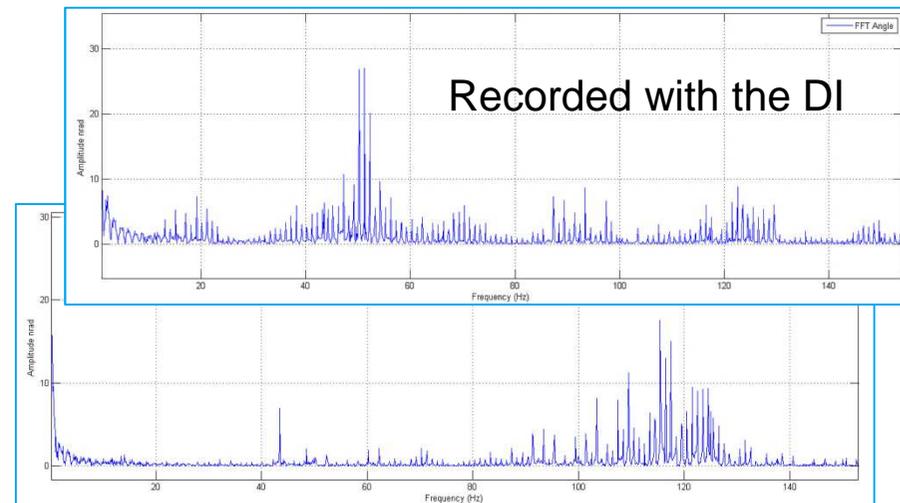
Further investigations at the DCMs with a micro-resonator

- Analysis of individual components through specific excitation of the natural frequencies due to micro-resonator.



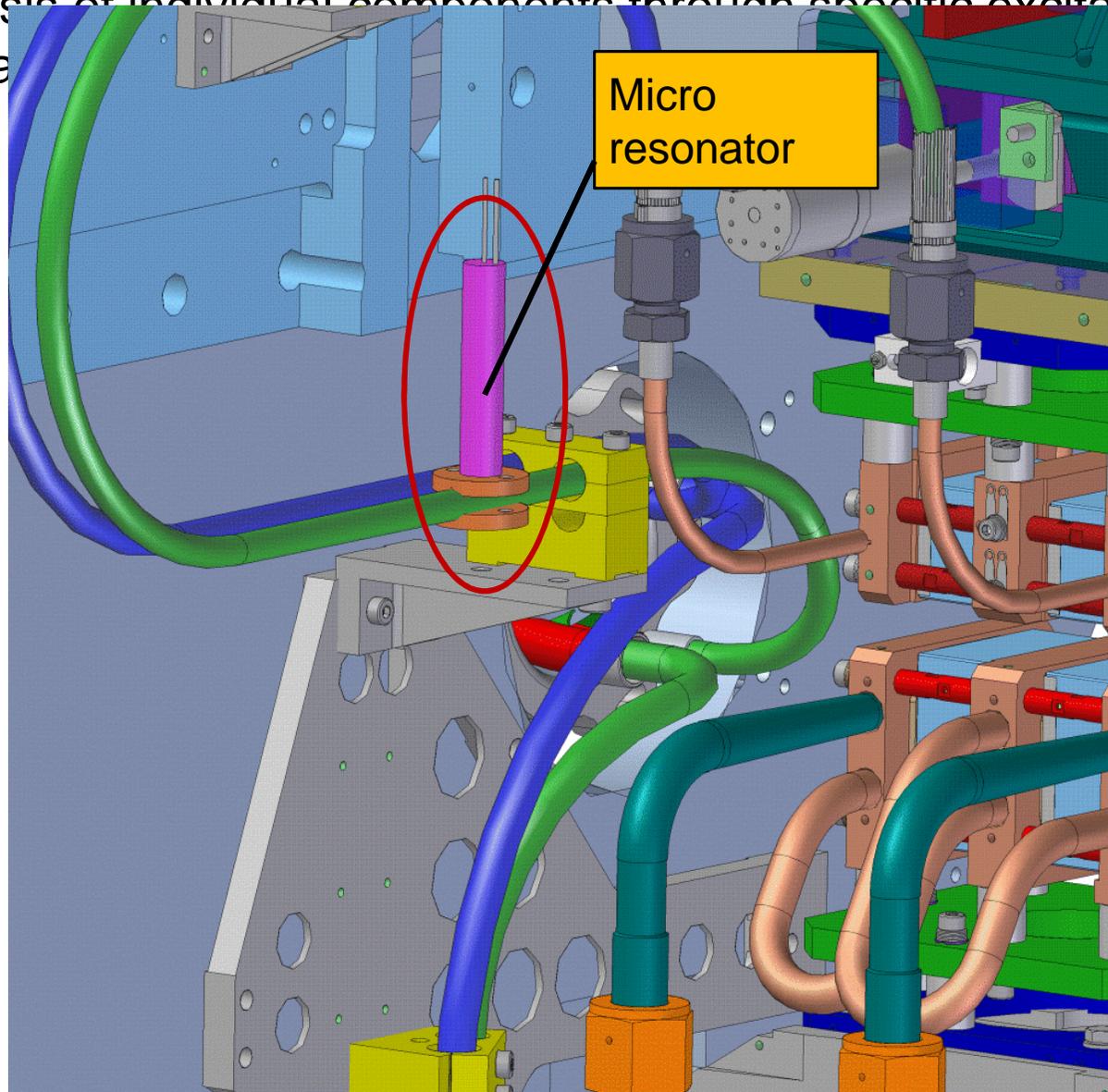
Advantages:

- Selective stimulation of components
- Uniform excitation
- Adjustable frequency
- Minor sensitivity to disruptions
- All natural frequencies visible



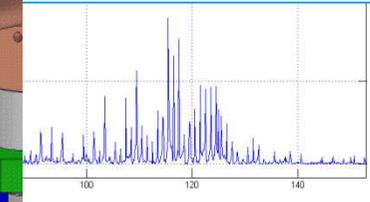
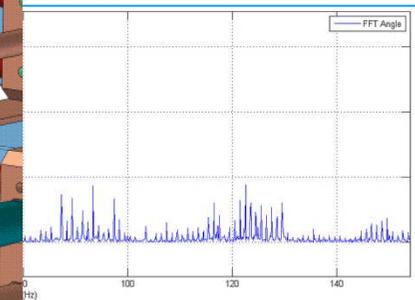
Further Investigations at the DCM

- > Analysis of individual components through specific excitation of the natural frequencies of components with the DI



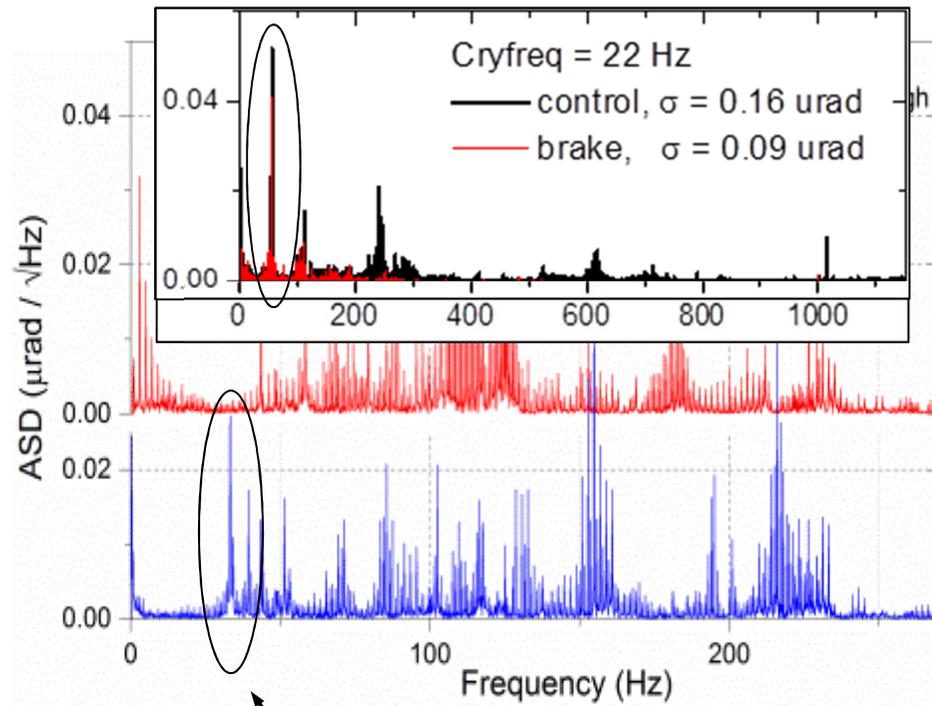
of components

y
disruptions
es visible

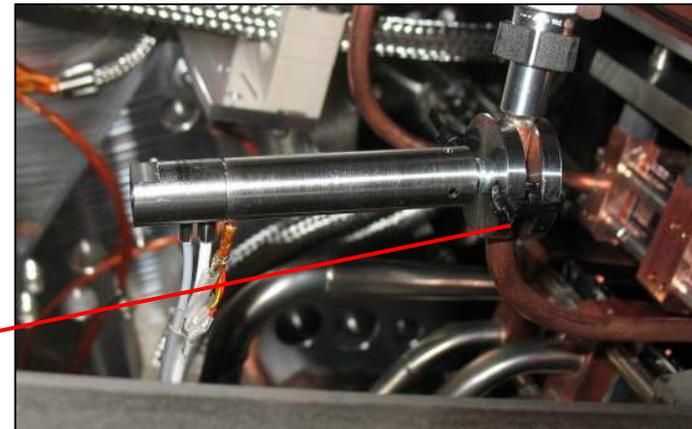


Further Investigations at the DCMs

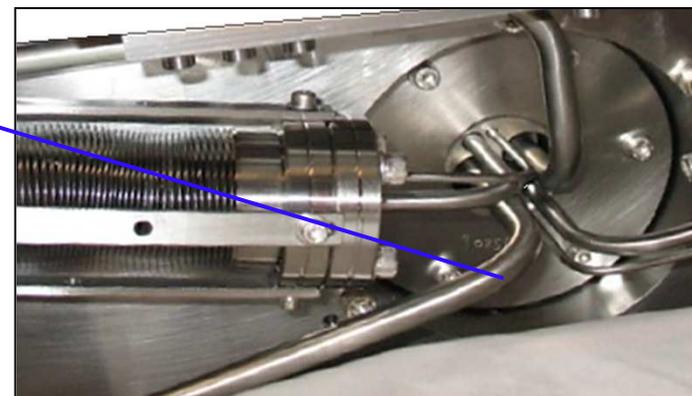
- Combined with the DI it is possible to assign specific frequencies to specific components



Problematic frequency range



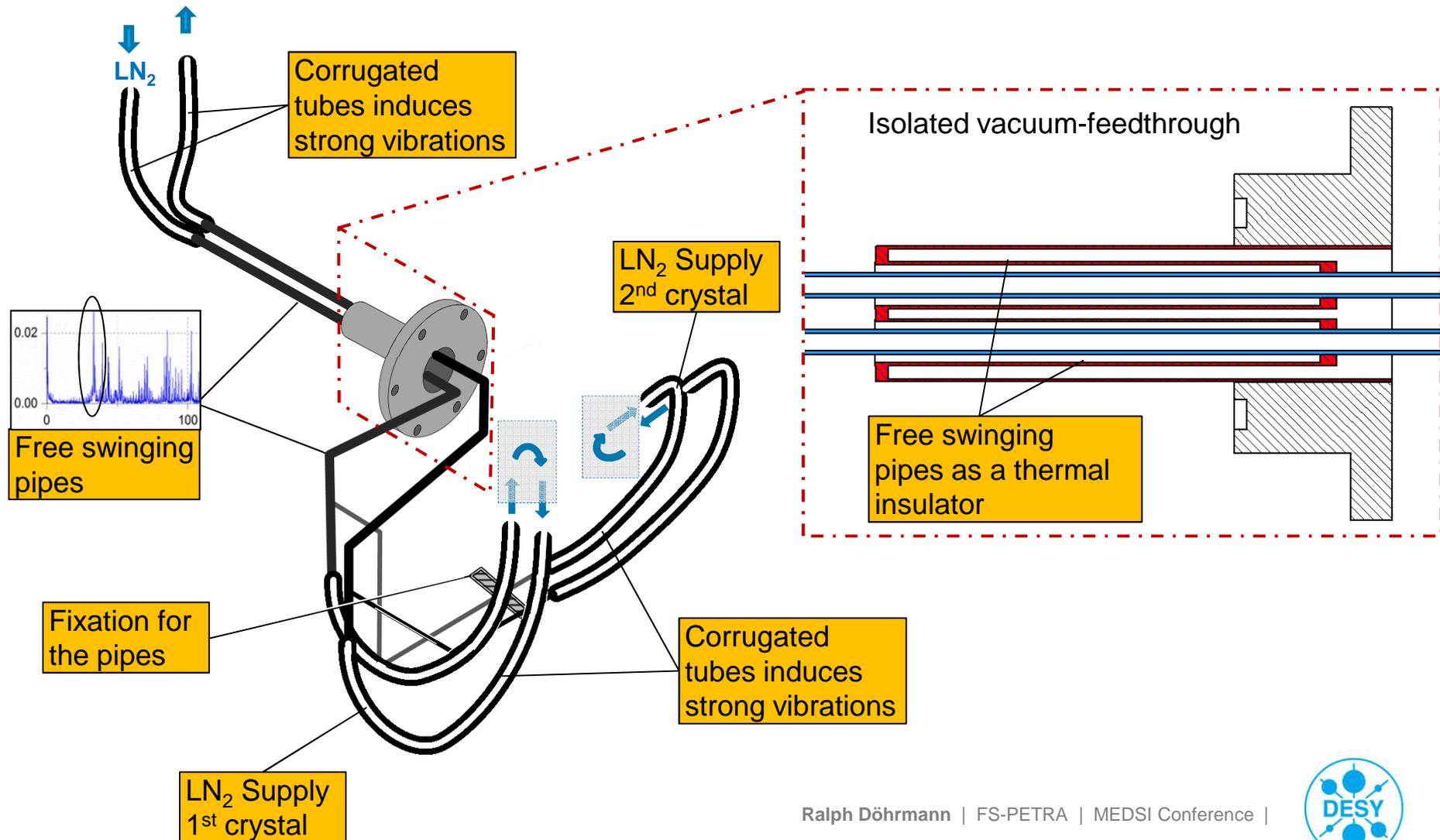
Crystal cage of the 2nd crystal



LN₂ Pipe of cryo-feedthrough

Stability considerations at the installed feedthroughs

- > Principle of the original feedthrough with LN₂ transfer system to the crystals (FMB-Oxford)



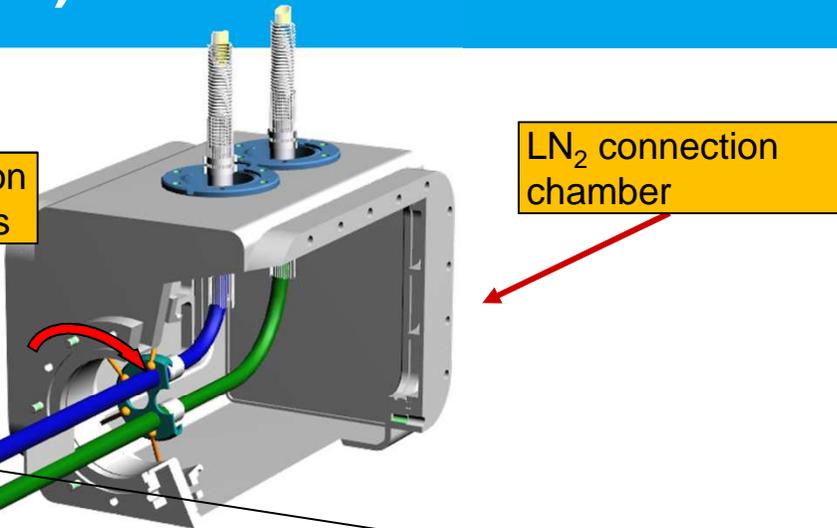
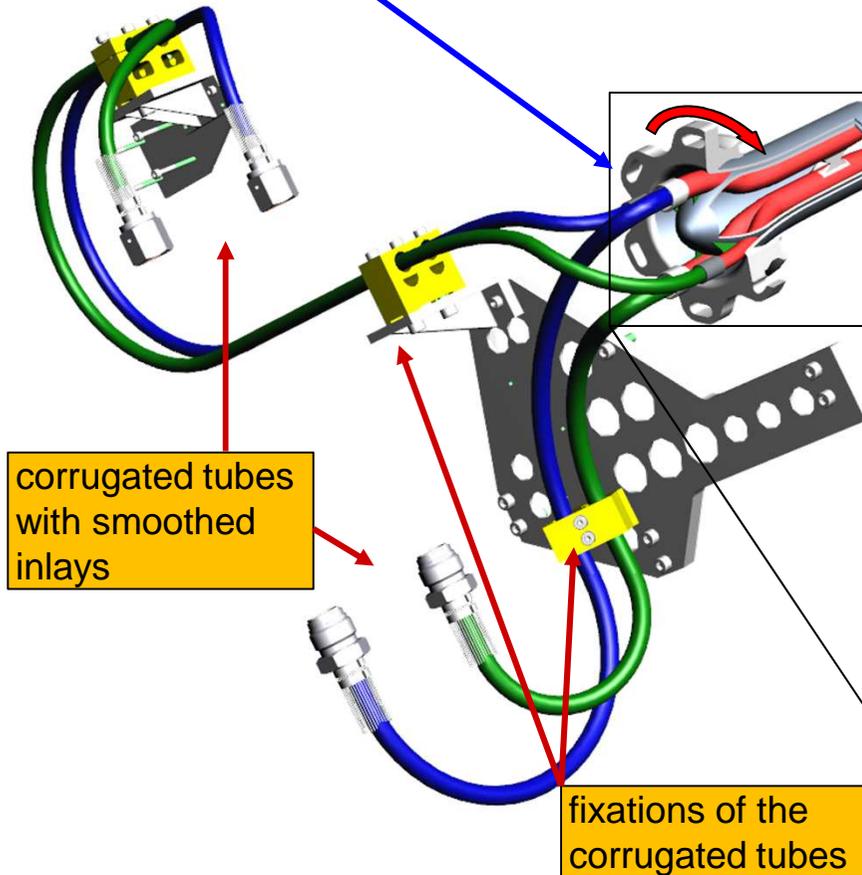
LN₂-Feedthrough (Prototype 2)

Optimized

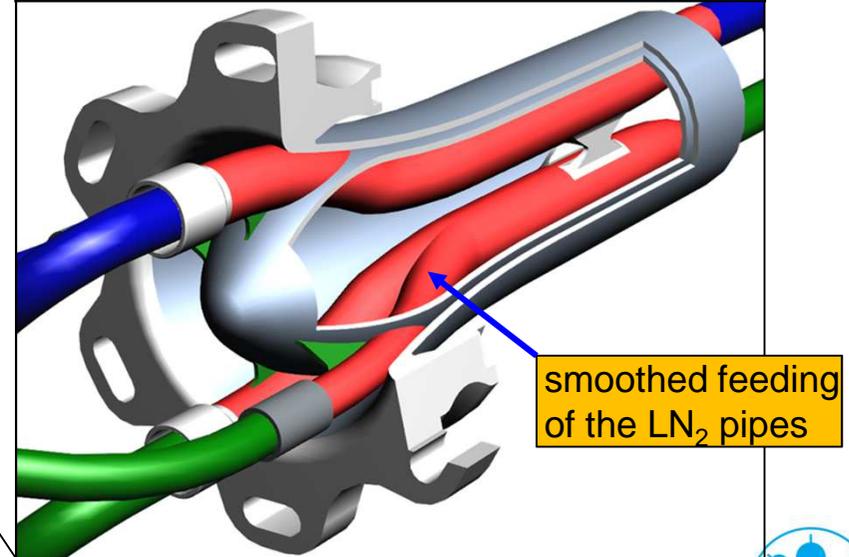
- > for stiffness (stability)
- > thermal insulation
- > LN₂ flow behavior
- > manufacturing engineering

additional fixation
of the inlet pipes

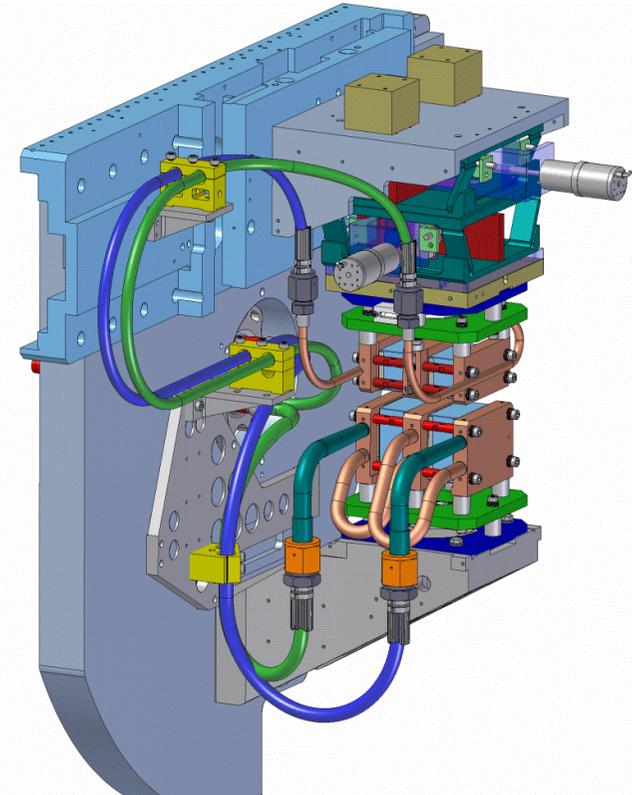
LN₂ connection
chamber



Produced by Selective Laser Melting (SLM)

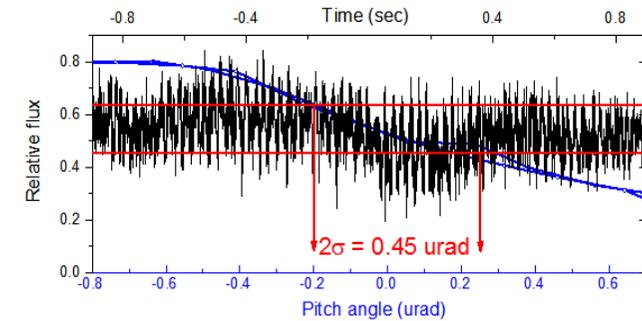


Present state of the DCM after Upgrade

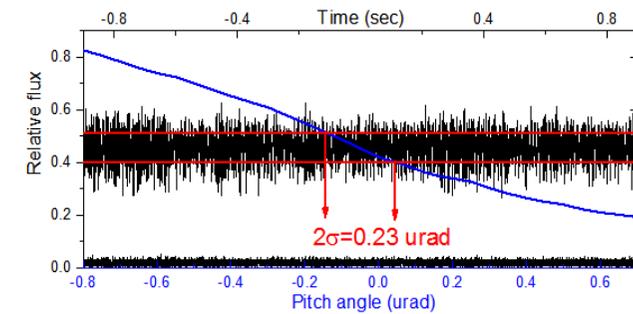


- Improved LN₂ Feedthrough
- Avoidance of long free-swinging components
- All corrugated tubes with inlays
- New routing of the tubes with additional fixation

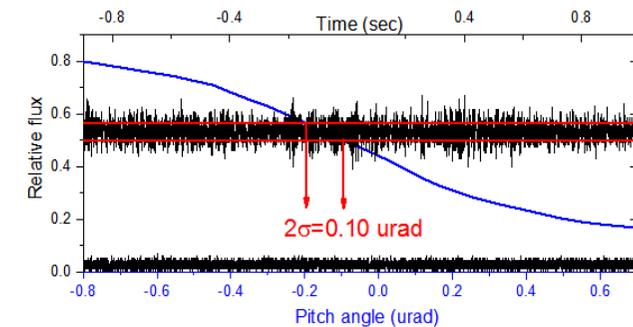
Before upgrade
in control mode
 $\sigma = 0,23\mu\text{rad}$



After upgrade
control mode
 $\sigma = 0,12\mu\text{rad}$



After upgrade
brake mode
 $\sigma = 0,05\mu\text{rad}$



Conclusions

- > A “Differential Interferometer” for vibration measurements directly at the DCM-crystals.
- > It was shown that the measurements of the DI correspond to those of the measured vibration of the SR-beam
- > Two sources of vibrations have been identified:
 - Vibrations due to the LN₂ system
 - Vibrations due to the Bragg axis servo-motor
- > Weak points in the mechanical design of the DCM have been identified
- > Constructive improvements in DCMs were installed.
- > In the best case ~50nrad stability (RMS) has been achieved with the upgraded DCM.



Acknowledgment

Ilya Sergeev



PETRA III Optical group

- Joachim Heuer
- Horst Schulte-Schrepping
- Jan Horbach

PETRA III beamline staff

- Hans-Christian Wille
- Hasan Yavas
- Gerald Falkenberg
- Ulrike Bösenberg
- Jörg Stempfer
- Michael Sprung
- Hanns-Peter Liermann
- Alexey Zozulya
- Alke Meents
- Tim Pakendorf
- Stefan Fiedler

DESY Groups

- FS- Workshop
- Central Workshops
- ZM2
- FS-BT

Thank you for your attention

