JJ X-Ray

X-Ray instruments ranging from standard slits to full beamlines

15 Jul 2020 – SKIF

JJ X-RAY
Danish Science Design

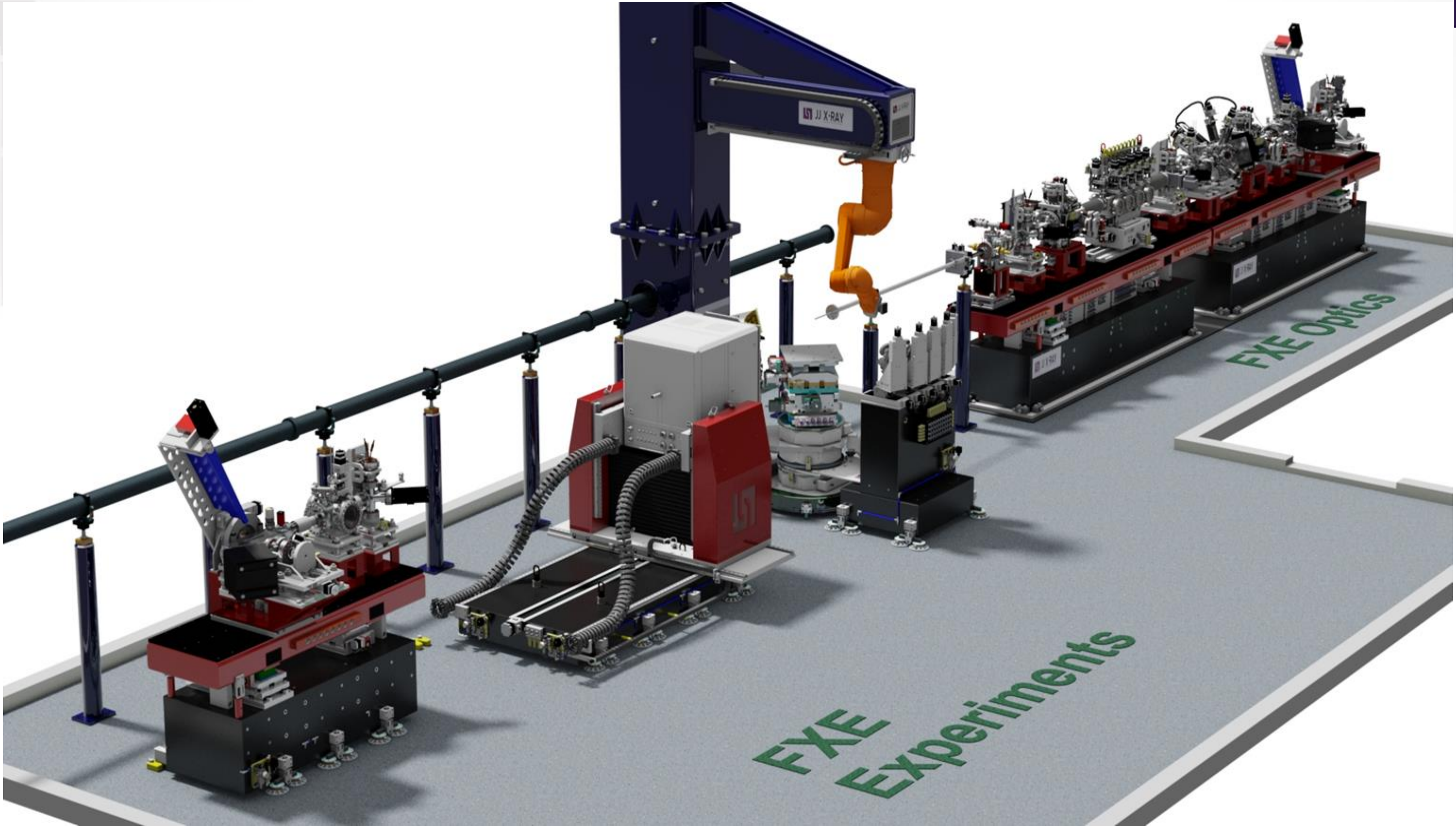
The product range of JJ X-Ray

- Standard components
  - Slit systems, including white beam slits with drain current capability
  - Precision stages with nrad and nm resolutions
  - Compound Refractive Lens systems

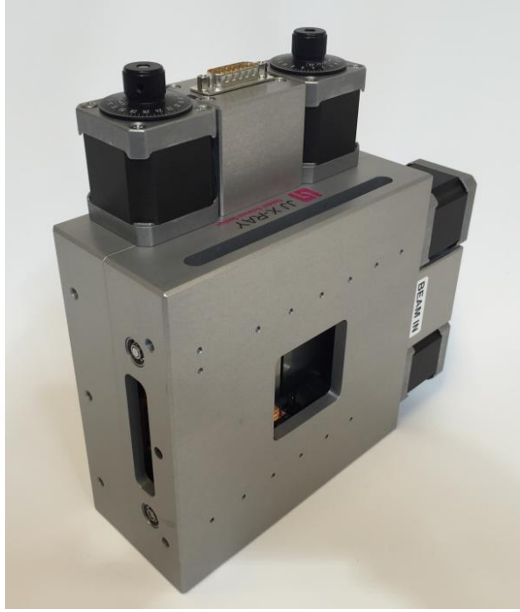
- Complete beamline solutions

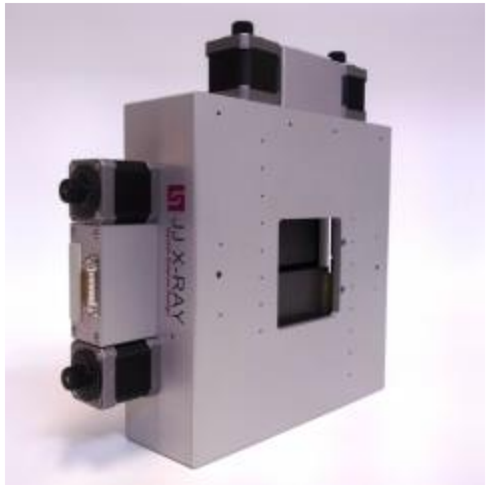
- Custom designed instruments and end-stations
  - Attenuators
  - Beam Imagers and positioners
  - Mirror systems
  - Emission Spectrometers
  - Diamond crystal-based optics
  - Sample positioning stages
  - Laue monochromators

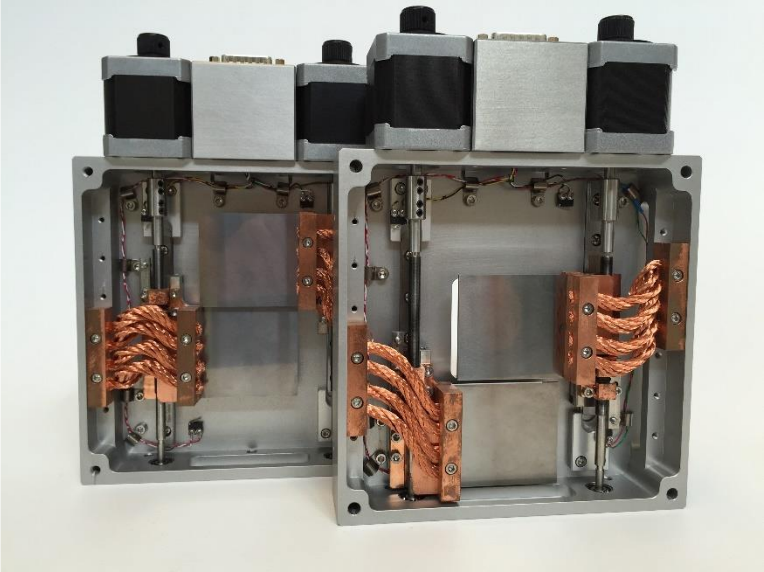
The FXE instrument at European-XFEL



JJ X-ray standard slits: Air, HV and UHV







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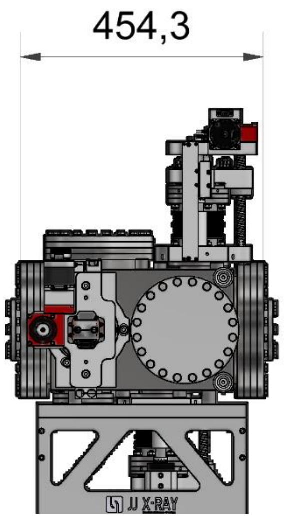
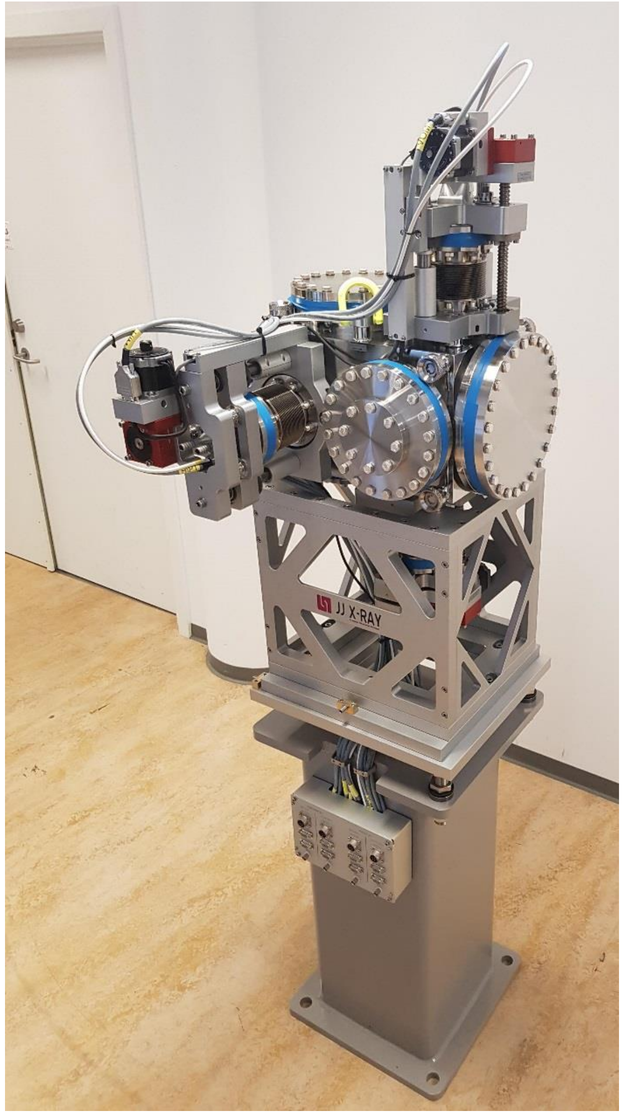
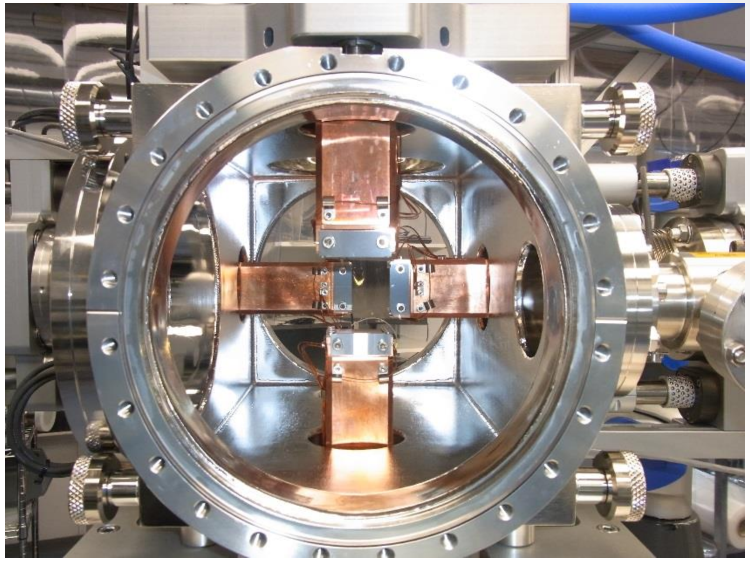
White beam slit system

Main Features

- 1500 W with drain current reading
- 4000 W without drain current reading
- Four independent blades
- Nano-polished beam defining entity
- Relative vibration less than 25 nrad RMS
- Compact: 455 mm end-to-end







On all beamlines on the new SIRIUS synchrotron in Brazil

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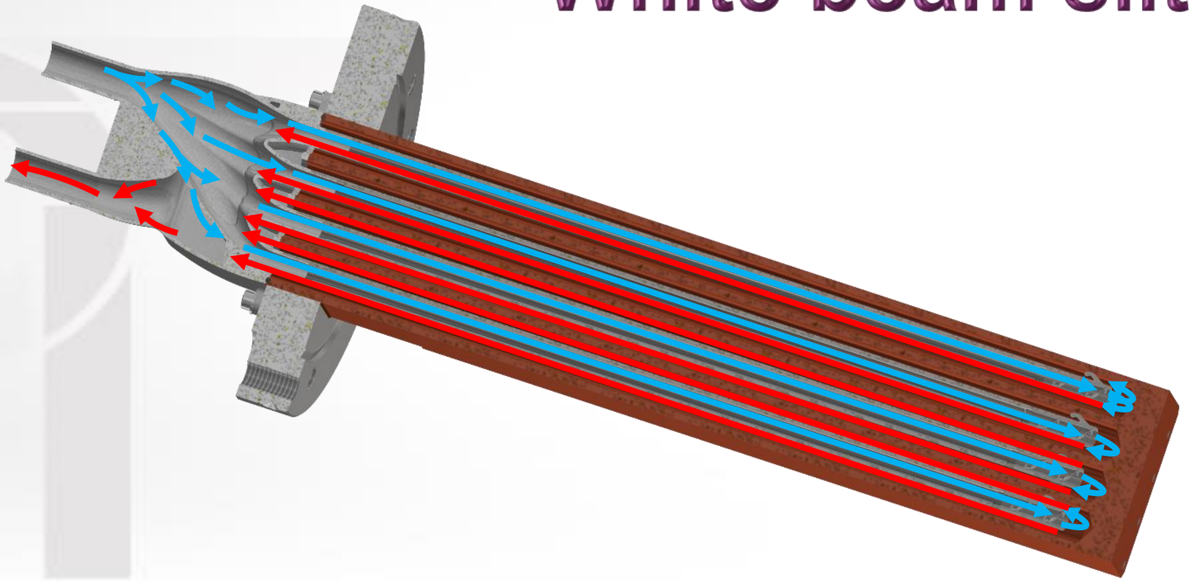
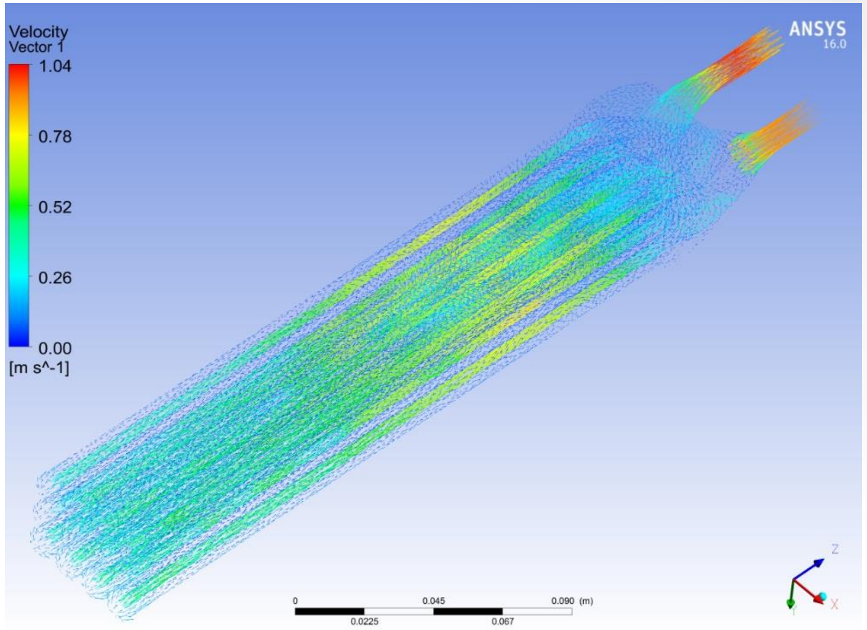
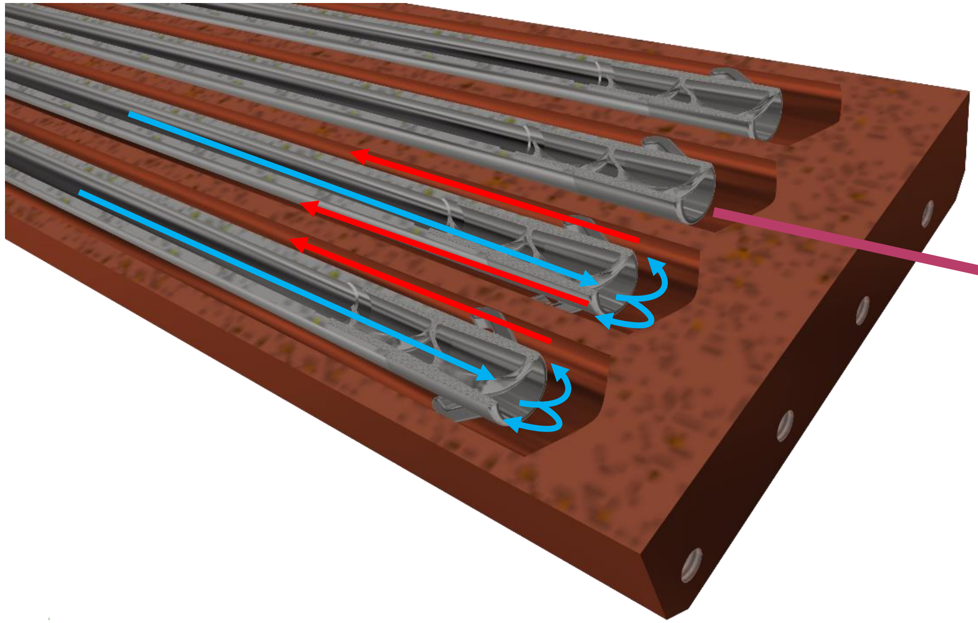
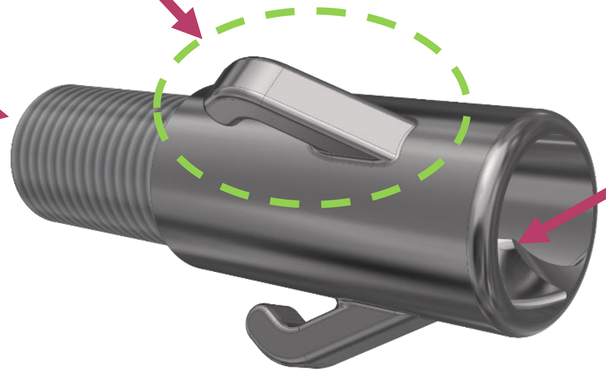
White beam slit system - Cooling









3x Anti-vibration springs on each Nozzle end

Internal spiral forces the water to rotate

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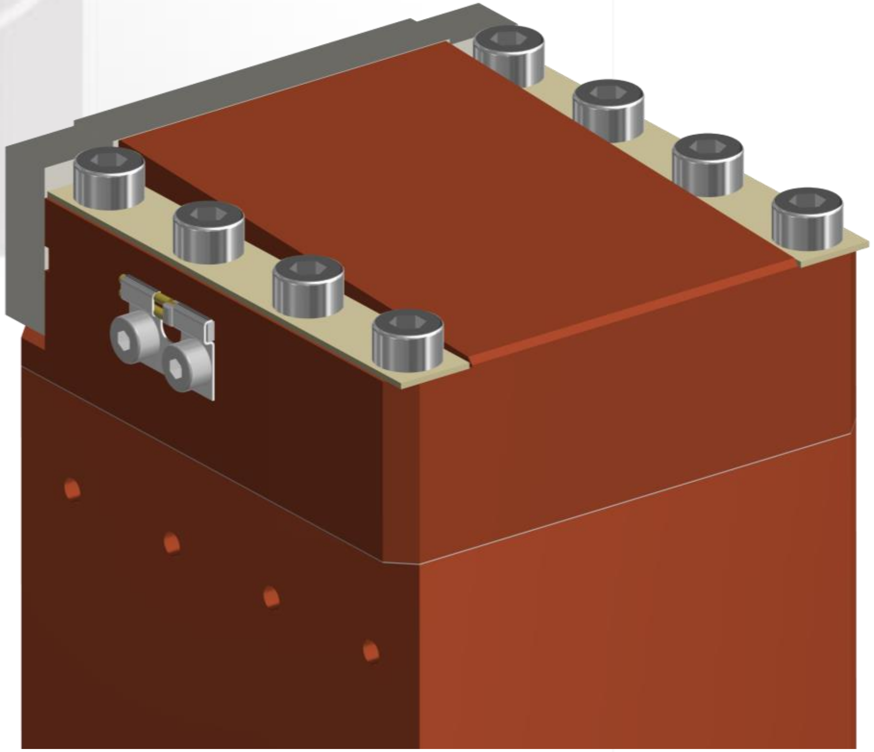
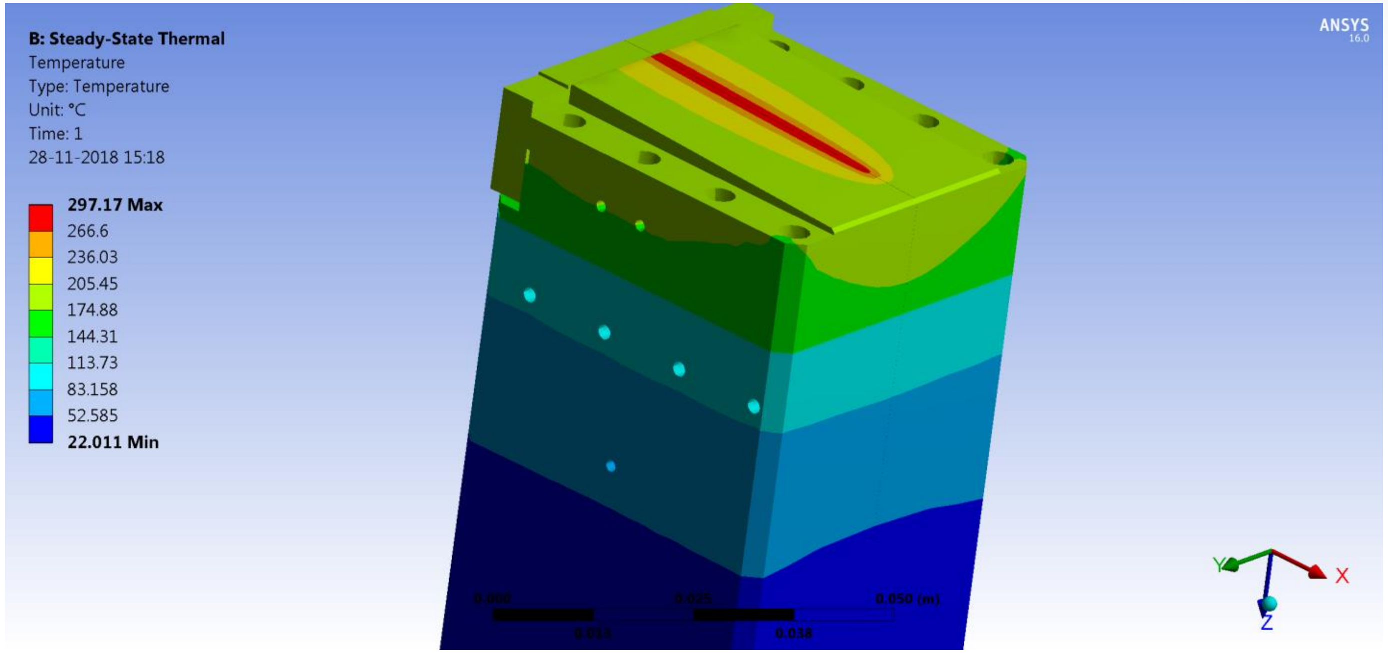
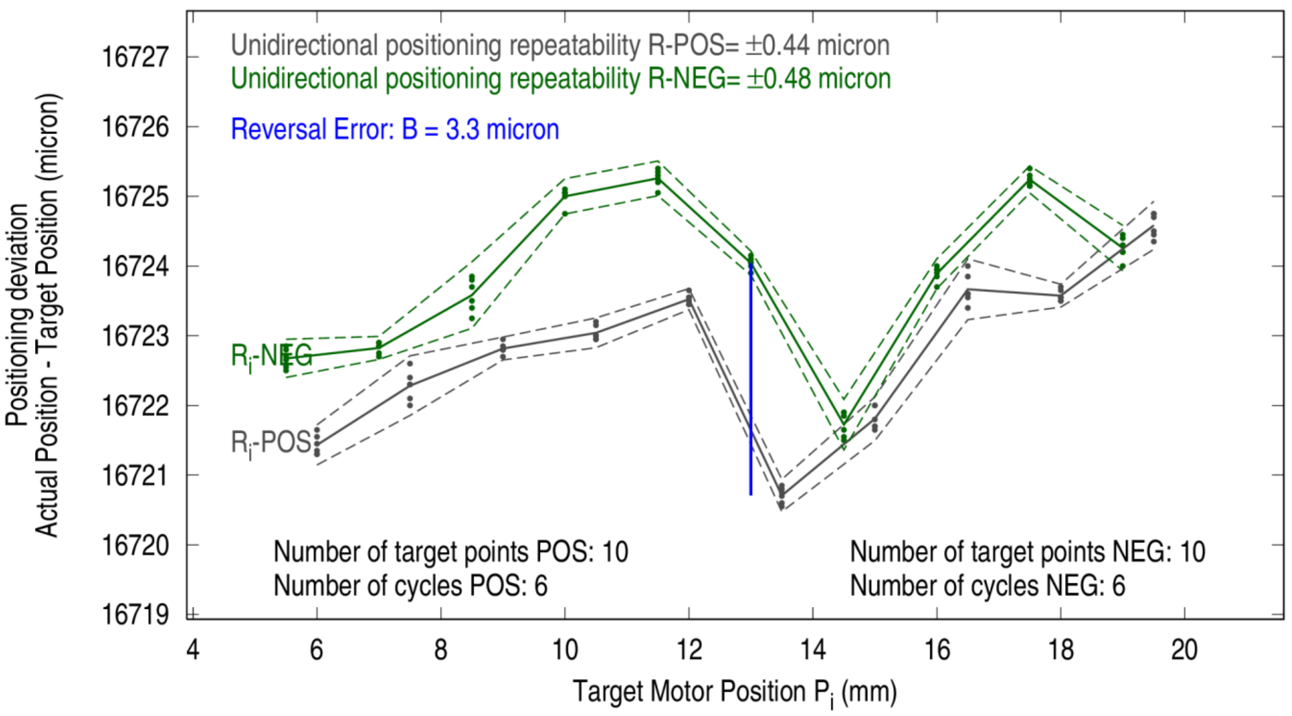
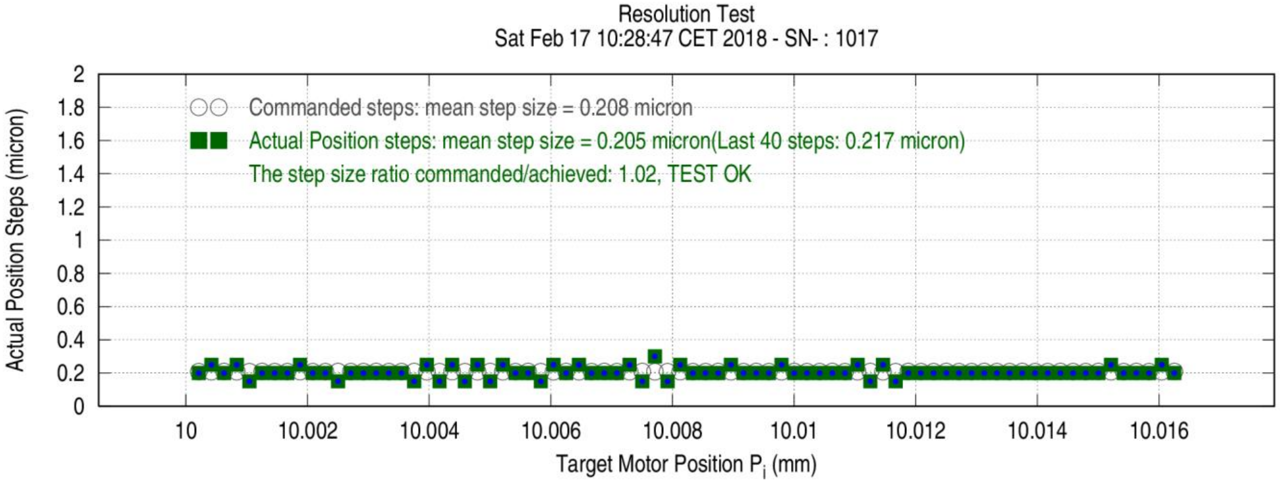
White beam slit system - Cooling

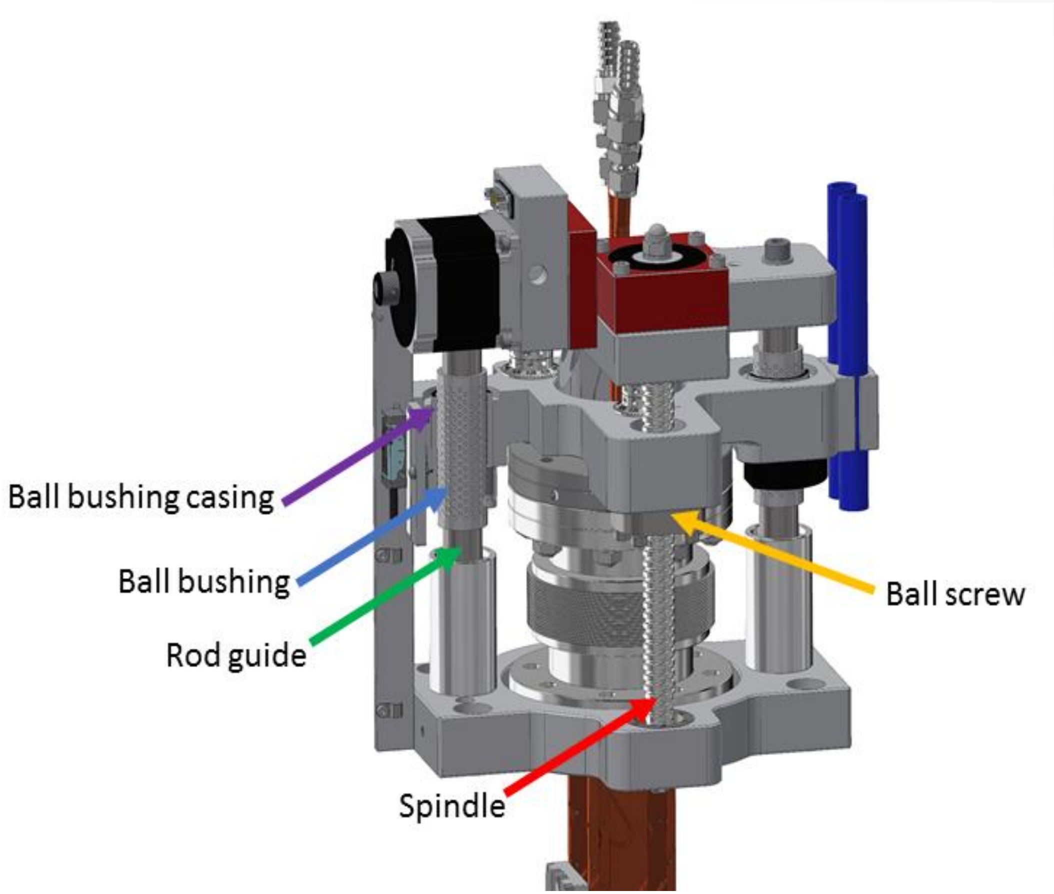




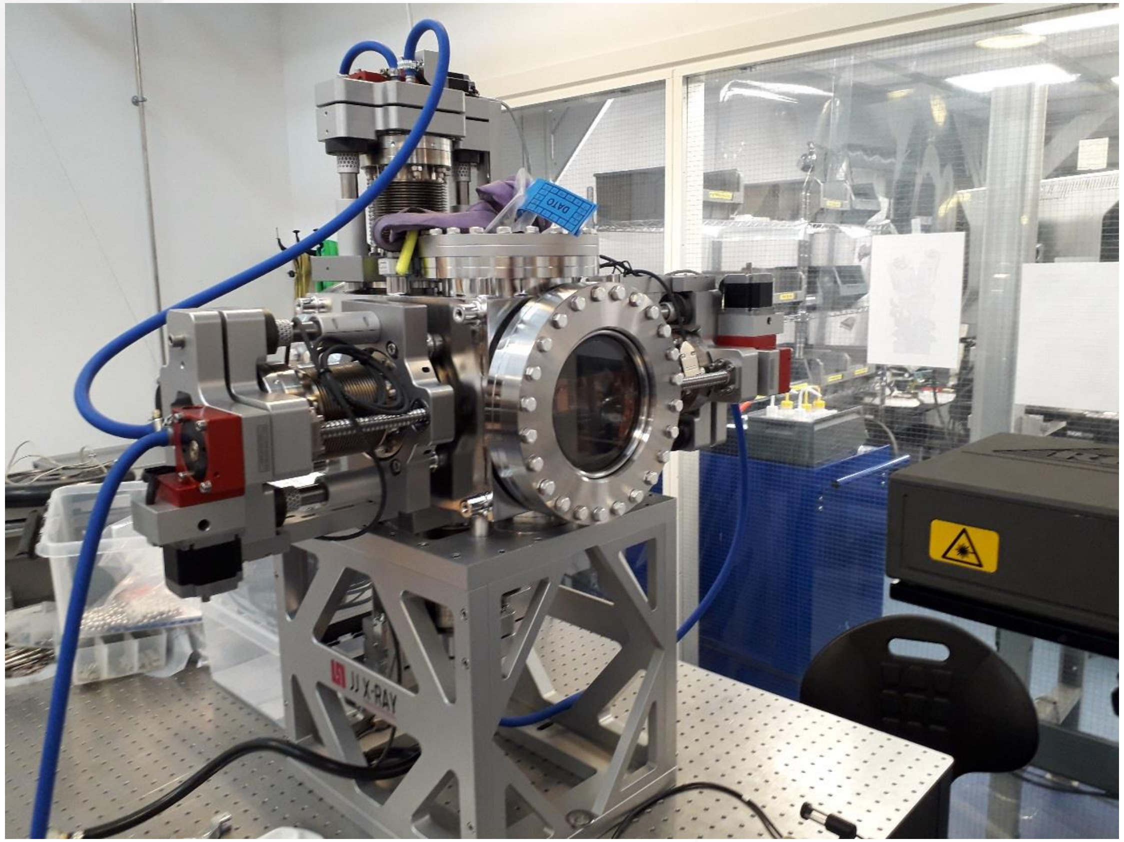
White beam slit system – Open loop performance

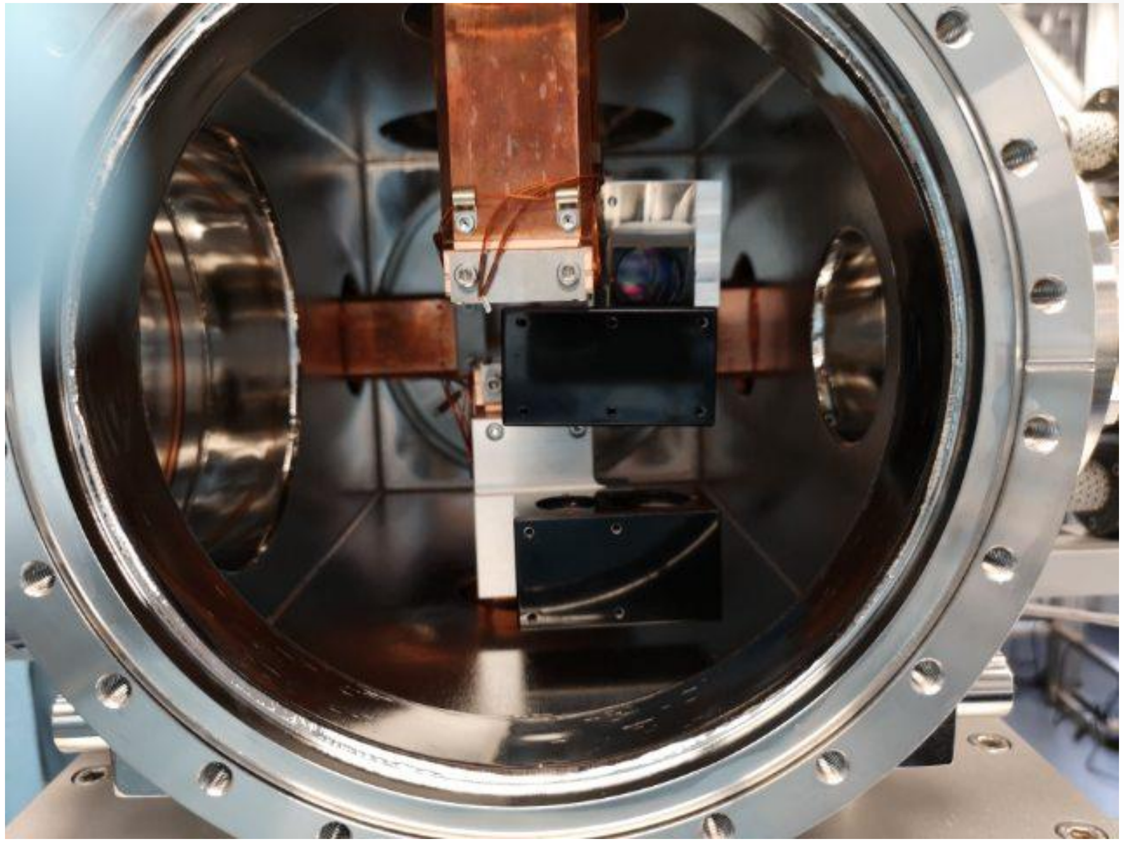






White beam slit system - Vibration





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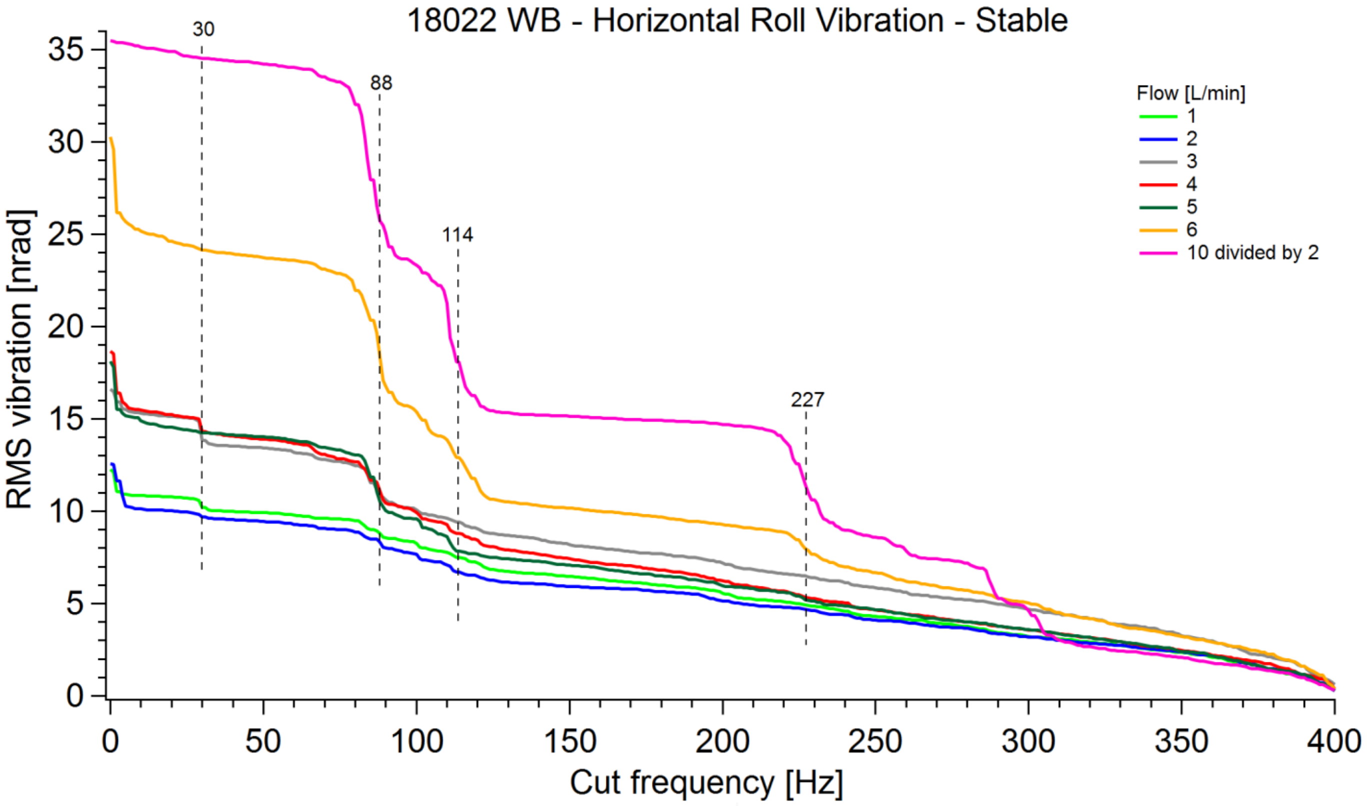
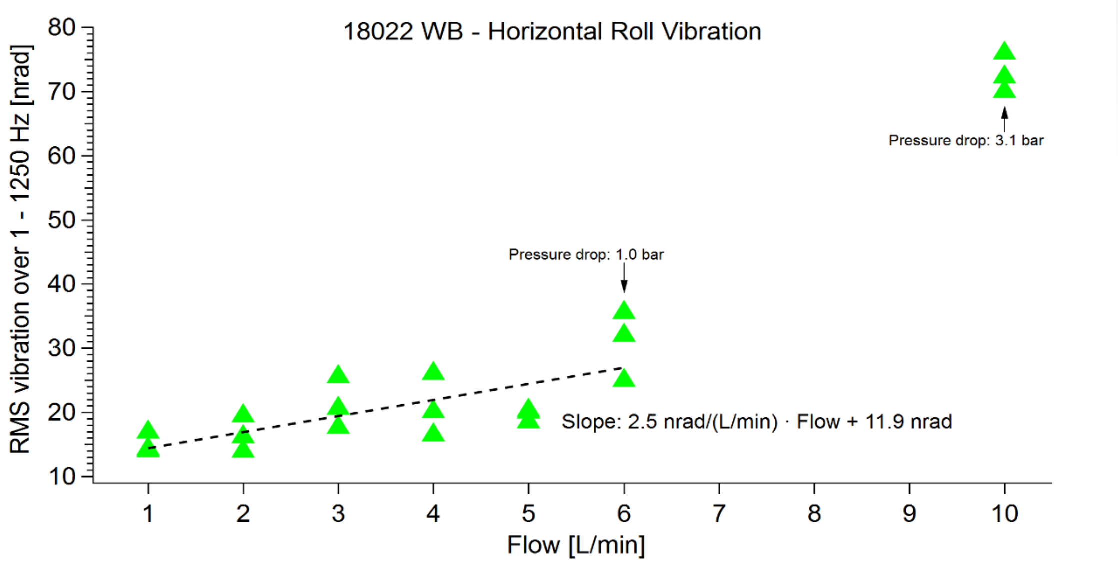
White beam slit system - Vibration





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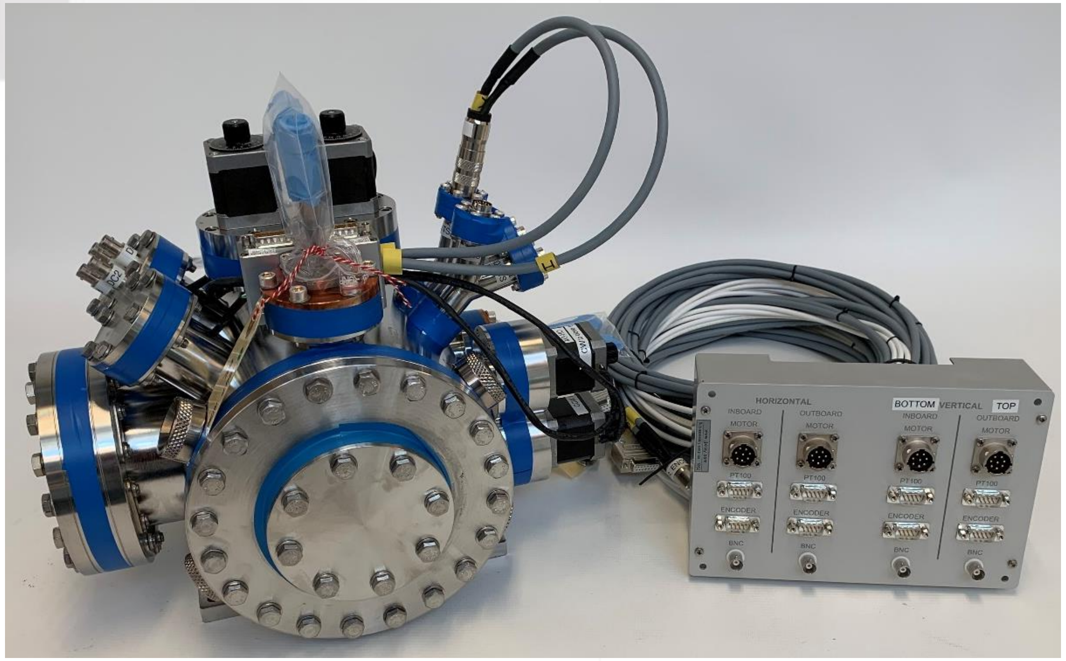
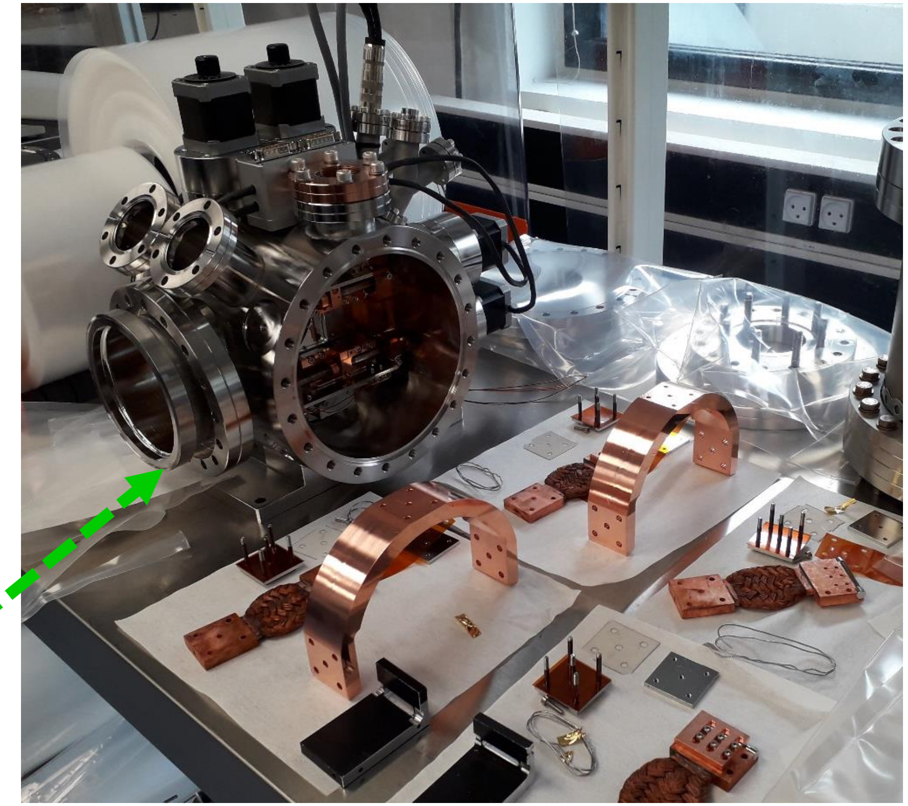
Pink beam slit system

Main Features

- 50 W with drain current reading
- Superb long-term stability – no vacuum forces influence the blade position
- Nano-polished beam defining entity
- Coating of beam defining entity possible: B4C, DLC or multilayer
- Compact: 238 mm end-to-end including reduction flanges

On all beamlines on the new SIRIUS synchrotron in Brazil





DN100 port for ionpump

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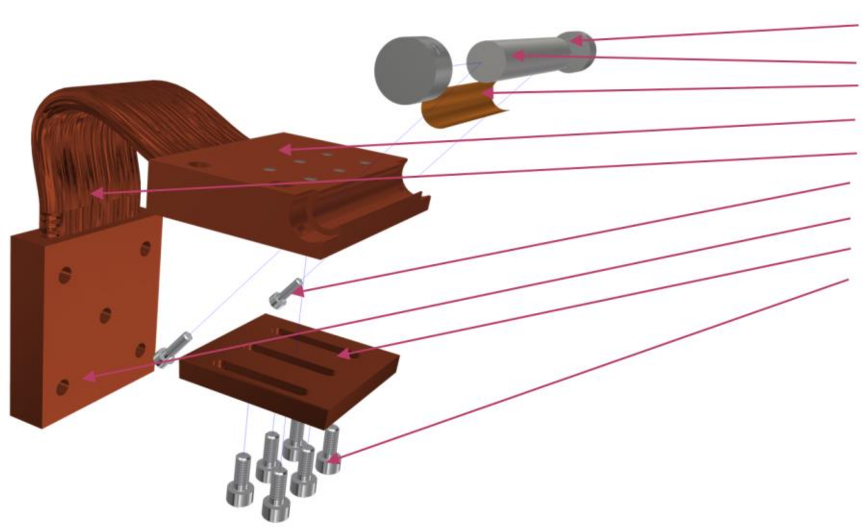
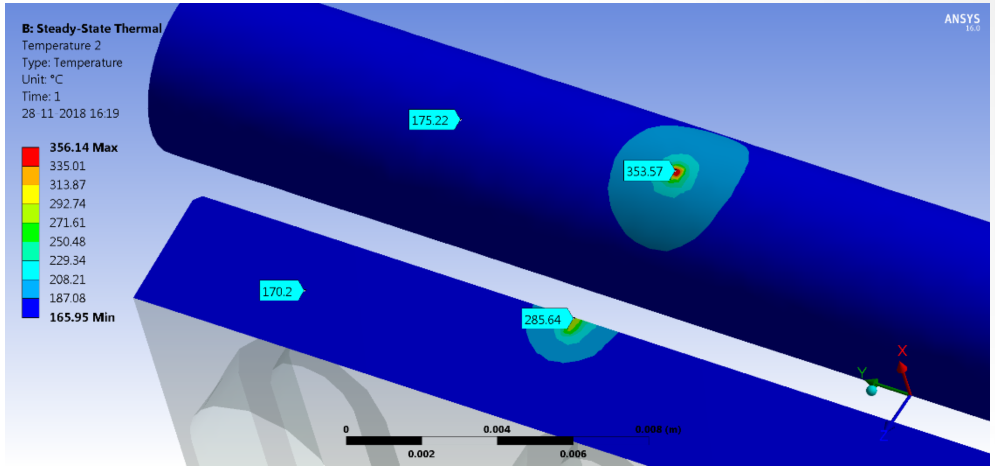
Pink beam slit system – cooling setup

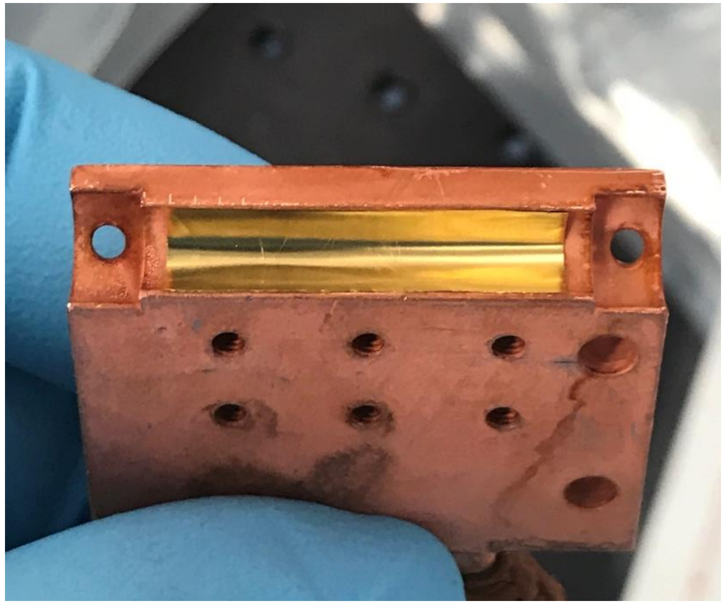


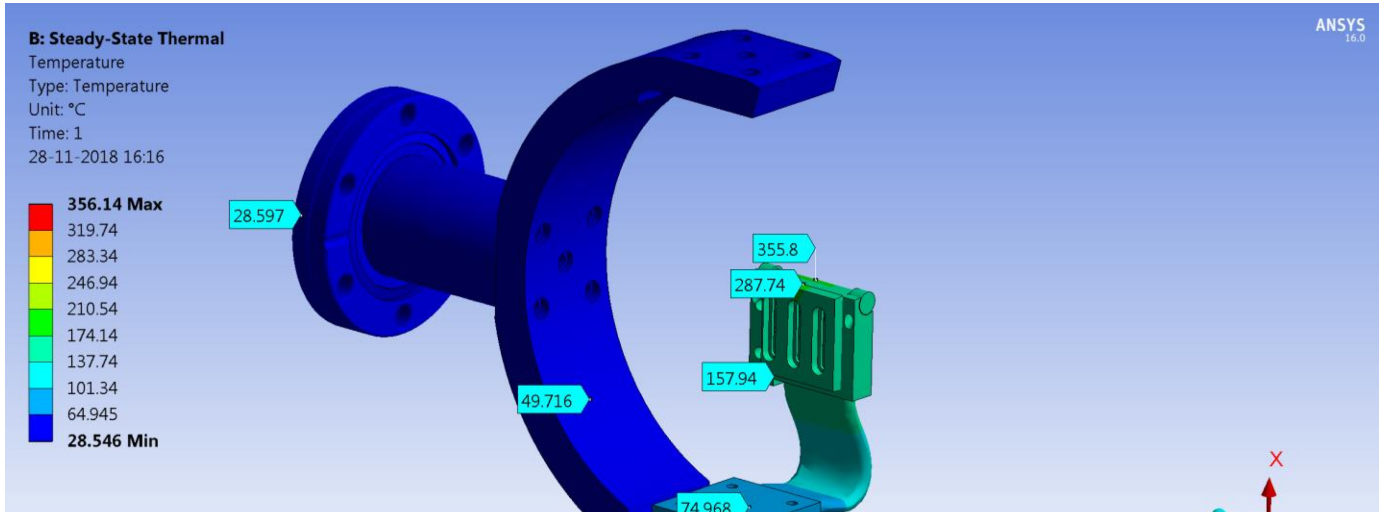
1. Nut
2. Tungsten rod
3. Gold sheet
4. Slit blade
5. Cobber braid
6. Screw
7. Cooling base
8. Cooling wedge
9. Screw

Item 4, 5 and 7 are silver brazed for best cooling efficiency.

Beam: 320μm x 80μm, 50 W







Electrical insulation while thermally conducting

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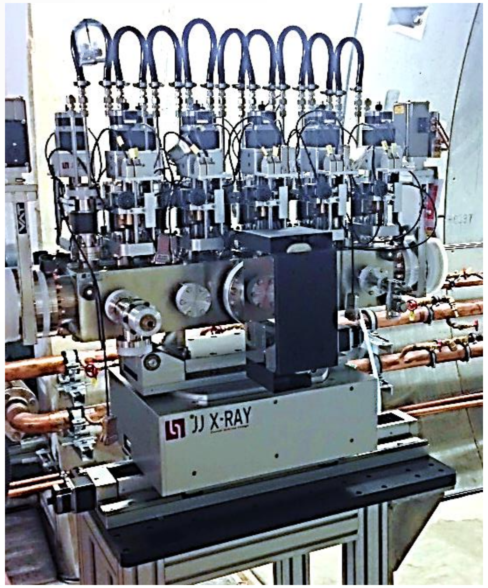
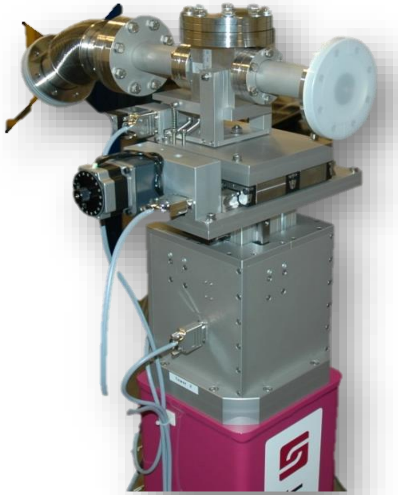
CRL Transfocator systems - cooled and non-cooled

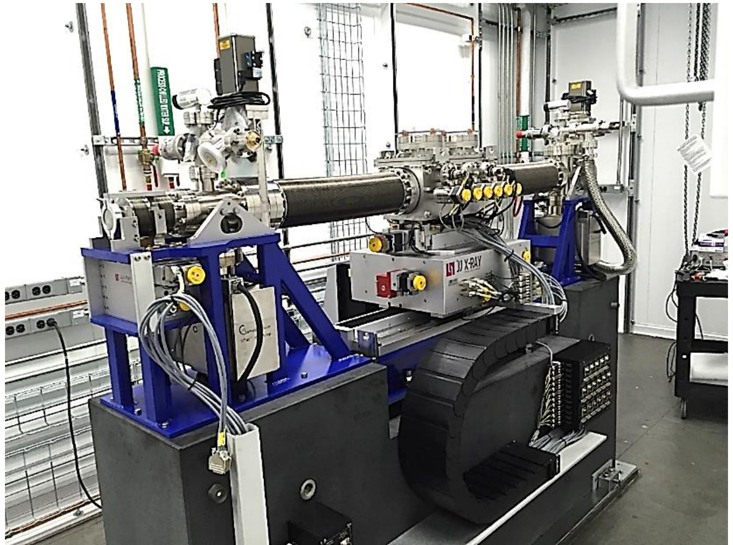
- We have more than 25 systems installed and in operation at 9 different facilities

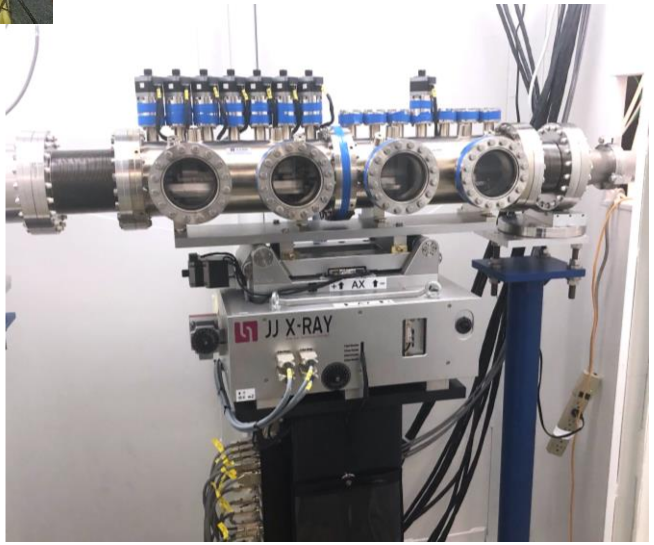
  APS, NSLS-II, SSRF, ESRF, LCLS, European-XFEL, CAMD, SSRF, NSRRC

- First system installed in 2006
- 2D, 1D, Single Energy, Tunable Energy, HV, UHV, monochromatic, water cooled …









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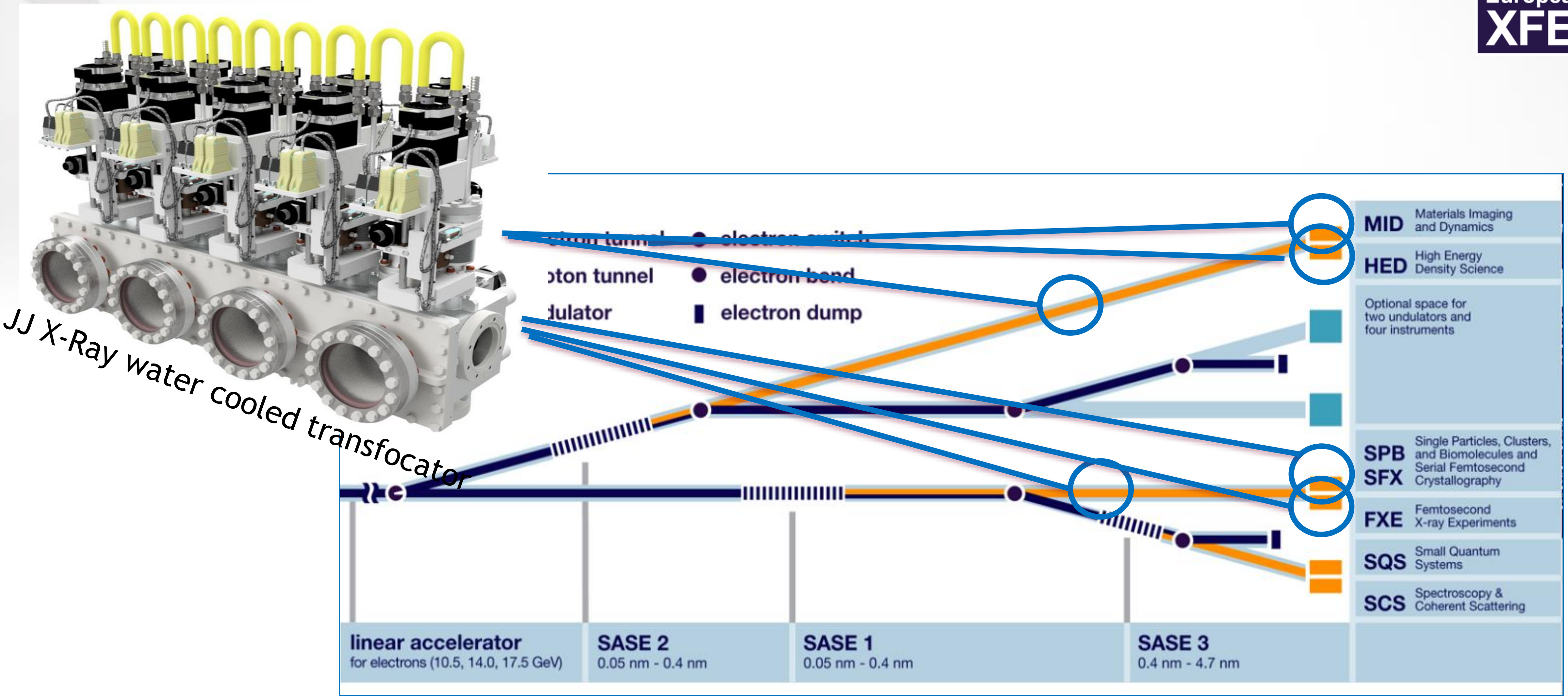
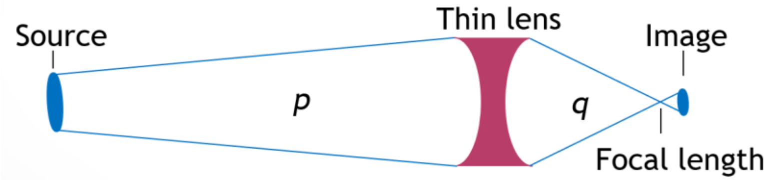
Refractive optics at European-XFEL



Compound Refractive Lenses, CRL's

- Easy to align
- Stable, < 100x less sensitive to vibrations than mirrors*
- Compact
- High thermal stability in the beam with a low settling time – superbly fitting white beam application
- Be, Al and Ni lenses available from RX Optics and integrated by JJ X-Ray
- Single Crystal Diamond lenses available from JJ X-Ray in-house production – 3rd party (Russian) raw diamonds welcome

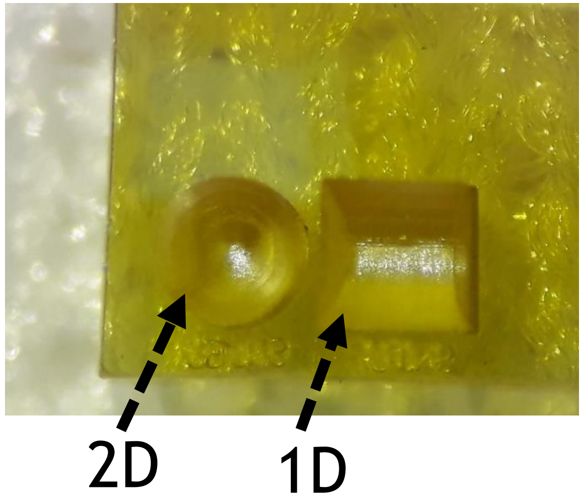


$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}\ , where\ \ f=\frac{R}{2N\delta}$$

2D focusing

1D focusing

2D *and* 1D focusing



*Lengeler, B. et. al. (1999). J. Synchrotron Rad. 6, 1153-1167

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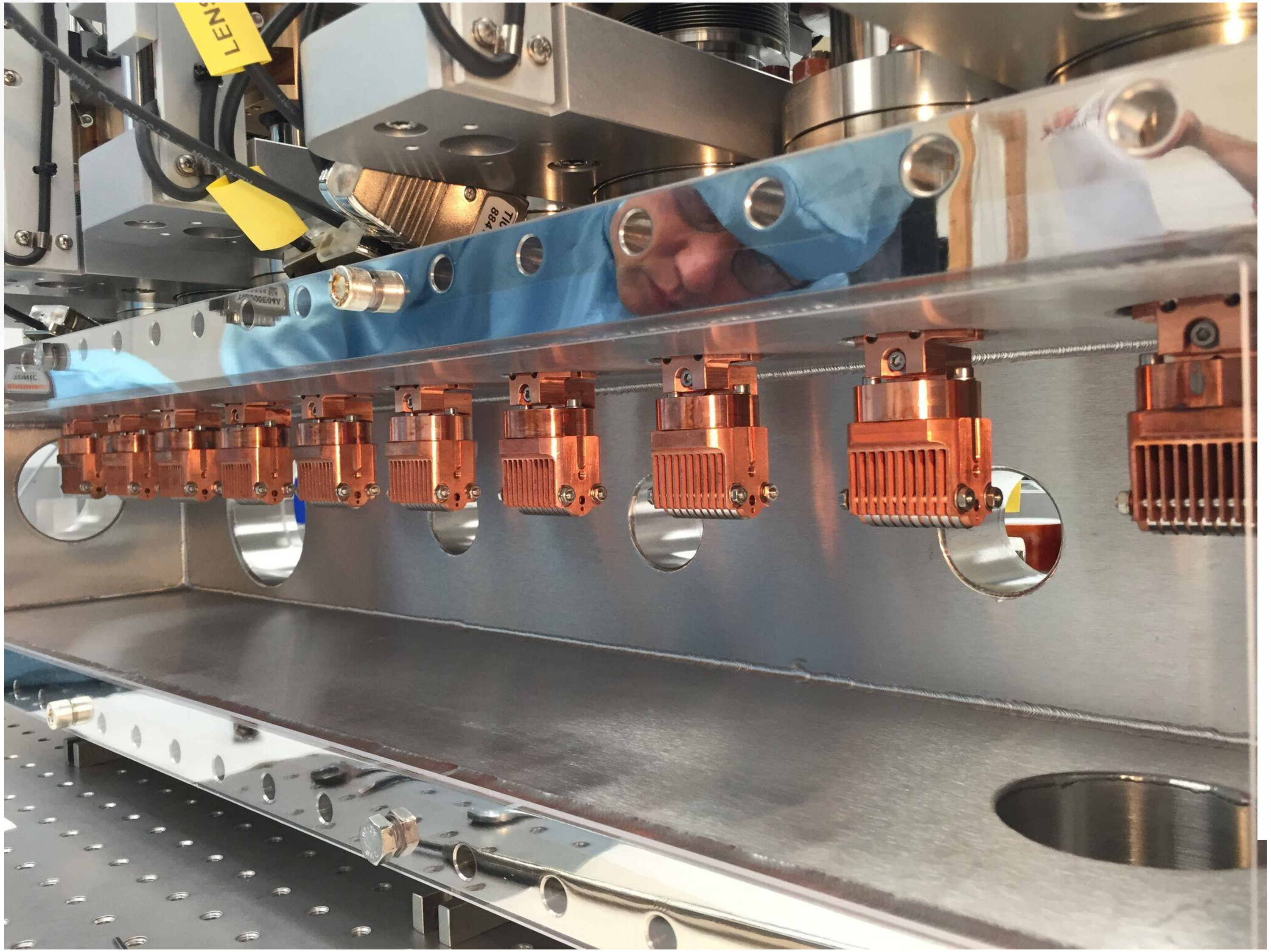
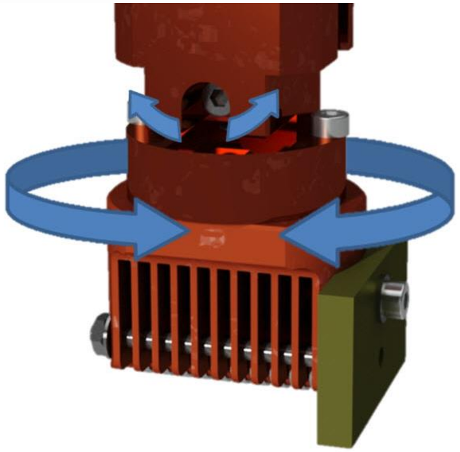
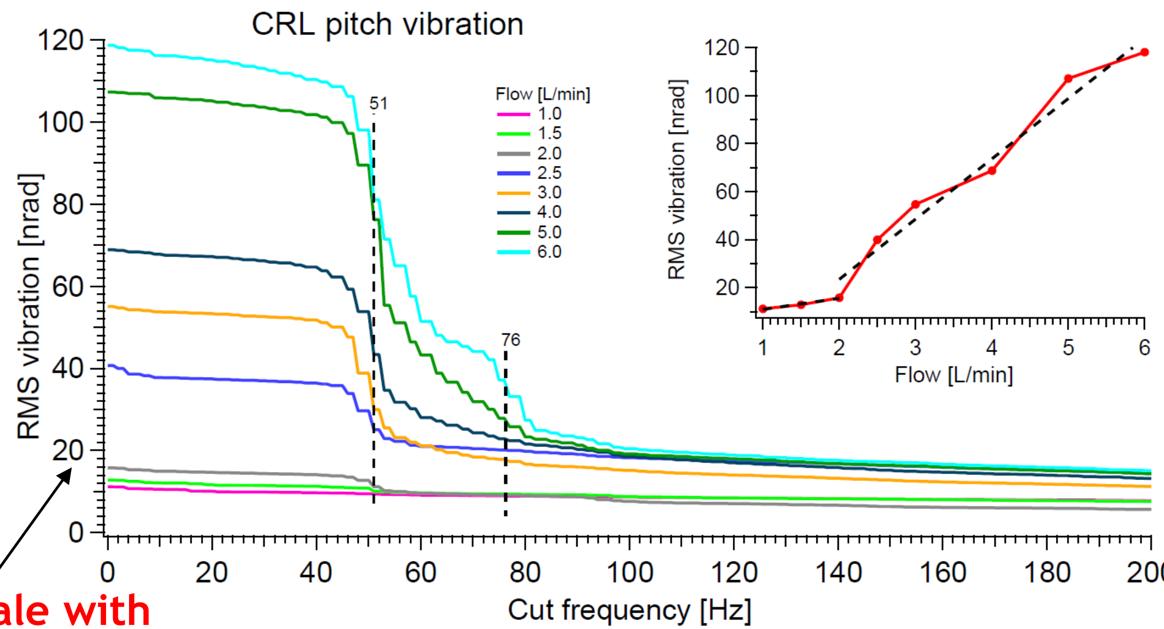
Water cooled UHV Transfocator for 1D and 2D lenses

- The 10 lens cassettes mounted with lenses and aligned

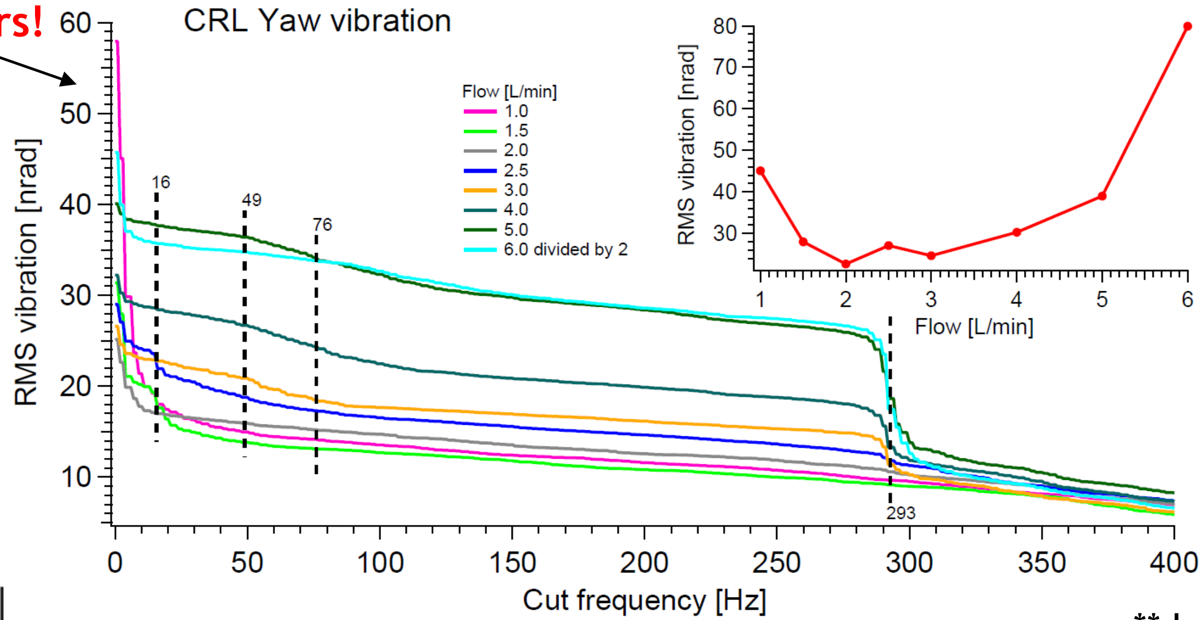


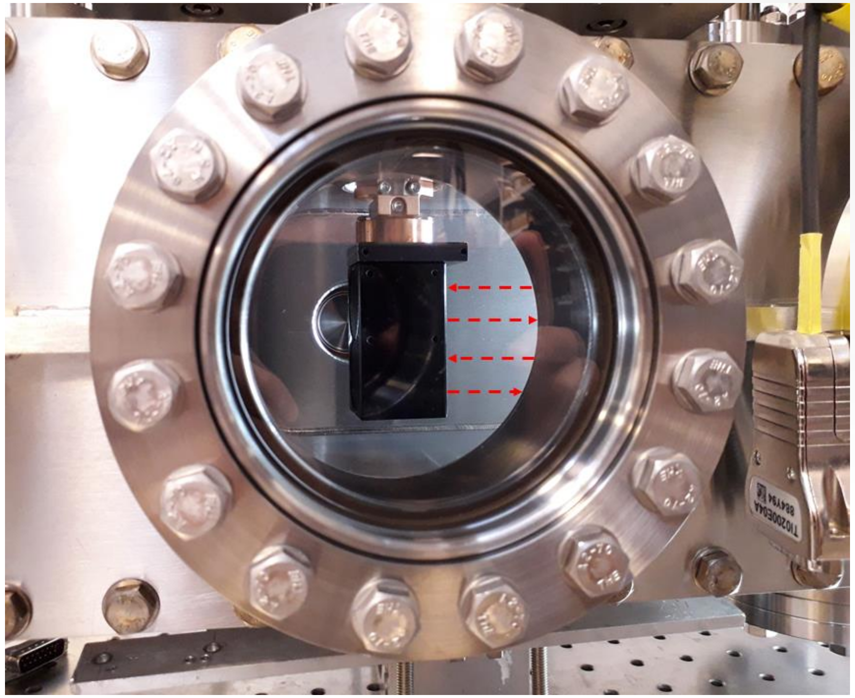


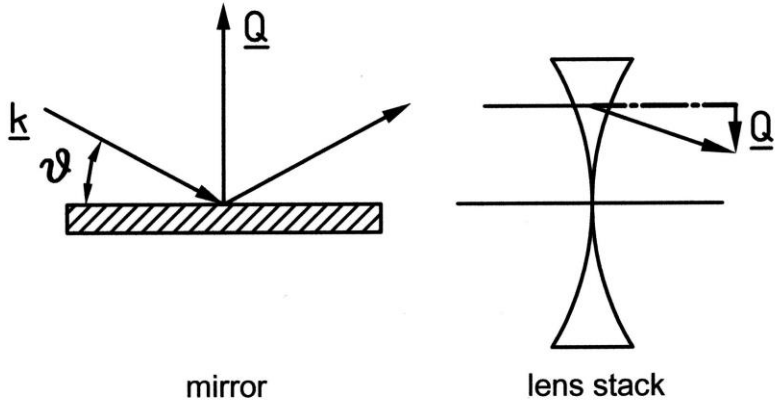
Water cooled UHV Transfocator vibration



Multiply scale with 0.01 to compare with mirrors!







$Q = 2k \sin \vartheta \approx 2k\vartheta$ $Q = \mathrm{sqrt}(N)\, k\, \delta$ **

** Lengeler, B. et. al. (1999). J. Synchrotron Rad. 6, 1153-1167.

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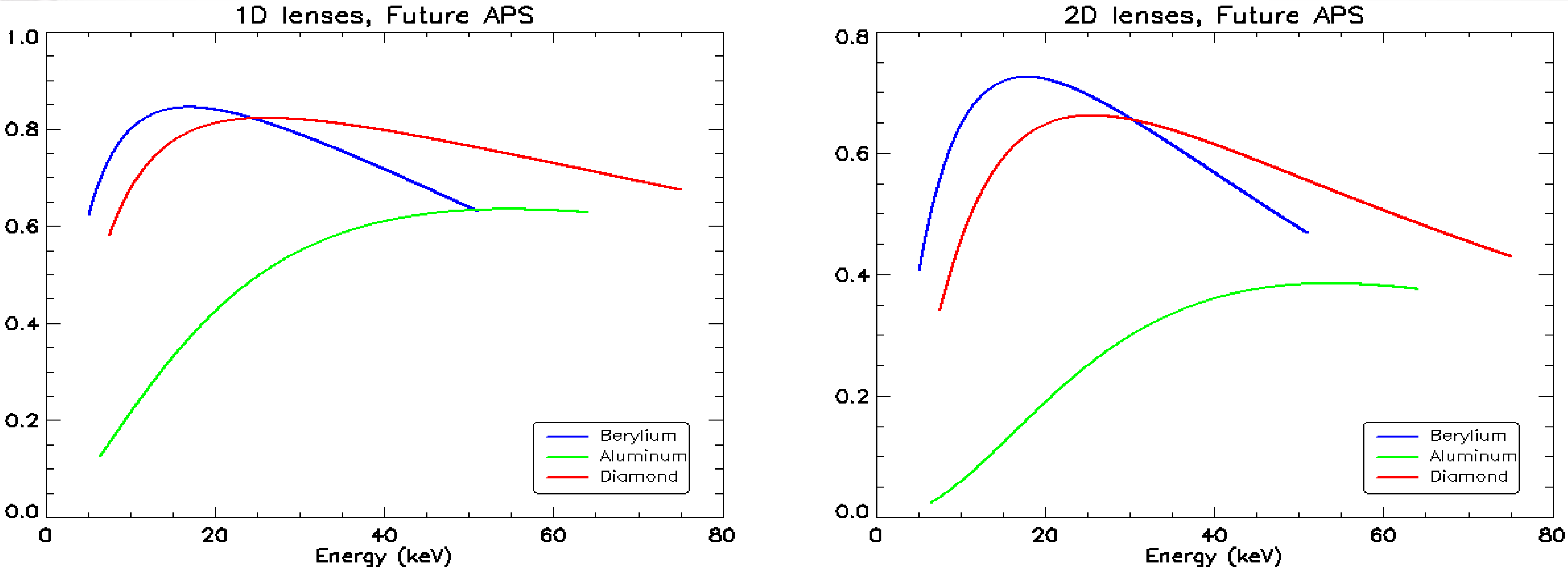
Different lens materials available

- Example from ChemMatCARS with U-APS parameters
- CRL at 46.7 m, focus at 56.5 m, 1-95 lenses
- Transmission vs. energy



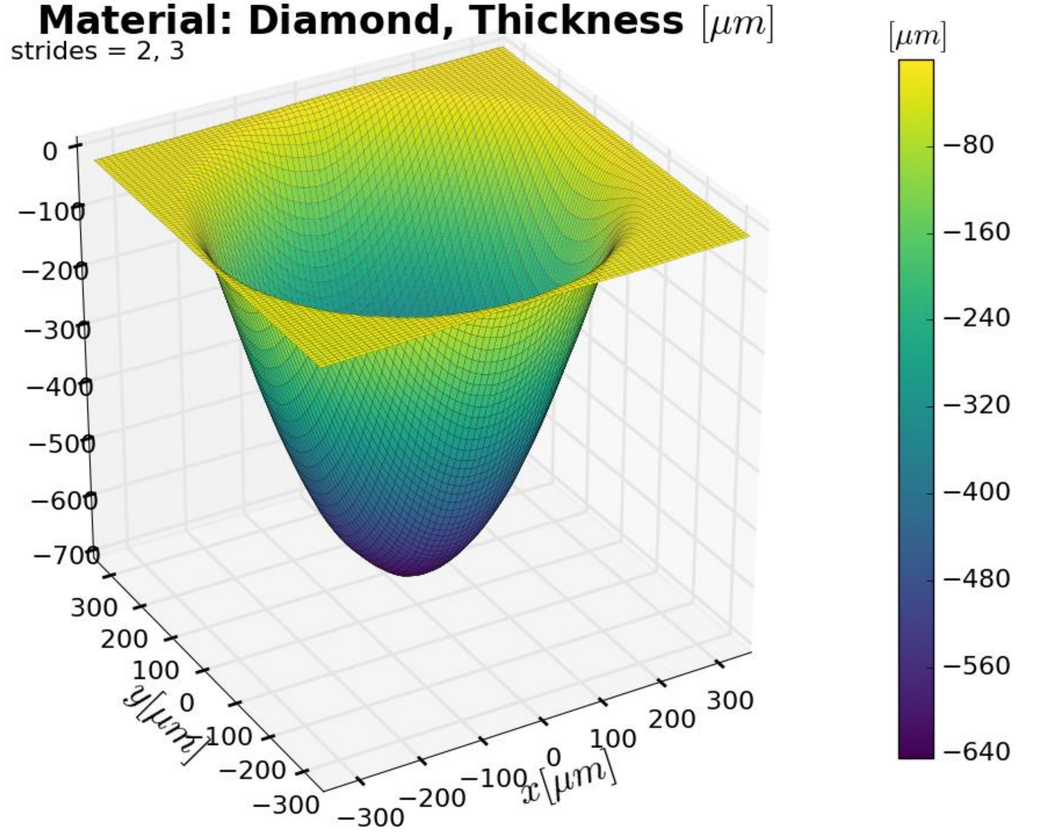
Mati Meron, 2018

JJ X-RAY Danish Science Design

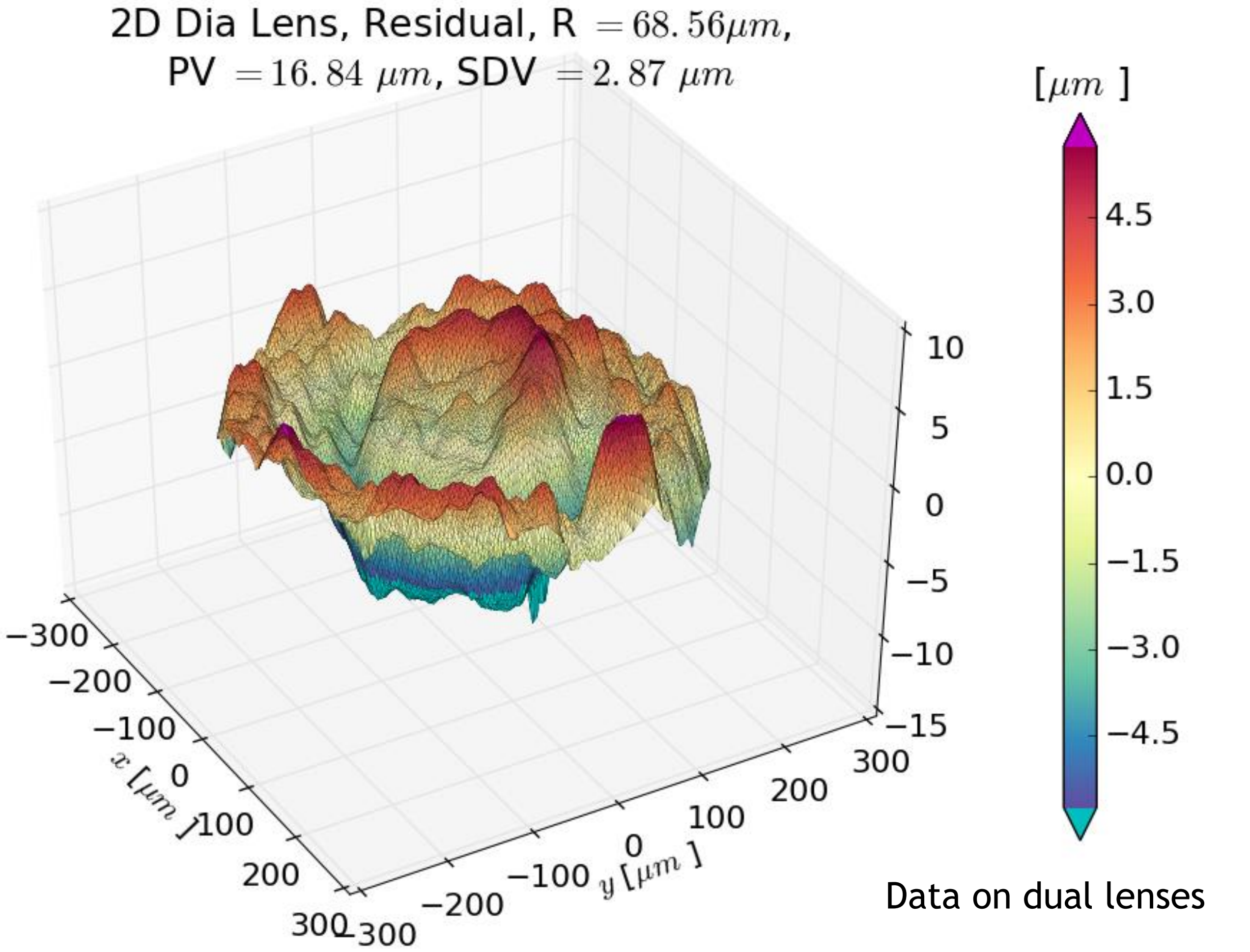
1BM, APS

JJ X-Ray Single Crystalline Diamond Lenses

APS measurements



Data on dual lenses



Data on dual lenses

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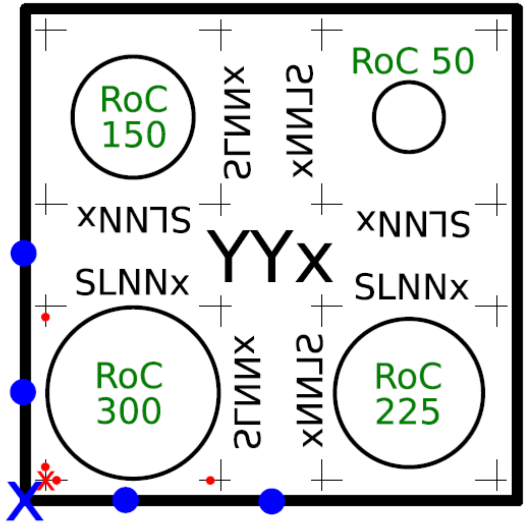
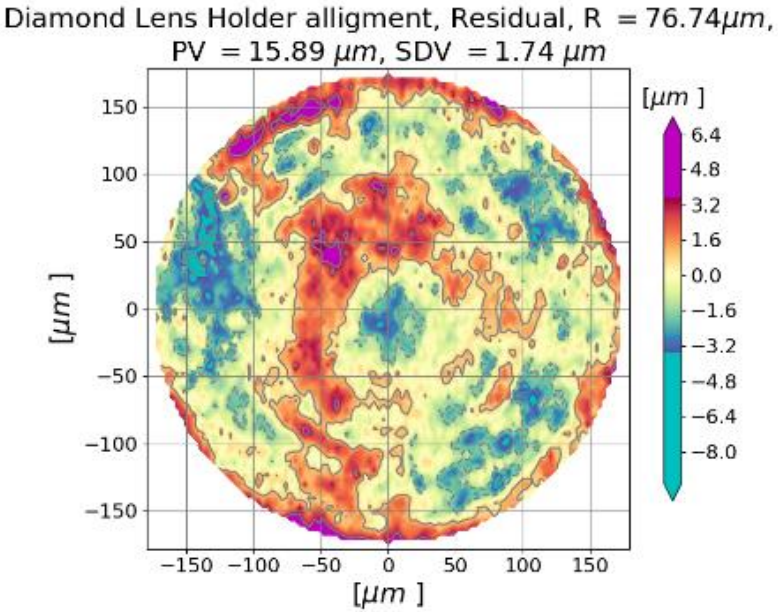
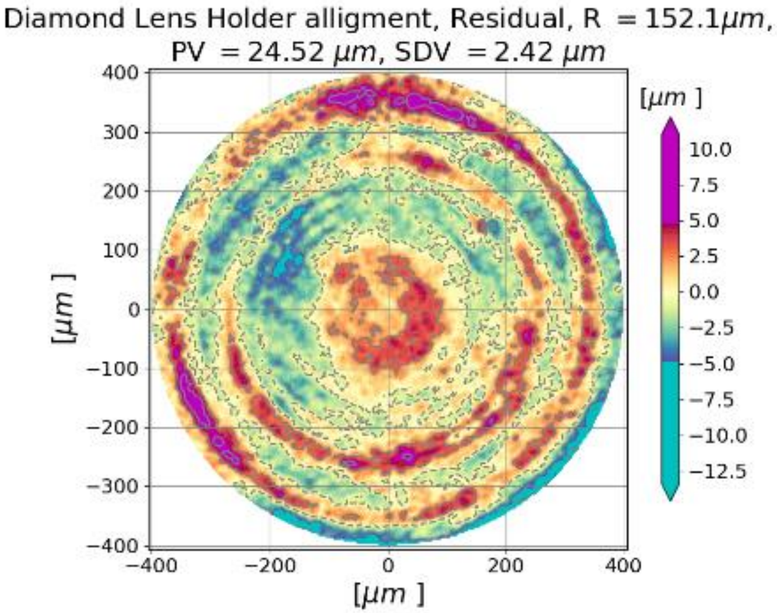
Lenses for synchrotron experiment

Talbot interferometry

RoC	50 µm	150 µm	225 µm	300 µm
Mean deviation RMS	(7.50 ± 1.14) µm	(2.78 ± 0.42) µm	(3.62 ± 1.43) µm	(2.10 ± 0.16) µm
Mean deviation RMS near apex	(1.39 ± 0.19) µm	(1.24 ± 0.17) µm	(1.15 ± 0.17) µm	(0.93 ± 0.14) µm
Fitted RoC of tilted lenses	(22.9 ± 0.94) µm	(72.0 ± 3.9) µm	(104.4 ± 3.9) µm	(144.8 ± 6.2) µm

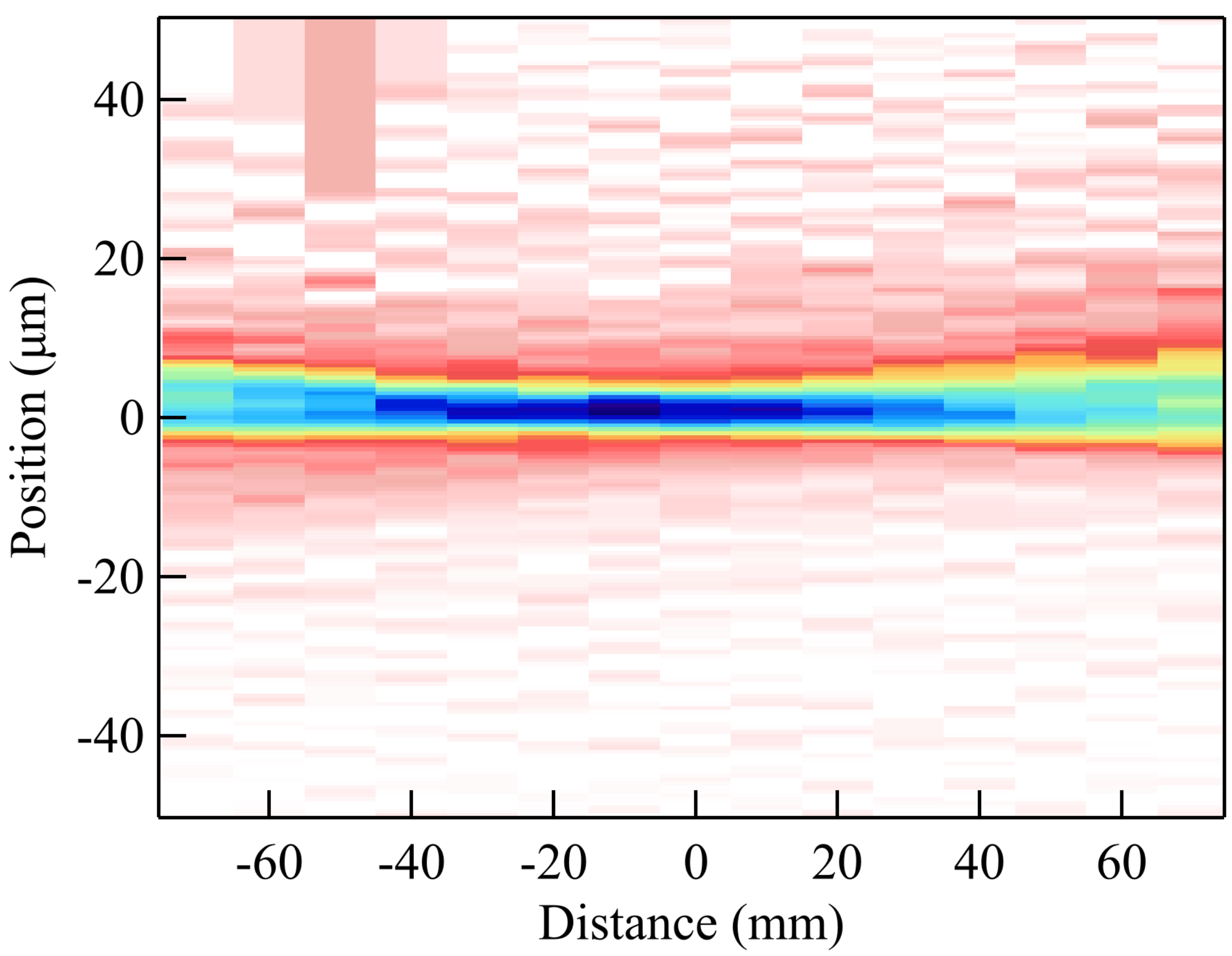


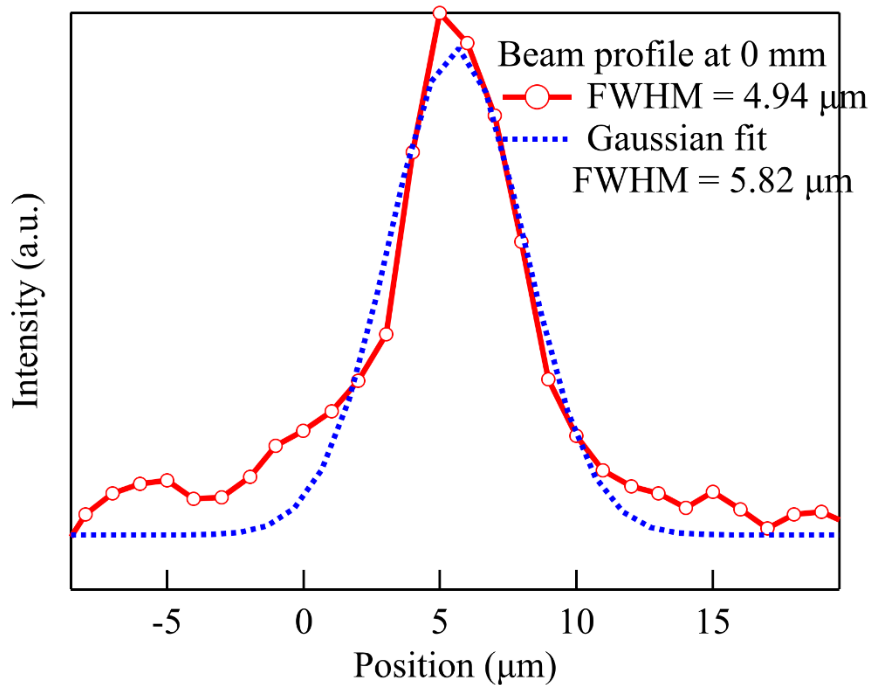


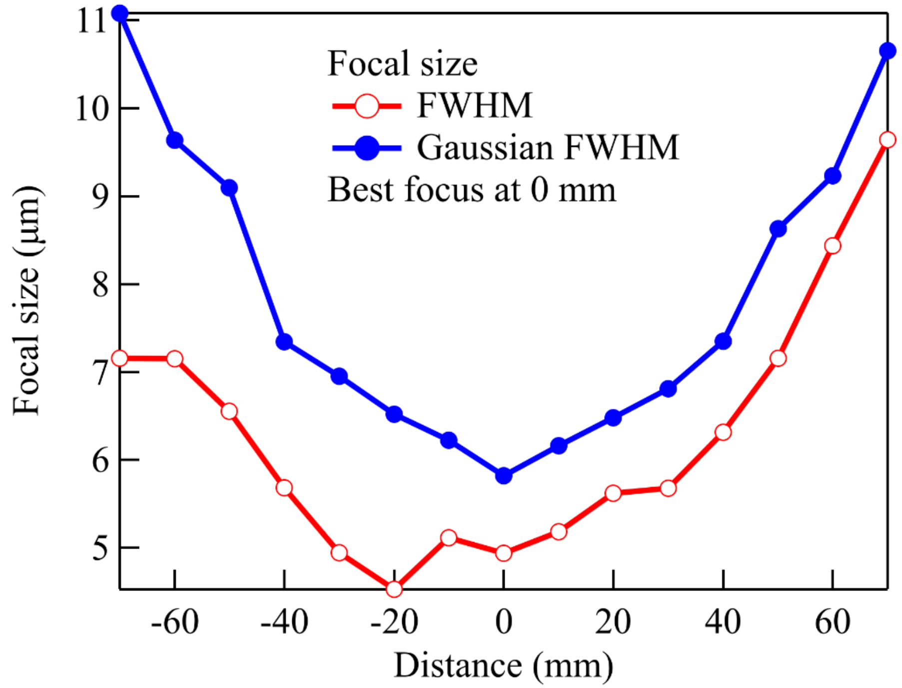


Single Crystalline Diamond Lenses
APS measurements

2.1 x theoretical focus on generation II lenses







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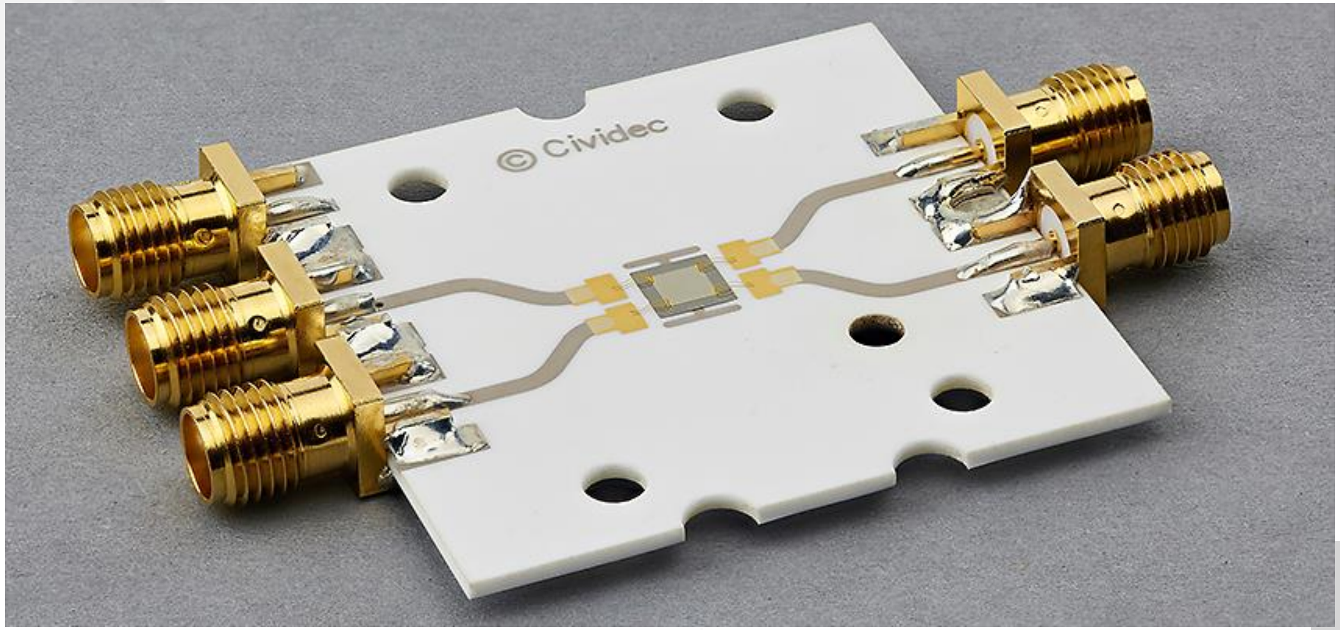
Synchrotron Beam monitoring – a JJ X-Ray and cividec collaboration



- Single crystal CVD diamond
- 2 μm gap between the pads

- Online feedback
- Full positional and angular beam characterization
- Beam intensity monitoring
- Detection of beamline and source instabilities
- Pink beam monitoring

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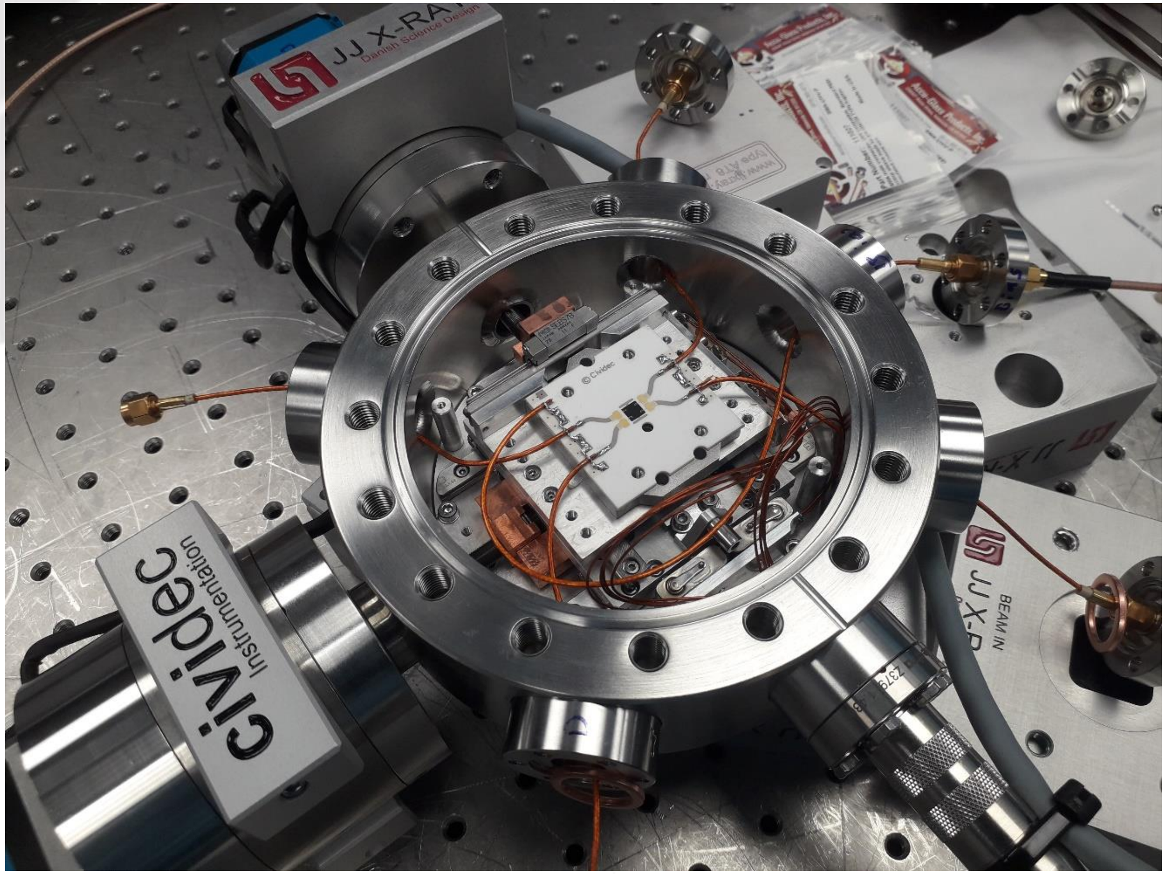
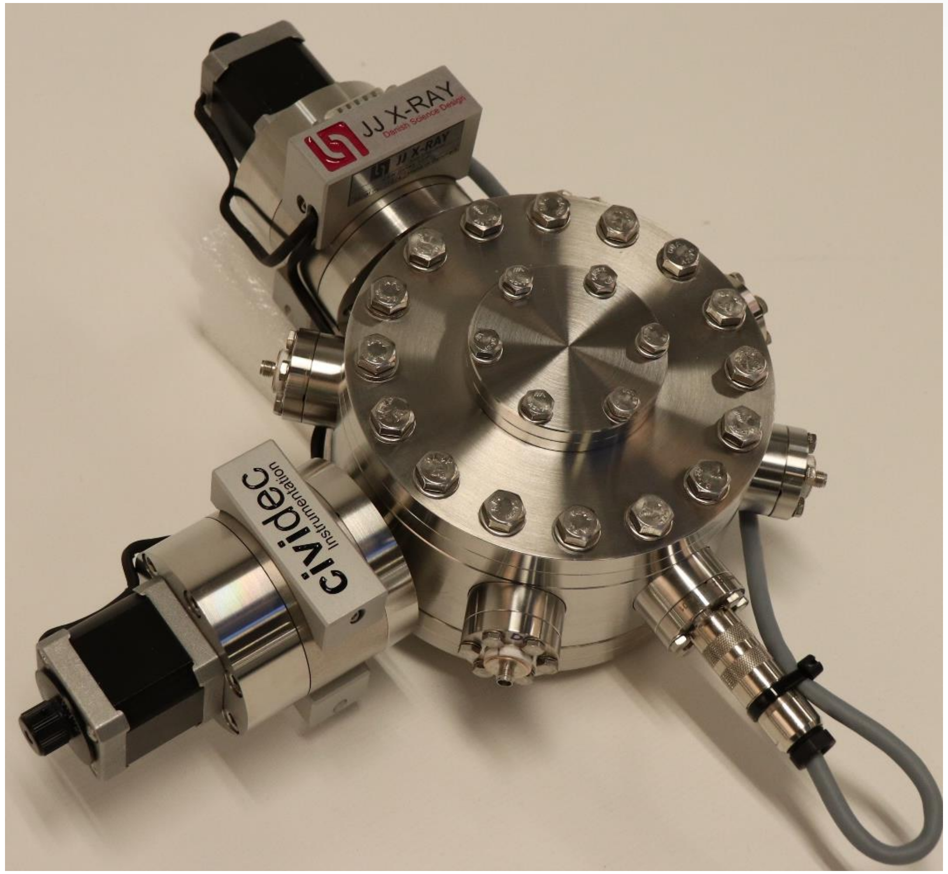
Synchrotron Beam monitoring – a JJ X-Ray and cividec collaboration

Position measurement resolution 0.37 nm at the NanoMAX beamline at Max IV*

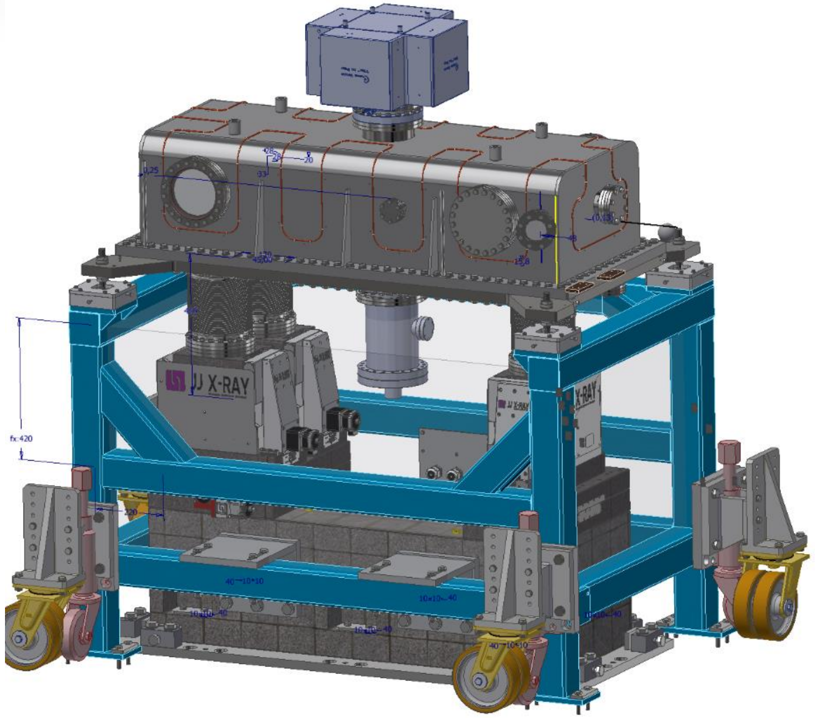


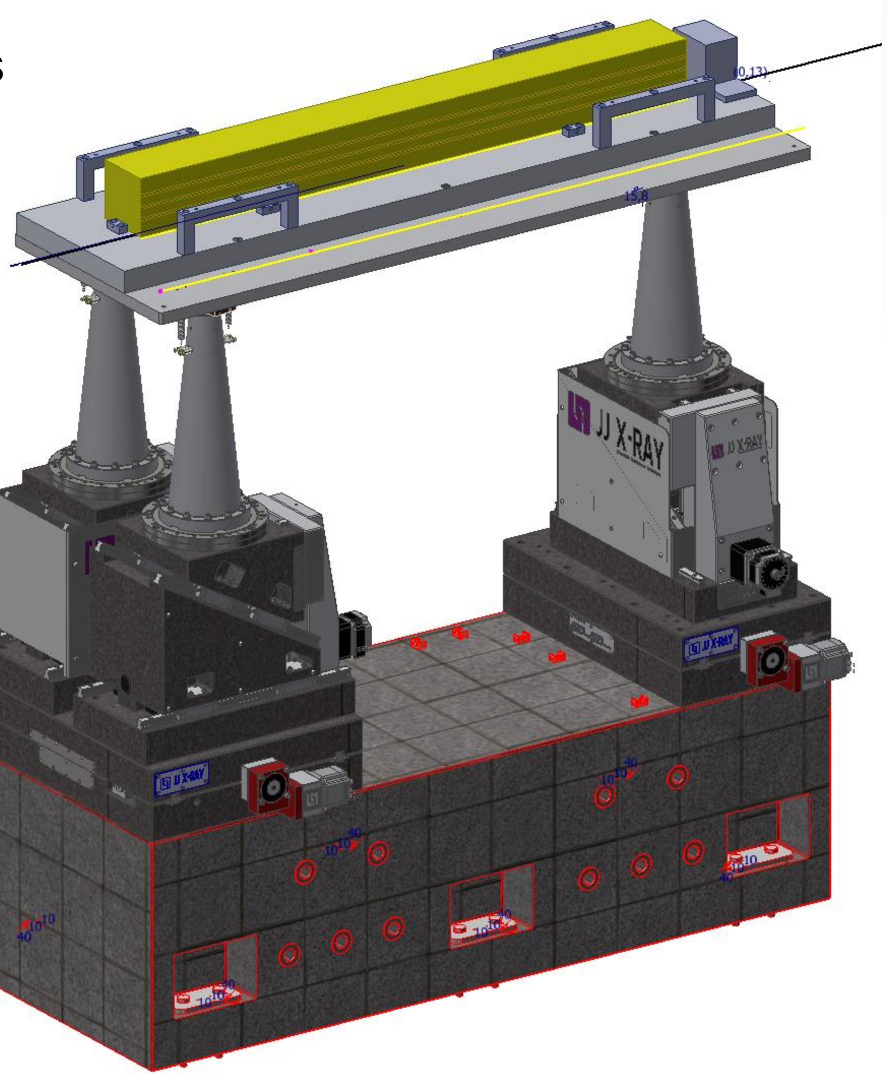


*https://doi.org/10.1063/1.5084683

Mirrors systems

- Full granite/Invar support for improved vibrational and thermal performance
- Optics sourced from all major vendors, e.g. Zeiss, Crystal Scientific, SESO and J-Tec
- Two and one actuator benders available
- Gravity compensation for vertical bounce systems
- Custom cooling schemes
- **Transfer function testing included**





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and much more...

Questions?

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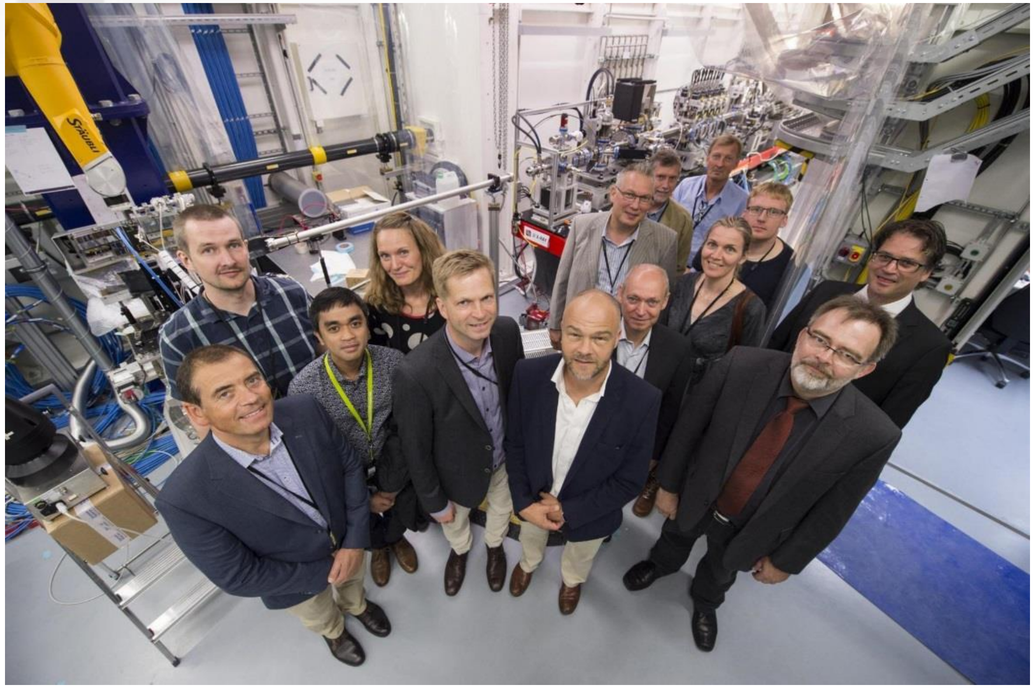
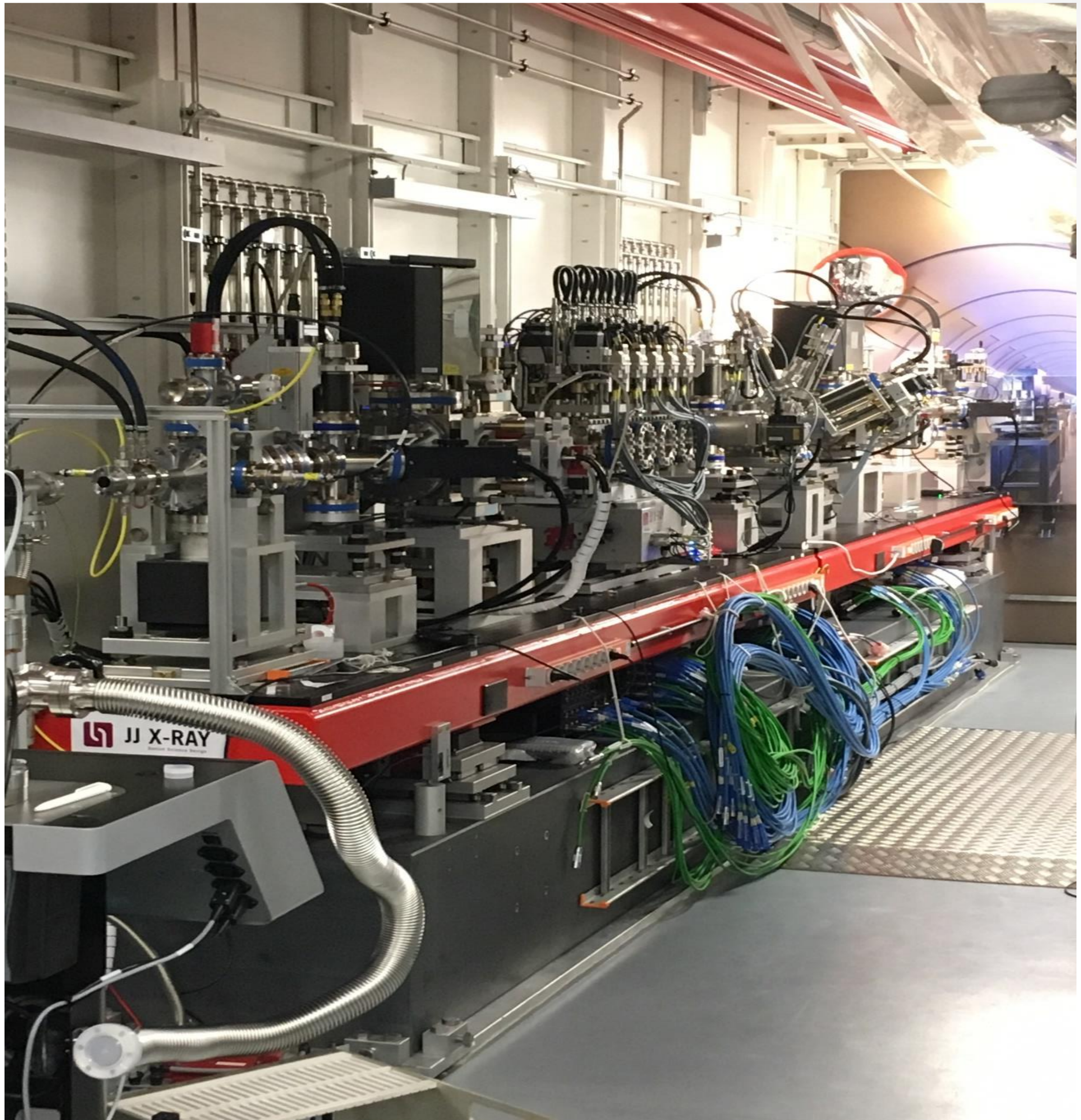
The FXE instrument at European-XFEL

European XFEL

The JJ X-Ray team at the inauguration of European XFEL September 2017





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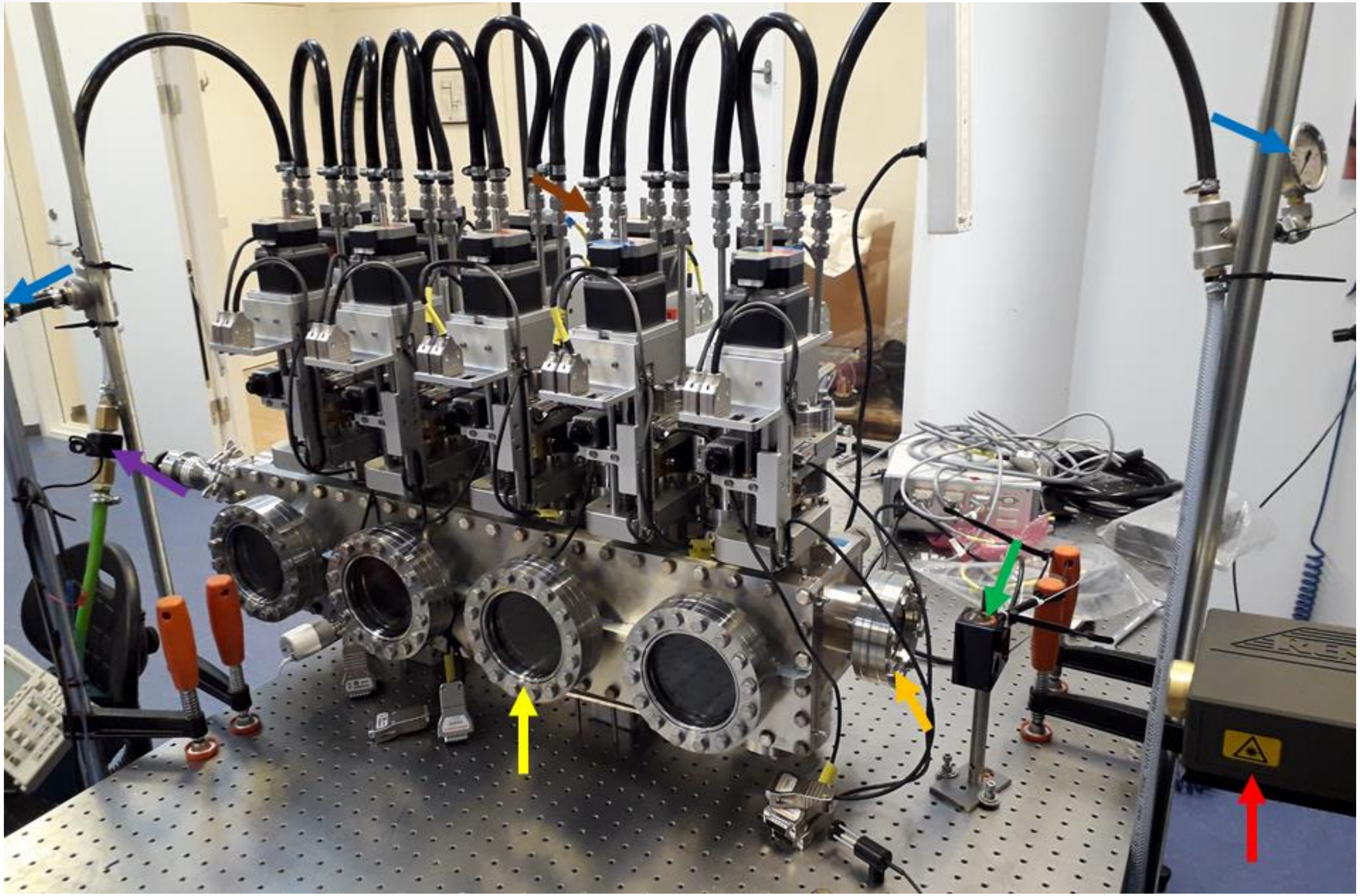
Water cooled UHV Transfocator vibration



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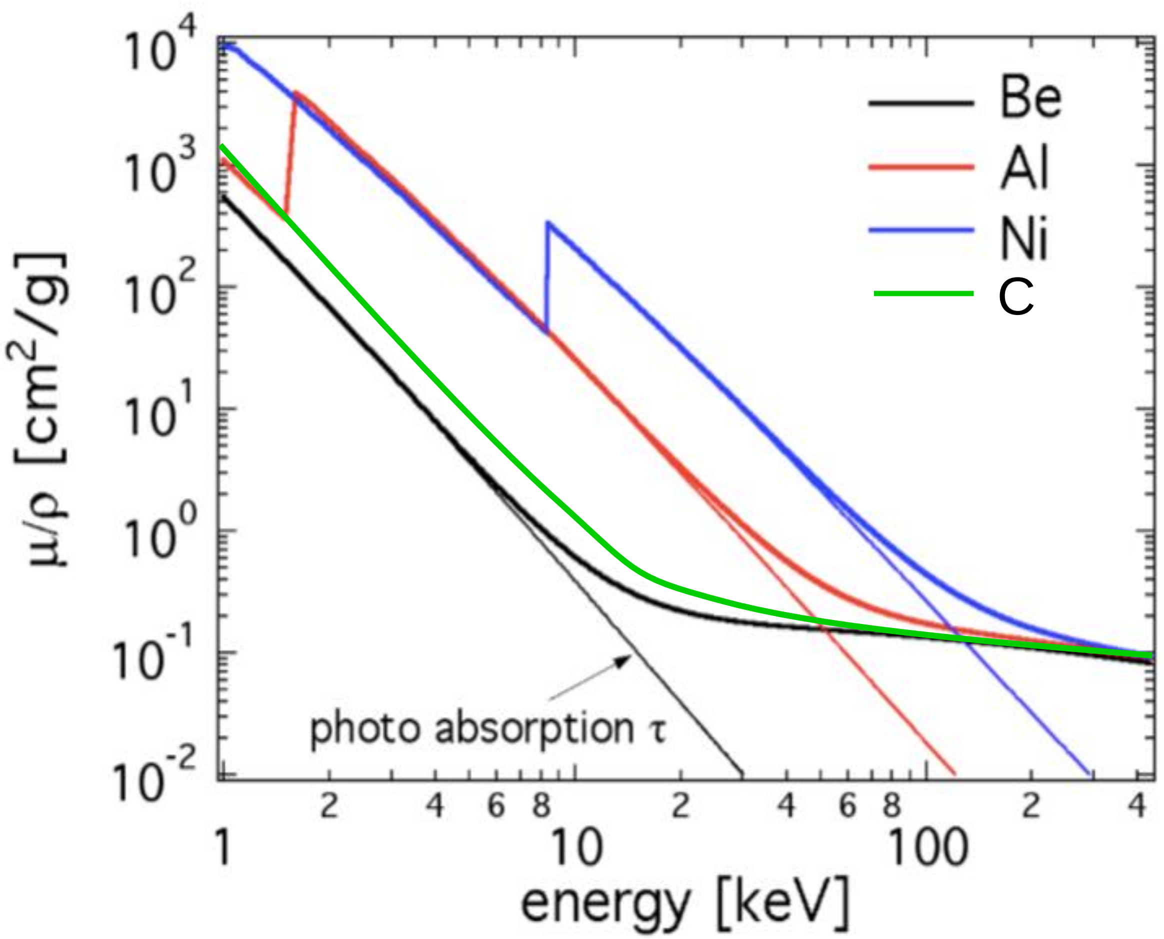
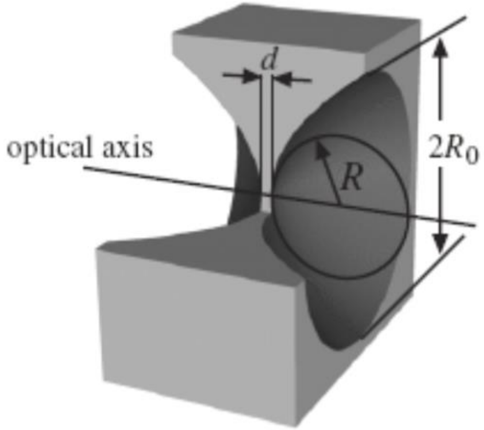
Different lens materials available

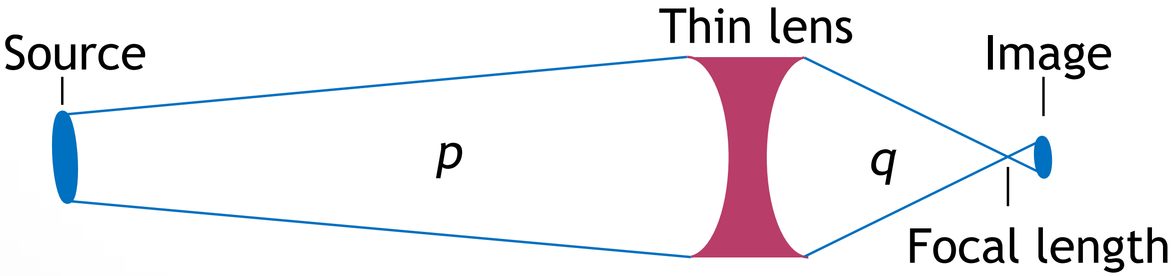
- Attenuation for different lens materials

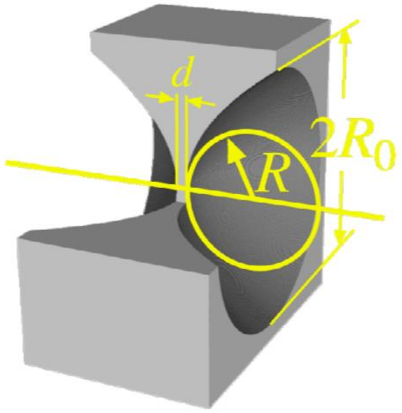


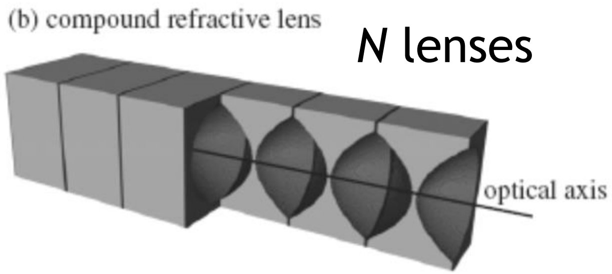


- Beryllium Lenses (2-40 keV)
- Aluminium Lenses (40-80 keV)
- Nickel Lenses (80–150 keV)
- **Diamond (5-90 keV)**

Compound Refractive Lenses or CRL's – the basics







Lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}\,, where\ \ f=\frac{R}{2N\delta}$$

where R is the radius of curvature at the apex, and δ is the real part of the refractive index:

$$n = 1-\delta-i\beta$$

The transmission through N lenses is:

$$T=\frac{R}{\mu N R_0^2}\left(1-e^{-\frac{\mu N R_0^2}{R}}\right)\cdot \underline{e^{-\mu N d}}$$

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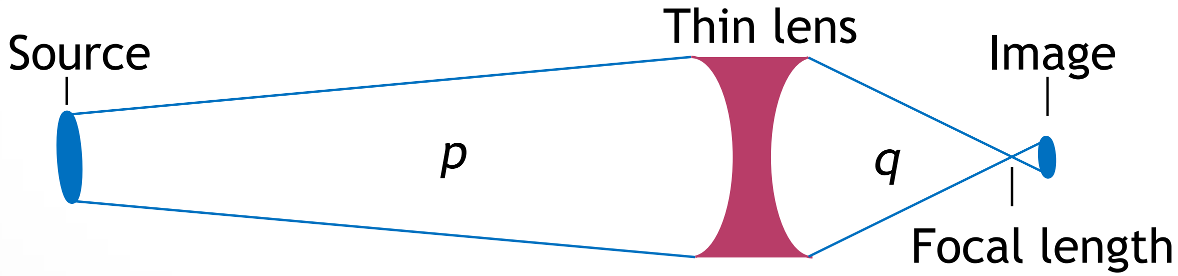
Compound Refractive Lenses or CRL's – the basics



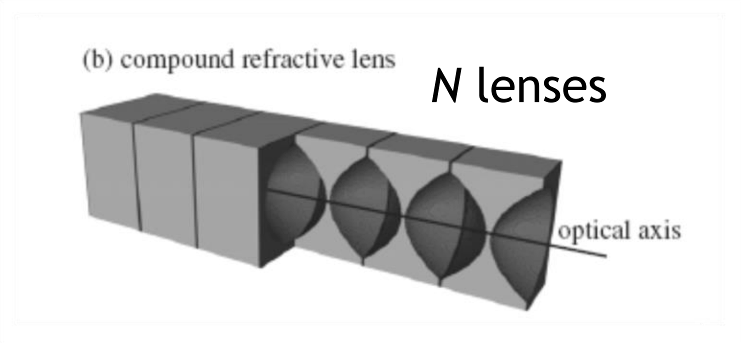
For a given beamline geometry the lens equation is fixed

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}, where\ f=\frac{R}{2N\delta}$$

but you want to minimize N and R and to choose δ to be large or, in general, μ/δ to be small.

The geometrical aperture $2R_0$ is limited by the effective aperture D_{eff} as:

$$D_{eff}=\sqrt{\frac{2R}{\mu N}}$$



For a given beamline geometry the lens equation is fixed

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}\ ,where\ \ f=\frac{R}{2N\delta}$$

but you want to minimize *N* and *R* and to choose δ to be large or, in general, $\boldsymbol{\mu/\delta}$ to be small.

The geometrical aperture $2R_0$ is limited by the effective aperture D_{eff} as:

$$D_{eff}=\sqrt{\frac{2R}{\mu N}}$$

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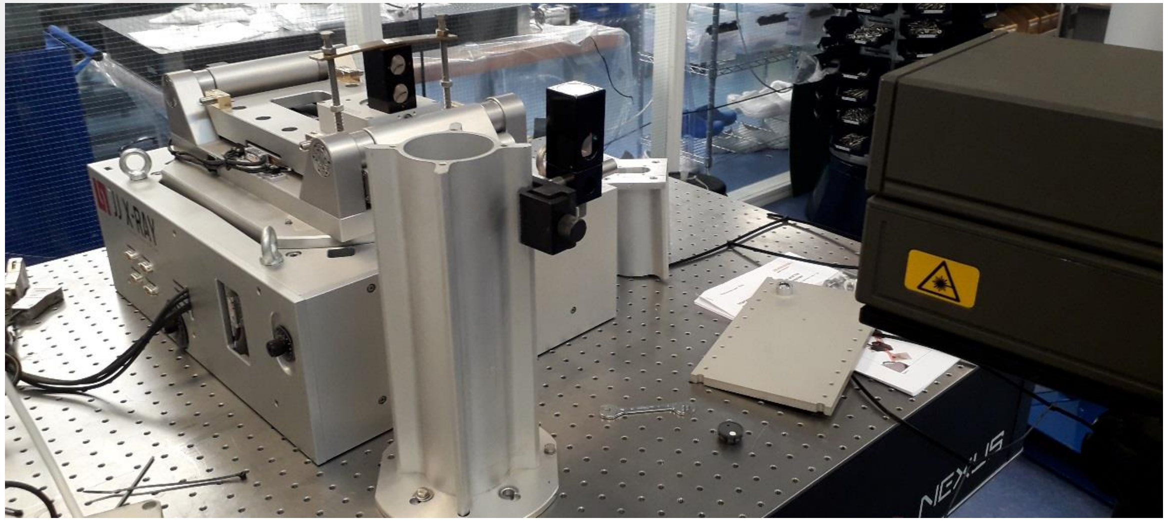
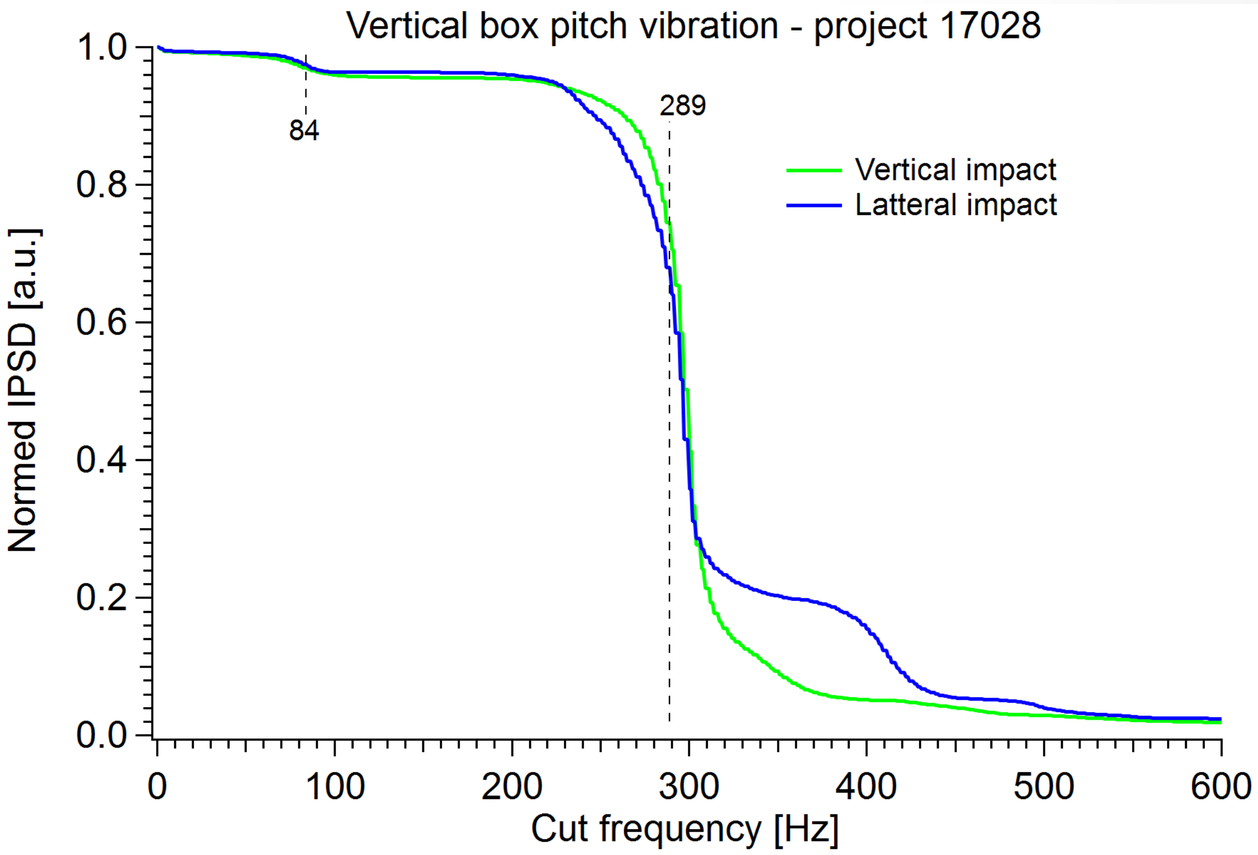
Water cooled UHV Transfocator box stability

- Main eigenmode at 289 Hz
- Compact design
- 4-way freedom





Mirror Benders

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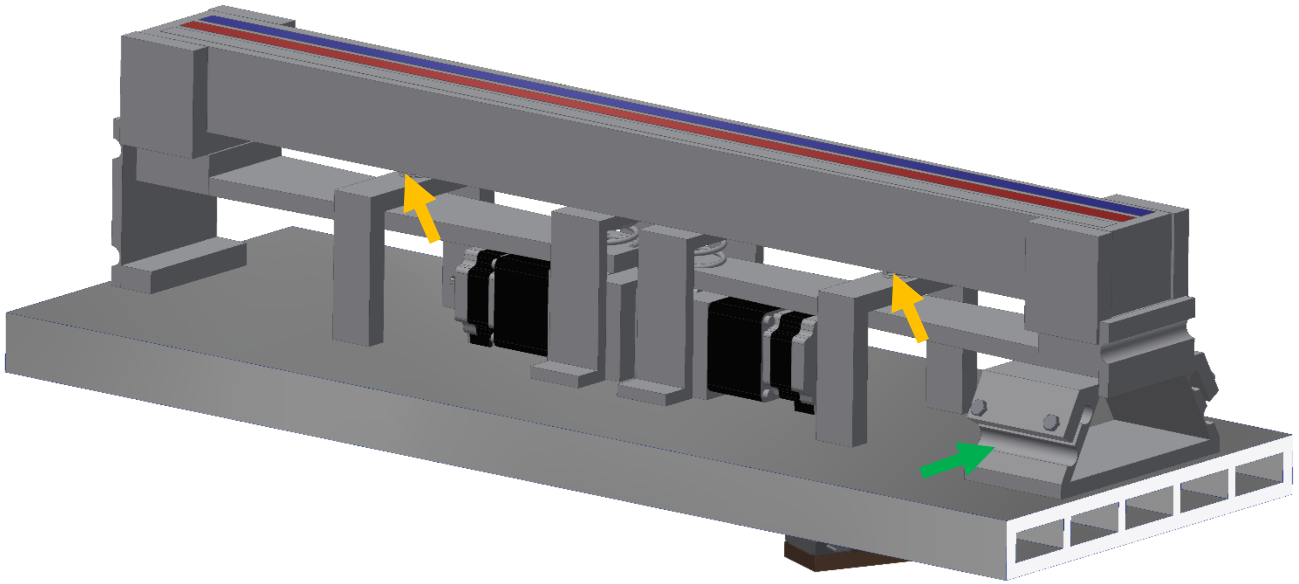
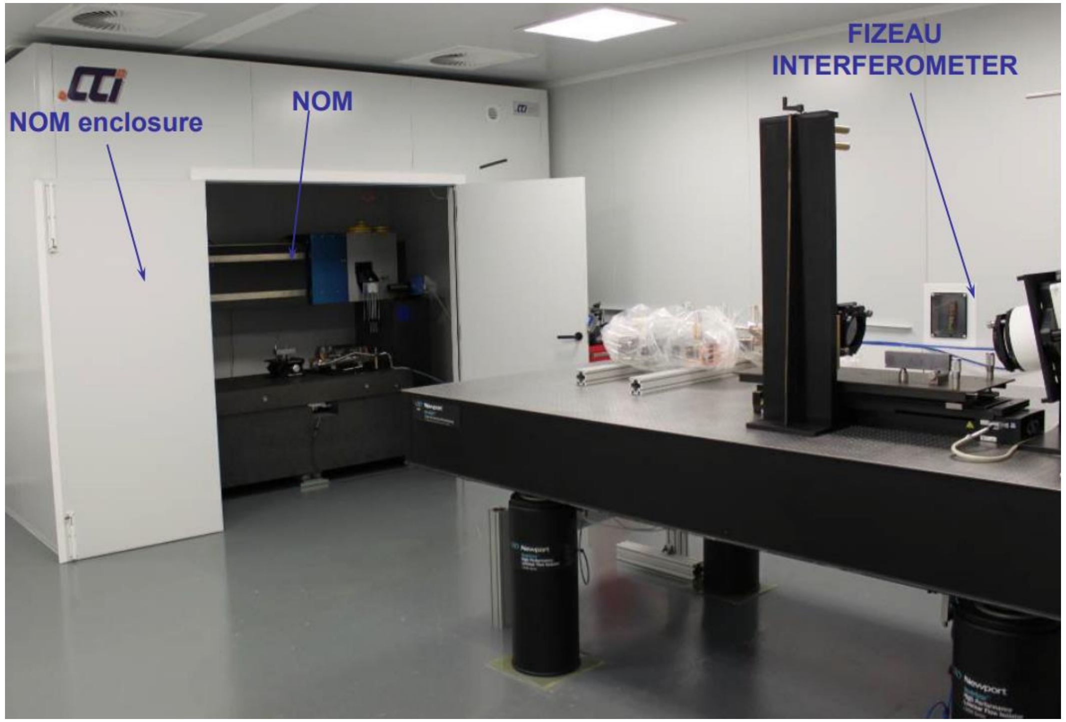
Features:

- Full UHV compatibility
- Renishaw encoding
- Two moment actuation
- High bending resolution through steel moment arms
- Gravity compensation
- Twist compensation
- Characterization at ALBA metrology lab

ALBA

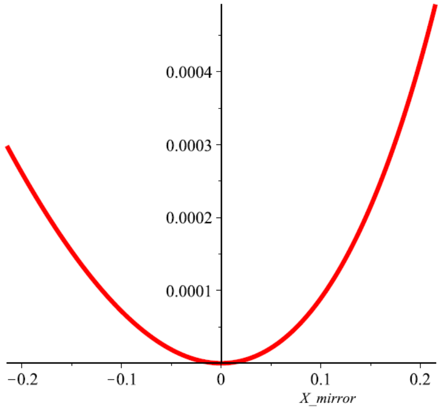




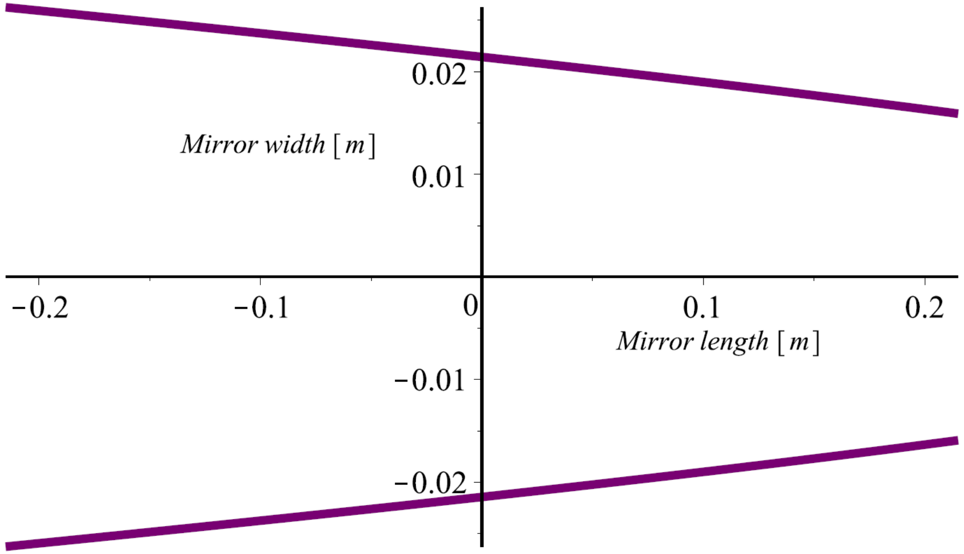
Mirror shaping

Ellipse :
p = 37.225 m
q = 0.4467 m
θ = 0.8°

Si mirror:
Length = 43 cm
Hight = 4 cm
Upstream bending moment = 600 N
Downstream bending moment = 600 N



$$MirrorWidth := -\left(8.471385542\ 10^{12}\ X\_mirror^2\right) \Big/ \left(-3.082047938\ 10^{14} + 1.853483527\ 10^{9} \sqrt{-1.662840750\ 10^{9}\ X\_mirror^2 - 6.115049467\ 10^{10}\ X\_mirror + 2.765039360\ 10^{10}} + 3.408066422\ 10^{14}\ X\_mirror\right)$$



Substrate shaping can be controlled down to few μm at little to no additional cost compared to rectangular substrates

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