Engineering challenges for the Photon Beam Transport at European XFEL

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APPEC Technology Forum 2018 – Veldhoven, Netherlands

November 11th, 2018

The good side of the Free-Electron-Lasers

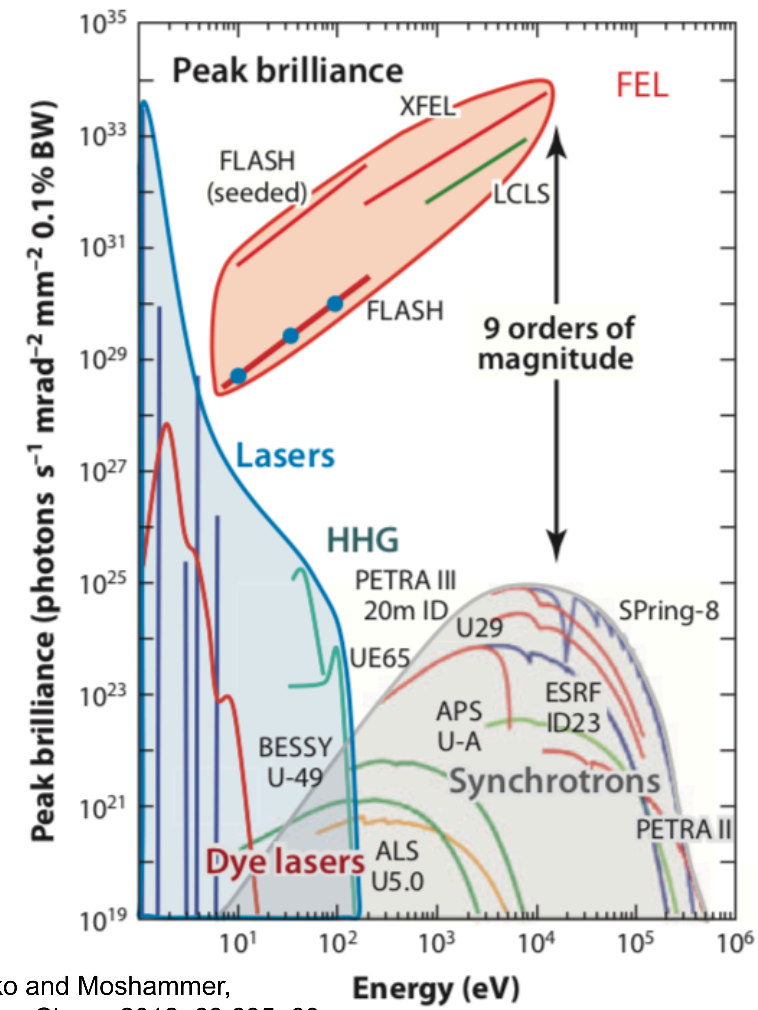
With respect to 3rd generation synchrotrons (ESRF, APS, Spring-8, PETRA3, …)

- Incredibly high peak brilliance
- Fully coherent photon beam
- Short pulse ≈ 10fs

- X-ray wavelength (XFEL: 5-0.05 nm)
- Almost monochromatic radiation (0.2% BW)

- New era in the time-dependant experiments

… BUT…

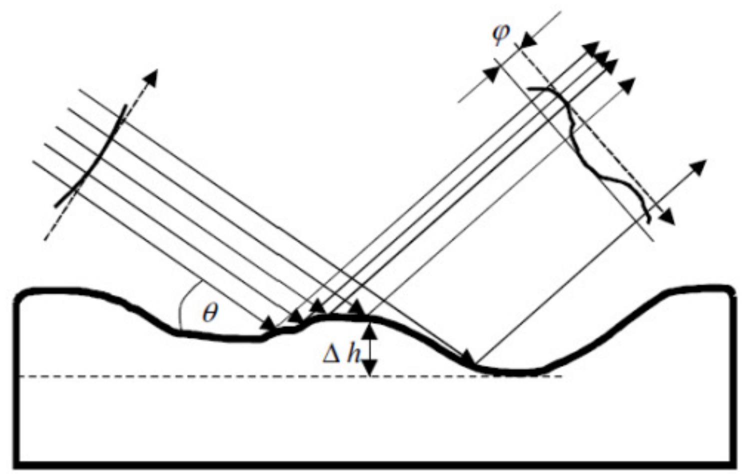


Ullrich, Rudenko and Moshammer,
Annu. Rev. Phys. Chem. 2012. 63:635–60

The “bad” side of FELs: engineering challenges

- Quality of the photon beam has to be preserved
- The beam has to be properly “manipulated” before the delivery to the experiment

- Long mirrors (1m) and long beamlines (up to 1km)
- Cooled (up to 100W)
- Outstanding quality (few nm PV for X-Ray)



F. Siewert et al., Optics Express 20, 4525, (2012)

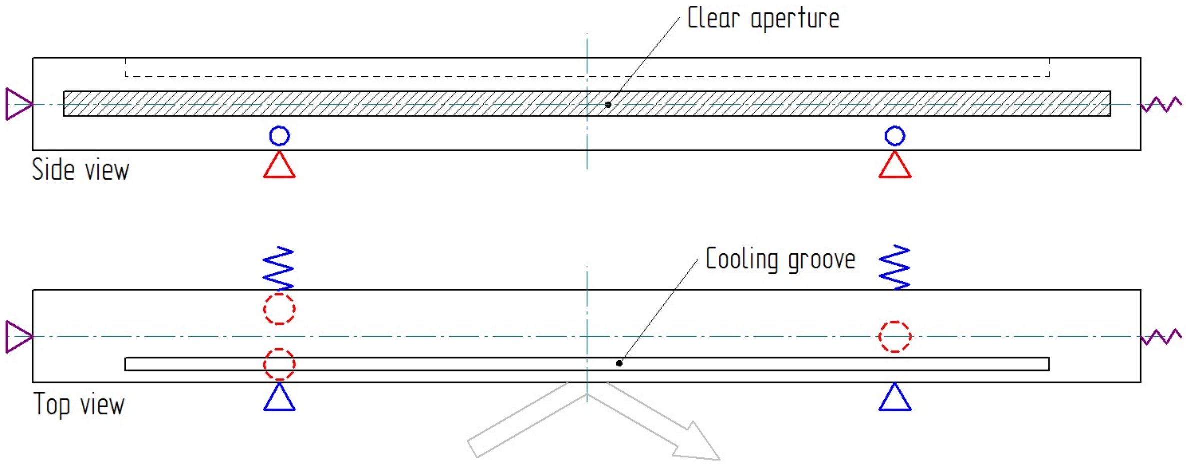
CHALLENGES:

- Mounts that preserves the mirror quality
- Thermo-mechanical stability

Mirror holder considerations

- Target the isostatic mount
  - Under-constrained… no comment
  - Over-constrained: deformation of the support means deformation of the mirror (in the isostatic support it is just a rigid body movement) = deterministic corrections are not possible.

- The classic scheme for side and upwards reflecting mirrors

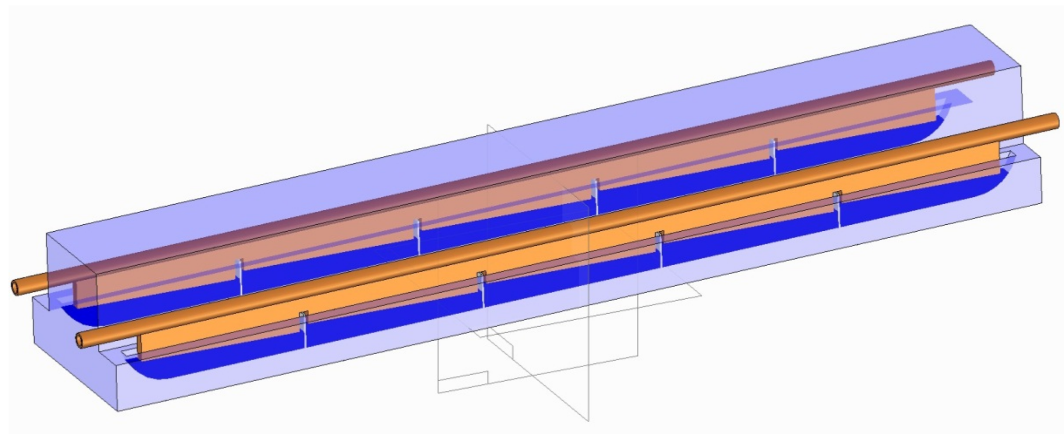


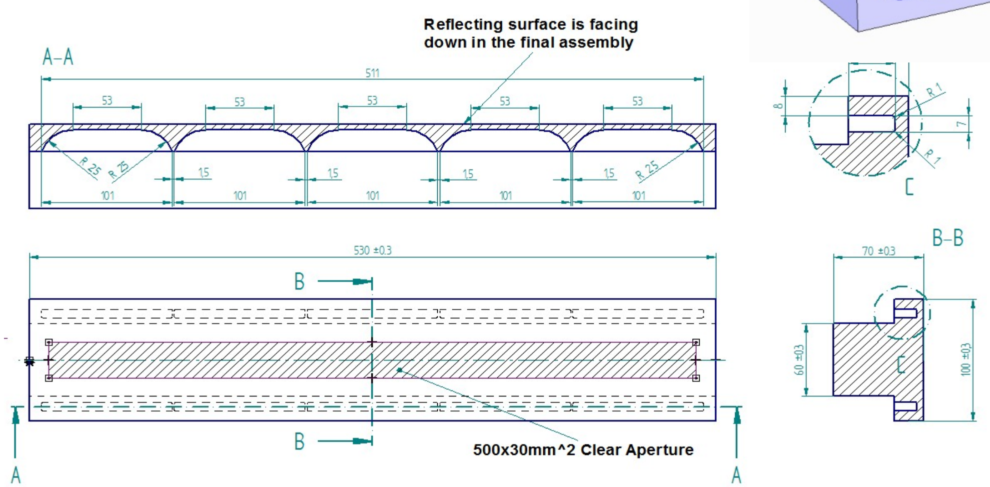
- What's about a down reflecting mirror? How can we arrange the supporting points?

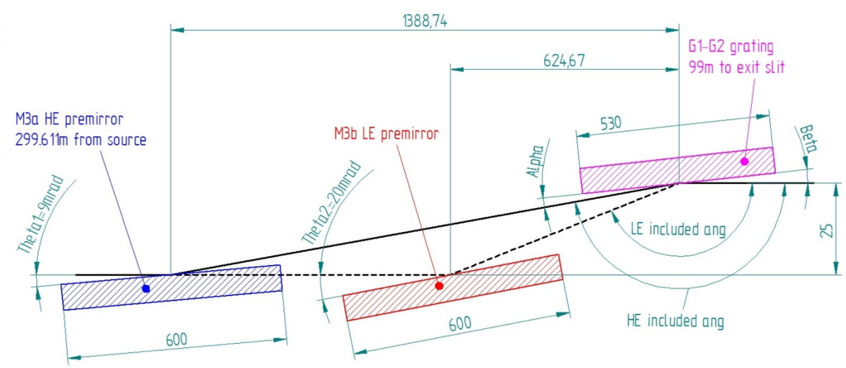
Real case: facing down mirror

Soft X-ray monochromator grating

- Flat substrate
- 530(L)x60(W)x70(H) mm3
- 6 kg mass

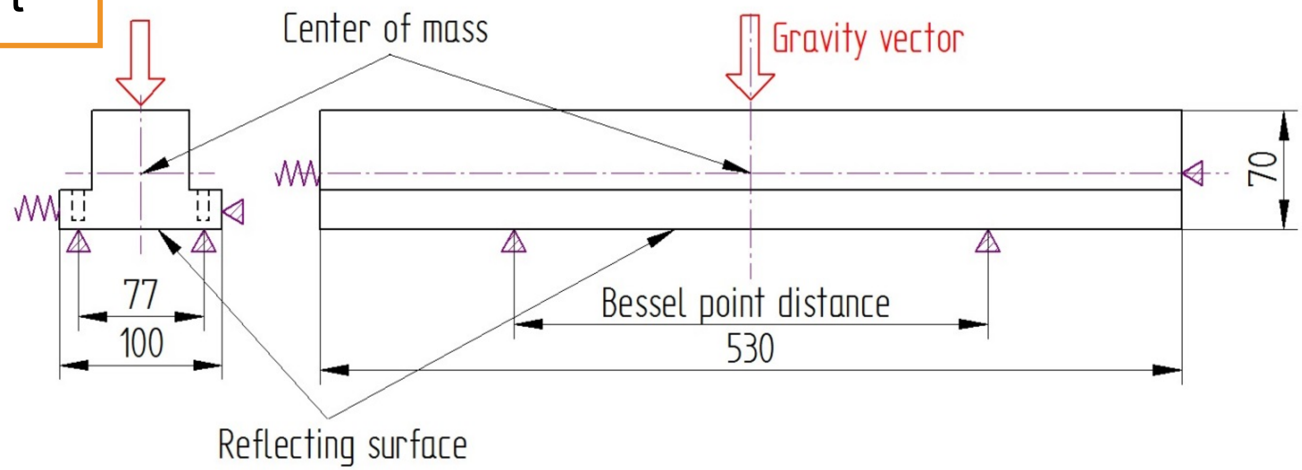


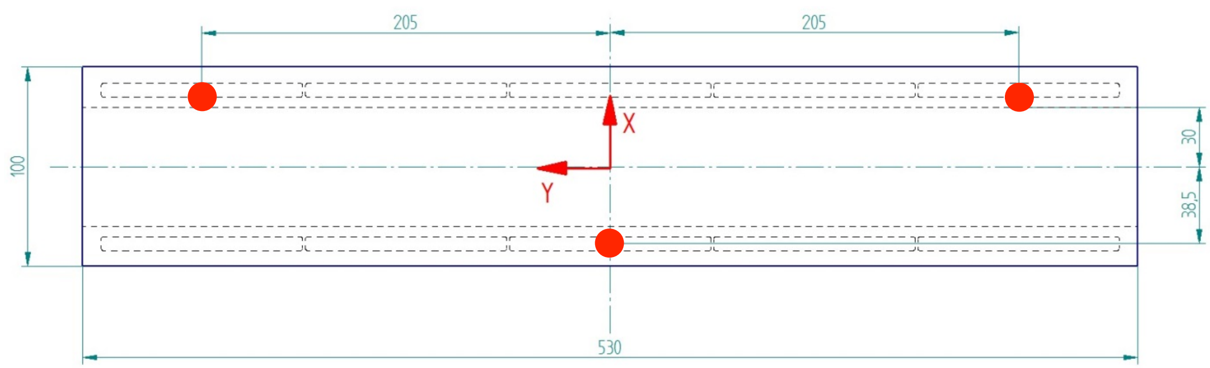




Possible options

4 points support

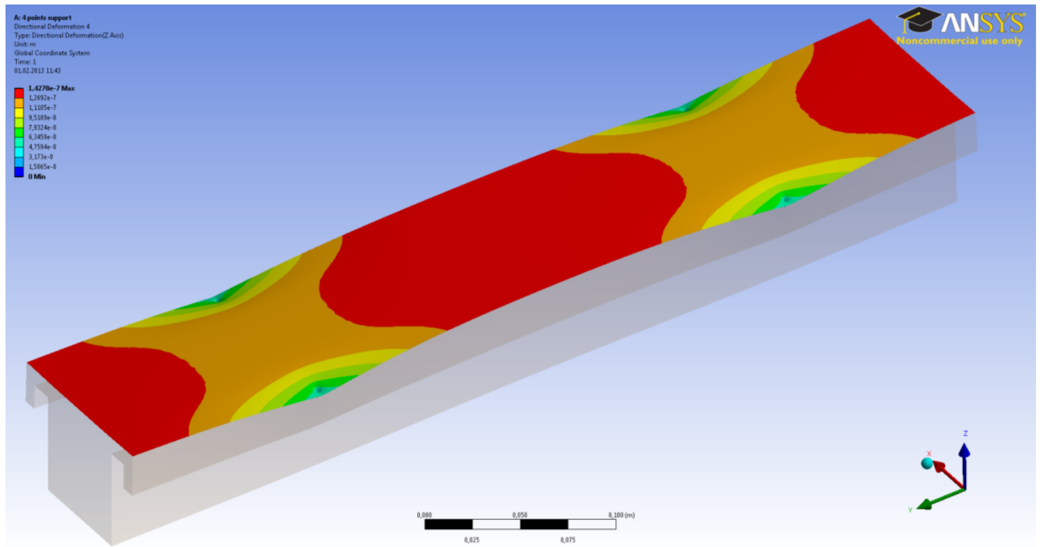


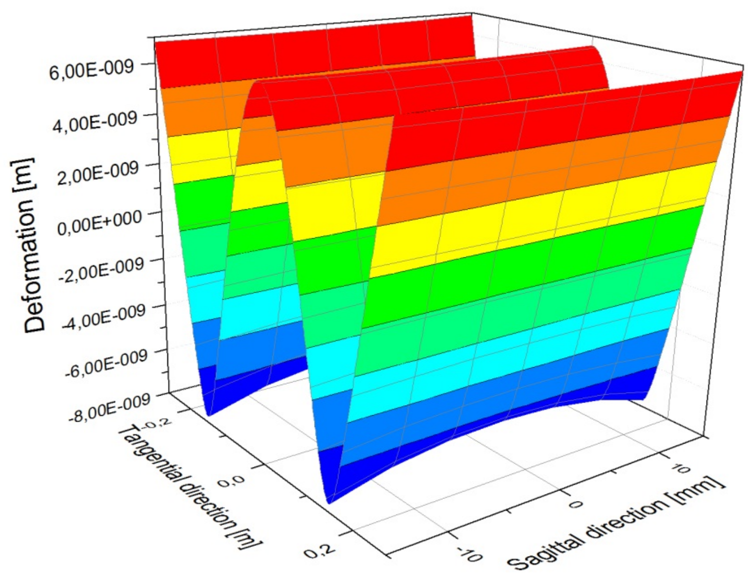


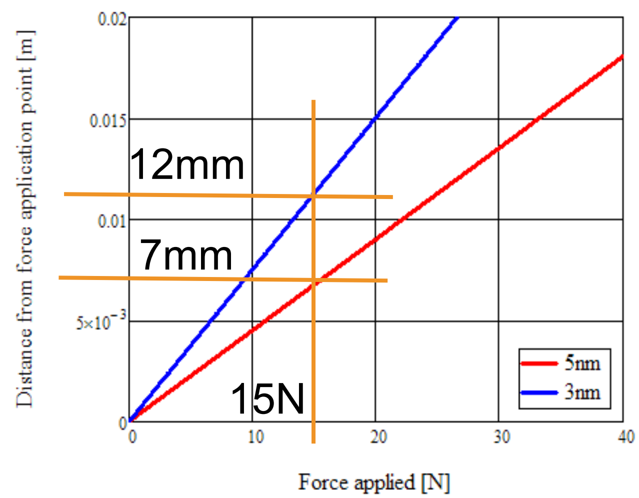
3 points support

4 Points – nominal case

- 12nm PV
- 1D polishing gives sub-nm surface
- Tip penetration still visible

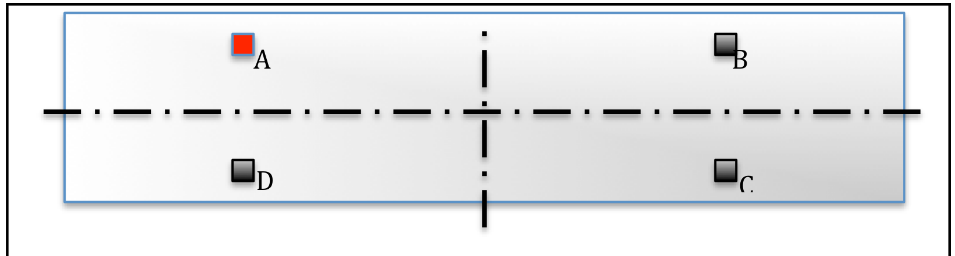




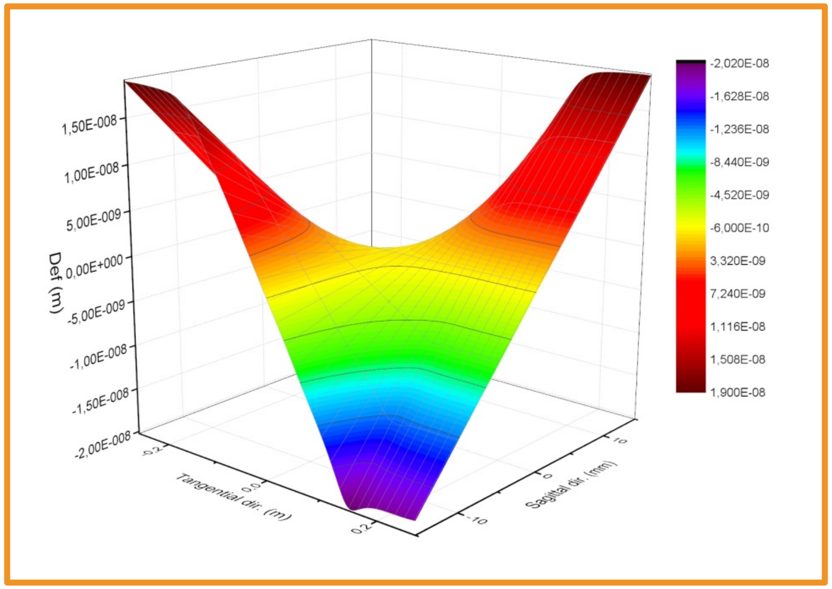


4 Points – misalignment case

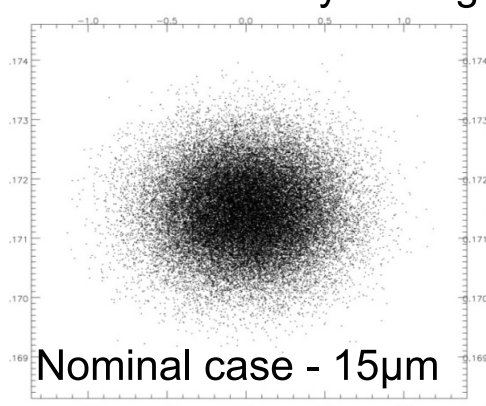
- 4th point misaligned (µm level) or spring with partial load
  - Zero force: worst case
  - Tilt correction and 1D polish
  - Sides of CA are flat but tilted



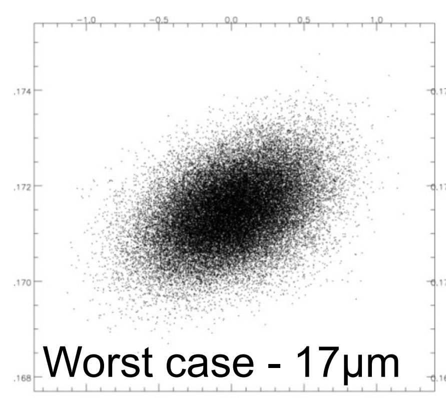
	A	B	C	D
0%	0	29.72N	0	29.72N
50%	7.43	22.29N	7.43N	22.29N
100%	14.86N	14.86N	14.86N	14.86N
150%	22.29	7.43N	22.29N	7.43N
200%	29.72	0	29.72N	0



Ray tracing simulations

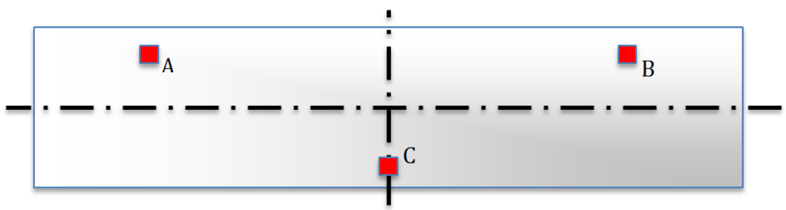


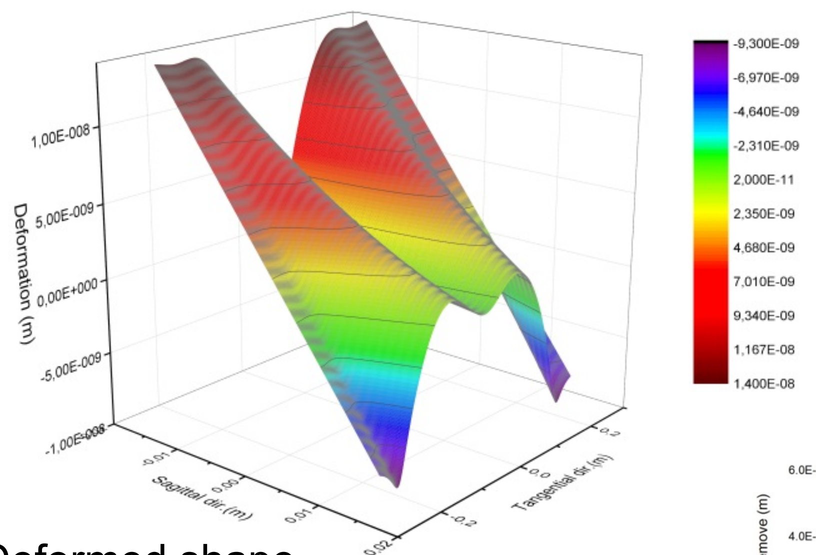
Nominal case - 15µm



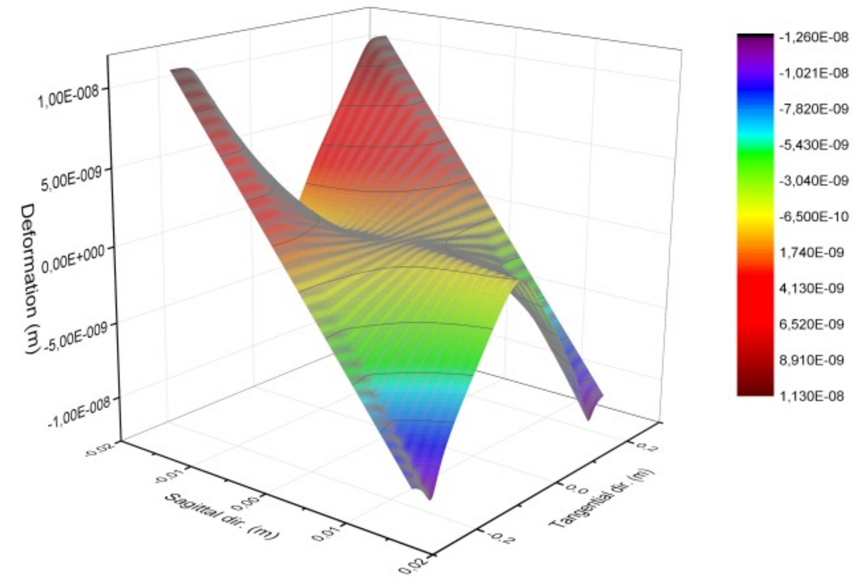
Worst case - 17µm

3 Points: unique solution



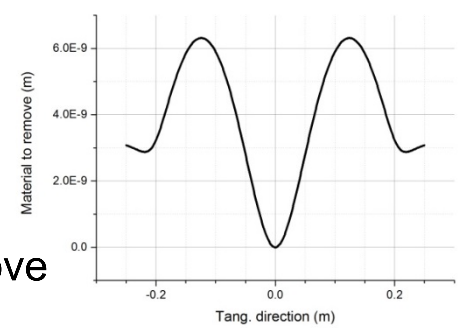


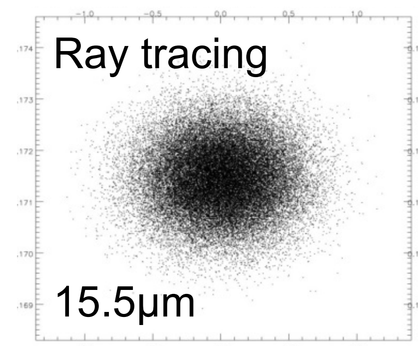
Deformed shape



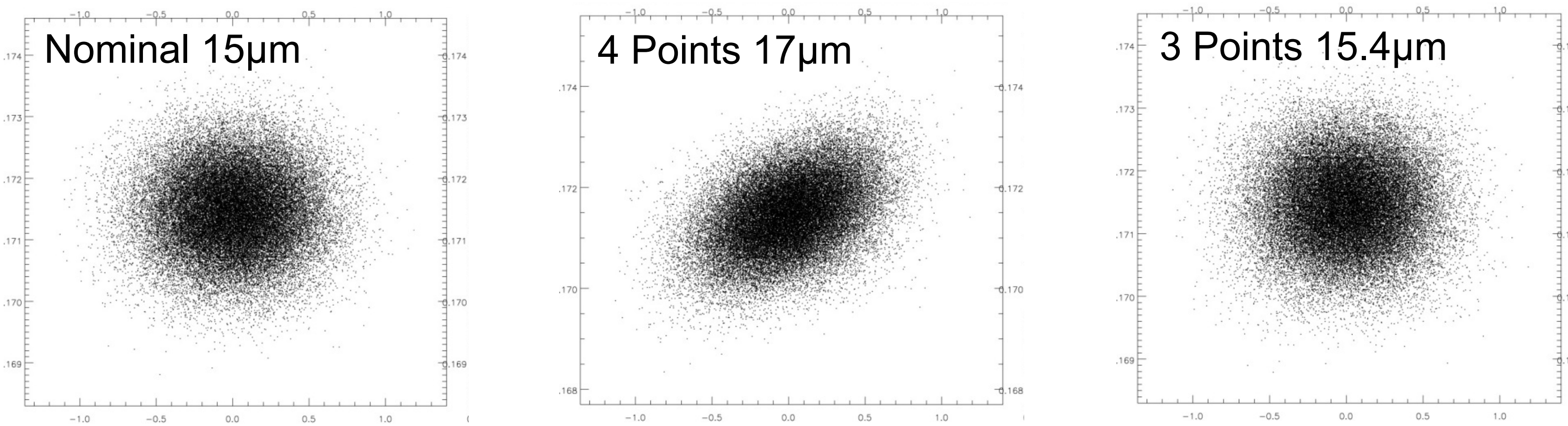
Final shape after 1D polishing

Material to remove





Solutions comparison



- Behaviour was confirmed by wavefront simulations: 3 points seems to perform better
- This is a very specific case, definitely not the general solution

- Highlight importance and influence of the support on the optics
- Adaptive systems help but good and reliable diagnostic is needed for proper tuning

Vibrational stability – measurement

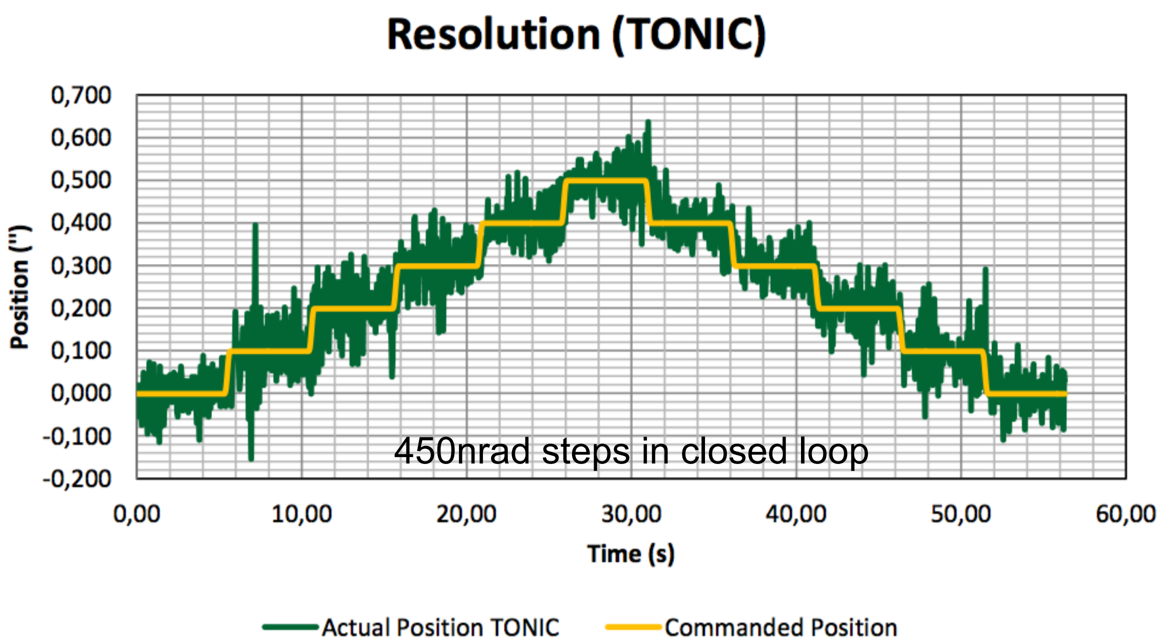
Very challenging spec: angular resolution of the grating pitch better than 50nrad rms

- More than 100kg cradle
- 1m long arm
- nm resolution of the actuator

FMB Berlin

Vibrational stability – measurement

Preliminary results (FAT) not so good: 150nrad rms



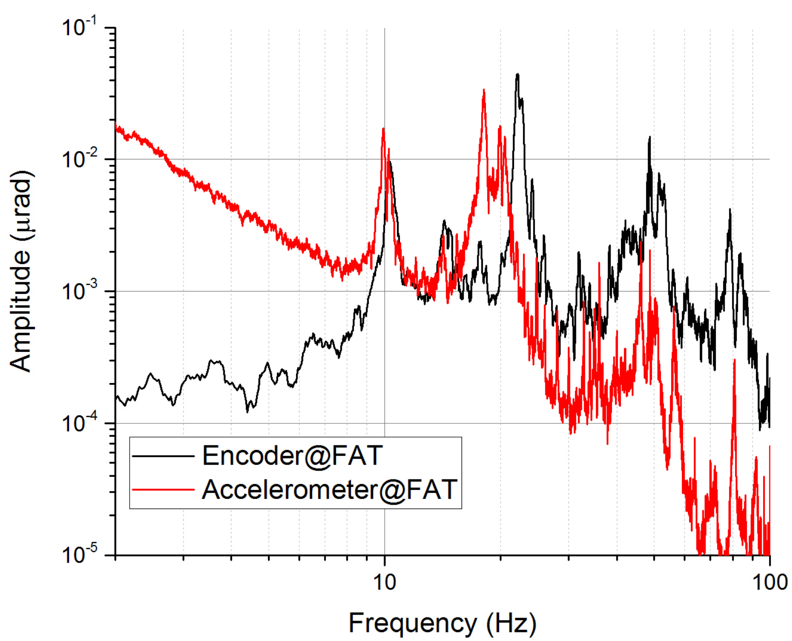
VIBRATIONAL MEASUREMENT CAMPAIN

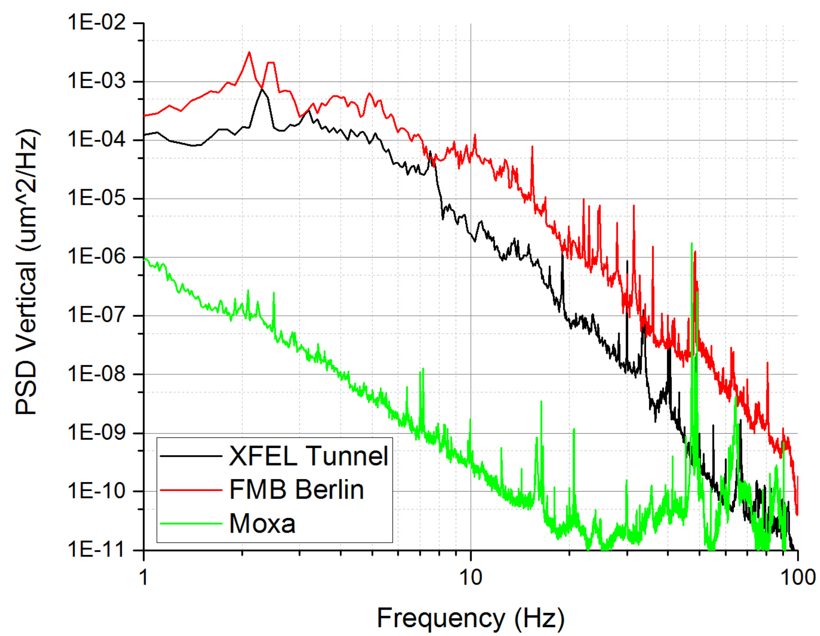
Vibrational stability – measurement

- Accelerometers mounted on front and back of the cradle
- PCB Piezotronics (0.1-200Hz) accelerometers
- A/D converter from Data Translation
- Vertical signal recorded and encoder

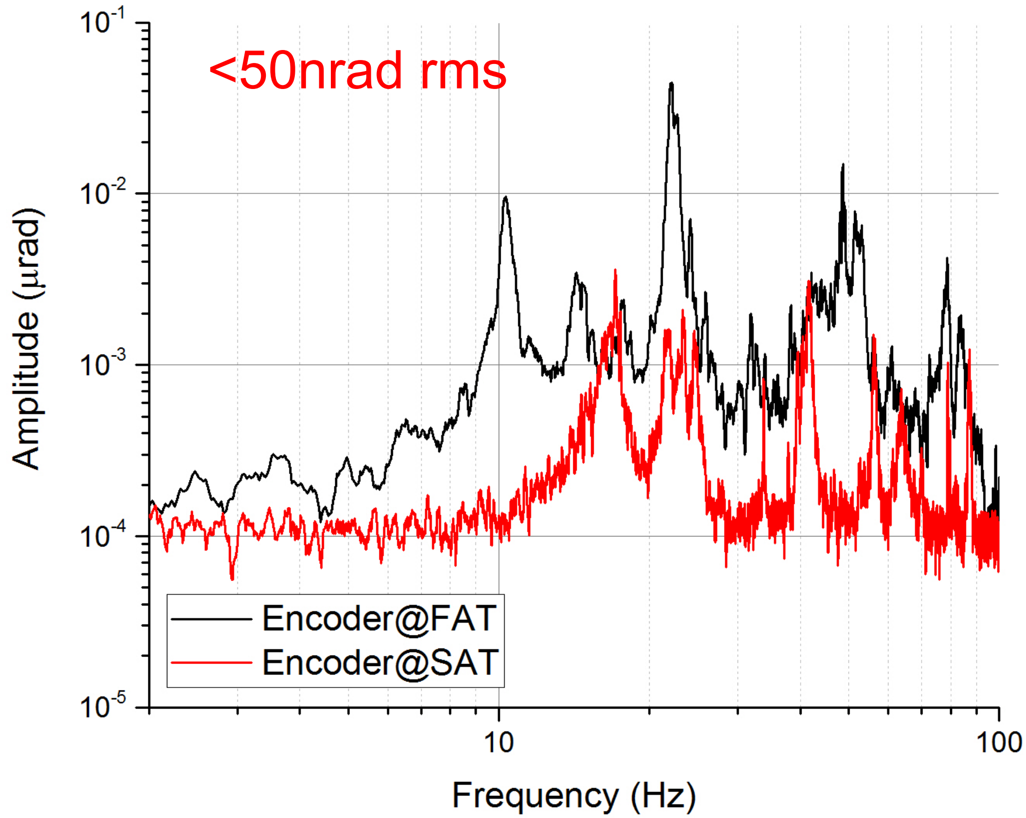
Vibrational stability – measurement

- Good agreement between encoder and accelerometers
- Hope to improve performance after installation in the XFEL tunnel





Vibrational stability – measurement



Final remarks

- Need of mirror holder to control deformation at the nm level
- Angular vibrational stability in the order of 50nrad rms
- Scale of phenomena difficult to measure (even worst with beam)

- So far only passive system implemented for vibrational control
- Active controls open new challenges and require effective diagnostic

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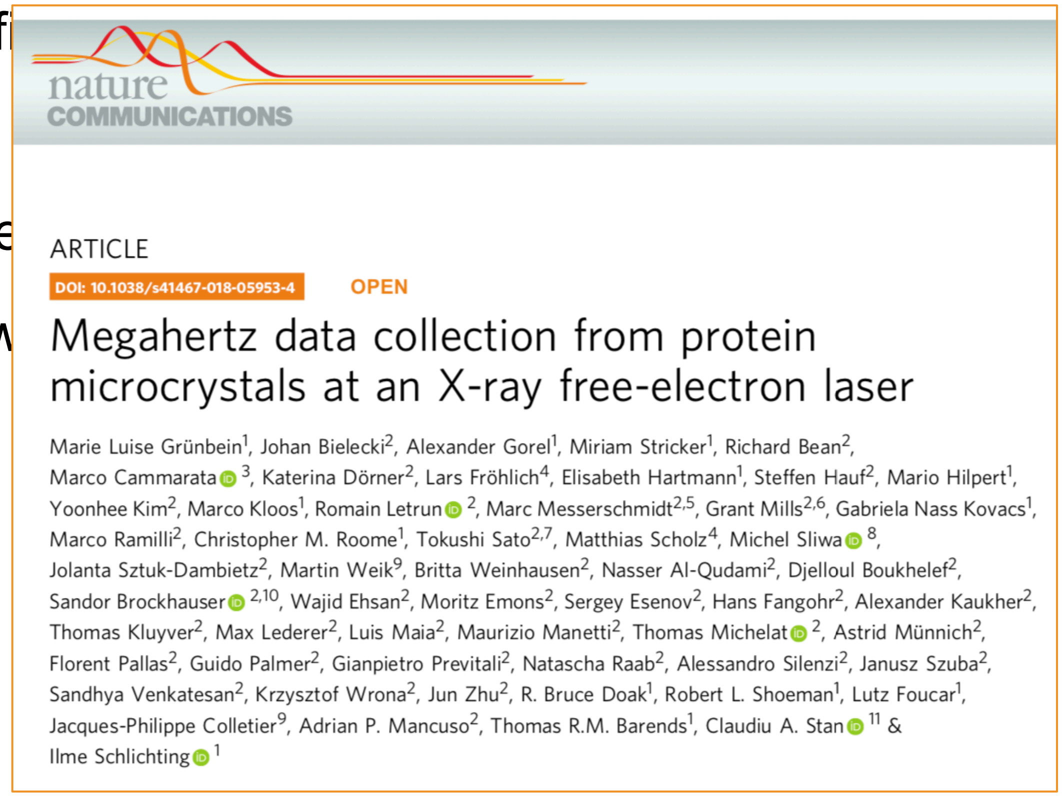

nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-05953-4 OPEN

Megahertz data collection from protein microcrystals at an X-ray free-electron laser

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Thank you for your attention