Nanometer level precise optics for new x-ray light sources: metrology and installation challenges

Maurizio Vannoni
X-ray Optics Group
European XFEL, Schenefeld (Hamburg area), Germany

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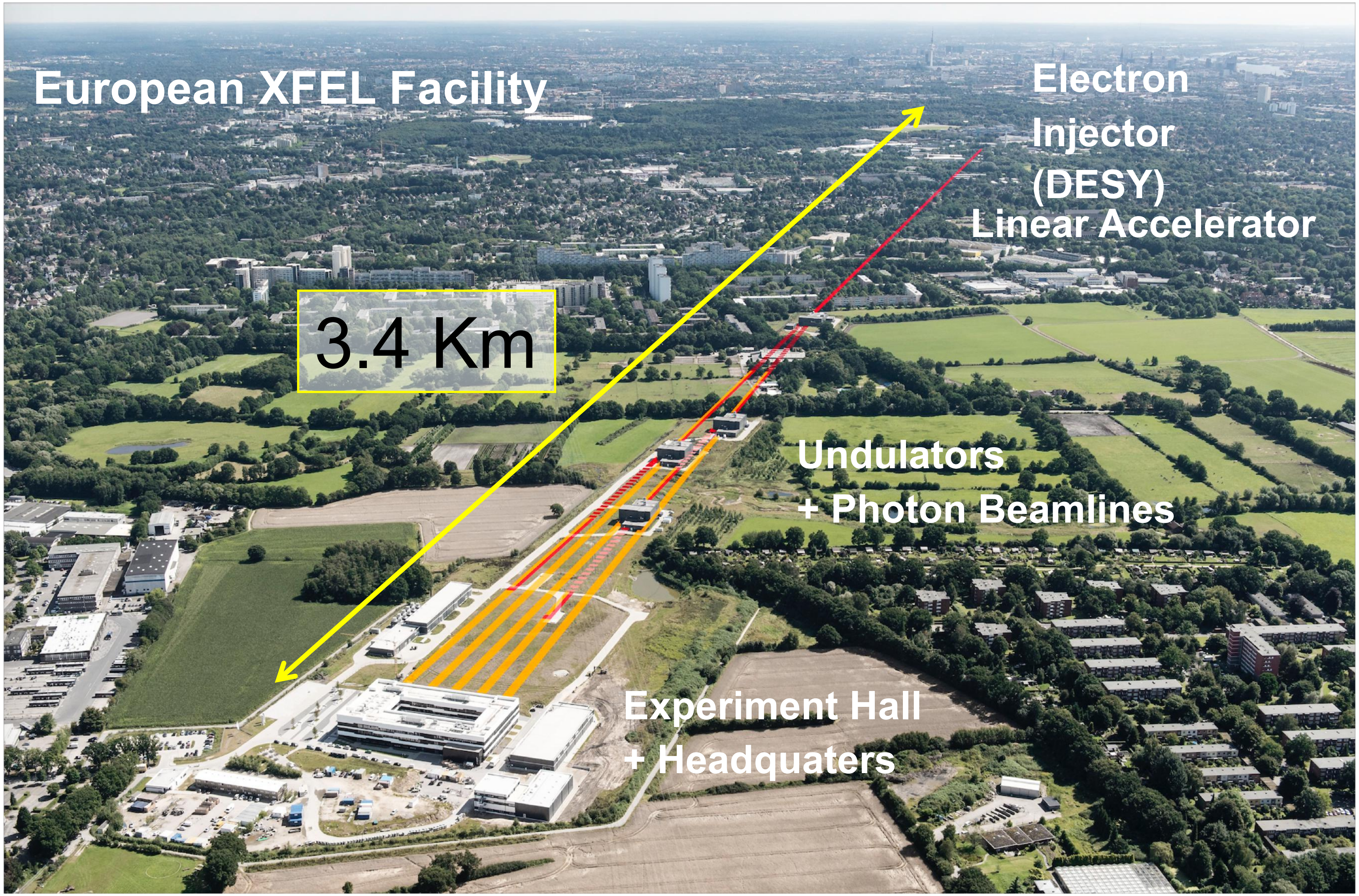
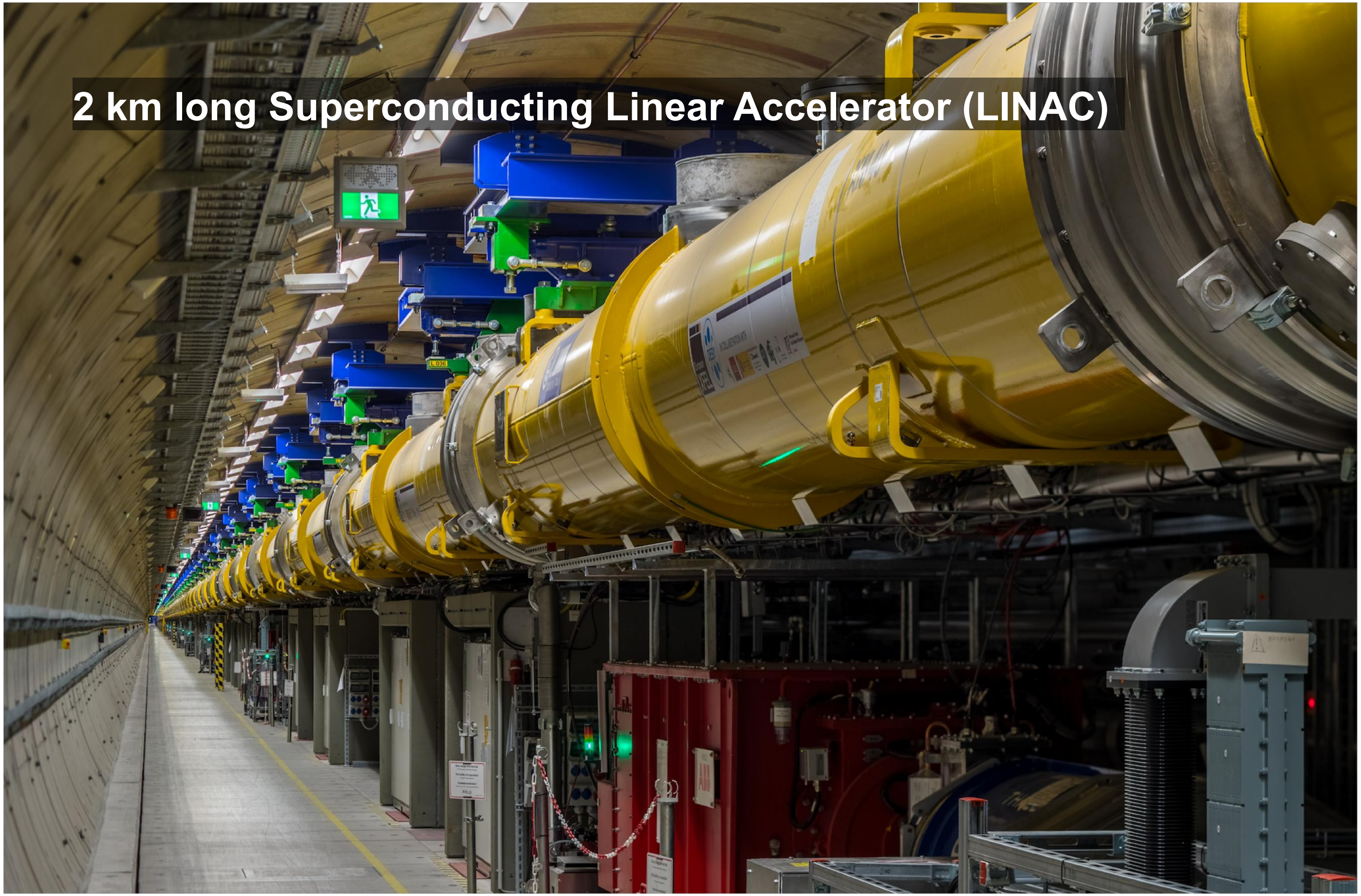
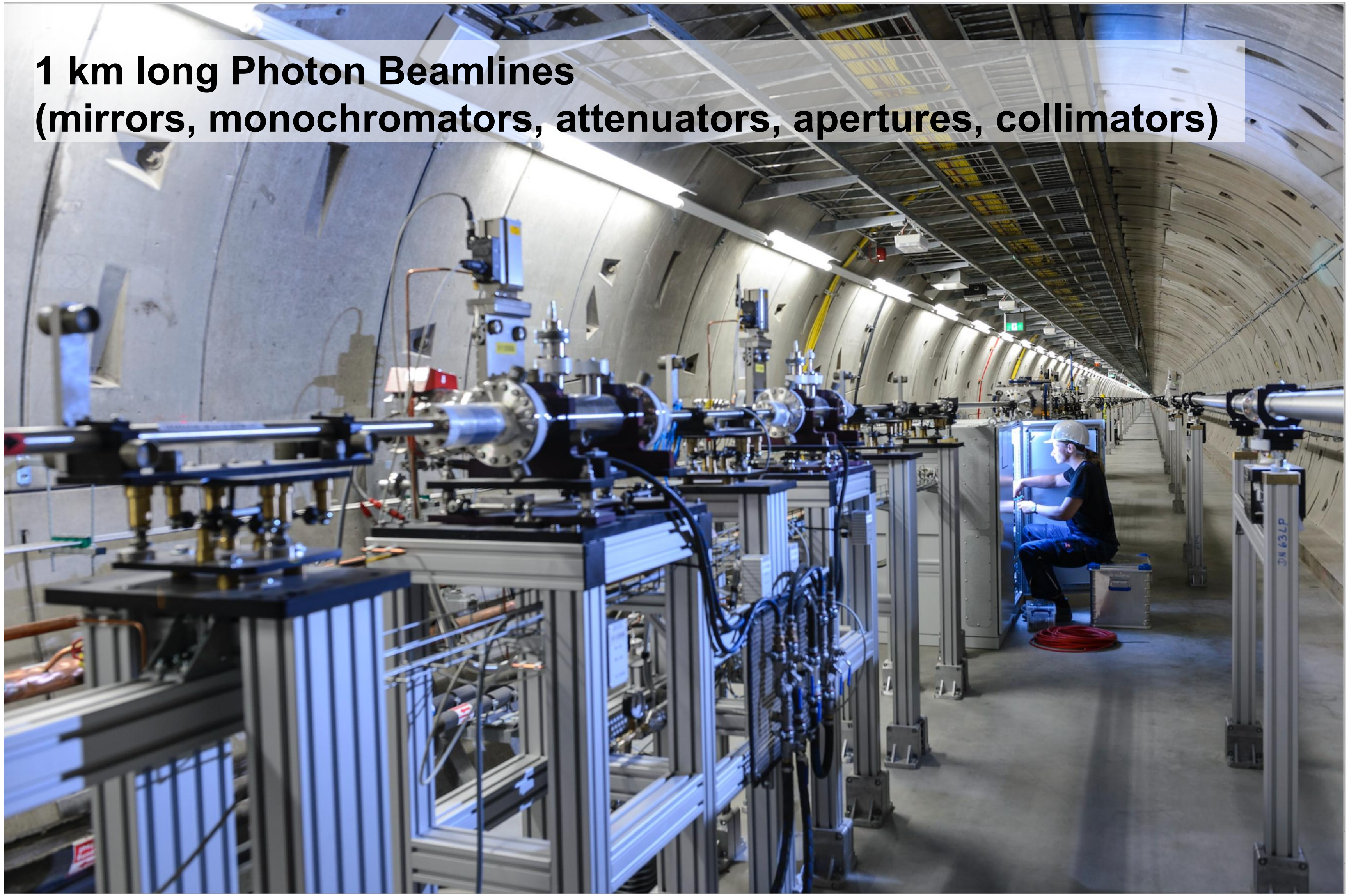

European XFEL Facility
Electron
Injector
(DESY)
Linear Accelerator
3.4 Km
Undulators
+ Photon Beamlines
Experiment Hall
+ Headquaters


2 km long Superconducting Linear Accelerator (LINAC)

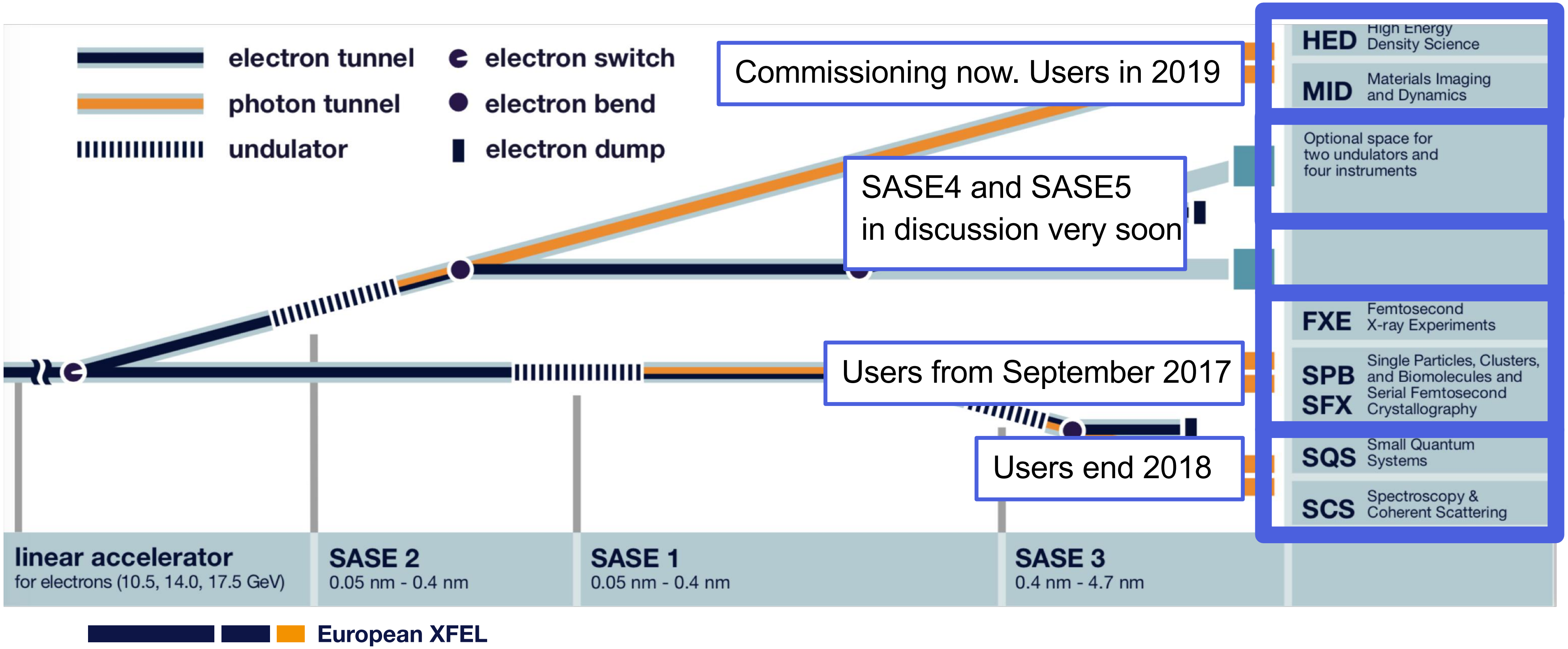
1 km long Photon Beamlines (mirrors, monochromators, attenuators, apertures, collimators)

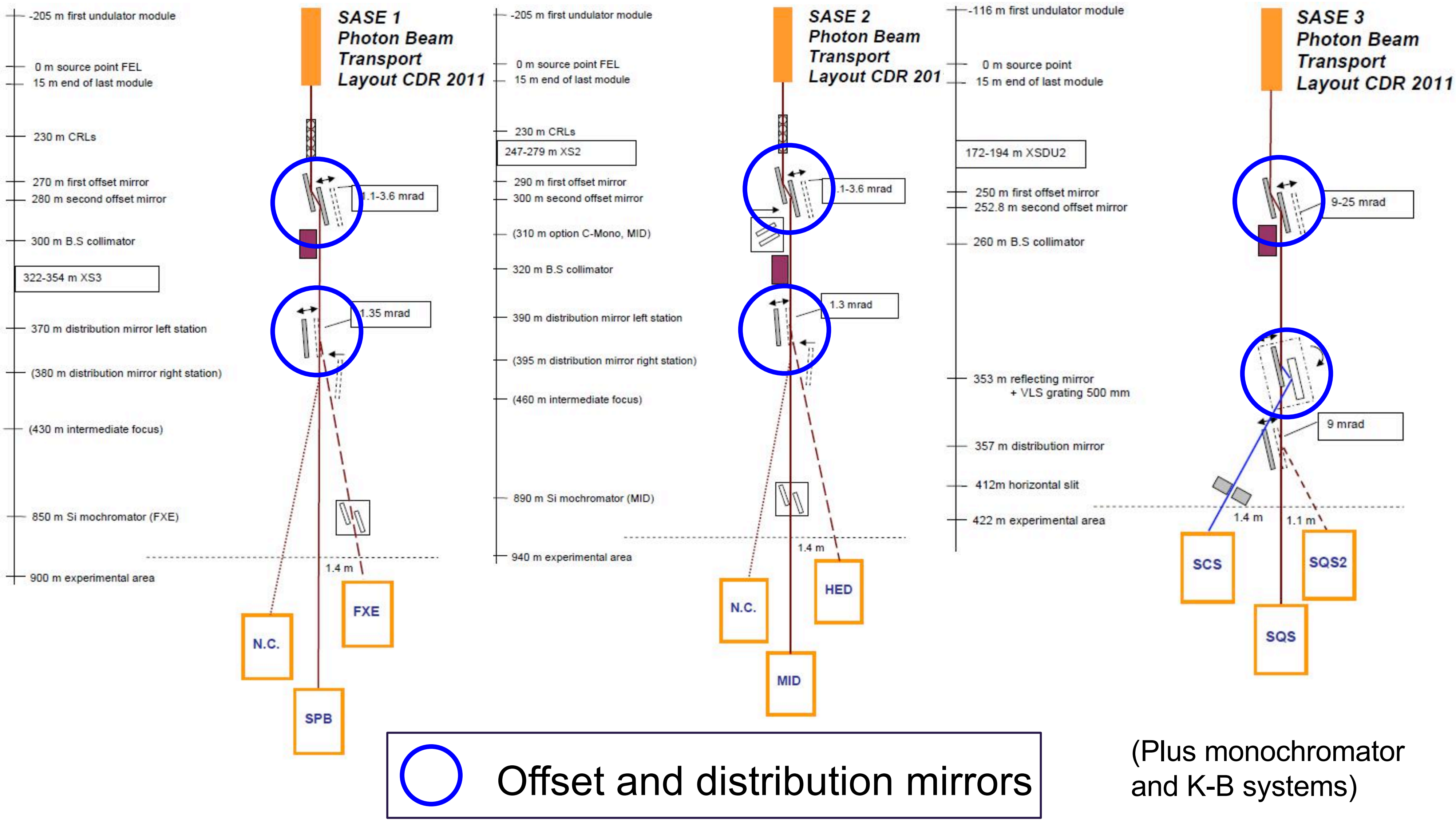



Experiment Hall, SASE1 area
FXE
SPB/SFX

Photon Beamlines

Undulator Segment	FEL radiation energy [keV]	Wavelength [nm]
SASE 1	3 - over 24	0.4 - 0.05
SASE 2	3 - over 24	0.4 - 0.05
SASE 3	0.27 - 3	4.7 – 0.4





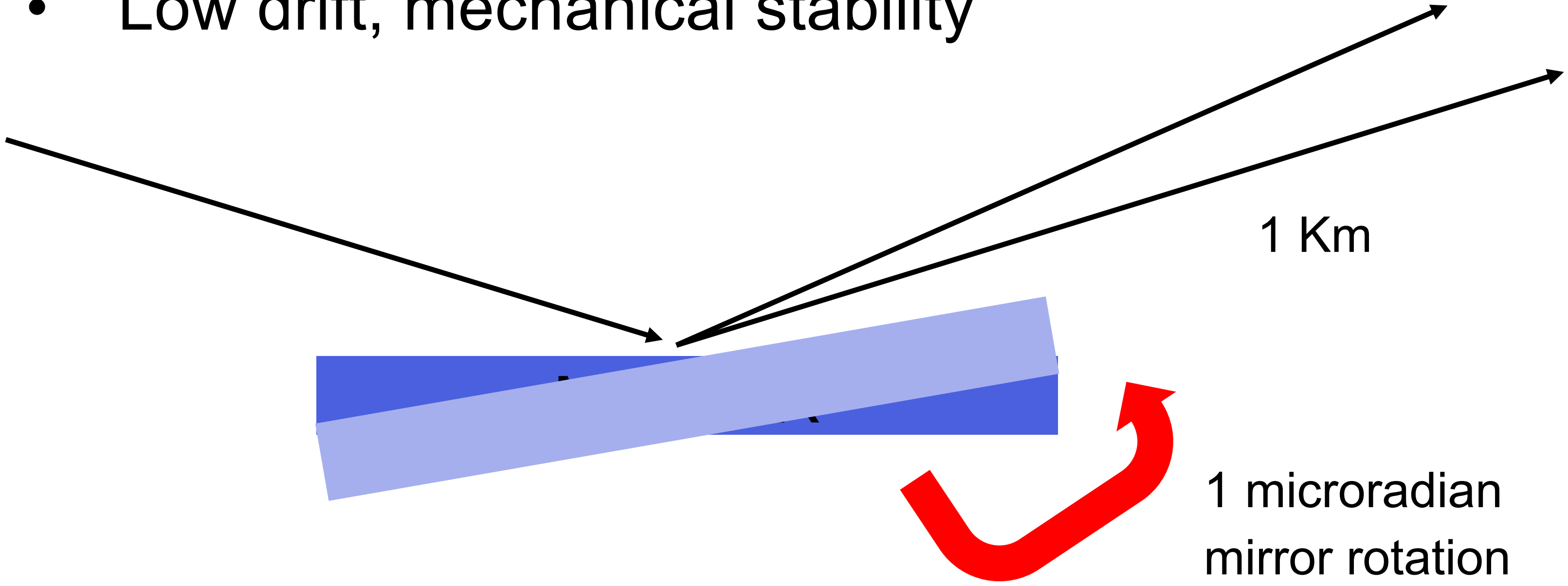
(Plus monochromator and K-B systems)

What are the challenges/opportunities for optics and mechanics?

Size of the beam:
from 1 mm to 3 mm

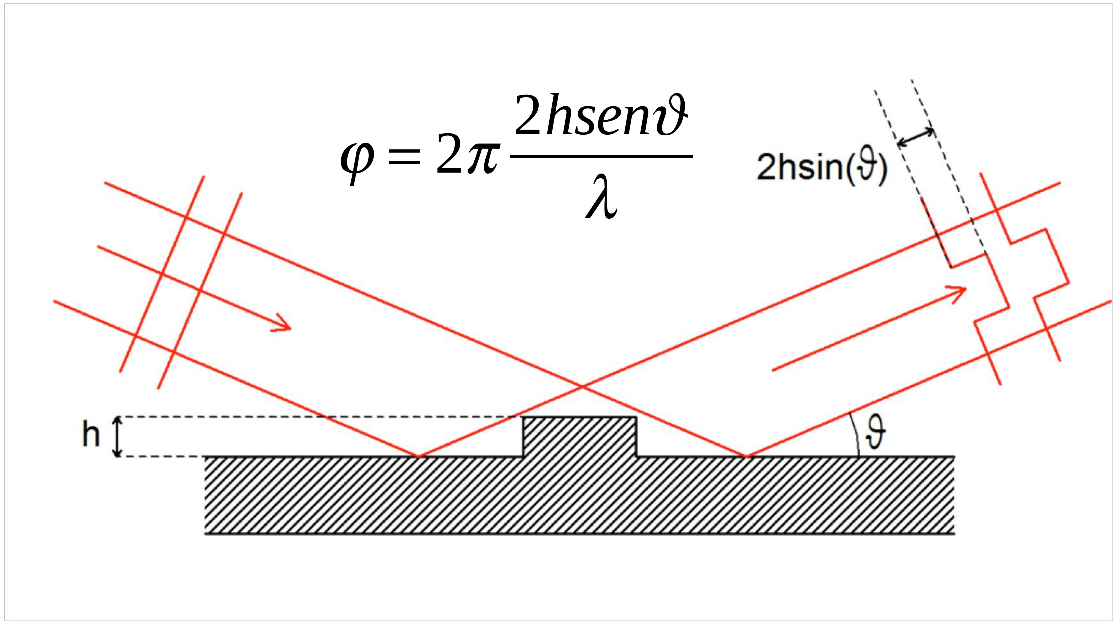
- Low level of vibrations

- Low drift, mechanical stability



= 500 nm of translation each side on the mirror

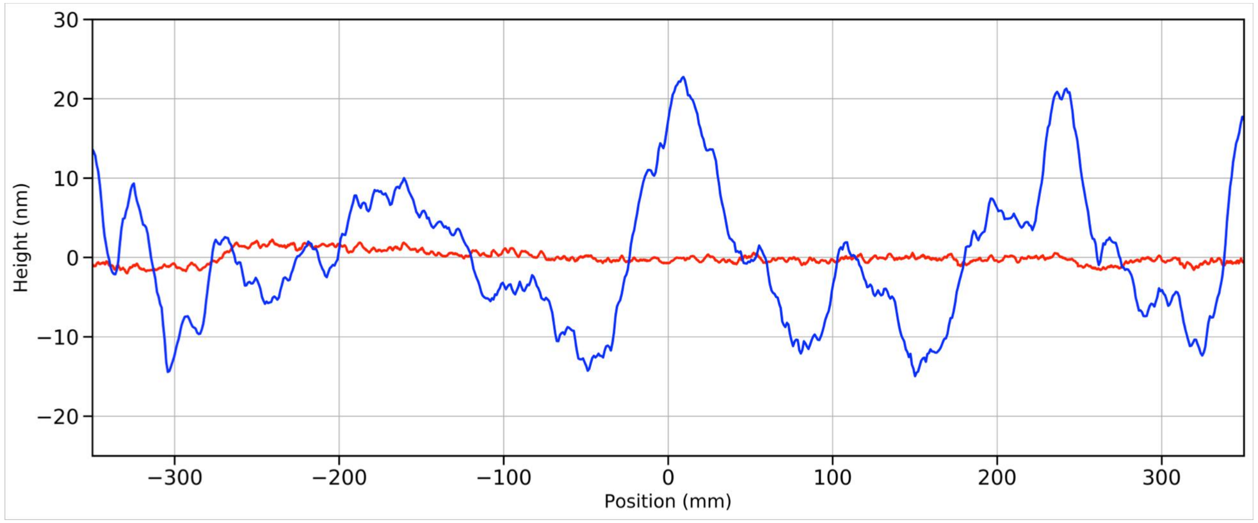
- Preservation of optical properties on the nm level



$$h_{rms} < \frac{1}{28}\sqrt{\frac{\pi}{r_e \rho_e}} \approx 1.5 \text{ nm (silicon)}$$

Level of polishing required
("magic number" depending only on material)

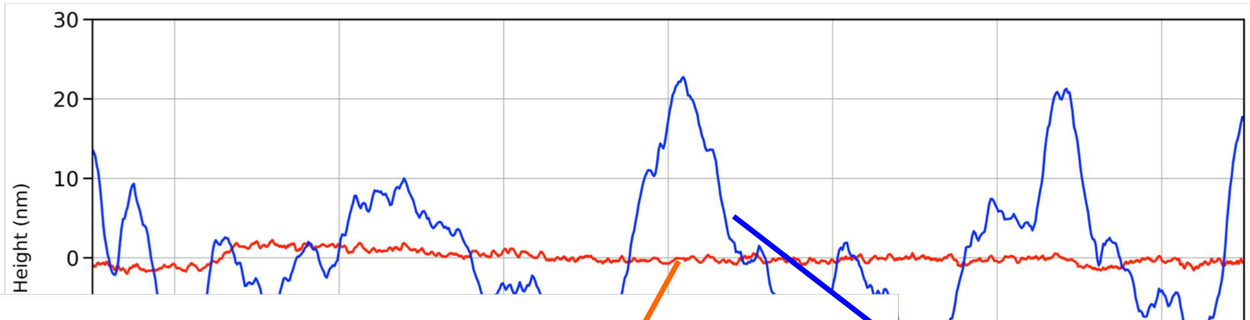
(Sinn, Samoylova, et al., "X-ray Optics and Beam Transport CDR", April 2011 and F. Siewert et al., Optics Express **20**, 4525)

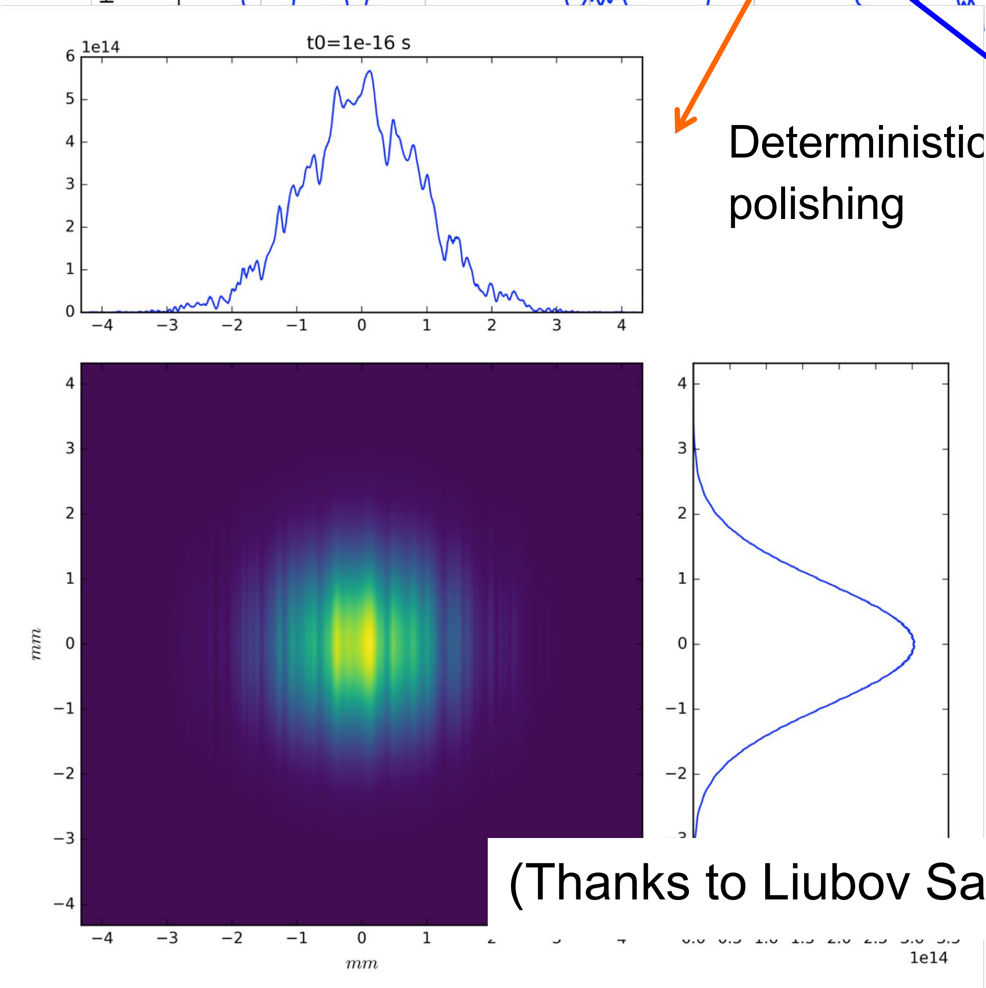


Simulations in practical case of EXFEL SASE1 M1

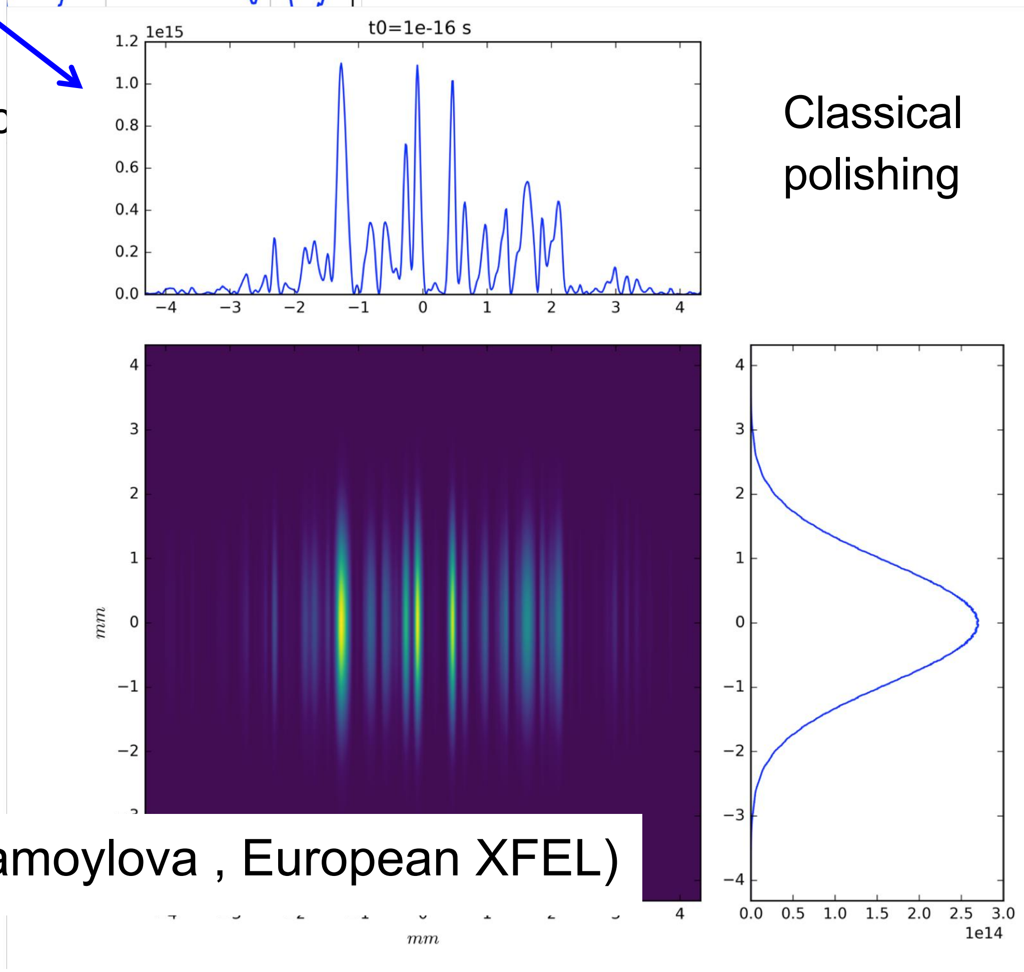
(Thanks to Liubov Samoylova , European XFEL)

Simulations in practical case of EXFEL SASE1 M1





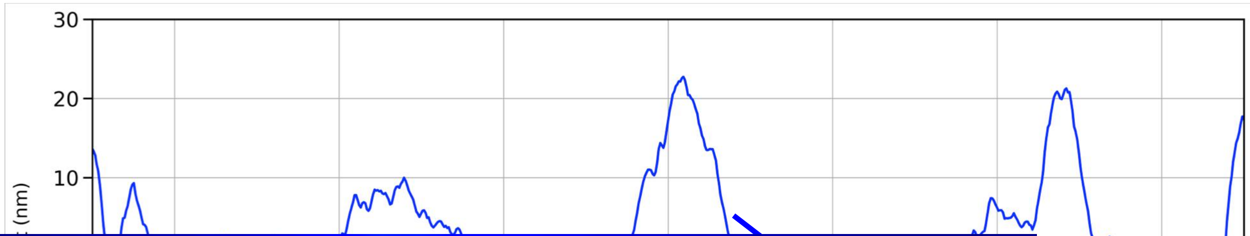
Deterministic polishing

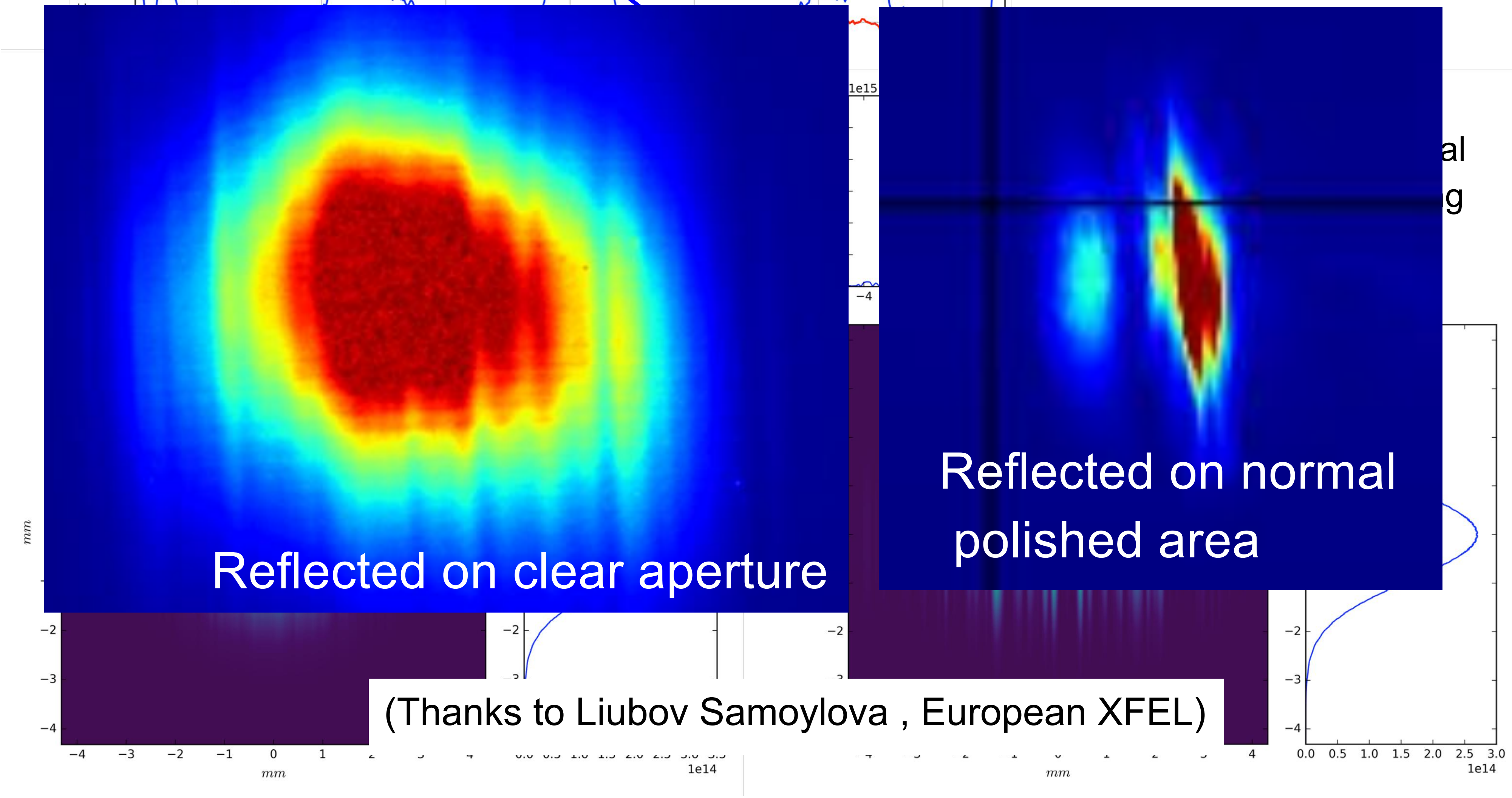


Classical polishing

(Thanks to Liubov Samoylova , European XFEL)

Simulations in practical case of EXFEL SASE1 M1





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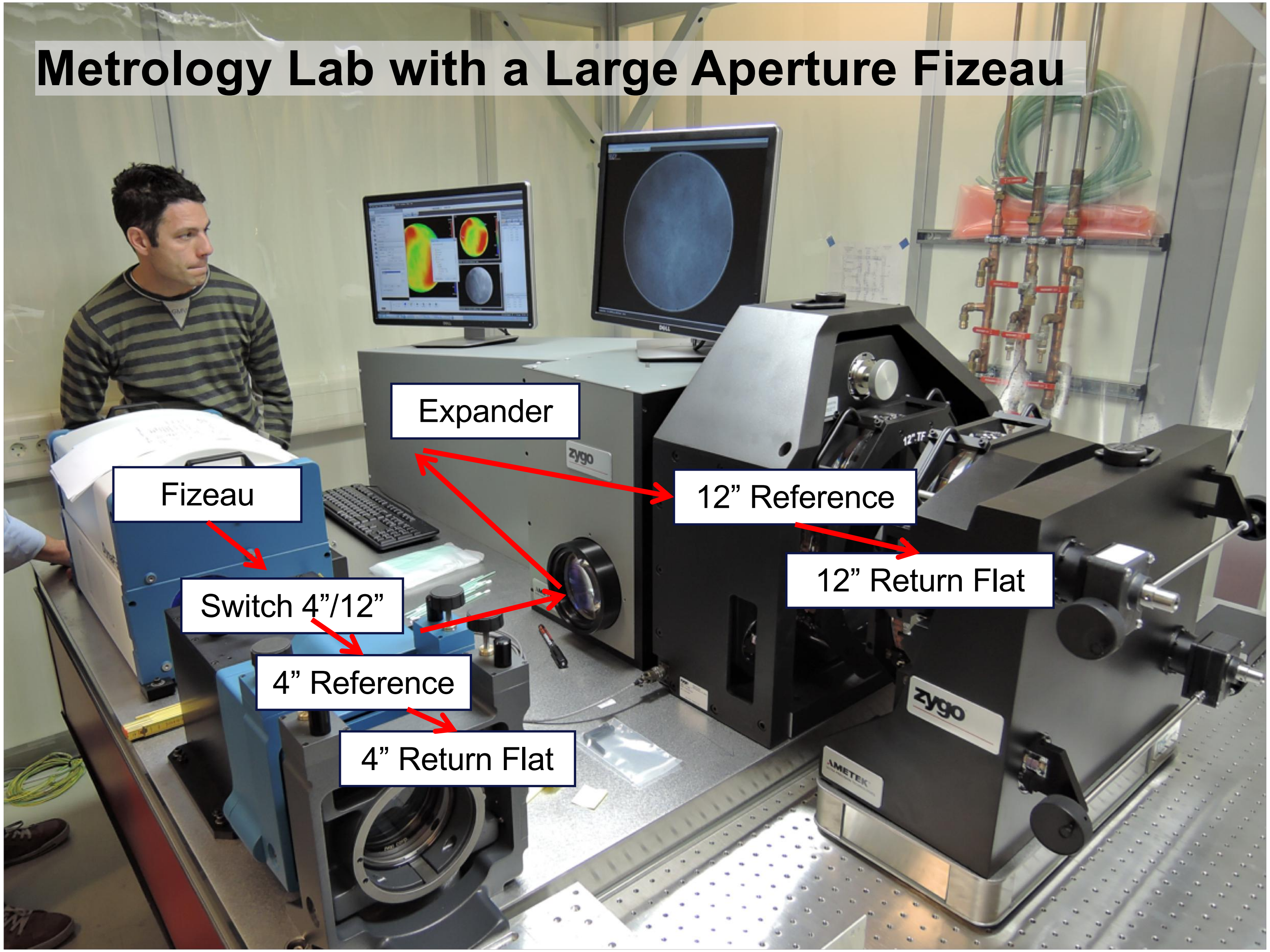
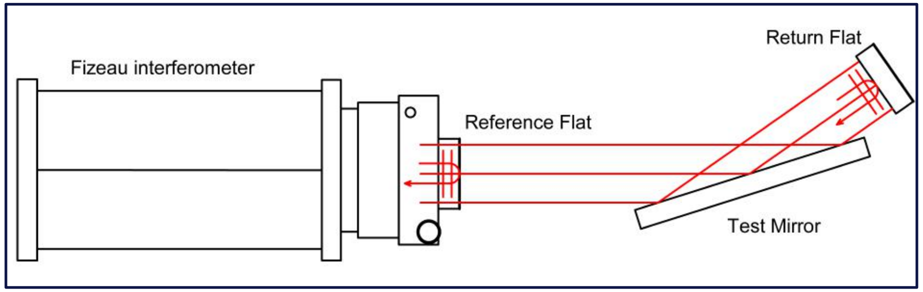
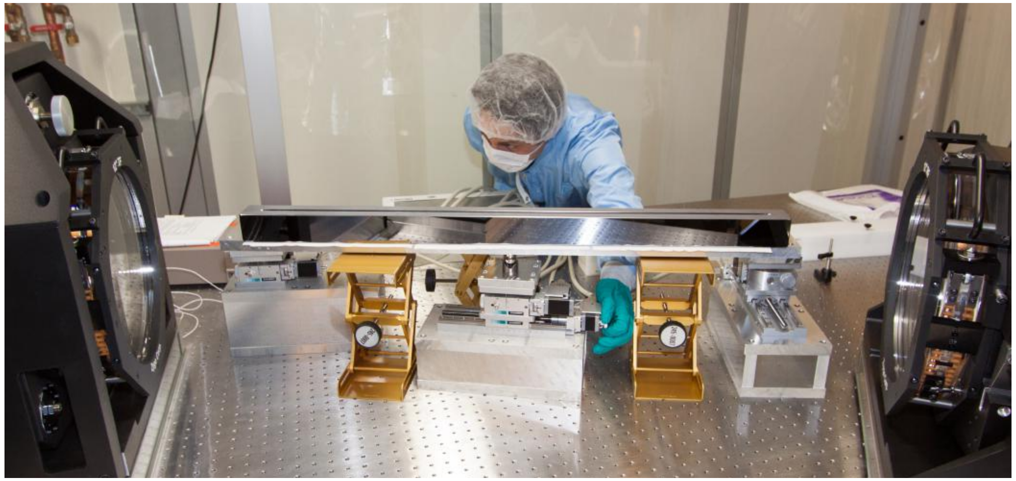
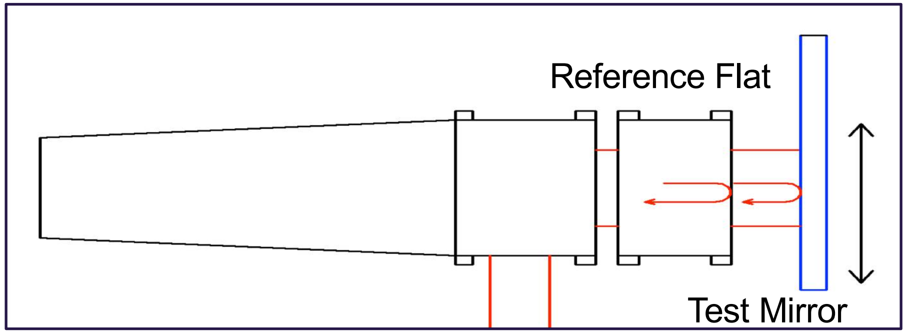
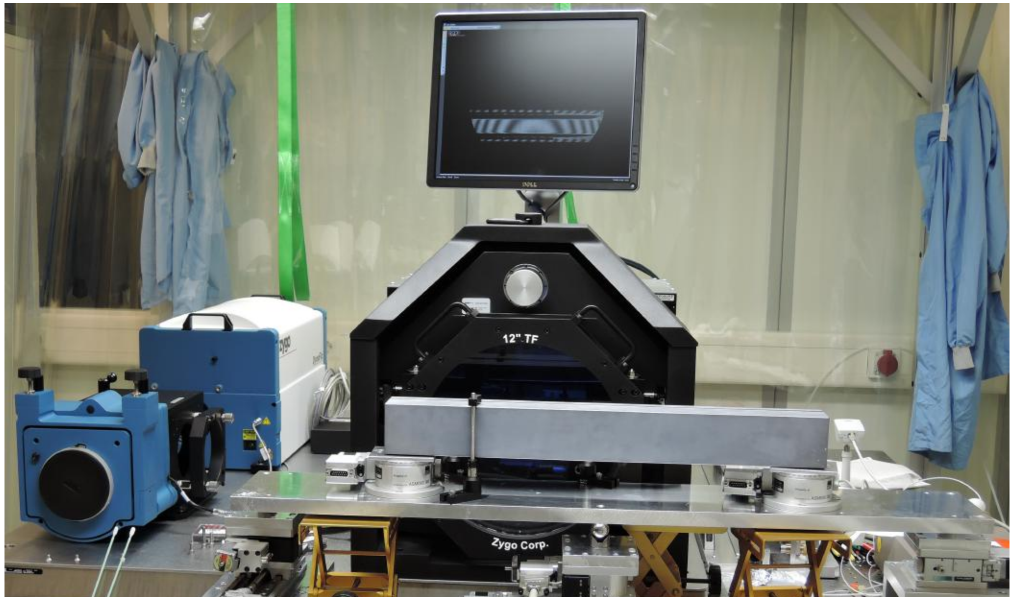

Metrology Lab with a Large Aperture Fizeau
Expander
Fizeau
12” Reference
12” Return Flat
Switch 4”/12”
4” Reference
4” Return Flat
zygo





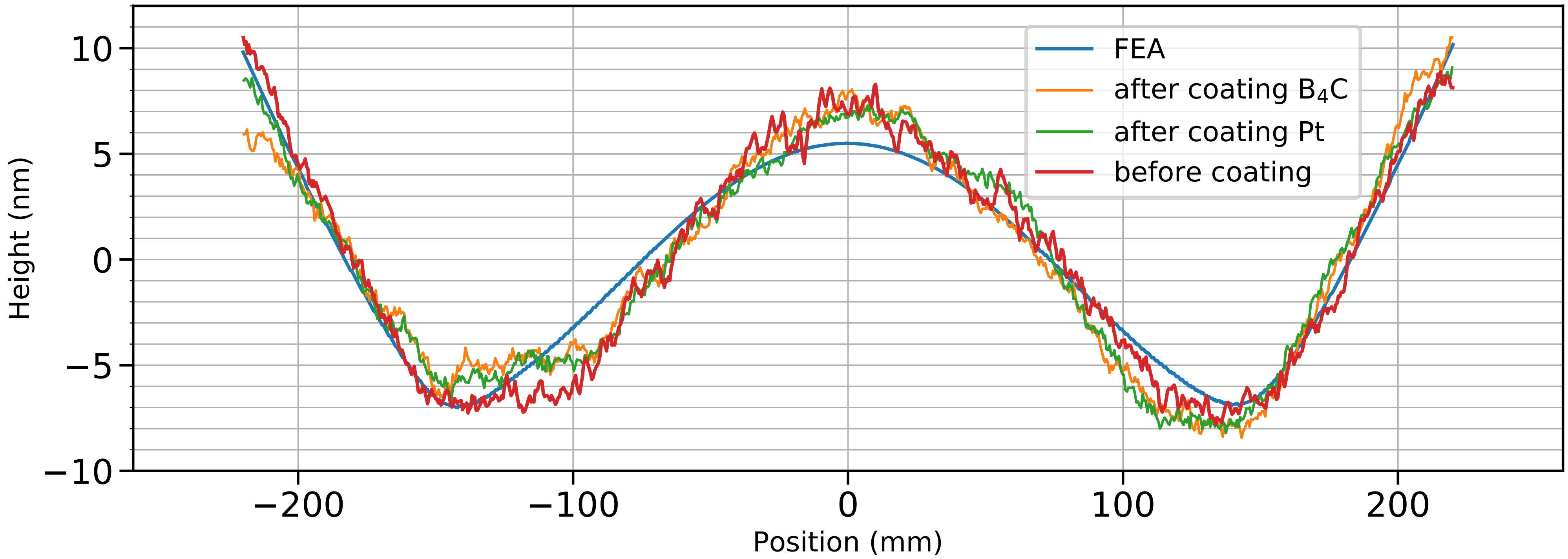
Grazing incidence setup
(faster but less accurate)





Stitching normal incidence setup
(more accurate but longer time)

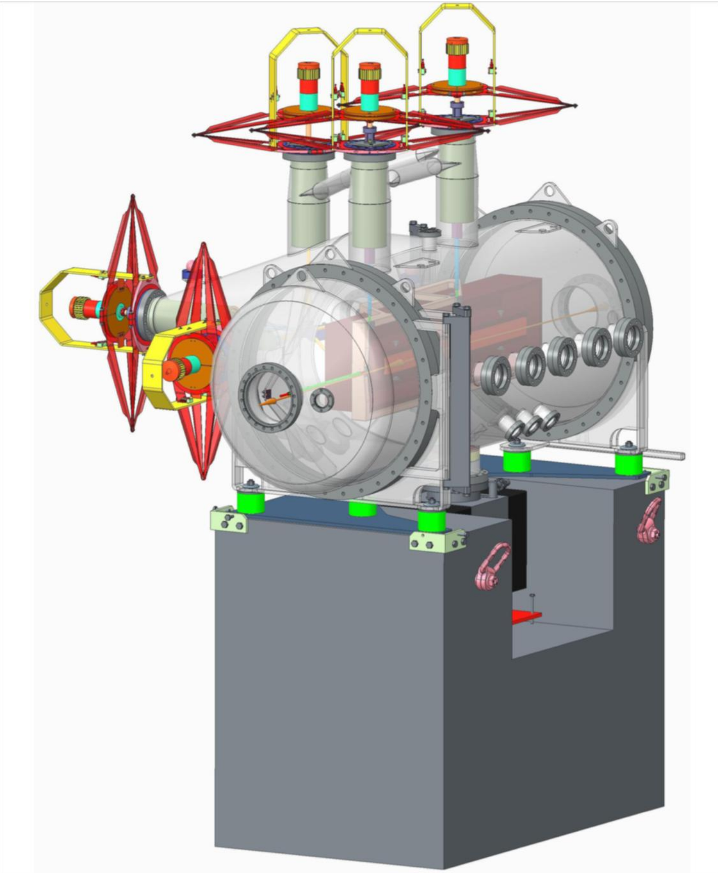
Measurements before and after coating, extremely reproducible (not mounted)

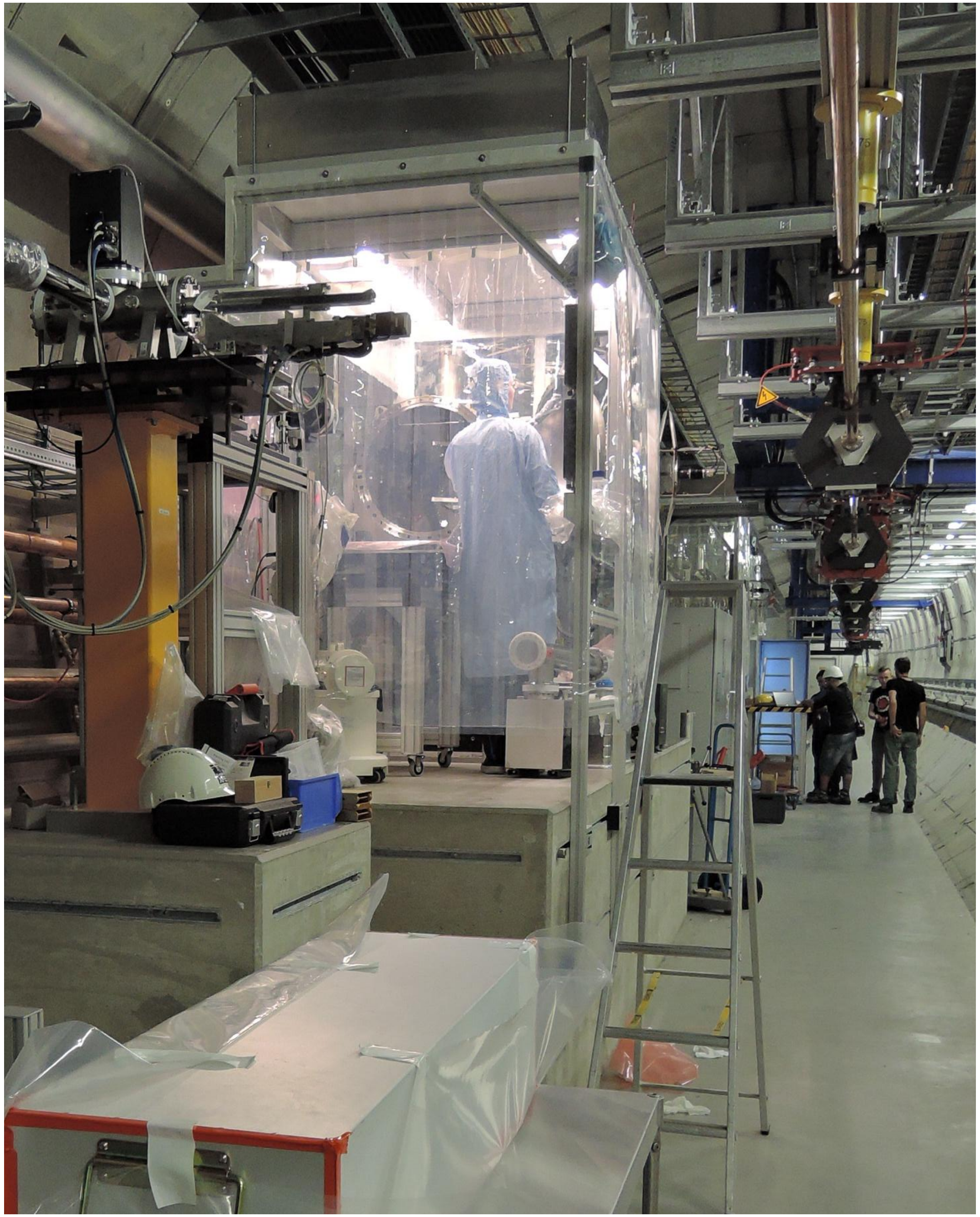


(shape is induced with deterministic polishing to correct gravitational deformation)

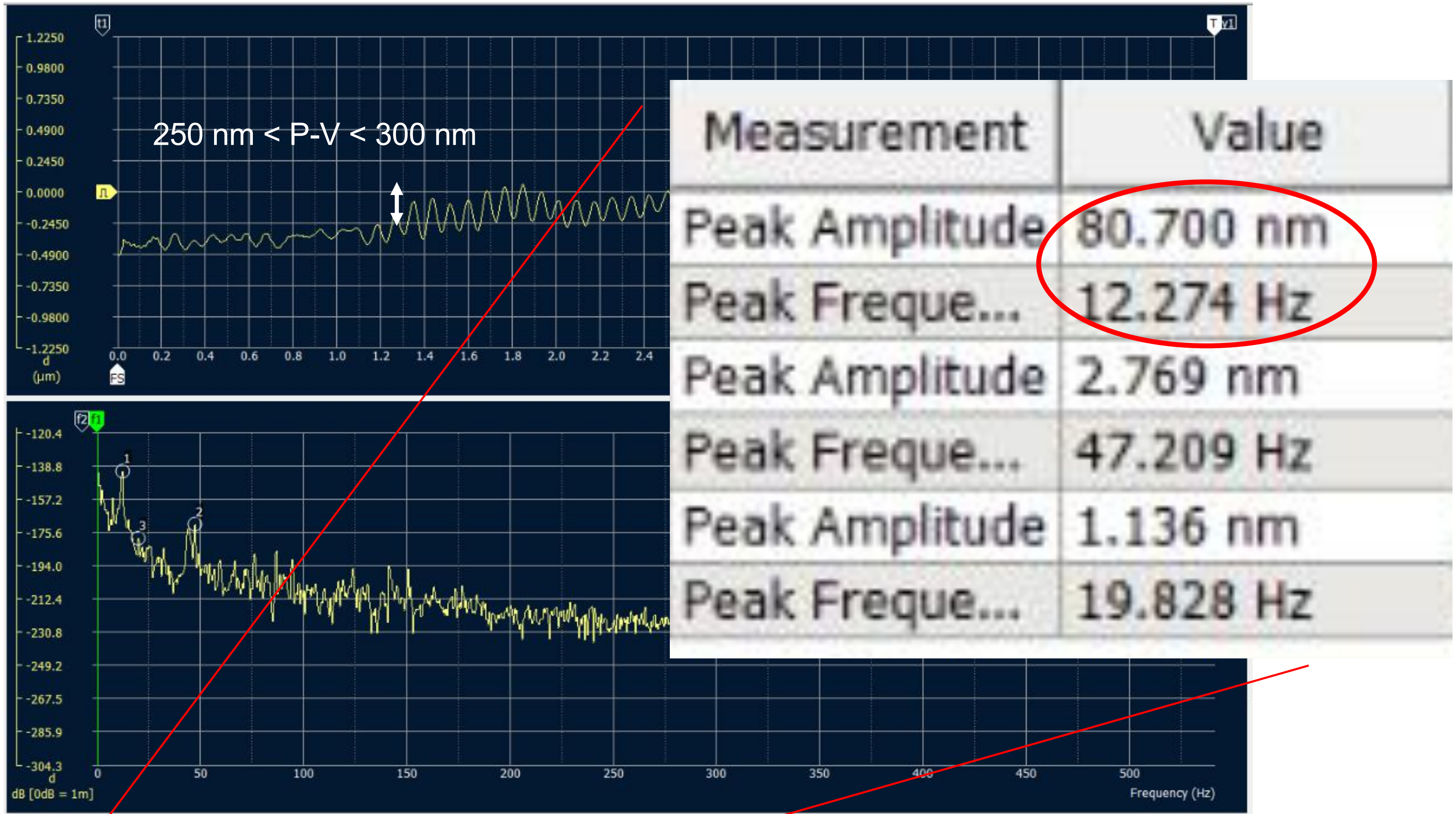
At this level the calibration of the Fizeau (reference alignment) and the alignment of the test mirror is not good enough…so the coating could be even better

Vibrations





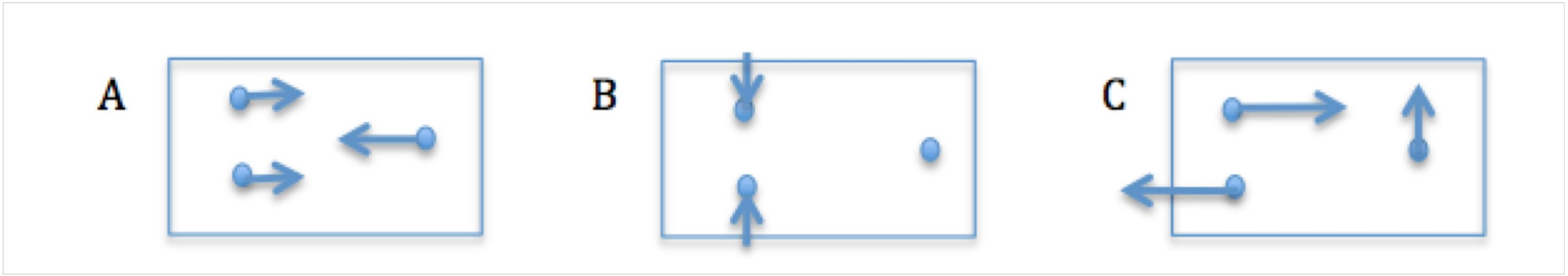
Design by Tino Noll and Antje Trapp
Produced by CINEL (Italy)



	Channel	Measurement	Value	Min	Max	Average	Capture Count	Taken From
1	Spectrum A...	Peak Amplitude	80.700 nm	80.700 nm	80.700 nm	80.700 nm	1	Visible Trace
2	Spectrum Fr...	Peak Freque...	12.274 Hz	12.274 Hz	12.274 Hz	12.274 Hz	1	Visible Trace
3	Spectrum A...	Peak Amplitude	2.769 nm	2.769 nm	2.769 nm	2.769 nm	1	Visible Trace
4	Spectrum Fr...	Peak Freque...	47.209 Hz	47.209 Hz	47.209 Hz	47.209 Hz	1	Visible Trace
5	Spectrum A...	Peak Amplitude	1.136 nm	1.136 nm	1.136 nm	1.136 nm	1	Visible Trace
6	Spectrum Fr...	Peak Freque...	19.828 Hz	19.828 Hz	19.828 Hz	19.828 Hz	1	Visible Trace

Installation: stiction forces on mirror supports

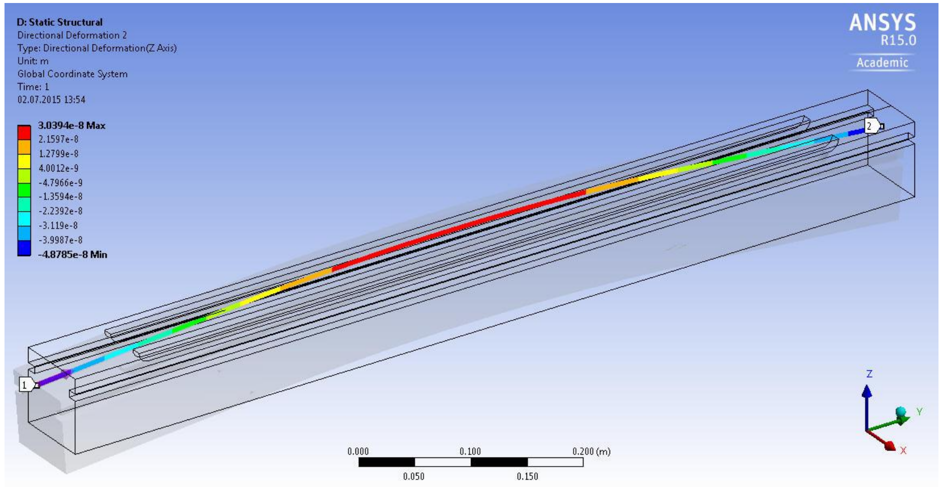
Residual stress after mounting or due to thermal expansion

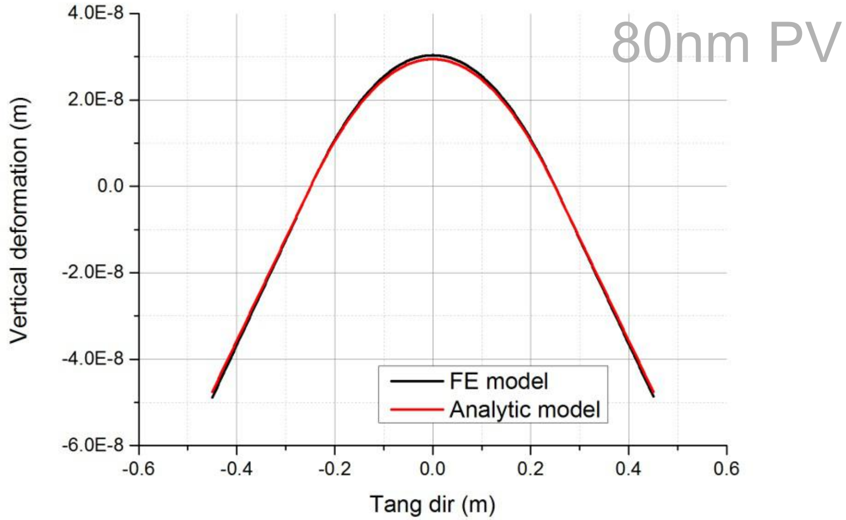


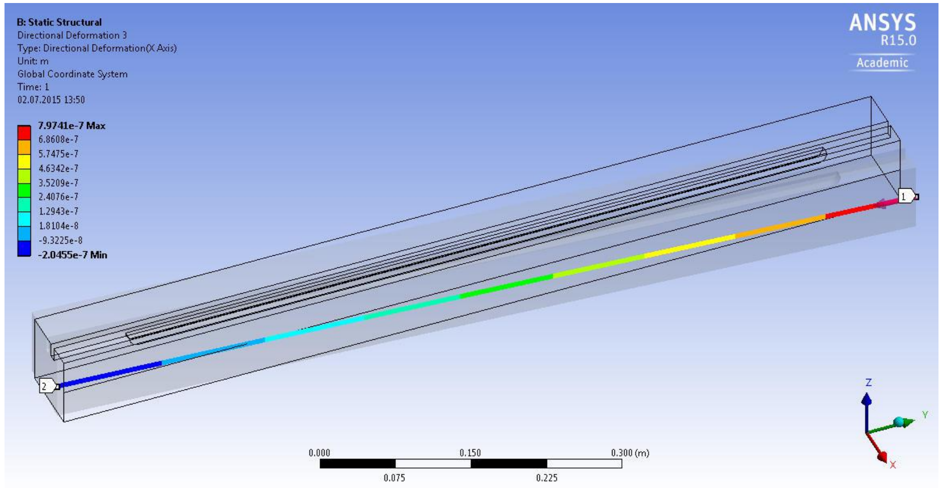
+ side fiducials or other parts in contact

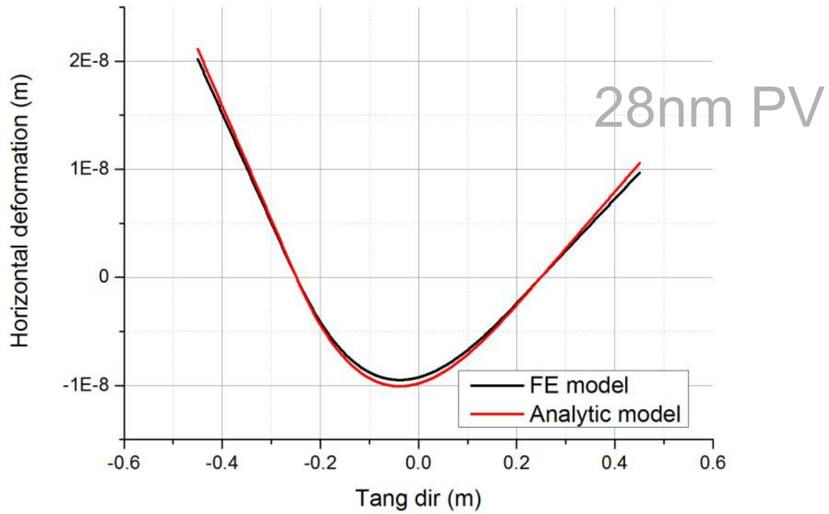
(Thanks to Harald Sinn, X-ray Optics Group Leader, European XFEL)

Stiction force effect in simulations



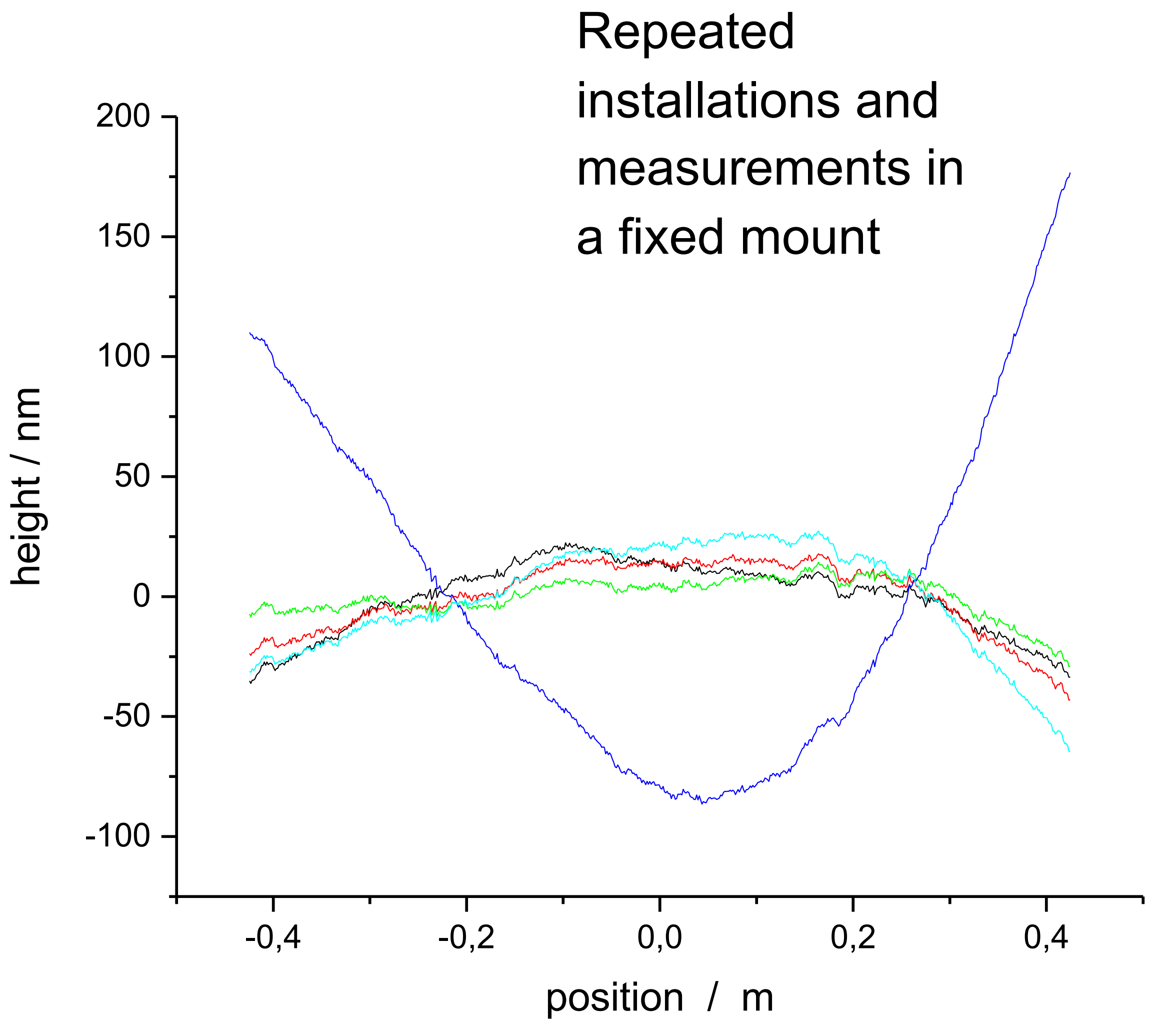






(Thanks to Daniele La Civita, European XFEL)

Stiction force effect in action !



Mounting a mirror can introduce stresses and deformations.
That’s why the optics have to be measured in their final mount

Here an example of reproducibility of installations in a fixed mount.

(Thanks to Silja Schmidtchen, European XFEL)

Conclusions

We presented here the general activity of metrology carried out at European XFEL :

- Grazing incidence (when we have to rush) and stitching method (when we have time)
- General reproducibility and repeatability very good
- Results compatible with expectations from measurements

What is still missing ?

- Study of the repeatability of the installation and development of a strategy to ensure a better installation (keeping the good measurements done in the lab)
- Automatization of the procedure
- Extension of the procedure to very curved mirrors (only stitching possible but the number of sub-apertures is increasing)
- Diagnostics on site (after installation)


Thank you for your attention!