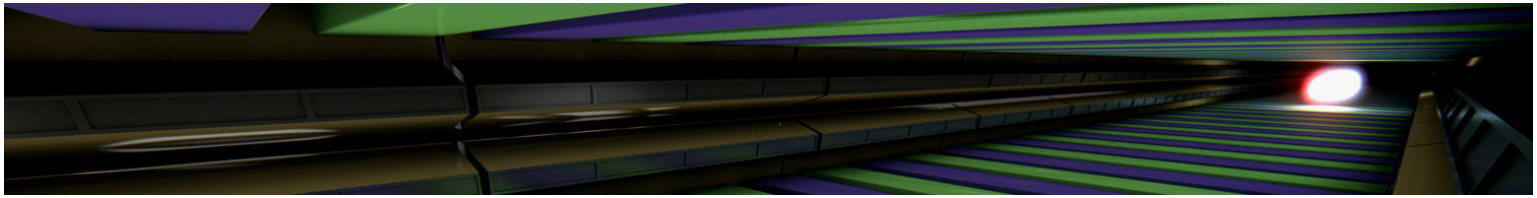

FEA Simulation for Adaptive Mirrors at European XFEL

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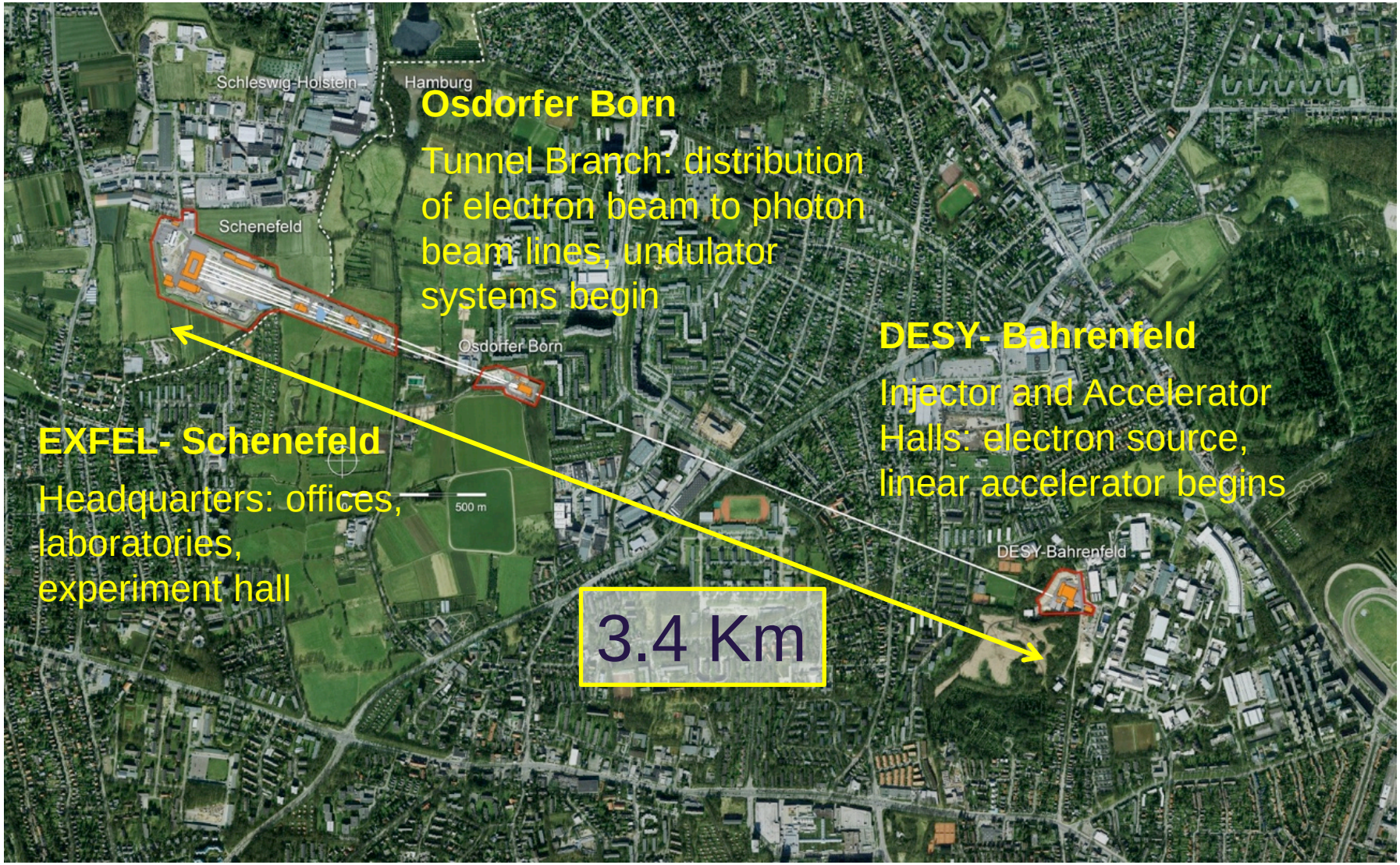
Contents

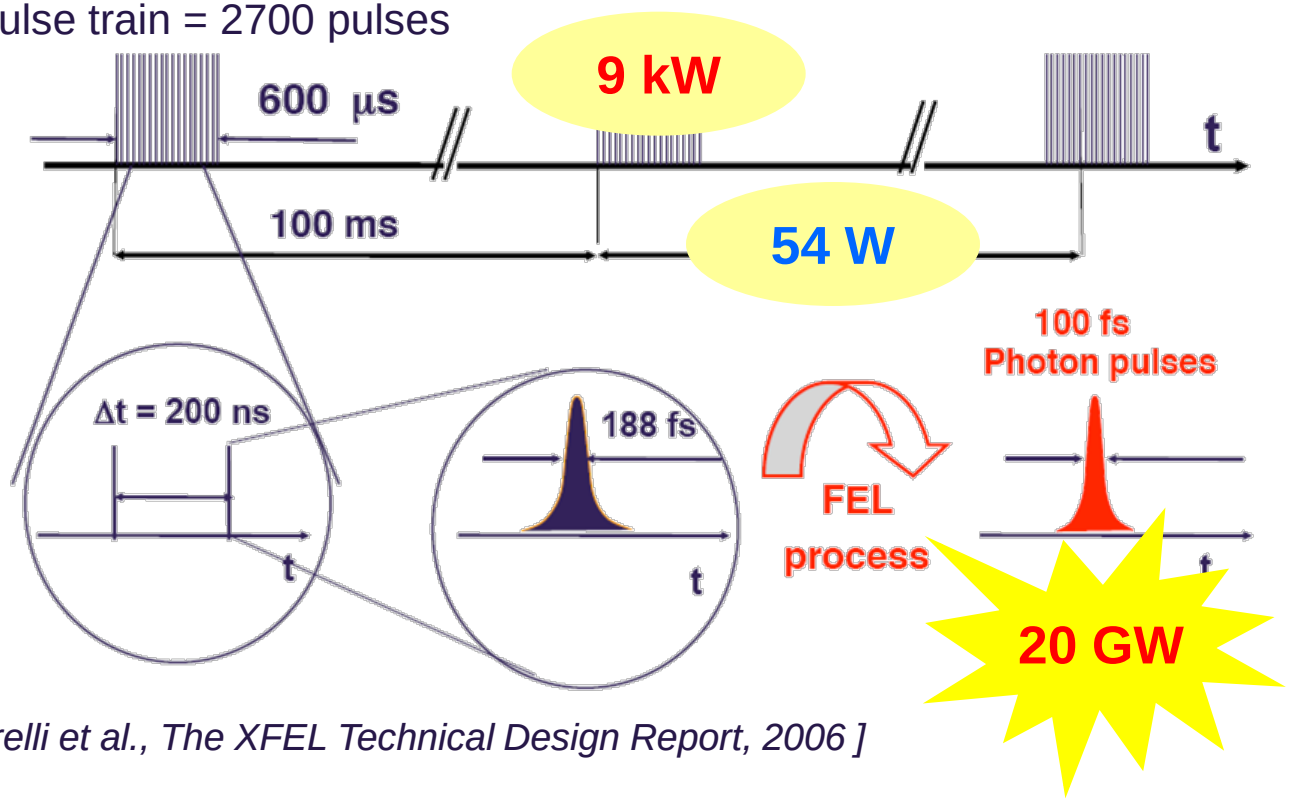
- Introduction of the European XFEL project and current status
- Adaptive mirrors design concept
- FEA simulation with heat load and electrical voltages
- Metrology measurements
- Conclusion: future modeling perspectives

Introduction of European XFEL



Extreme heat load & time structure in EXFEL

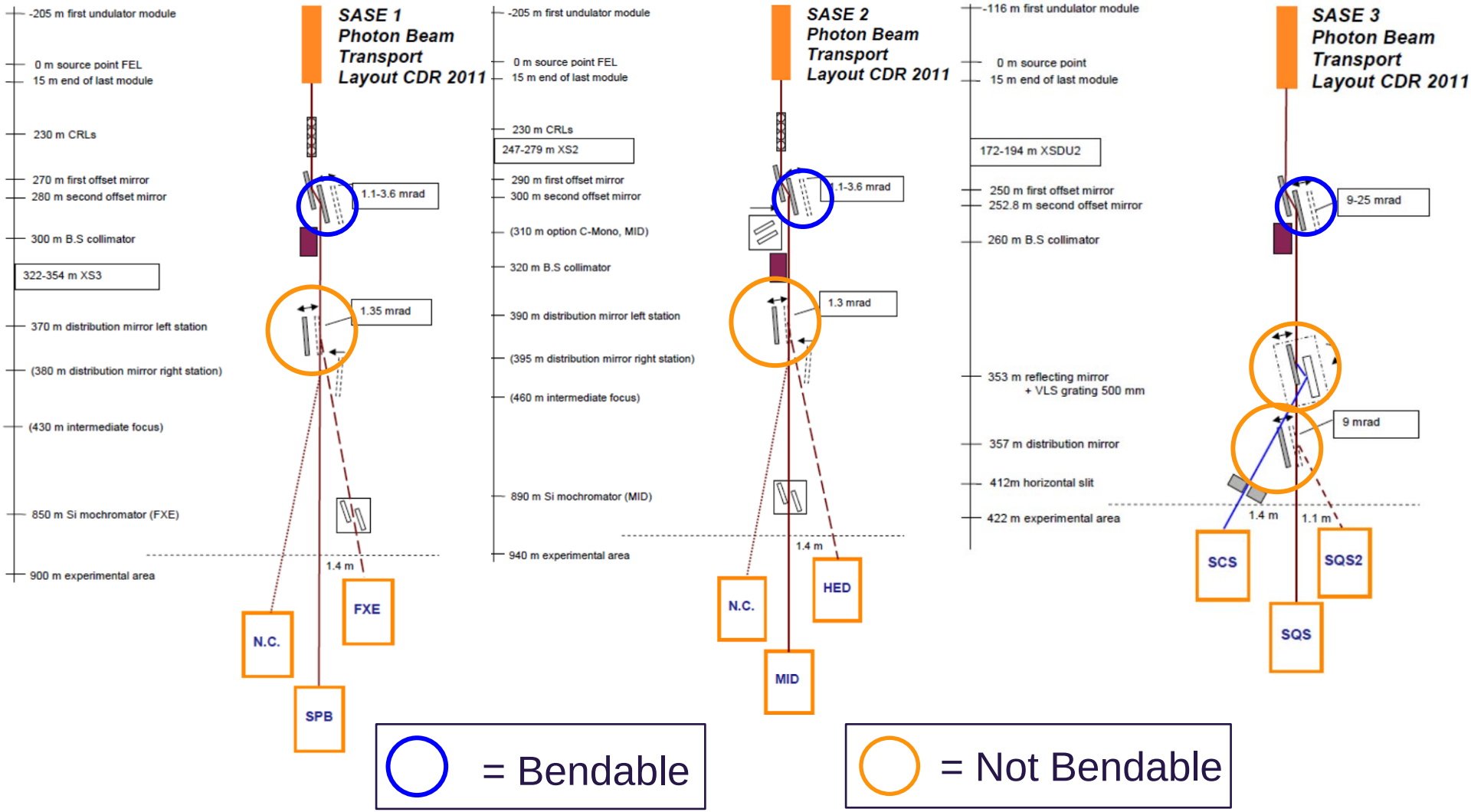
1 pulse train = 2700 pulses



[M. Altarelli et al., The XFEL Technical Design Report, 2006]

- Energy: $Q_{/pulse} = 12.3\times10^{3}\,\mathrm{eV}\times10^{12}\times1.602\times10^{-19} = 2\ \mathrm{mJ}$
- Power: $P_{/pulse} = \dfrac{2\ \mathrm{mJ}}{100\ \mathrm{fs}} = 20\ \mathrm{GW}$ $\quad P_{/pulse\ train} = \dfrac{2\ \mathrm{mJ}\times2700}{0.6\ \mathrm{ms}} = 9\ \mathrm{kW}$

Bendable mirros in distribution system



Optics specification

	Mirror specifications	Prototype specifications
Substrate size (LxWxH)	950x52x52mm^3	950x52x52mm^3
Optical surf (mer x sag)	850x20mm^2	850x20mm^2
Substrate Material	Single crystal silicon	Single crystal silicon
Surface coating	B_4C	none
Figure	Flat	Flat
Cooling system	InGa eutectic bath	Groove present but not used

Height error (Peak to Valley) (4th order polynomial removed)	<2 nm	<20 nm
Slope error (root mean square)	<0.05 urad <0.5 urad sagittal	<1 urad <0.5 urad (3rd order removed) <5 urad sagittal
Roughness (@10x) rms	<0.3 nm	<0.3 nm No points over 0.6 nm
Radius of curvature	>600 km	>50 km >1 km sagittal
Bending capability	-50 km to flat to +50 km	-50 km to flat to +50 km

Collaborations

Technical specifications
coordinate the collaboration & FEA

Mirror chamber design (Tino Noll)
Metrology lab (Maurizio, Frank Siewert)

European XFEL
(WP 73)

HZB

SESO
(JTEC, etc.)

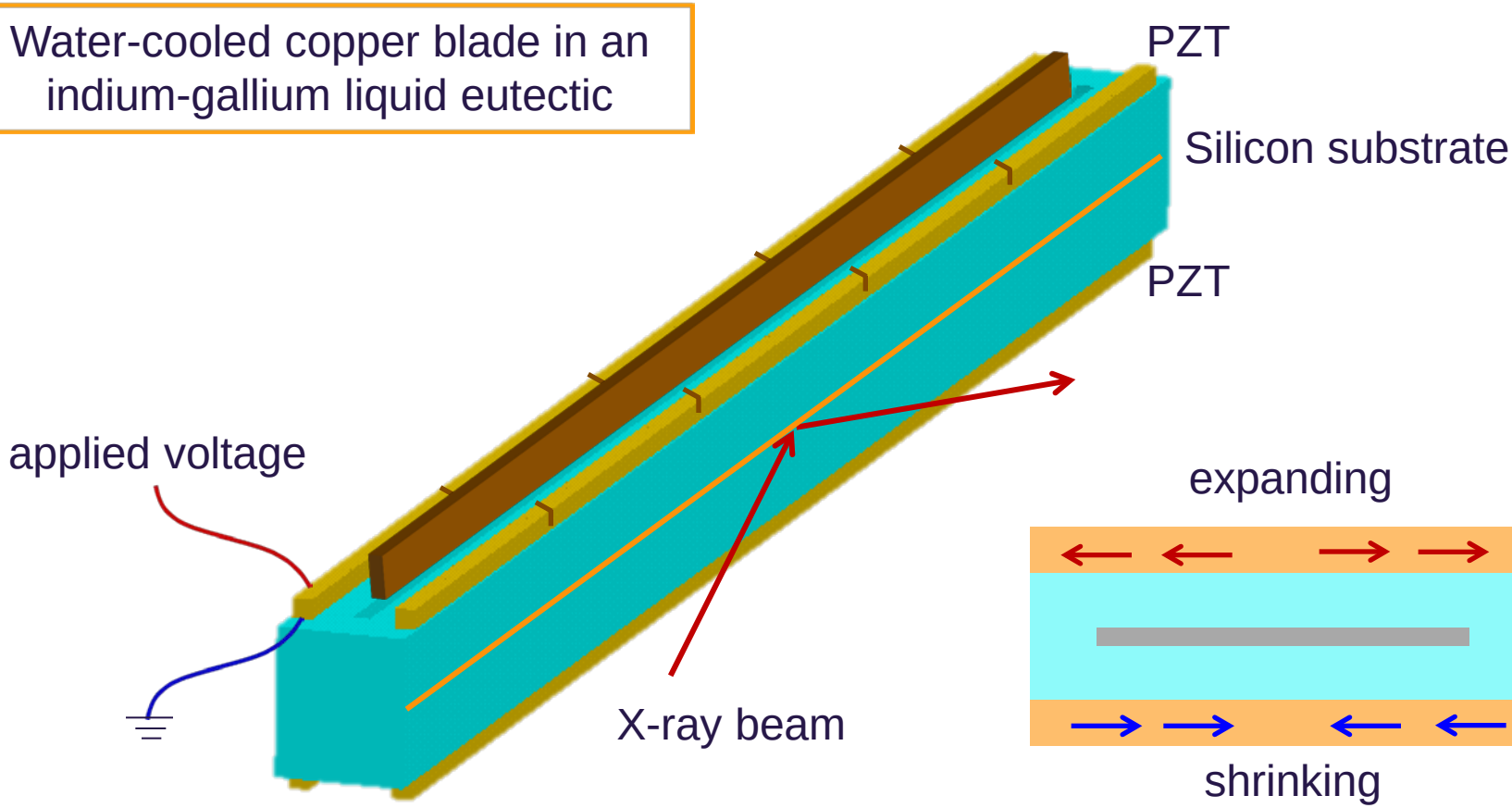
Bruker /ASC, CINEL
(Riccardo Signorato)

Provide the mirror substrate,
PZT actuators and other
necessary components

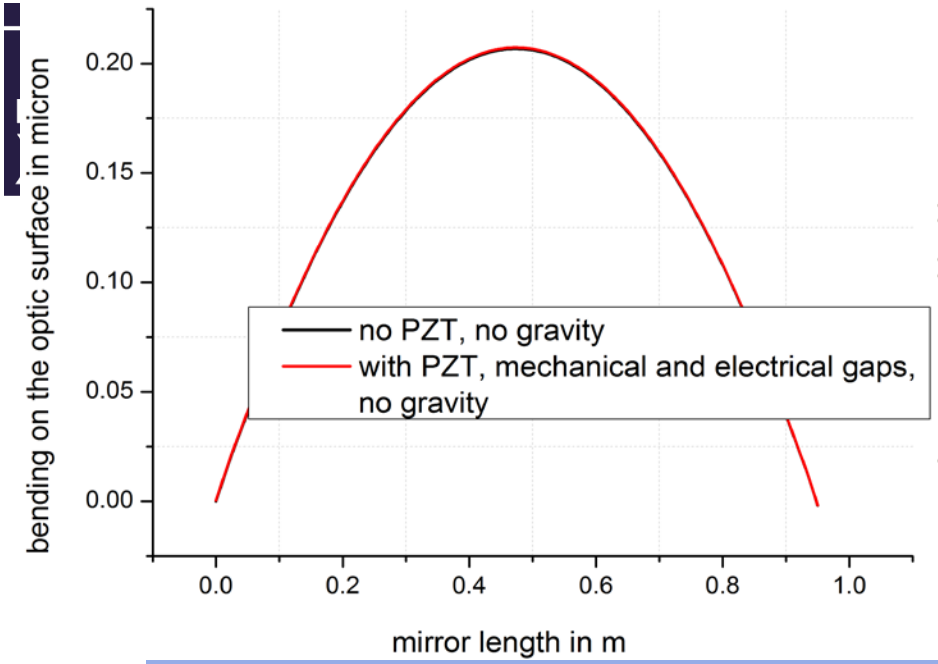
develope and build the mirror prototype
including bending and cooling mechanisms

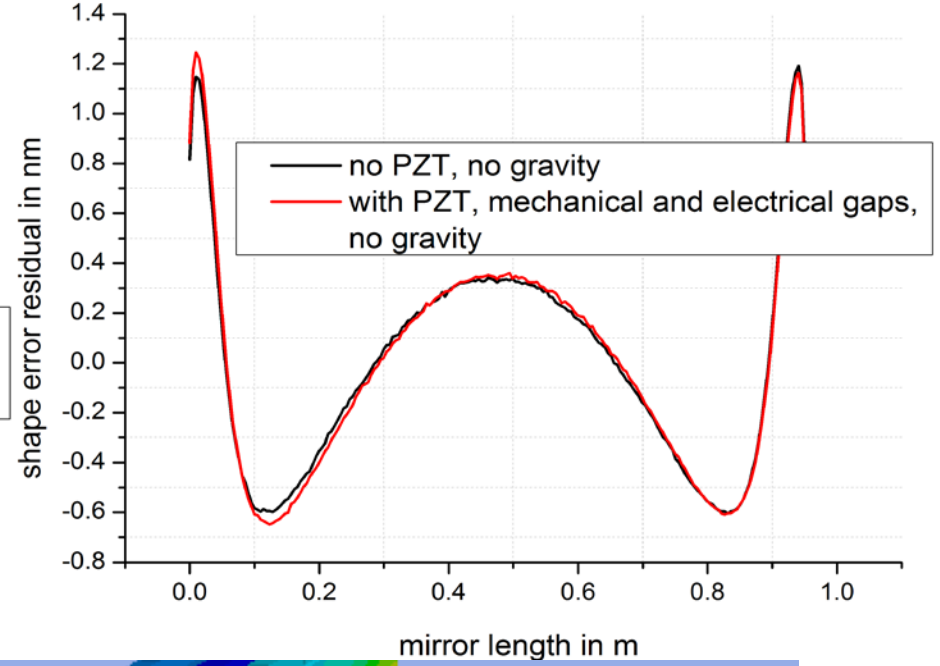
Adaptive (bimorph) mirror model

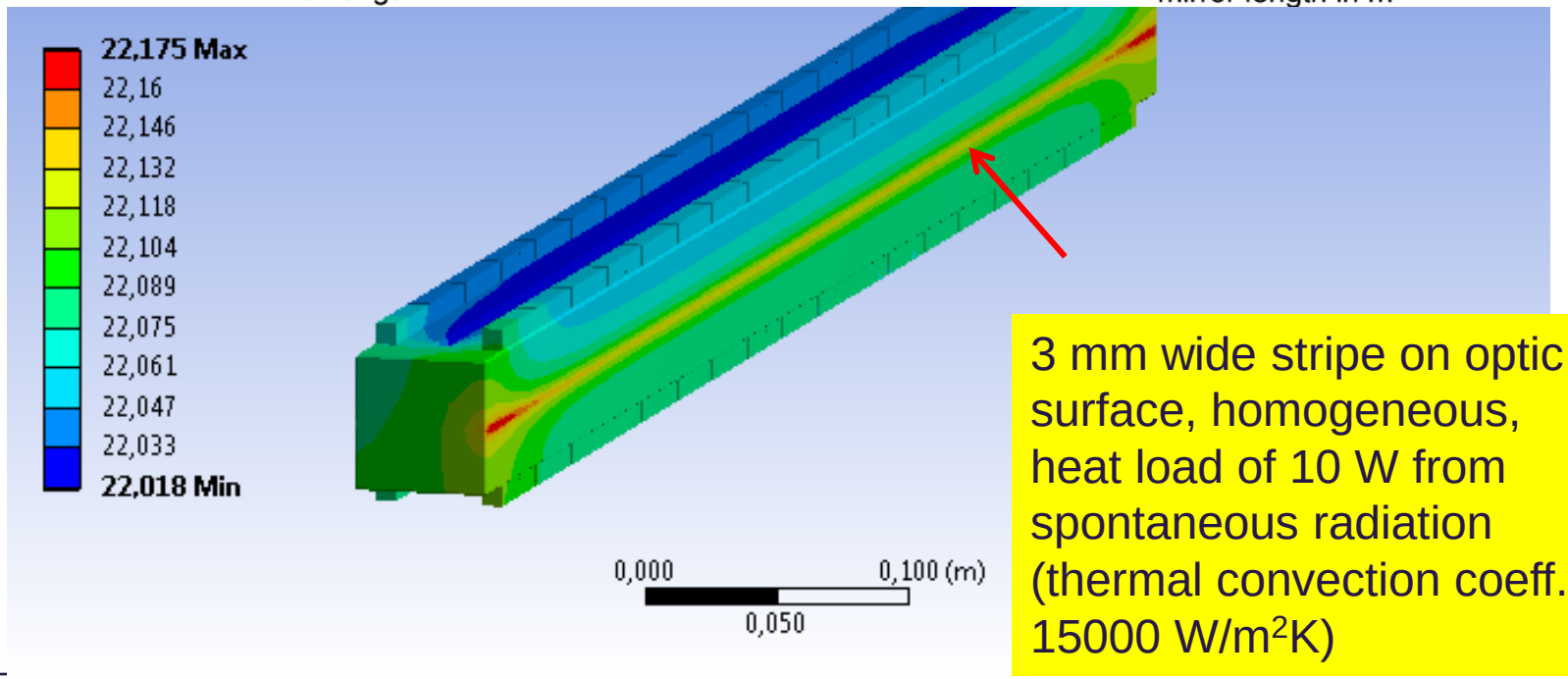
Water-cooled copper blade in an indium-gallium liquid eutectic



Bending capability top view

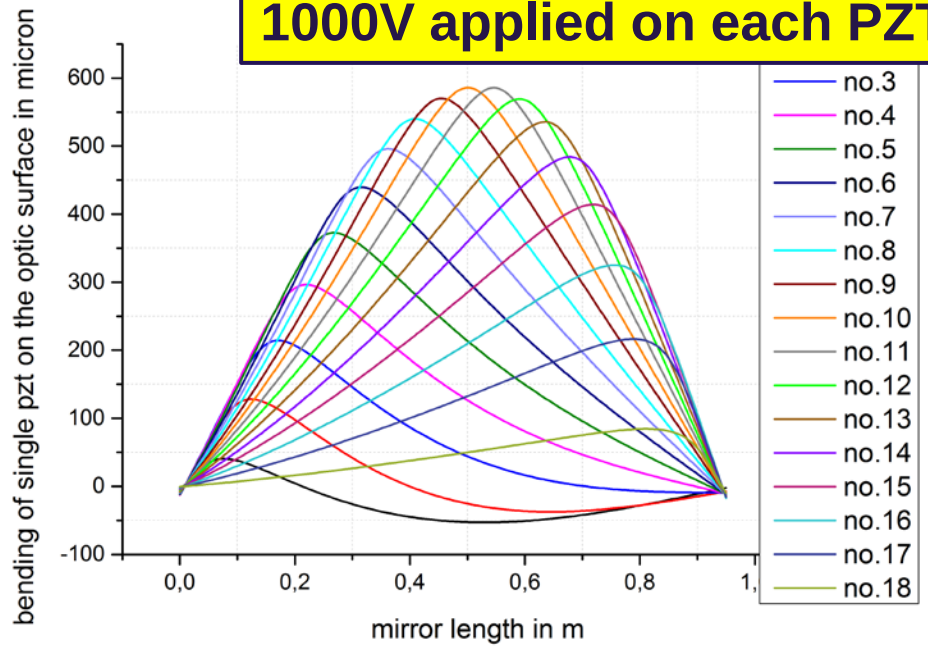


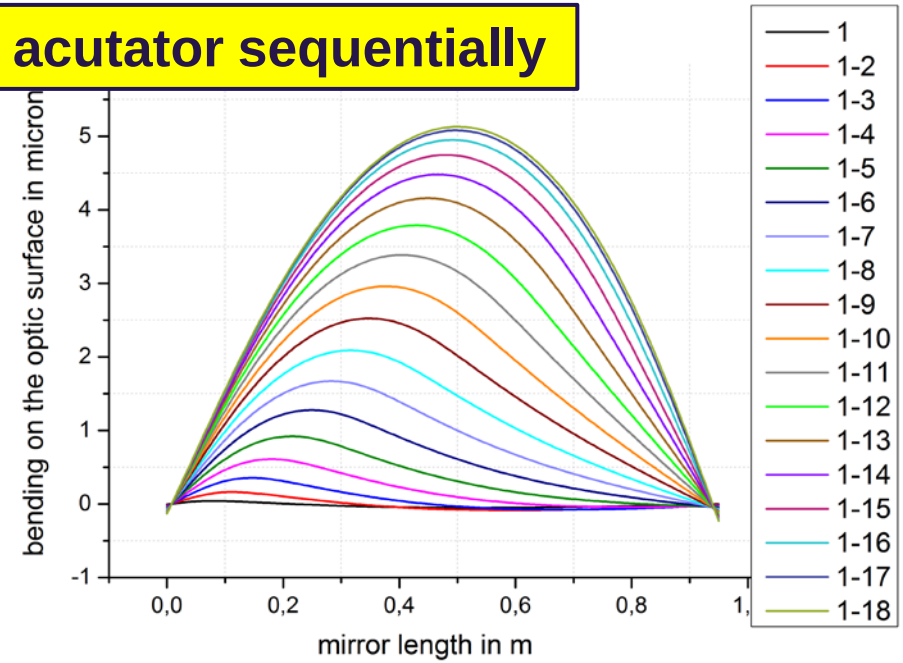


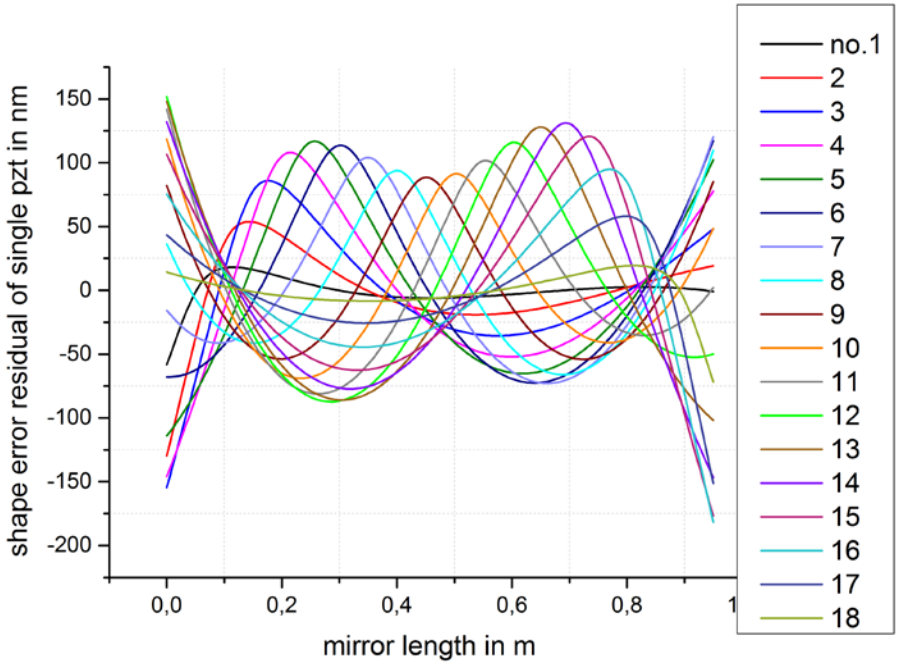


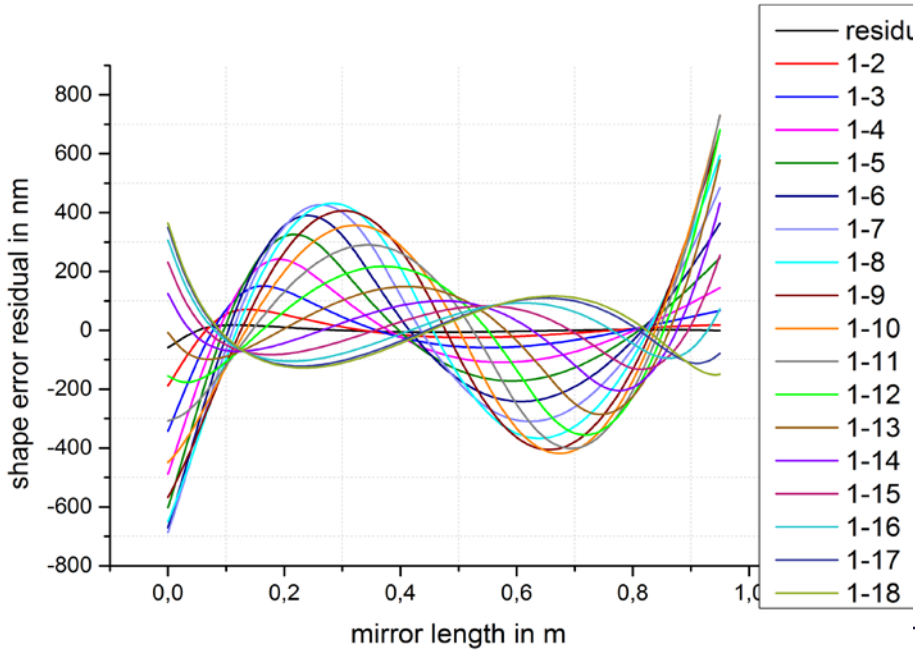
3 mm wide stripe on optic surface, homogeneous, heat load of 10 W from spontaneous radiation (thermal convection coeff. 15000 W/m^{2}K)

1000V applied on each PZT acutator sequentially





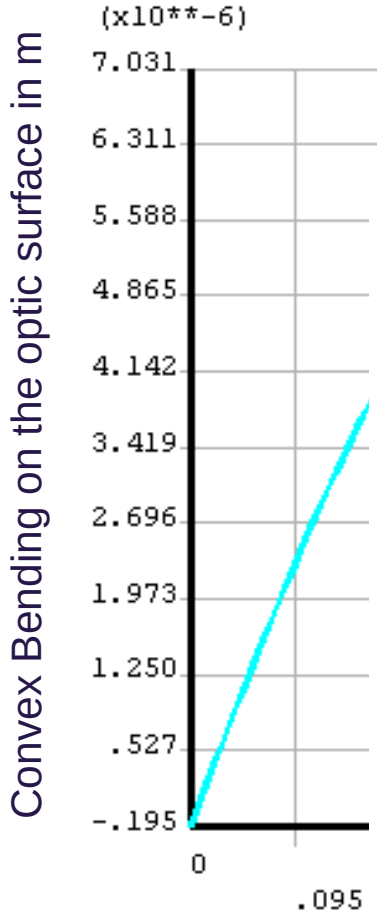


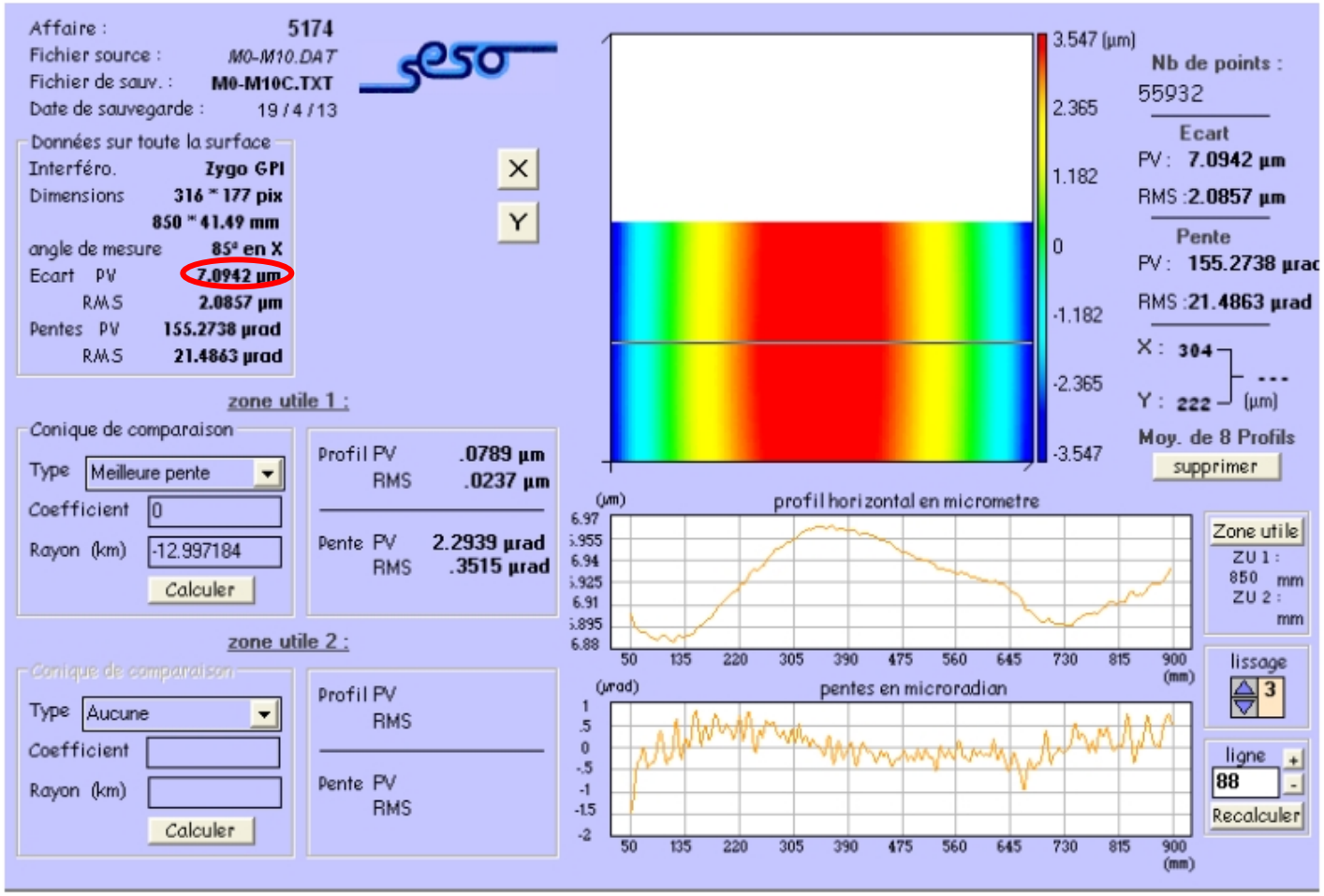


Simulations V.S. Measurements (1000V)

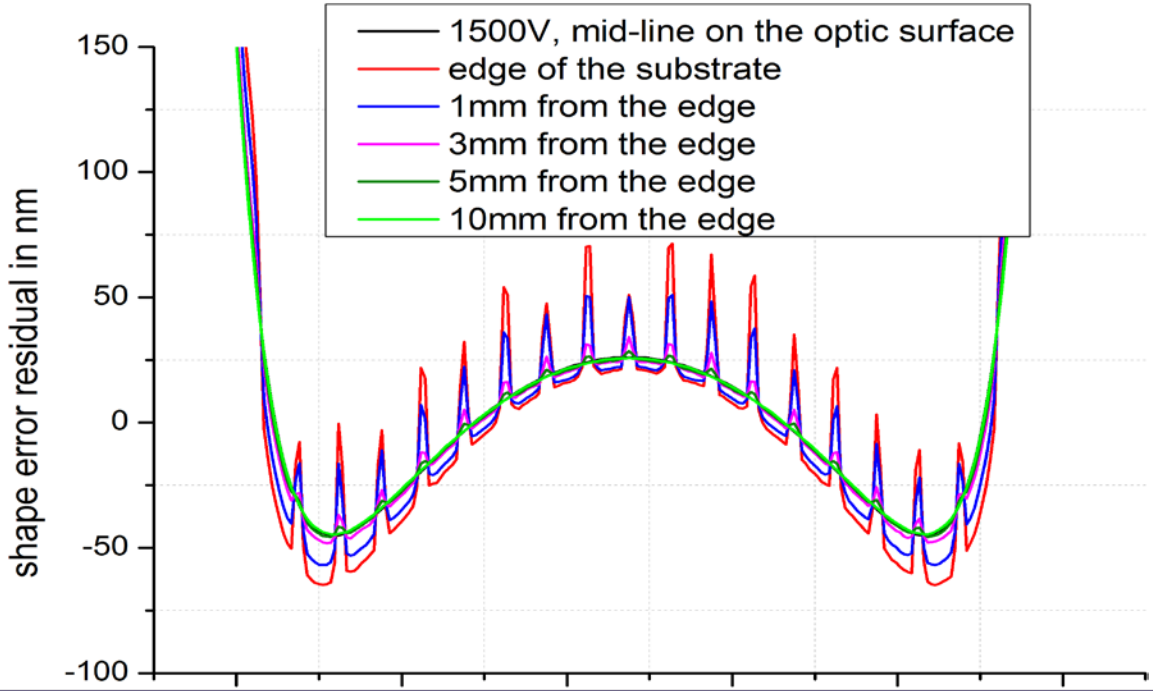
PV (ANSYS): 7.22 µm

PV (SESO): 7.09 µm

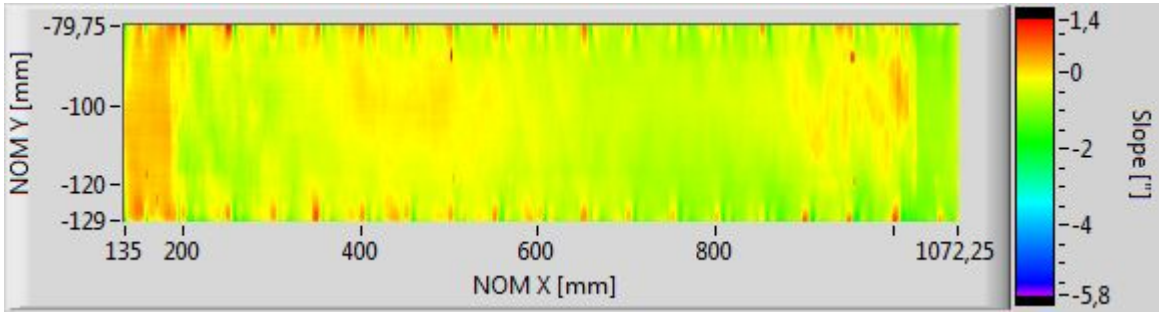




Slope Map with Piezo Prints

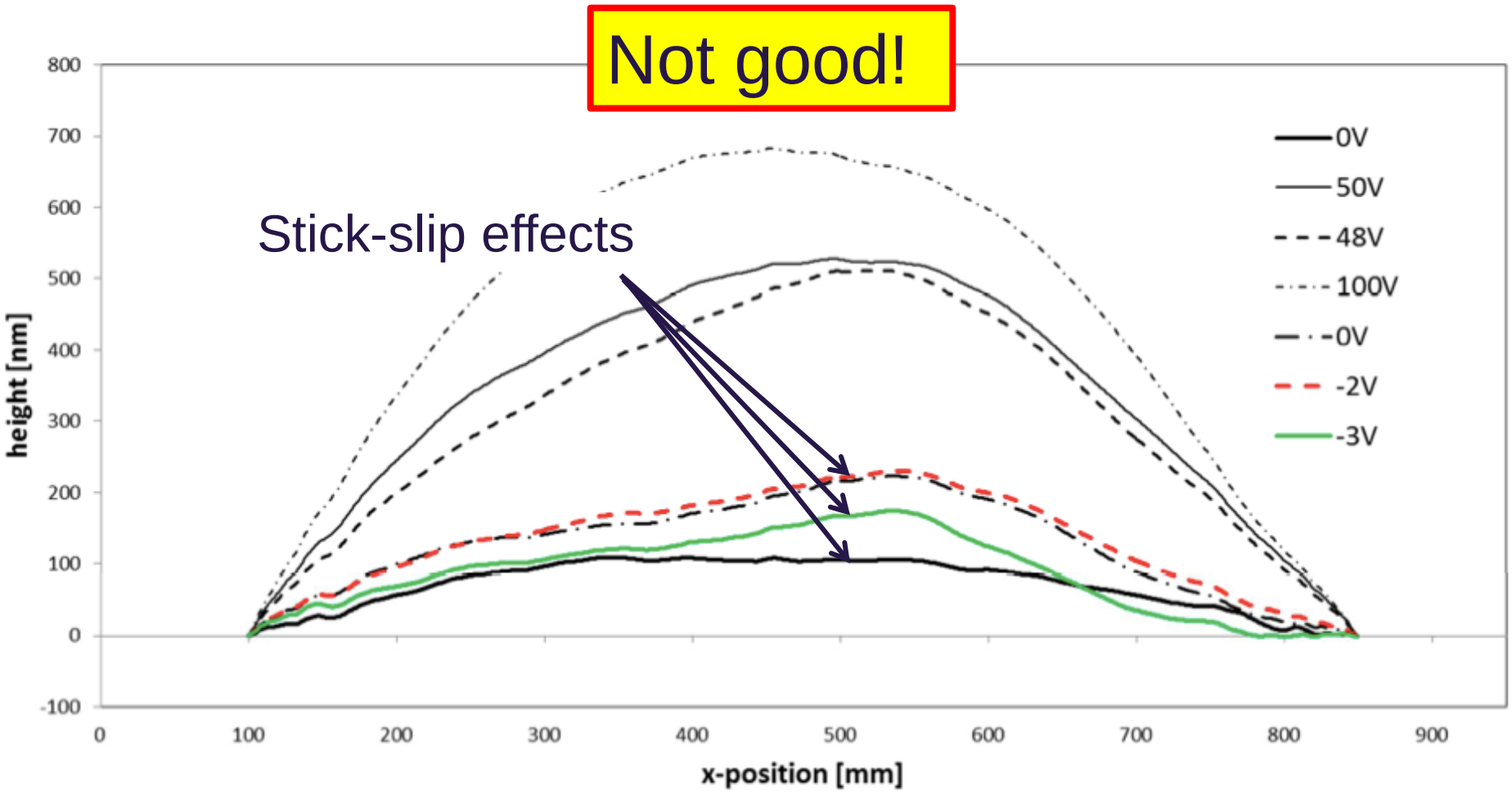


No effect of PZT are observed on the optic surface



Mirror shape at different voltages

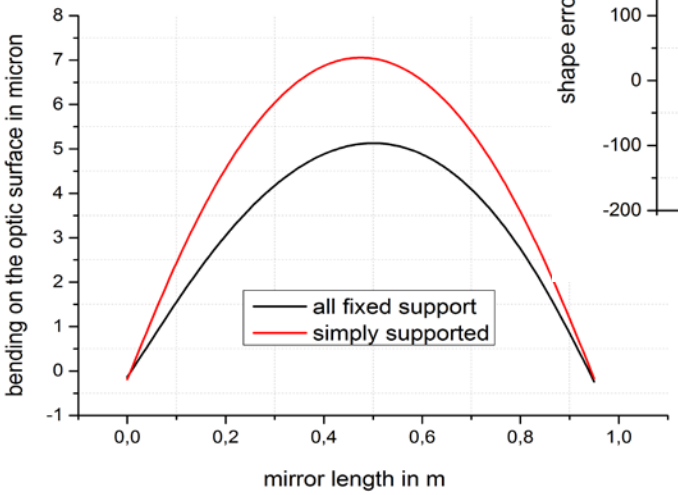
HZB Helmholtz Zentrum Berlin

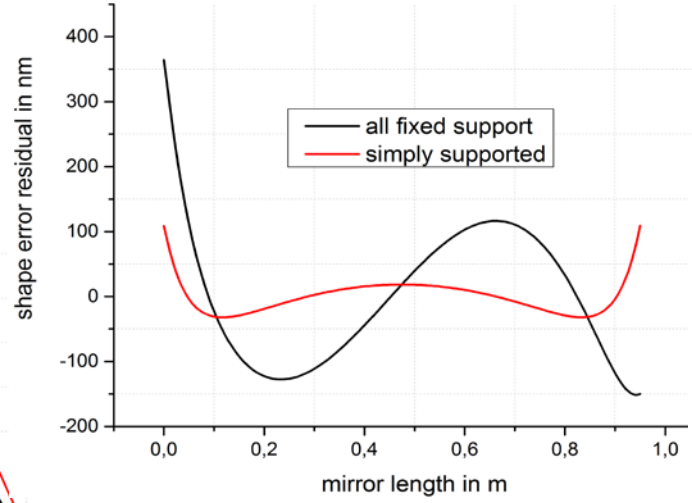


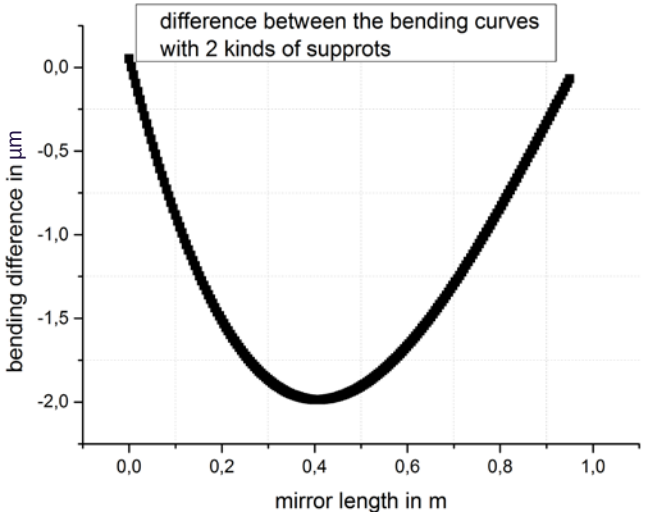
Initial 0V state: **R = 652km**
Moving back to 0V state: **R = 368km**
-3V state: **R = 680km**

3 Points Support bending (Fixed vs. Simply supported)

Bottom view of the mirror







Conclusions

- FEA Simulations agreed well with initial SESO and HZB measurements (~ 600 nm/100 V)
- Deformations due to the radiation are in the extent of adjustable, Stress and strain concentration are in the safety range
- No influence visible from piezos in optical area (so far…)
- 2 nm PV NOM measurements seems possible (measurement setup should be improved)

Next steps to do with the prototype:

- Adaptive ability of the piezos (min. PV per applied voltage)
- Investigate the relations between friction bending and different supporting concepts

X-Ray Optics and Beam Transport Group

THANK YOU FOR YOUR ATTENTION