F. Siewert, J. Buchheim, T. Höft (HZB / BESSY-II)
S. Fiedler, G. Bourenkov (EMBL-Hamburg)
R. Signorato (Bruker ASC)

Characterization and optimization of adaptive bimorph-mirrors by use of the BESSY-NOM

Layout of EMBL @ PETRA-III beamlines

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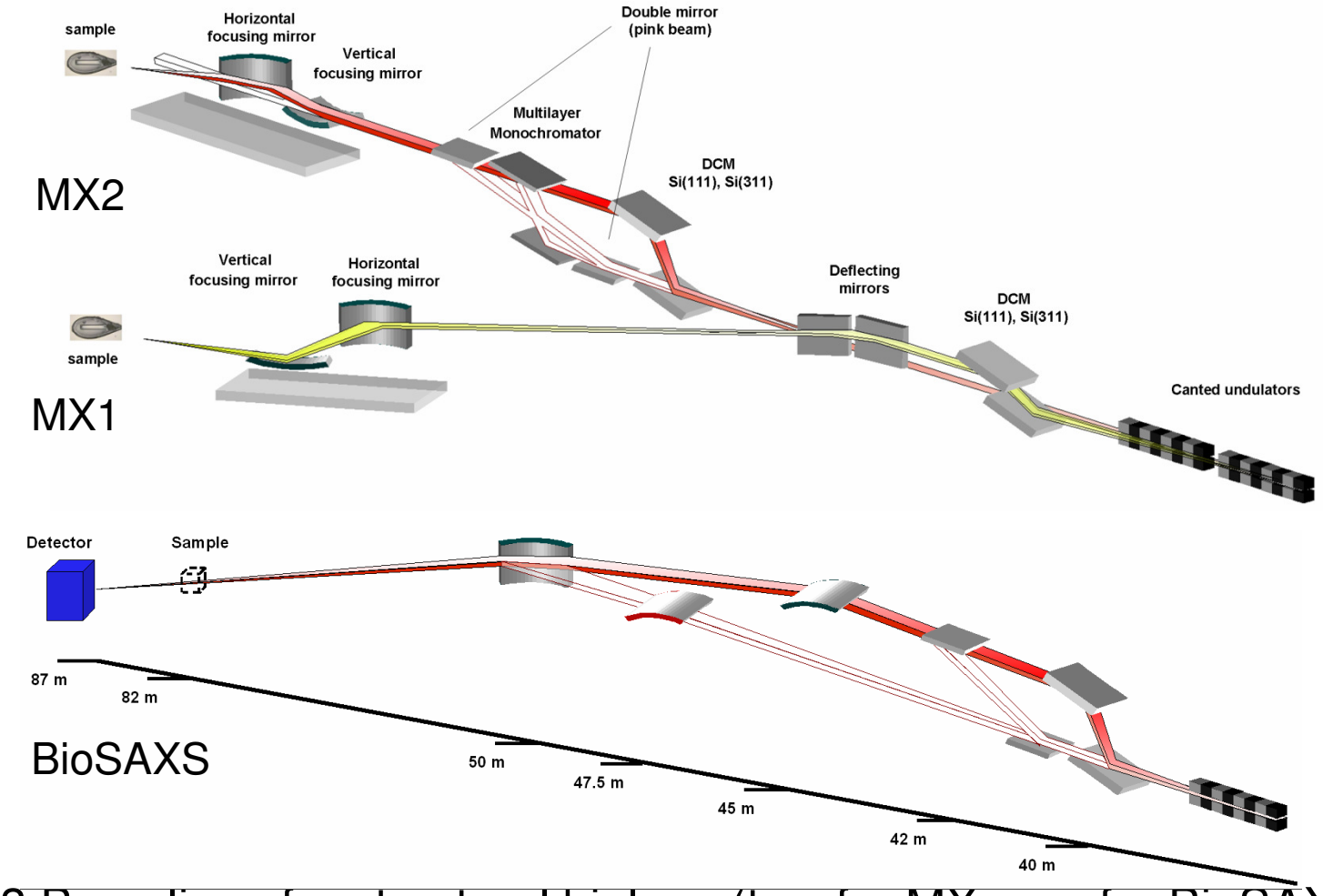


- 3 Beamlines for structural biology (two for MX, one for BioSAXS) with similar layout but with very different demagnification ratios.
- All equipped with bimorph adaptive mirrors in KB geometry.

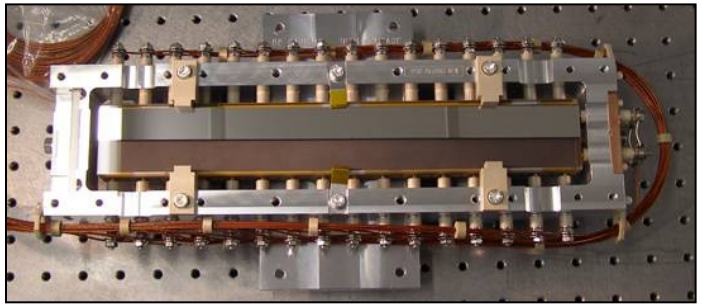
Design paramter for the bimorph mirrors

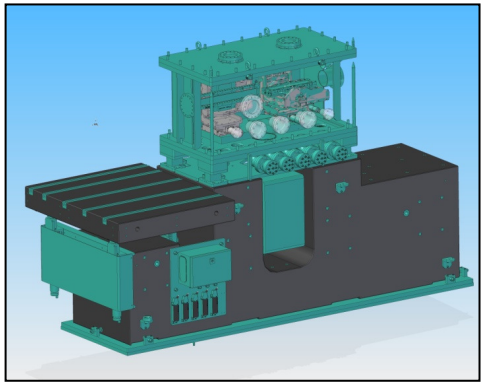
HZB Helmholtz Zentrum Berlin

Parameter	BioSAXS VFM	BioSAXS HFM	MX1 VFM	MX1 HFM	MX2 VFM	MX2 HFM
Position from source [m]	45	50	53.25	52.75	59.92	60.4
Focal distance [m]	37 (+0/-5)	32 (+0/-5)	4 (+1.5/- 0.5)	4.5 (+1.5/- 0.5	1.48 (+1.0/-0.01)	1.0 (+1.0/-0.01)
Optical surface [mm²]	250 x 30 VFMs 400 x 30 HFMs					
Substrate	SiO2					
Coating	SiO2 +Rh				SiO2 +Rh+Pt	
Energy range [keV]	4-20		4-17		7-35	
Focal size [micron]	64	200	13	28	7 (1) superpolished	9
No. of electrodes	16 VFMs, 24 HFMs					
Shape	elliptical					
Roughness [Å]	<1.5					
Slope error [µrad]	<1 (w/o optimisation) , 0.5 (with optimisation)					

-Beamprofile optimisation needed in “out of focus” position

- Check of slope error at HZB / BESSY-II





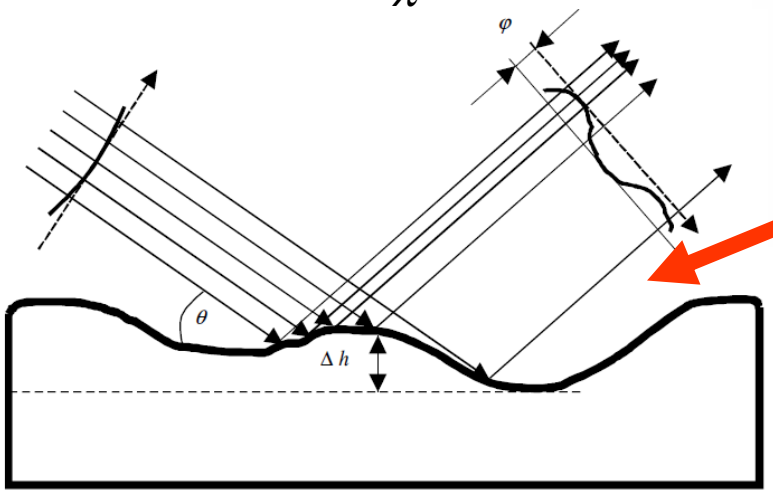
Mirror quality and beamline performance

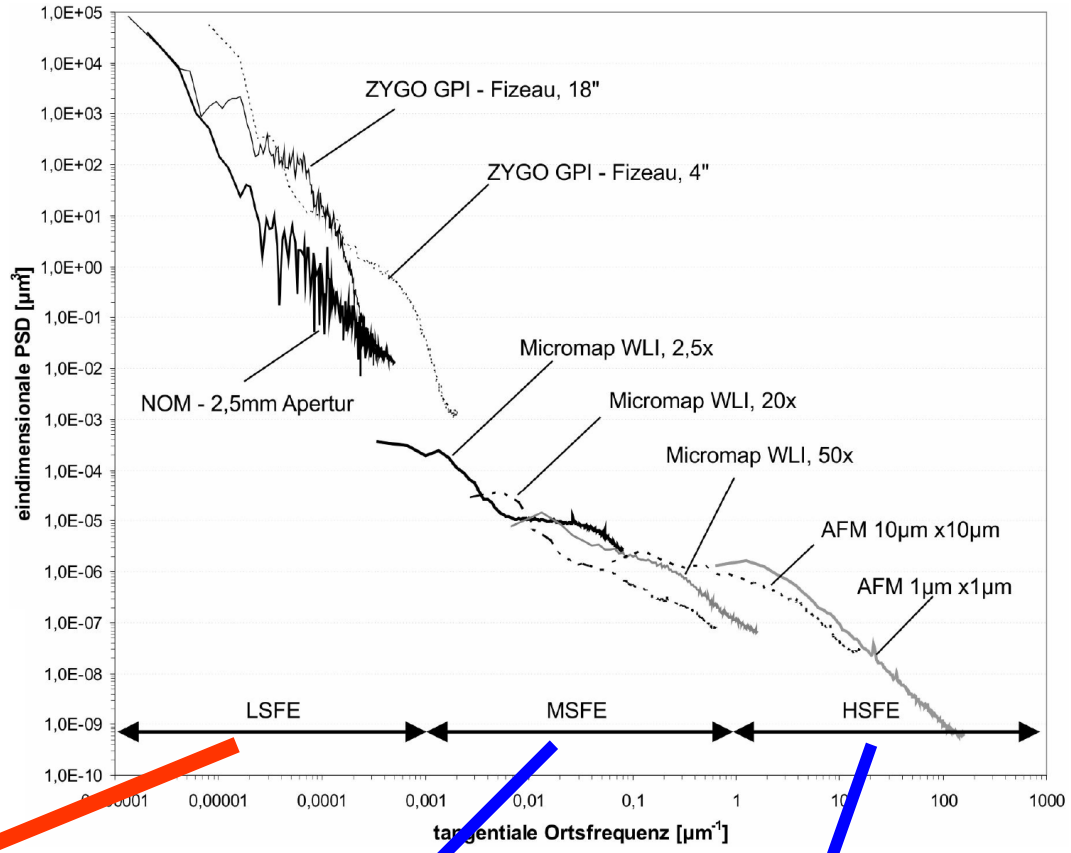
Slope measuring profiler are ideal tools to characterize active and adaptive optics for X-ray application

- long optics > 1m length
- flat or curved
- linking mirror electronics + NOM

wavefront distortion

$$\varphi = \frac{2\Delta h \sin\theta}{\lambda}$$

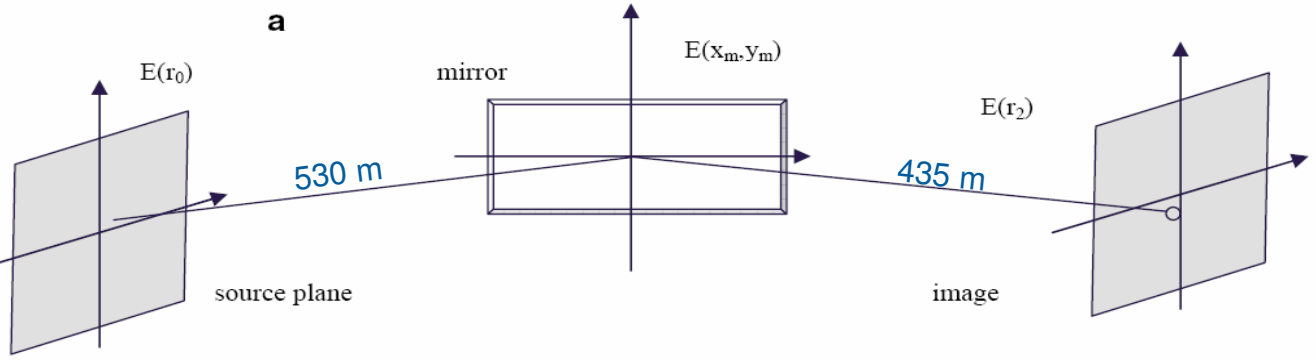




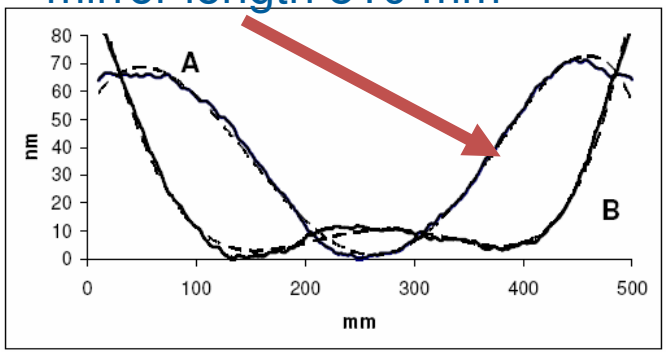
small angle scatter

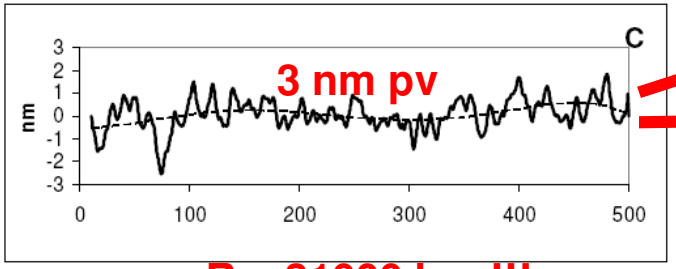
wide angle scatter

Wavefront simulation for a plane mirror at Europ.-XFEL

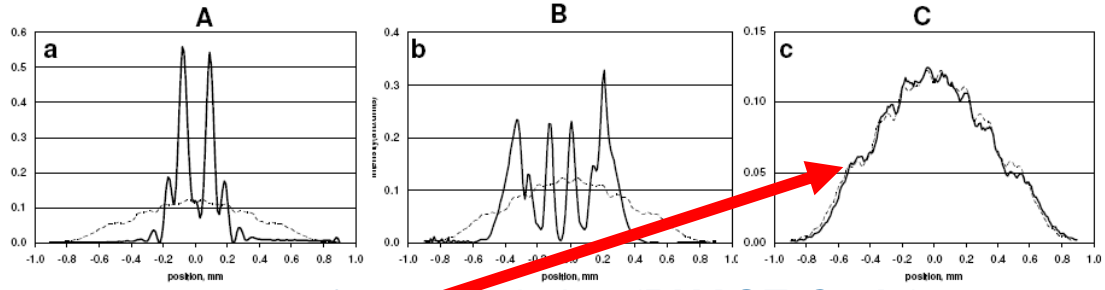


real mirror profile
(NOM-data)
– mirror length 510 mm



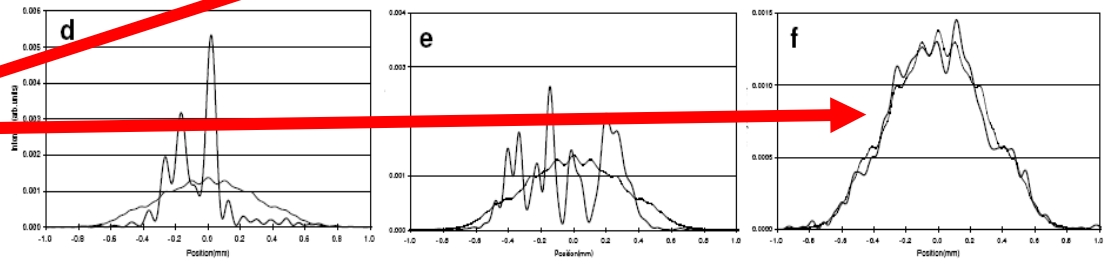


R = 31000 km !!!



wavefront simulation (**PHASE-Code**)

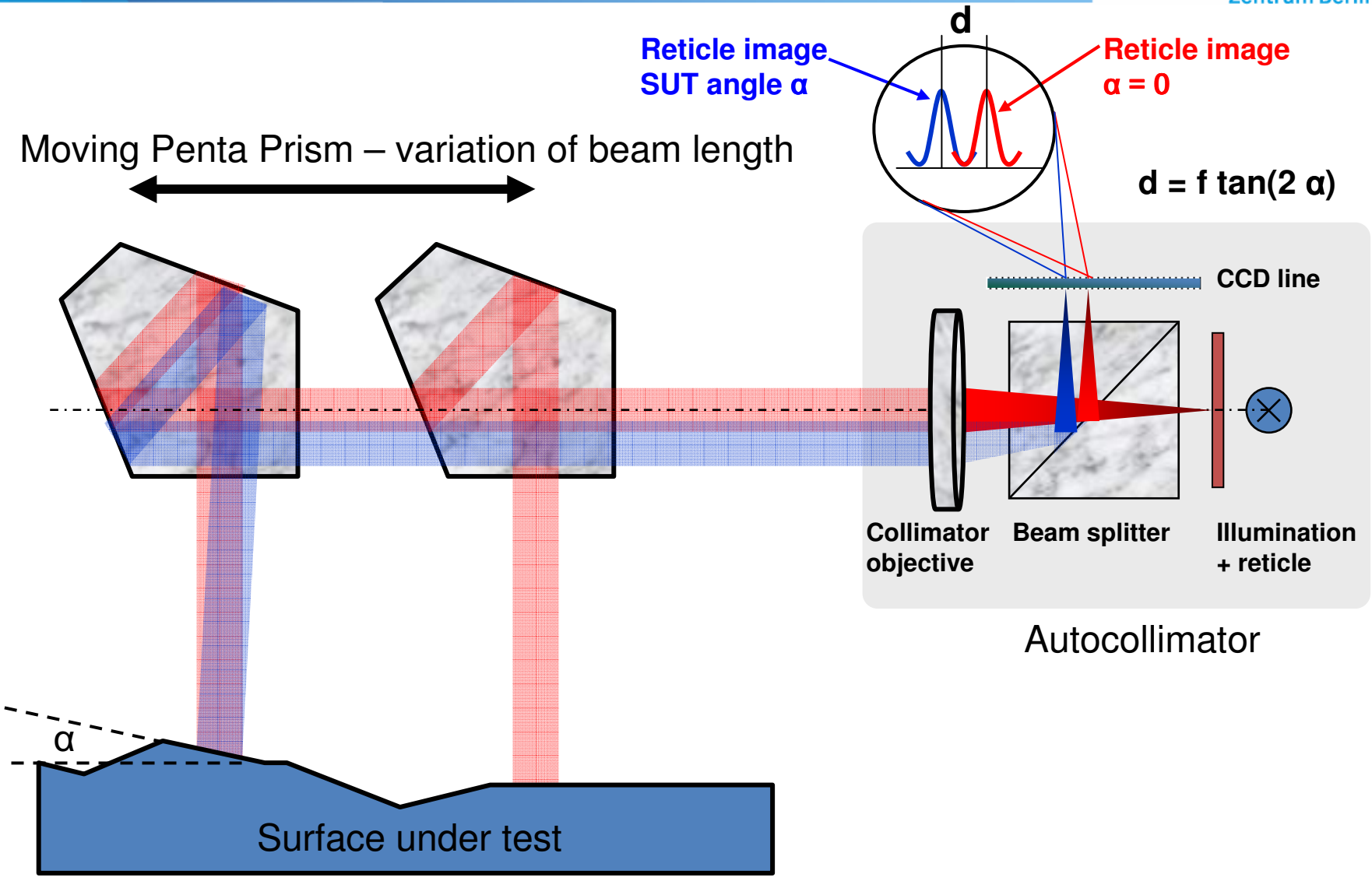
J. Bahrdt, in Physical Review Special Topics **10** (2007) 060701 (15)



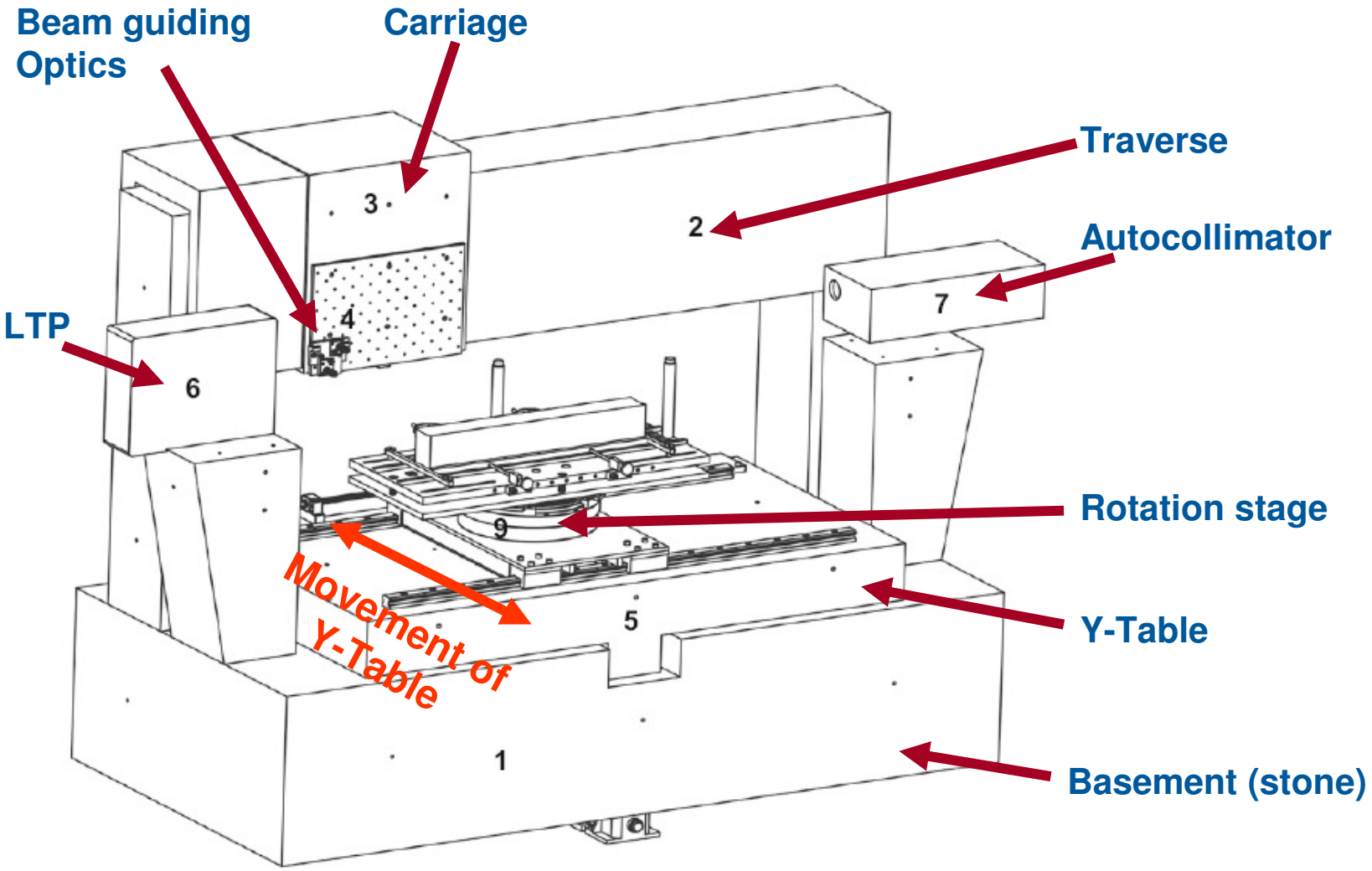
K. Yamauchi et al.: in Applied Optics **44** 6927-6934 (2005)

L. Samoylova, H. Sinn, F. Siewert, H. Mimura, K. Yamauchi, T. Tschentscher, „*Requirements on Hard X-ray Grazing Incidence Optics for European XFEL: Analysis and Simulations of Wavefront Simulations*“, Proc. of SPIE 2009

How to measure Optics ? – let`s take the Slopes !



Set-up of the NOM



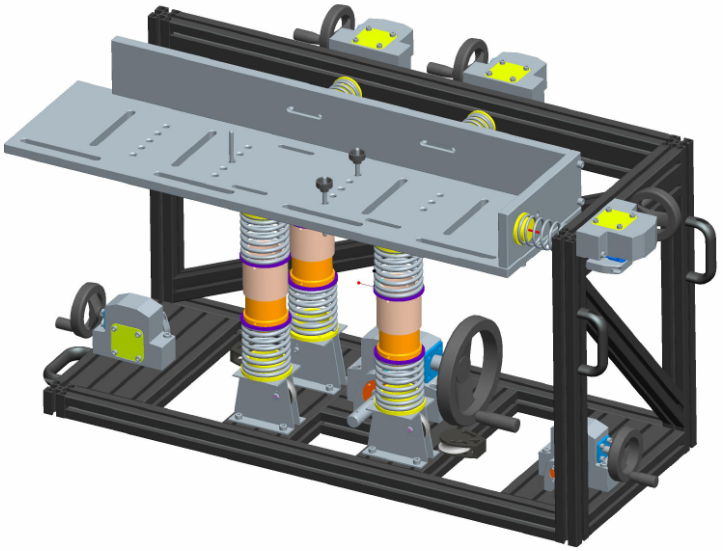
F. Siewert et al.: „The Nanometer Optic Component Measuring Machine: a new Sub-nm Topography …“ SRI 2003, AIP Conf. Proc.

Optics set-up of the NOM

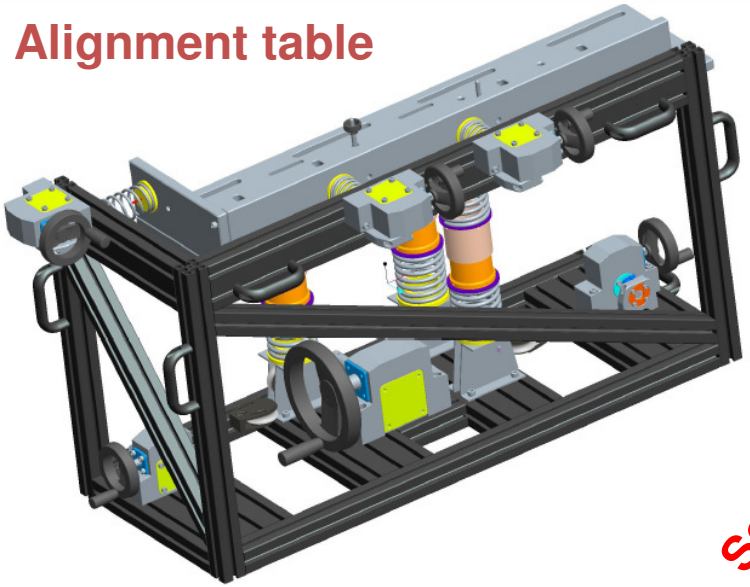
Direct slope measurement device - no reference surface

F. Siewert et al.: „The Nanometer Optic Component Measuring Machine: a new Sub-nm Topography …“ SRI 2003, AIP Conf. Proc.

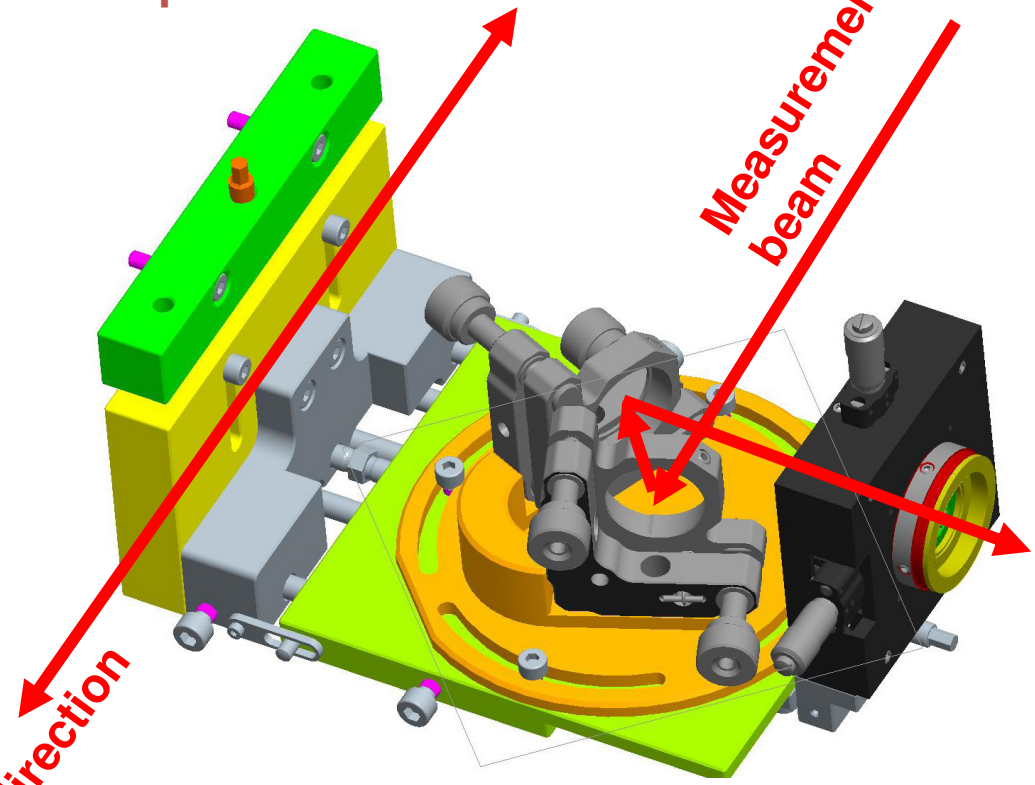
NOM-upgrade to enable face side measurements



Alignment table



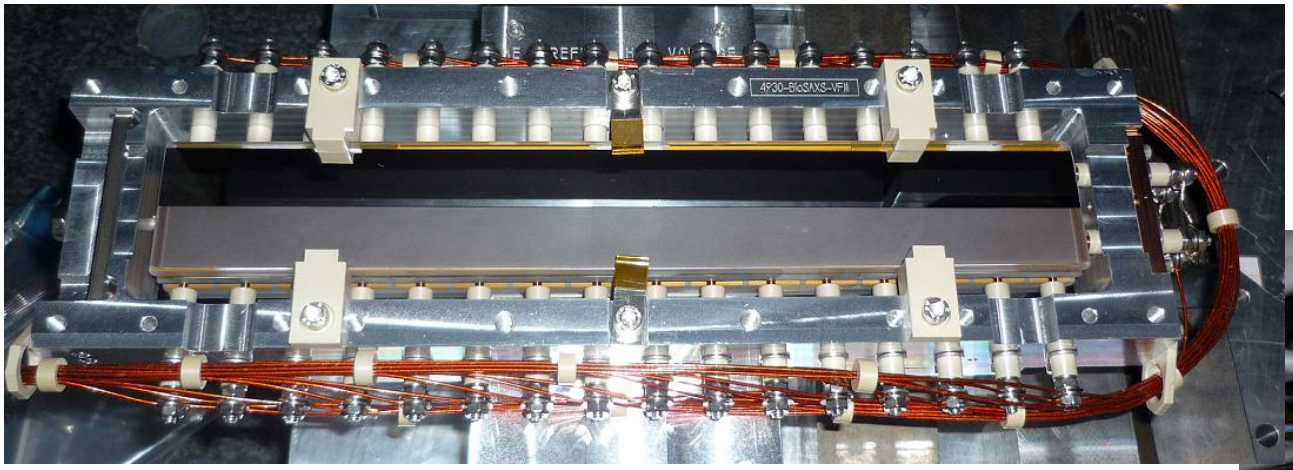
Face side mount of open penta prism



See also poster by Jana Buchheim

Inspection and characterization of Bimorphs

HZB Helmholtz Zentrum Berlin



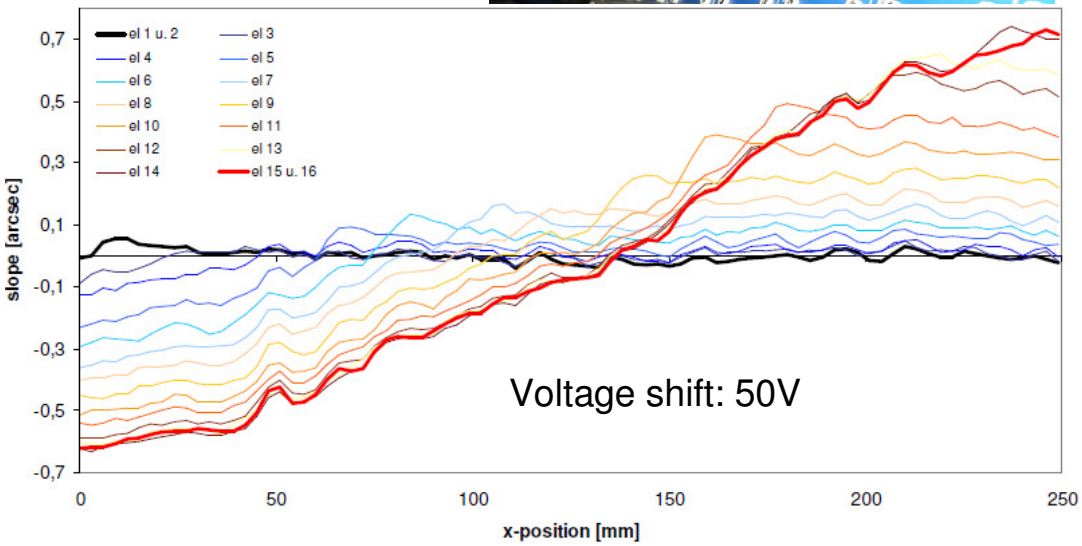
Bimorph-mirror with 16 electrodes BIOSAX-VFM for EMBL-Hamburg

The cabling for 16 electrodes

- Each Electrode needs to be characterized individually
- It is time consuming
- **It can be very boring !**

Let`s save time,
LabVIEW based software
for automatic
electrode characterization

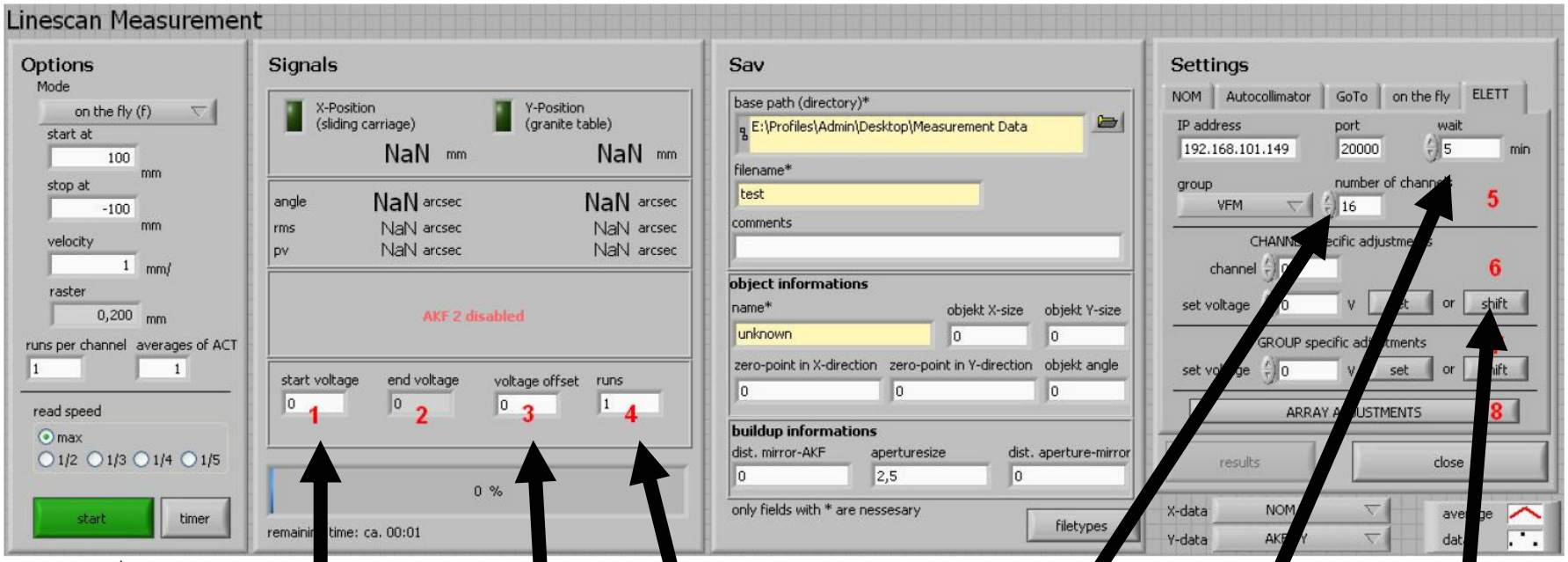
$$\begin{pmatrix} V_{E.1} \\ V_{E.2} \\ V_{E.3} \\ . \\ . \\ V_{E.16} \end{pmatrix} = (H^T H)^{-1} H^T \delta f_0$$



Inspection and characterization of Bimorphs

HZB Helmholtz Zentrum Berlin

A LabVIEW – based software for automatic characteriztation of bimorph electrodes



start voltage

NOM-parameter

voltage shift

No. of line scans / electrode

No. of electrodes

Waiting time after voltage setting

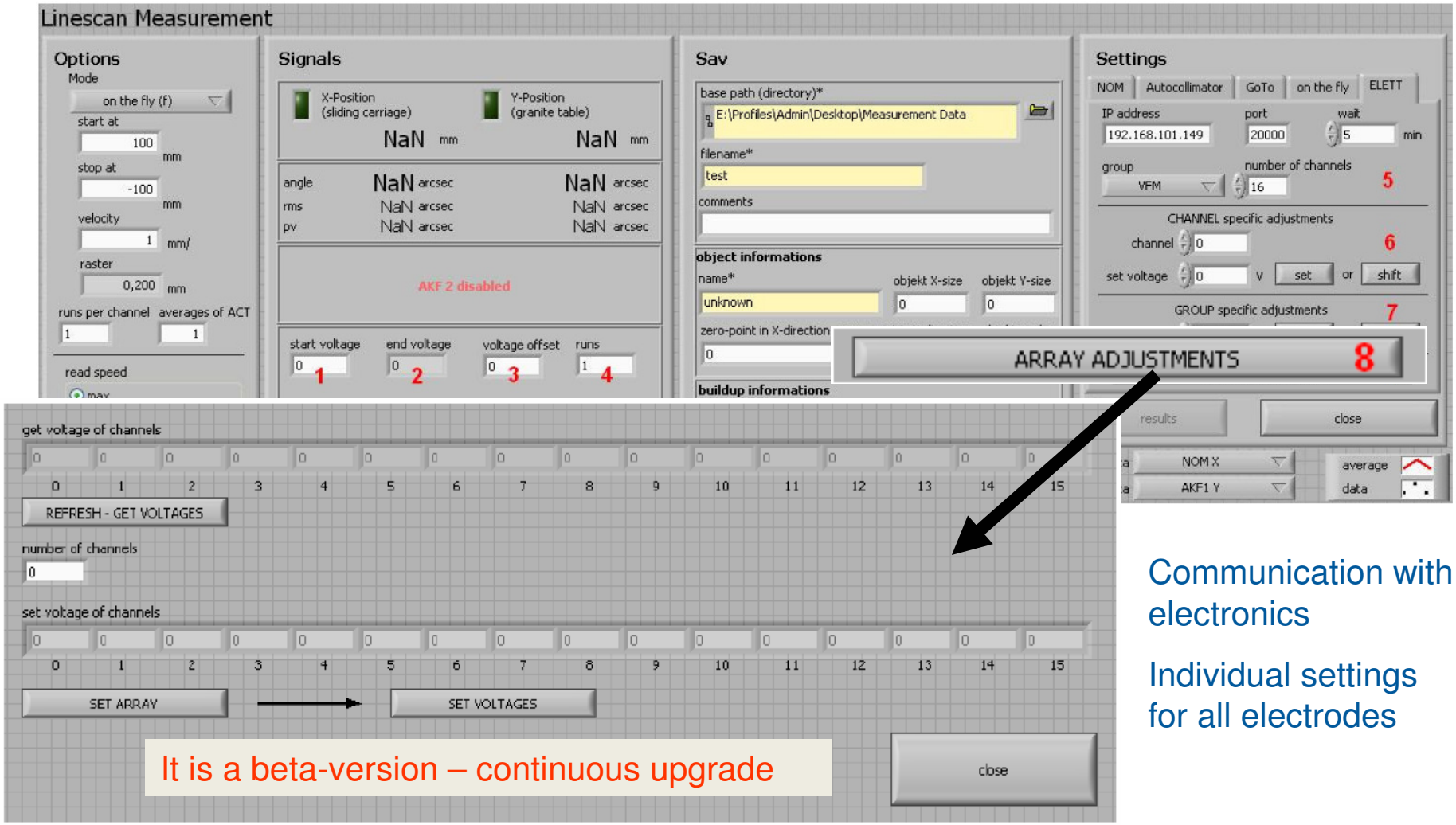
shift of individual electrodes

Measurements can be performed over night

Inspection and characterization of Bimorphs

HZB Helmholtz Zentrum Berlin

A LabVIEW – based software to enable automatic characteriztation of bimorph electrodes



It is a beta-version – continuous upgrade

Communication with electronics

Individual settings for all electrodes

Inspection and characterization of Bimorphs

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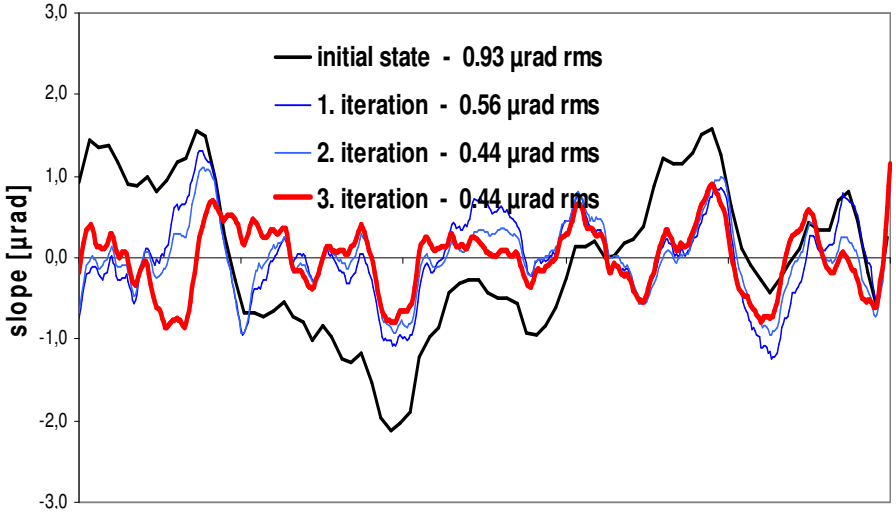
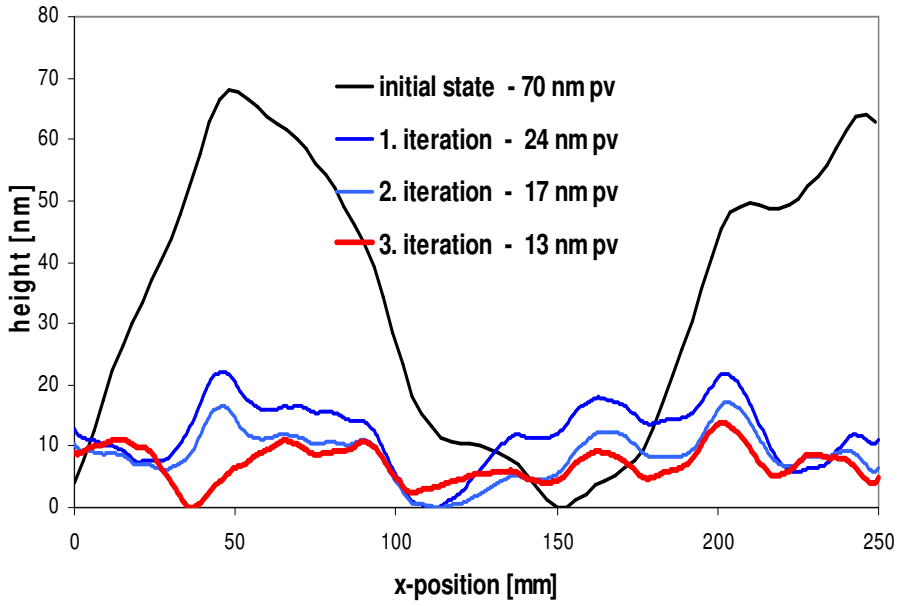
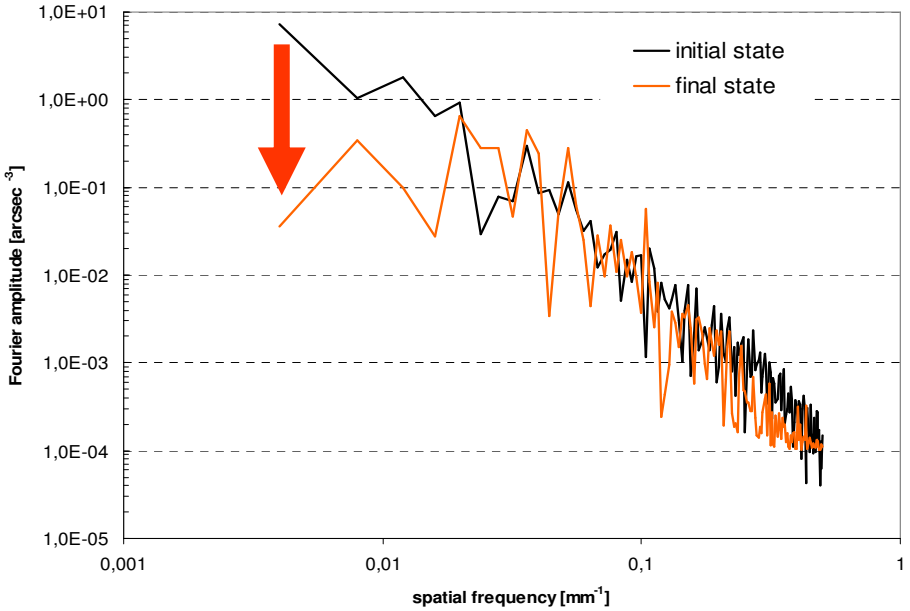




EMBL at PETRA-III

Mirror MX1-VFM – 16 Electr.

residual slope	residual figure error
0.93 µrad rms	70 nm pv
0.44 µrad rms	13 nm pv



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Inspection of a super-polished mirror

- an example:

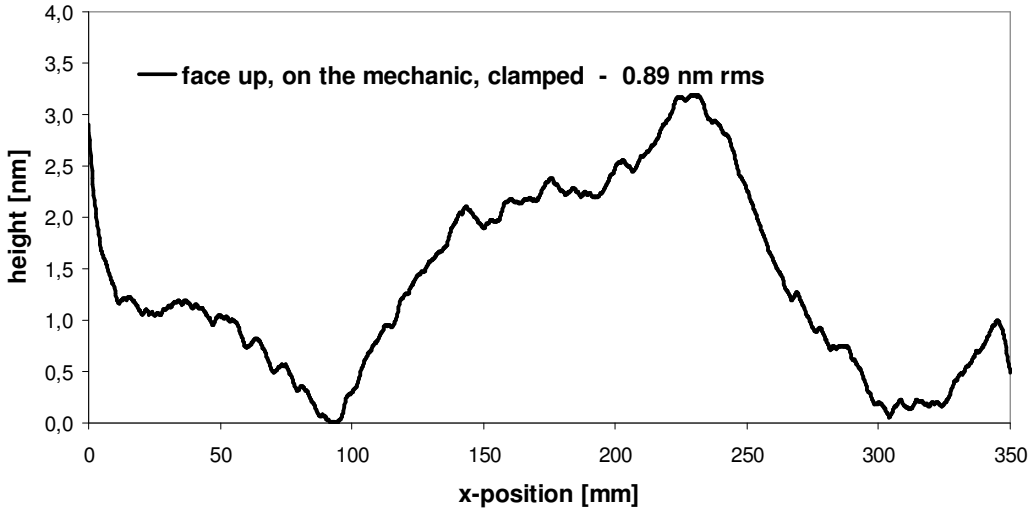
Diffraction limited focusing mirror for SLAC

HZB Helmholtz Zentrum Berlin

Ultra-precise metrology of
sub-nm accuracy
enable shape preserving alignment of ultimate optical elements

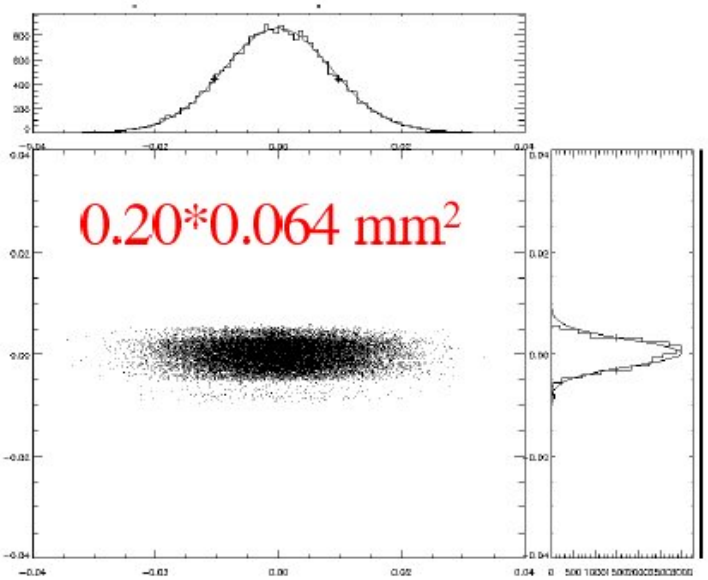
Nanometer accuracy on a macroscopic scale

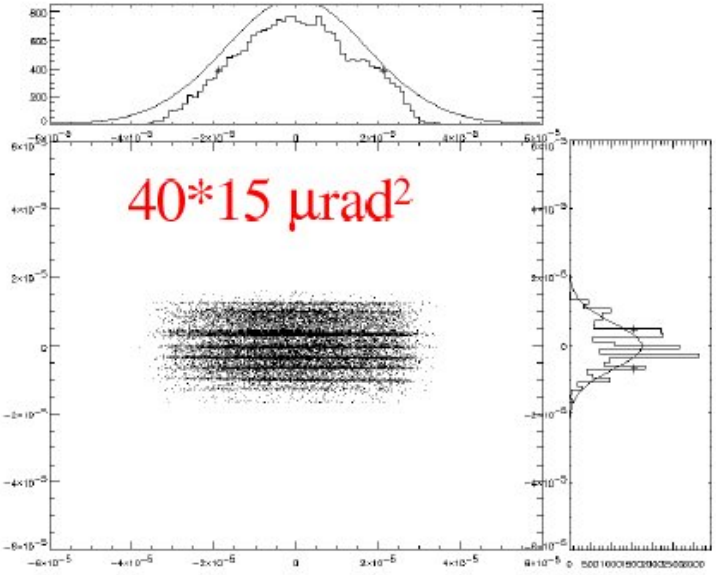
Size	:	370 × 50 × 50 mm^3
Source dist.	:	420 000 mm
Image dist.	:	8 300 mm
Incidence angle	:	3.59 mrad
Slope err. (mer)	:	0.061 µrad rms
Fig. error	:	0.89 nm rms / 3.5 nr
Roughness	:	≤ 0.2 nm rms



F. Siewert, J. Buchheim, S. Boutet, R. Signorato, *A first diffraction limited KB-focusing mirror pair for the Linac Coherent Light Source – high resolution slope measuring deflectometry for mirror characterization*, under preparation to be published

Initial simulations of beamprofile with design values for BioSAXS - VFM





- Simulation with Shadow for BioSAXS beamline.
- Simulation assumed 0.5 µrad slope error.
- Xray source size of PETRA III: 6 x 140 µm² (rms)

Simulated beamprofile with NOM-metrology data for BioSAXS - VFM

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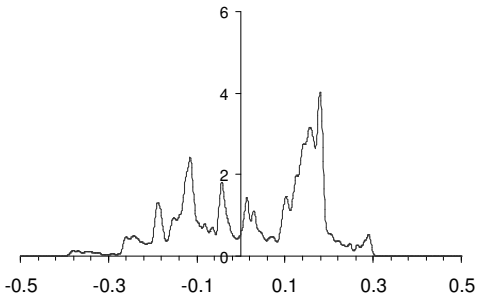
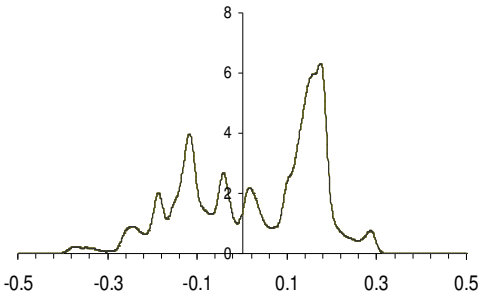
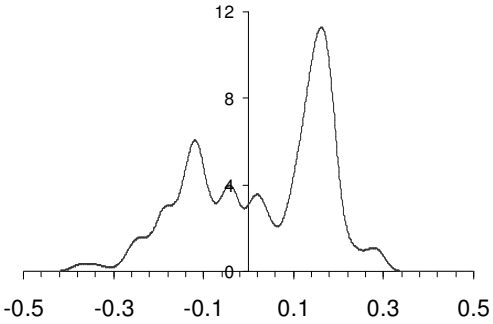






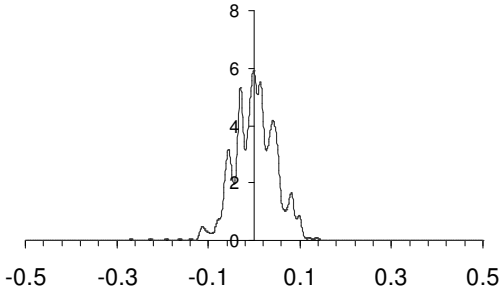
no optimisation (0V)

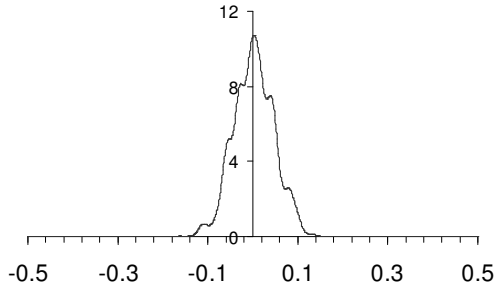
effective source size

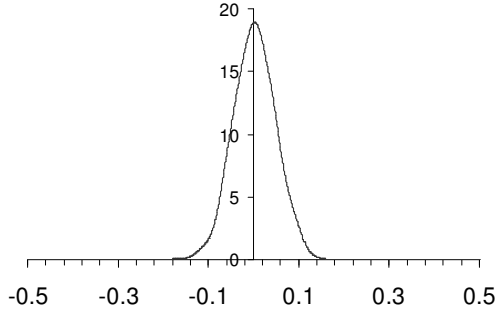
σ_y=5.4 µm

σ=11 µm

σ=22 µm







optimised

Conclusions

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- Standard type bimorph mirrors can be optimized to < 0.5 µrad slope error state

- Automatic characterization of bimorph electrodes can be done over night
  - time saving !

- simulations have shown a significant improvement of beamline performance if bimorphs are working as designed

- Superpolished mirrors of 0.05 µrad slope error can be inspected by use of NOM slope measuring profiler

- Tests with super polished bimorph mirror are planned for April / May 2011

- The principle design of bimorphs have not changed for many years, further development is needed for future applications like at XFEL

Acknowledgements:

thanks to:

L. Samoylova, H. Sinn : European XFEL, Hamburg

K. Yamauchi : Osaka University, Osaka

JTEC Ltd., Kyoto

S. Boutet : LCLS, Stanford

for the scientific cooperation