The Nanometer Optical Component Measuring Machine: a new Sub-nm Topography Measuring Device for X-ray Optics at BESSY

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Motivation

Engineering Conception and Design

Technical Parameter

Measurement Results

Conclusions

Motivation

The quality of optical components limits the potential performance of a SR-beamline

New optical components beyond the 0.1 arcsec rms limit require metrology tools of 3 - 5 times superior accuracy

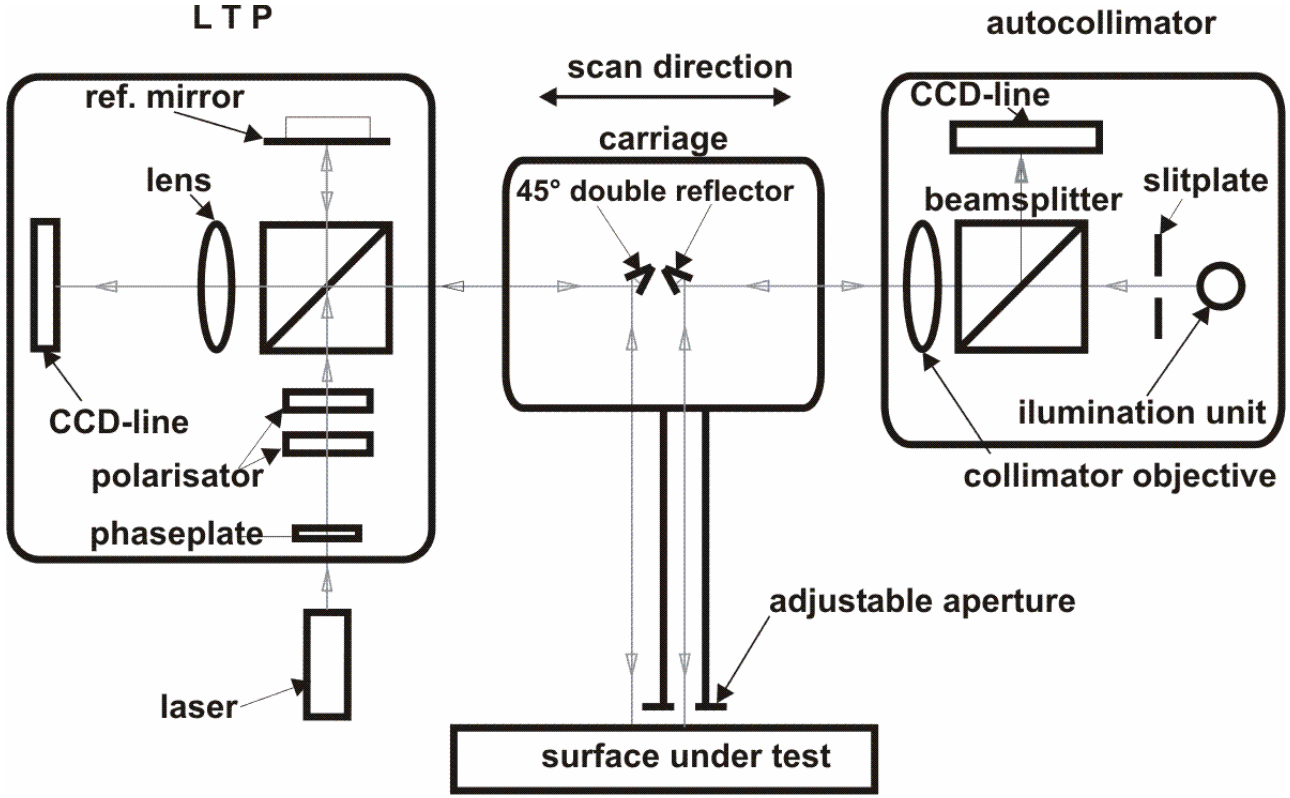
A manufacturer independent metrology is essential for a critical inspection of delivered and mounted optical elements

desired specifications of SR-beamline components and required accuracy of metrology tools

surface shape	size length [mm]	slope error [arcsec rms]	shape deviation [nm rms]	[nm p-v]	required measuring uncertainty slope error [marcsec]	shape deviation [nm rms]
plan	300	0.03	3	10	10	1
	150	0.02	1.5	7	6	0.5
spherical	300	0.05	3	10	15	1
	150	0.03	1.5	7	10	0.5
aspherical	300	0.06	6	20	15	2
	150	0.05	3	15	10	1

Engineering Conception and Design

Optical set-up scheme of the NOM (side view)



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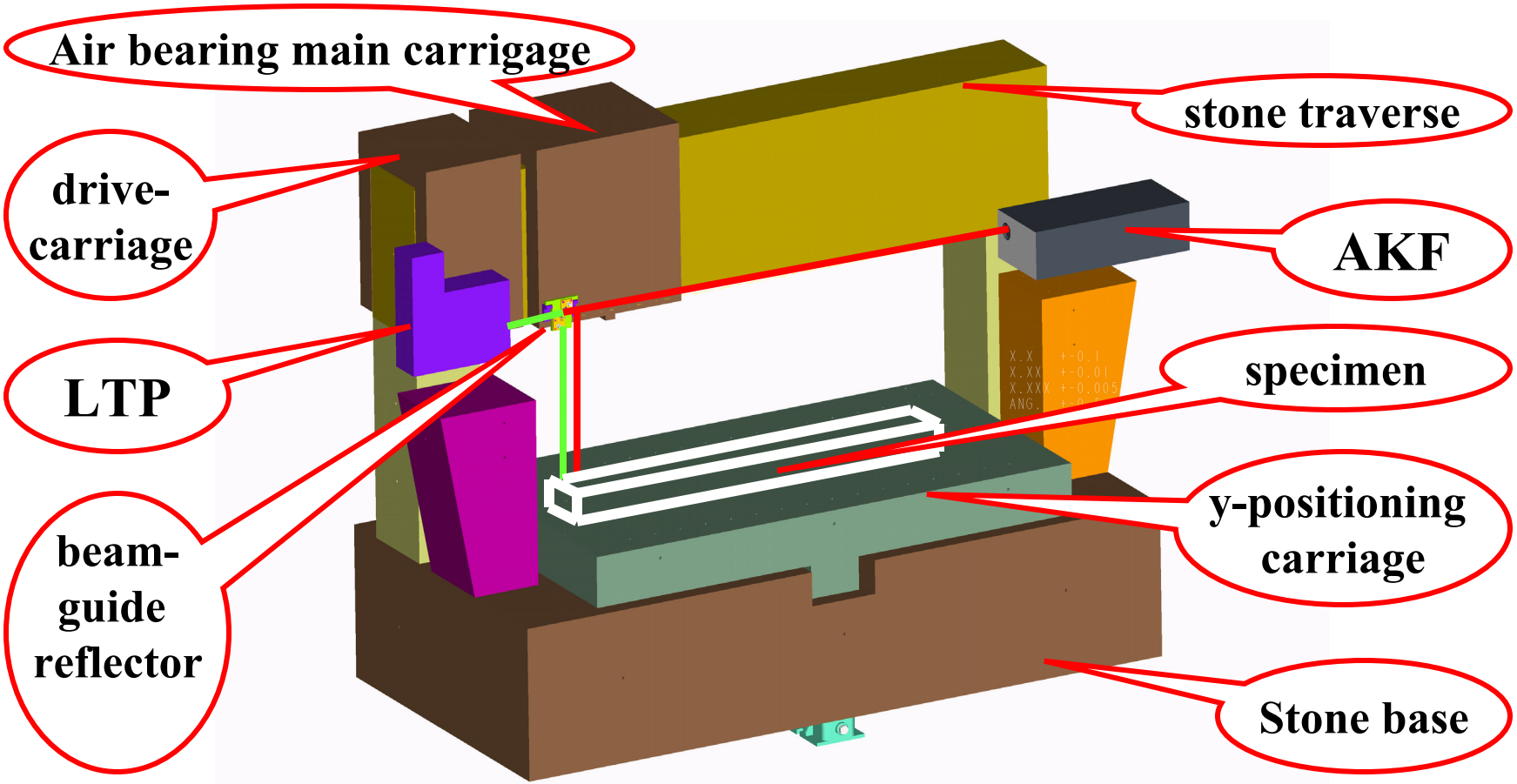
Nanometer Optical component Measurement machine NOM



Stone Table and Carriage System with aerostatic bearings

Nanometer-Optical component Measuring machine - NOM

Complete head-load of the NOM < 2 W,
Thermal isolation of the NOM by a double walled and thermal-bridge free housing - low influence of air turbulence on the measurement

Engineering Conception and Design

LTP-head and Autocollimator are mounted stationary and opposite to each other
- two 45° double reflectors to guide the test beam to and from the specimen

Material of the mechanical parts is stone - total weight: 4 t
high heat capacity, low thermal conductivity, vibration damping - low eigenfrequency

Measurement carriage with stiffed, preloaded airbearing (low weight double carriage system with torque free coupling)

Complete head-load of the NOM < 2 W

Thermal isolation of the NOM by a double walled and thermal-bridge free housing
- low influence of air turbulence on the measurement

Technical Parameter

Measuring area: 1200 mm in length, 300 mm laterally
Accuracy of guidance of the scanning carriage: 1 µm (range of motion: 1.3 m)
Reproducibility of the scanning carriage movement: < 0.01 arcsec rms

Technical Parameter of the NOM-Sensors

	LTP	Autocollimator
view angle	± 6.6 mrad	± 1.5 mrad
measurable radius of curvature	1 m	10 m
spatial resolution	1 mm	2 mm
reflectance	4 – 100 %	4 – 100 %

Software

hardware control

drive (6 axis)
motor parameter
axis control
position control

sensors
implementation of sensor-library
read-out AKF
read-out LTP

measurement

measurement
operating control
time scheduled meas.
measurement of multiple SUT

measuring options
Single-line-, multiple-, or 3d- scan
step-by-step, on-the-fly
autocallibration, automatic adjustment

presentation of results

numerical data

hardcopy print out

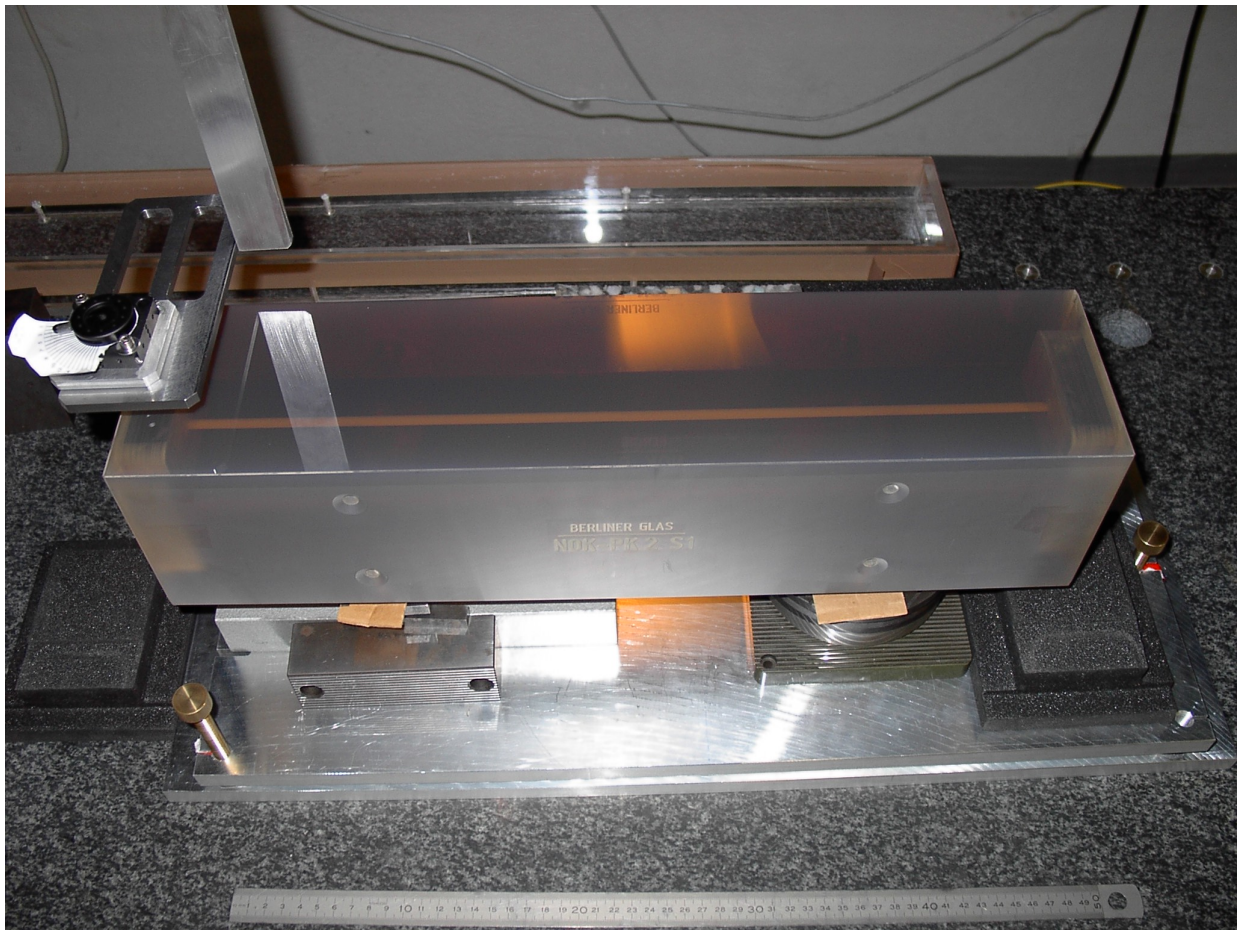
graphically representation

Measurement Results

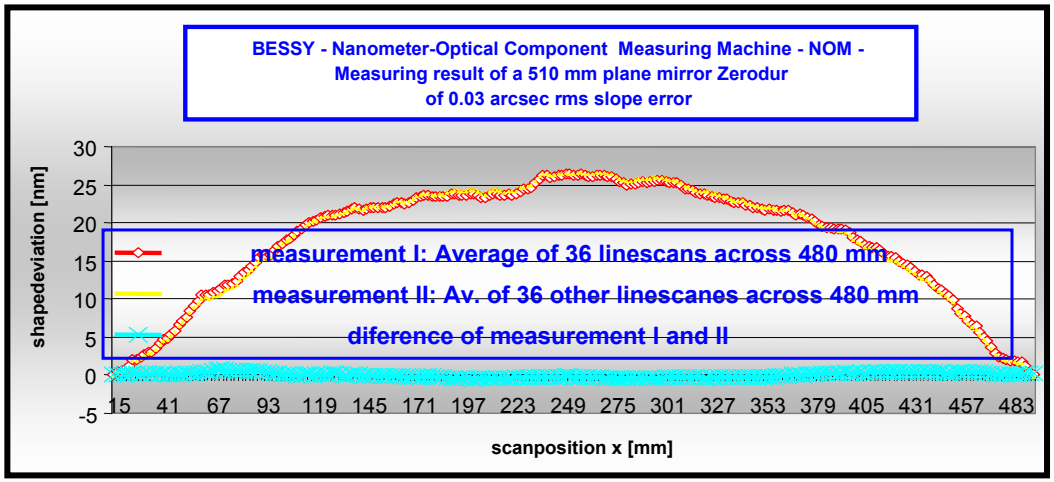
line-scan on a 510mm mirror - substrate material: Zerodur™

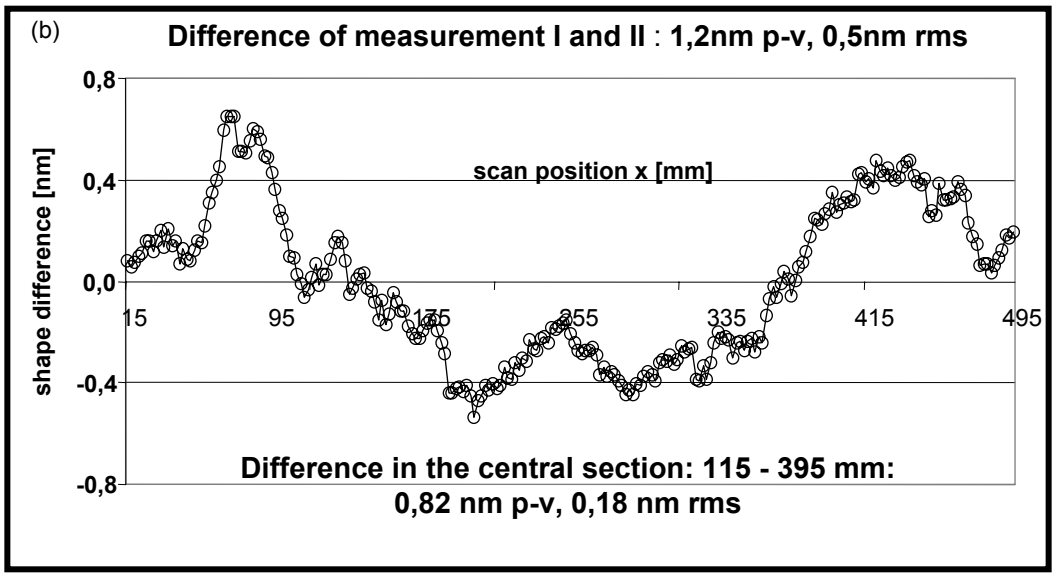
Method for 3d-Surface scan

line-scan on a 510mm mirror - substrate material: Zerodur™



NOM (AKF)- Measuring result Zerodur™-specimen 510 mm - Reproducibility





Measuring result:

sagitta:

(26,5 +/- 1,2) nm p-v

(< λ/20) +/- λ/1000) p-v

slope (1 marcsec = 0,001 arcsec) :

(213 +/- 4,5) marcsec p-v

(33,5 +/- 4,5) marcsec rms

Result with circle fit:

radius: - (1083 +/- 4) km;

height:

(4,4 +/- 0,6) nm p-v

slope:

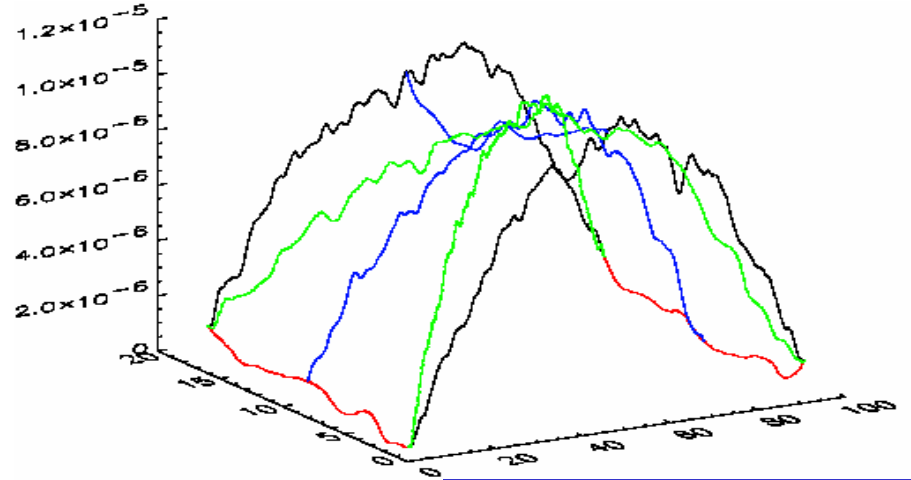
(20,4 +/- 0,4) marcsec rms

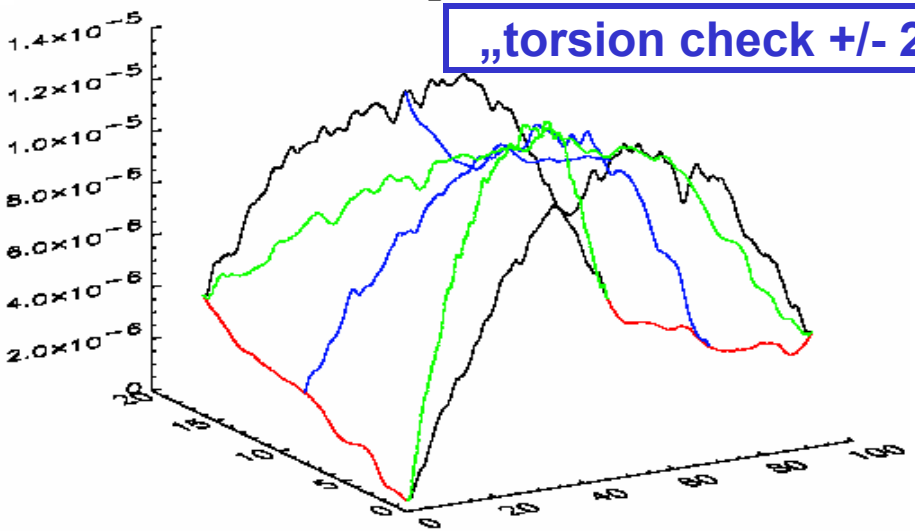
= (98 +/- 2) nrad rms

Reproducibility (480 mm)

< 0.5 nm rms;

0,2 marcsec rms = 1nrad rms



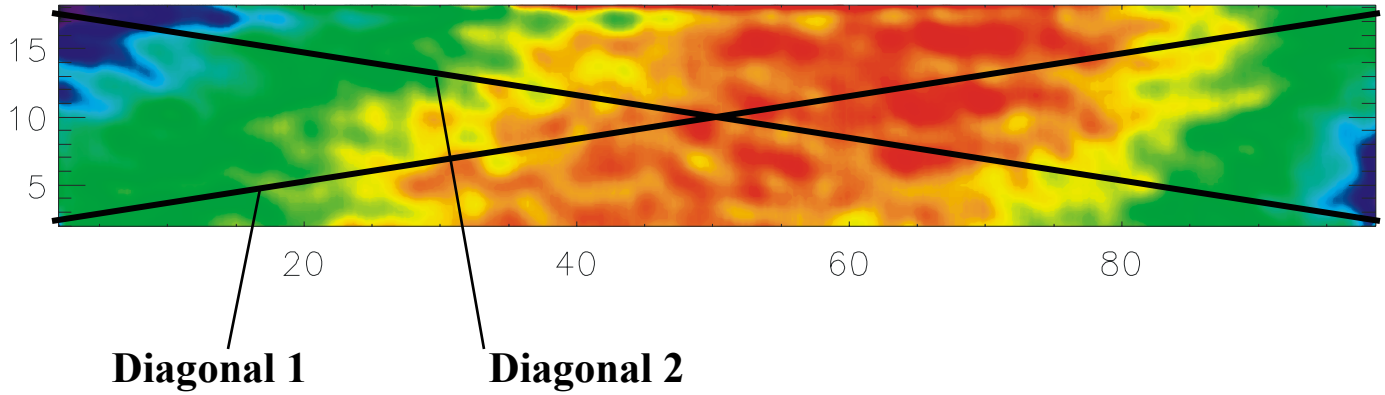


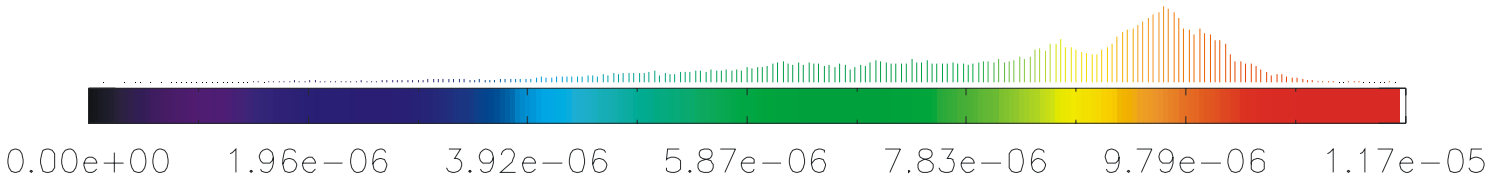
„torsion check +/- 2 nm“

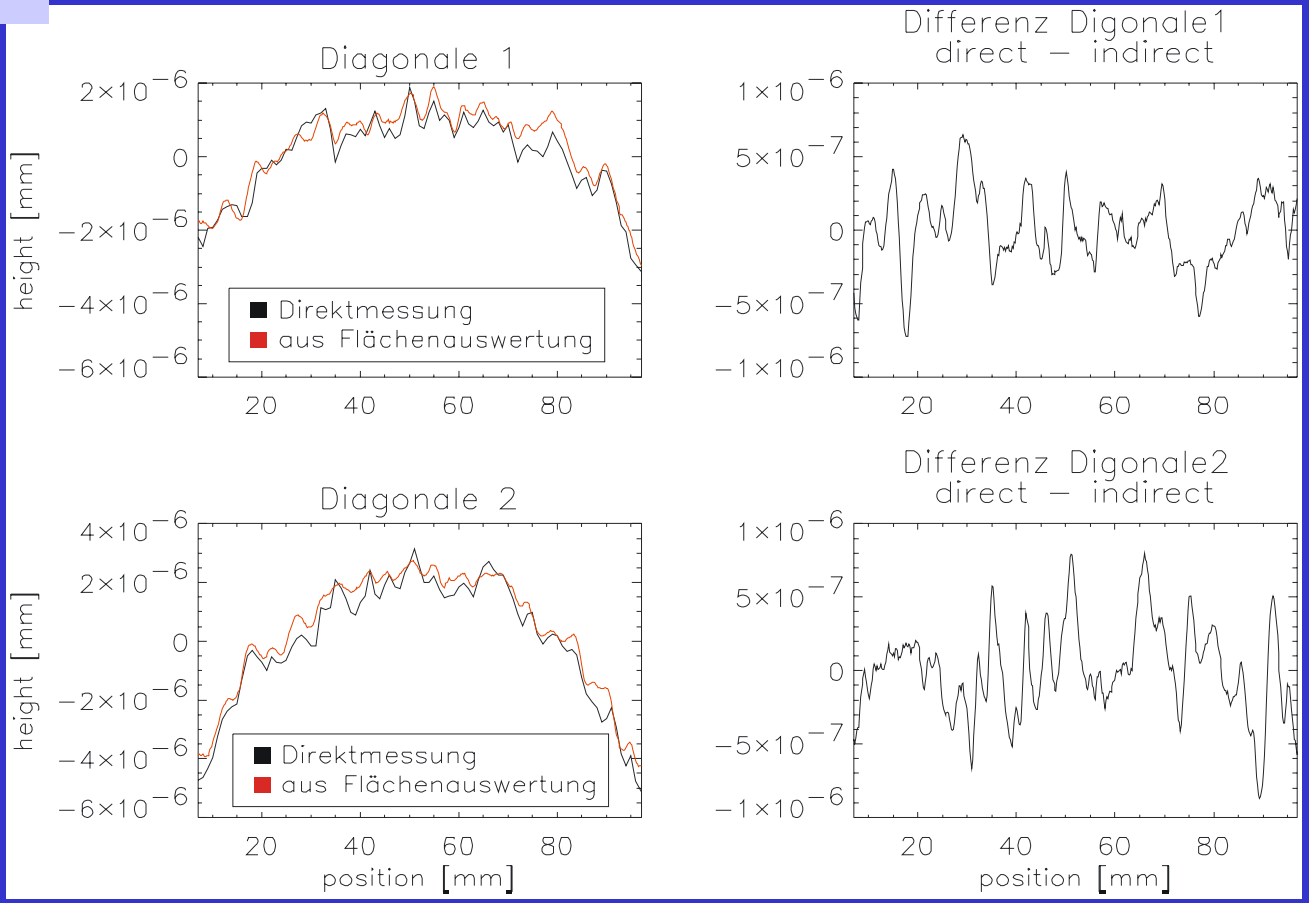
3d-measurement of surfaces

1. surface scans: parallel sampled line-scans in meridional and sagittal direction
2. measurement of the two diagonals as single-line-scan
3. Comparison of direct scanned diagonals with diagonals gained from surface scan

3d-surface-scan
Torsion -5,5nm: conformity of diagonals: 0,29 nm rms
80.000 measuring points, time: 8h
11,8 nm p-v 1,9 nm rms



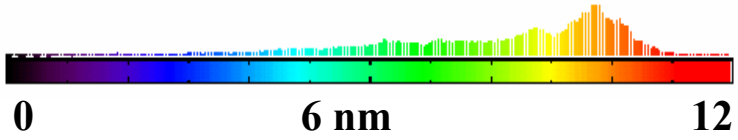


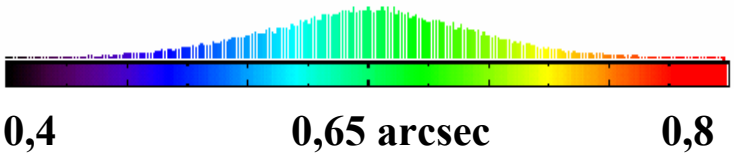


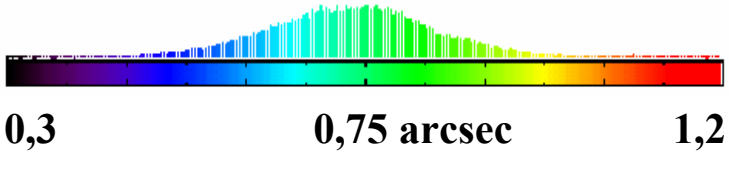
difference diagonals 1 = +/- 0.249 nm

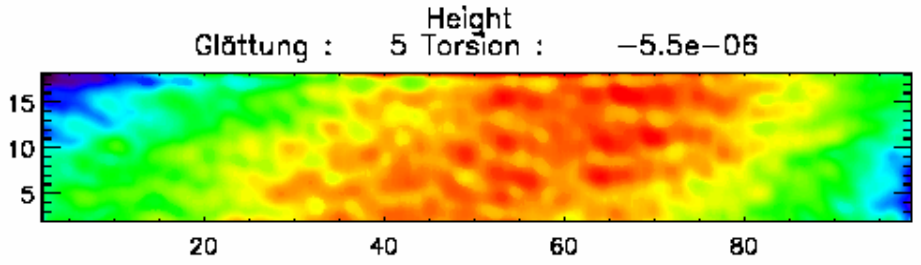
difference diagonals 2 = +/- 0.302 nm

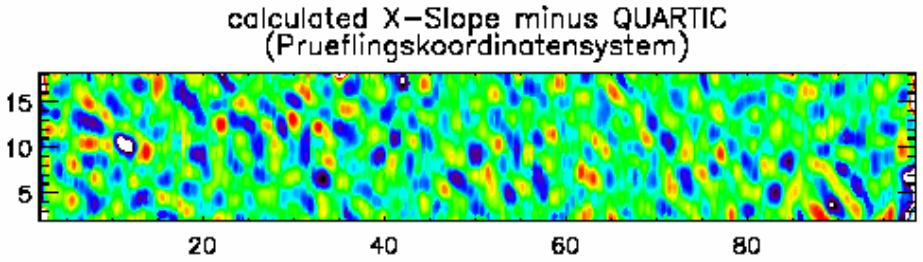
average diagonals 1 and 2 = +/- 0.277 nm

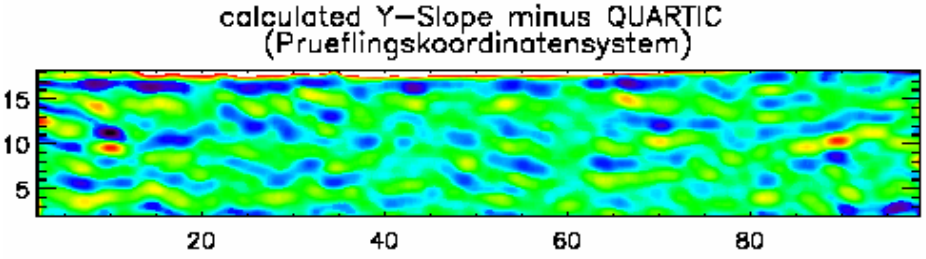












Map of calculated slope-deviation in meridional and sagittal direction to view the quality of surfaces regarding use in SR-beamlines

result of 3-step 3d-measurement:

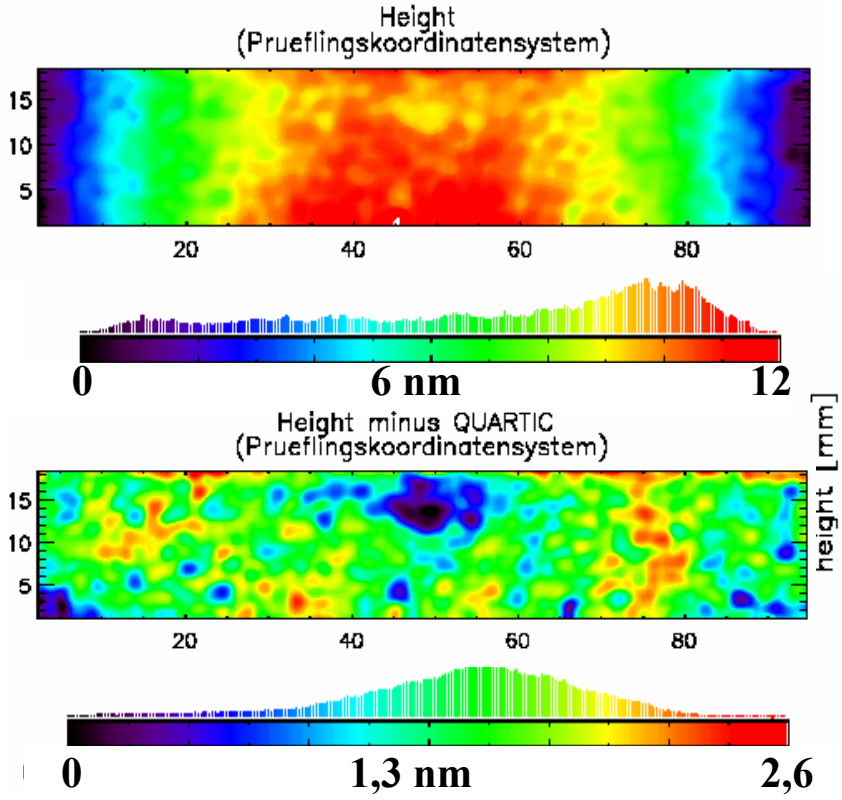
	unfitted	fitted (quartic)
x-slope [arcsec p-v]	2,1	2,1
x-slope [arcsec rms]	0,07	0,06

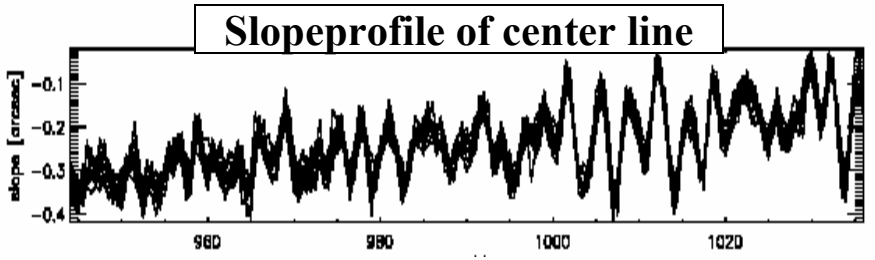
	unfitted	fitted (quartic)
y-slope [arcsec p-v]	1,9	1,9
y-slope [arcsec rms]	0,14	0,14

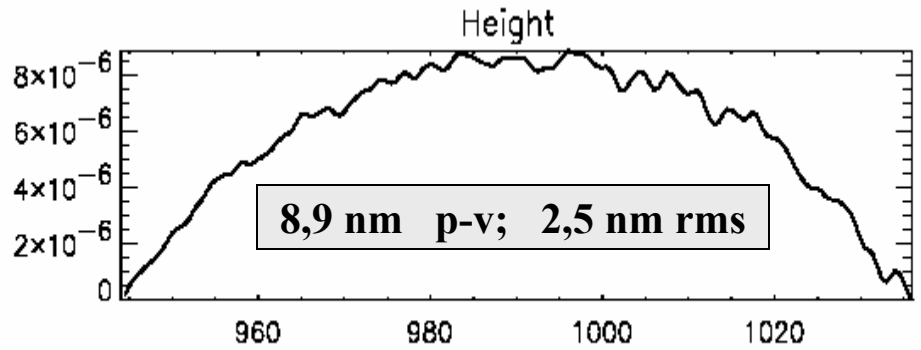
3d and line-scan measurement on a 100mm Si-grating blank

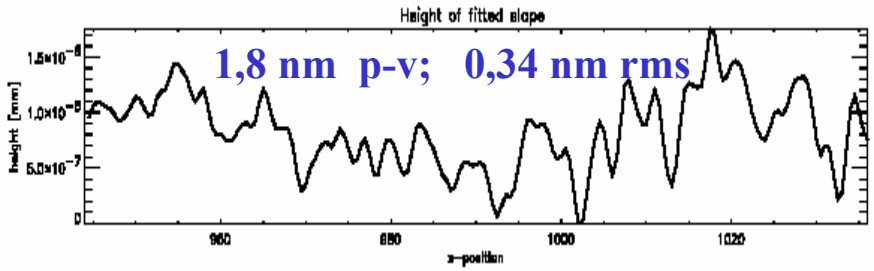
scan length =92 mm; dx=0,5 mm, aperture: 2mm, 3 different x-start (704; 794; 944 mm); 5 AKF-start-angle (-0,3...1,6“)

result of 60 line-scans: (0.074 +/- 0.002) arcsec rms; (0.059 +/- 0.002) m arcsec rms; bestfit: [R = (- 125 +/- 12) km]:



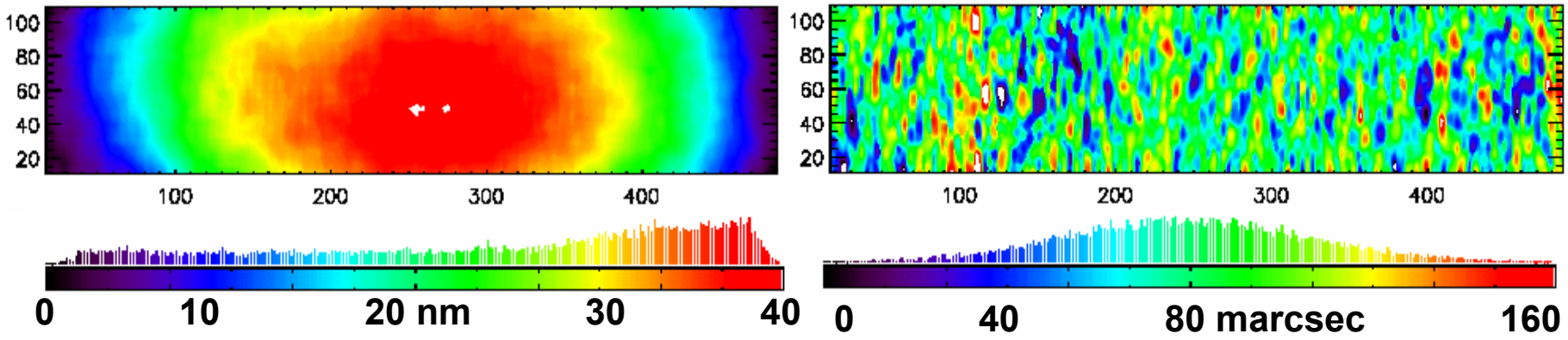






3-D-imaging of a 600 cm² plane surface with AKF

height: 40 nm p-v; fit: 1,3 nm rms **slope fit**: p-v:160; rms: 25 marcsec



Conclusions:

The Hybrid conception of the NOM by use of two different Type Sensors: LTP and Autocollimator has been demonstrated

First measurements demonstrates a estimated measurement uncertainty in the range of 0.01 arcsec rms and a correspondingly high reproducibility

A practicable method for 3d scanning has been developed

Ion beam milling supported by NOM-measurements leads to optical components of previously not achieved quality beyond the 0.1 arcsec rms limit

The development of the NOM is not finished - the application of a new modified autocollimator is intended (free aperture: 1 - 1.5 mm)

The shown state of the NOM represents a five to tenfold improvement compared to the present state of the art of surface measuring techniques.

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