First Measurements with the APS Optical Slope Measuring System (OSMS)

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Barcelona, 4th to 6th July 2012

Outline

- The development of the APS-LTP-II / APS-OSMS
- The APS OSMS / flat mirror measurement
  - Alignment
  - Repeatability test
  - Systematic error test
  - Reliability test
- Elliptical KB mirror measurements (APS OSMS, APS LTP-II, APS Stitching)
- Conclusion
- Acknowledgements

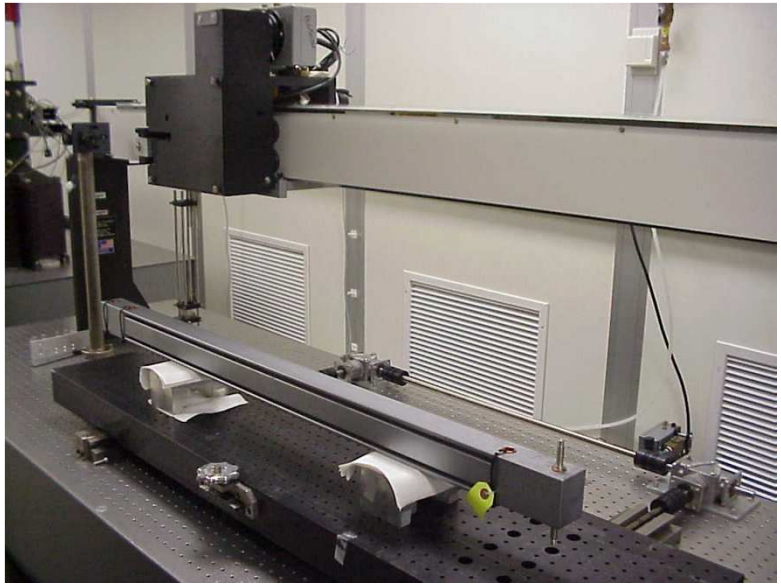
The APS OSMS and the APS LTP-II

The APS OSMS (2012)

Slope accuracy: Phase I < 100 nrad
Phase II < 50 nrad

The APS OSMS (See talk by Lahsen Assoufid et al, this workshop).

The APS LTP-II (1999)

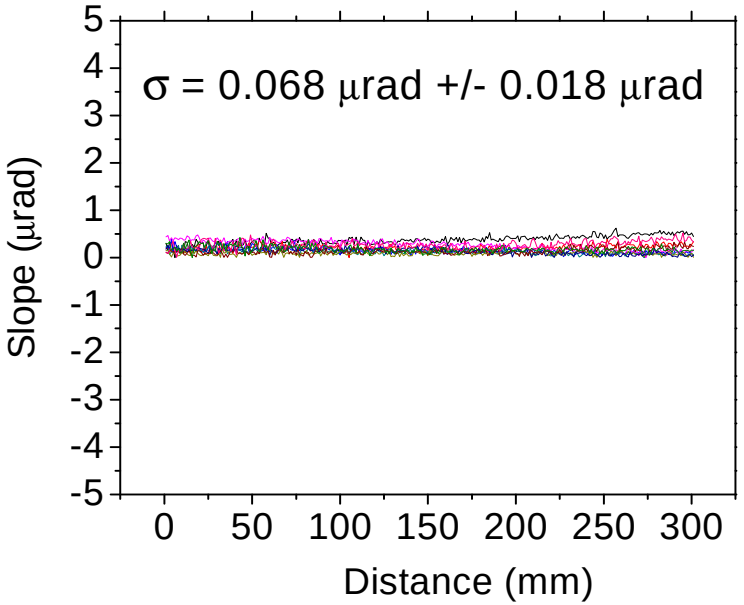


Slope accuracy: RMS=0.3 µrad

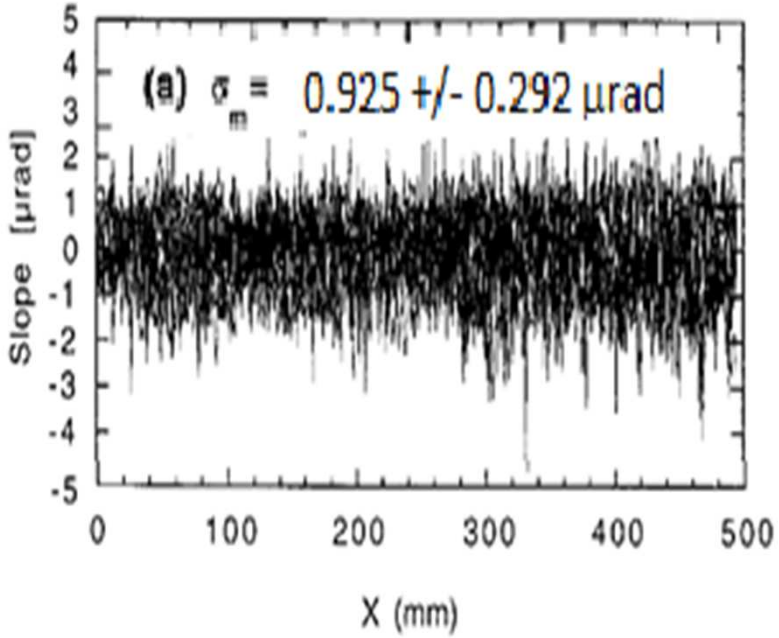
P.Z. Takacs, E.L. Church, C. Bresloff, and L. Assoufid, Appl. Optics, 38,(25) (1999), 5468-5479.

Comparison of the repeatability measurement results acquired with the APS OSMS (2012) and the LTP-II (1999)

Method: 1. Performed 10 scans in same conditions.
2. Found the deviation of the single scan - the average of the 10 scans.
3. Calculated the average of the rms of the 10 deviation profiles.



2012 with the APS OSMS
Mirror: 350 mm Si substrate

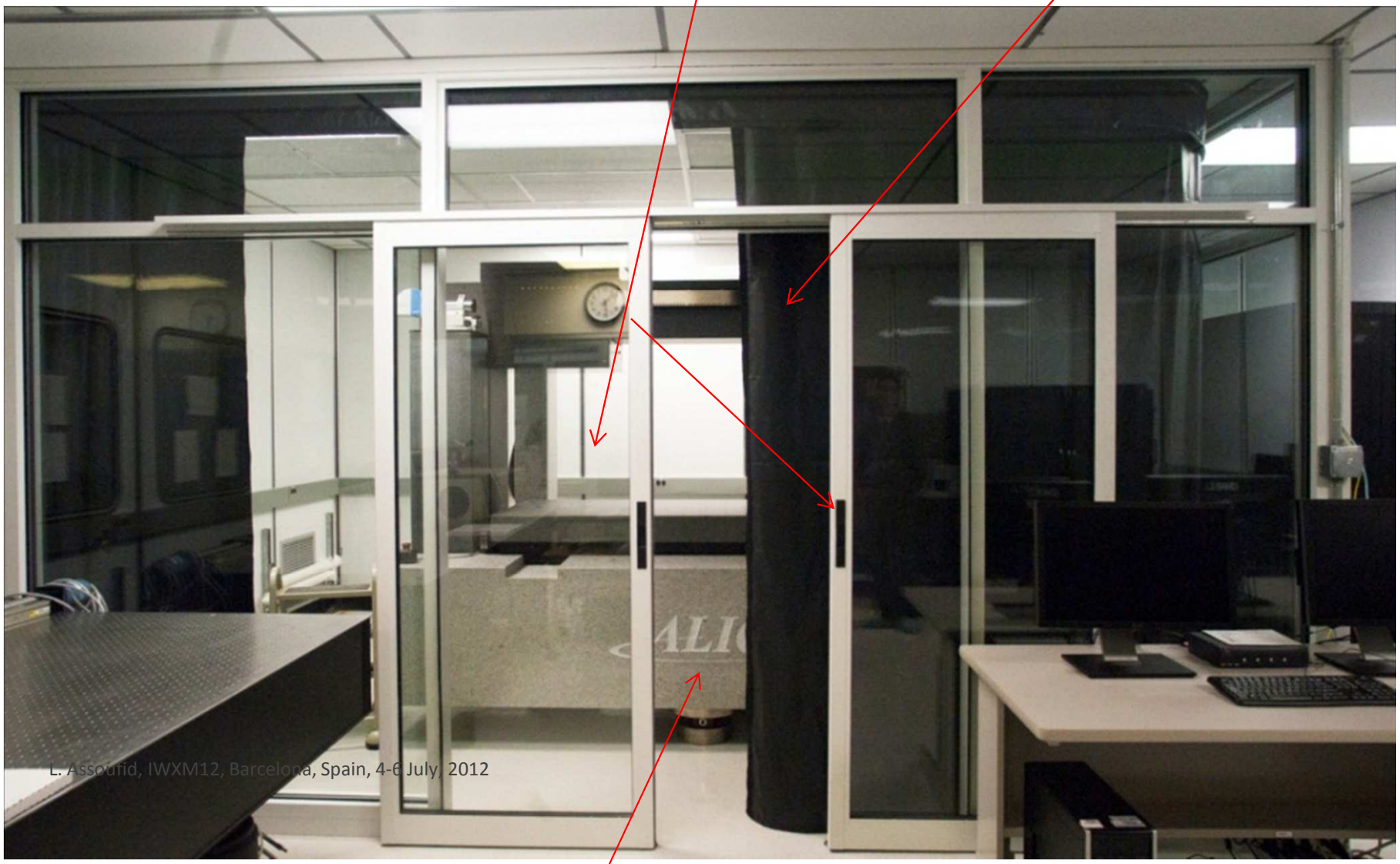


1999 with the APS LTP-II
Mirror: 500 mm Si substrate

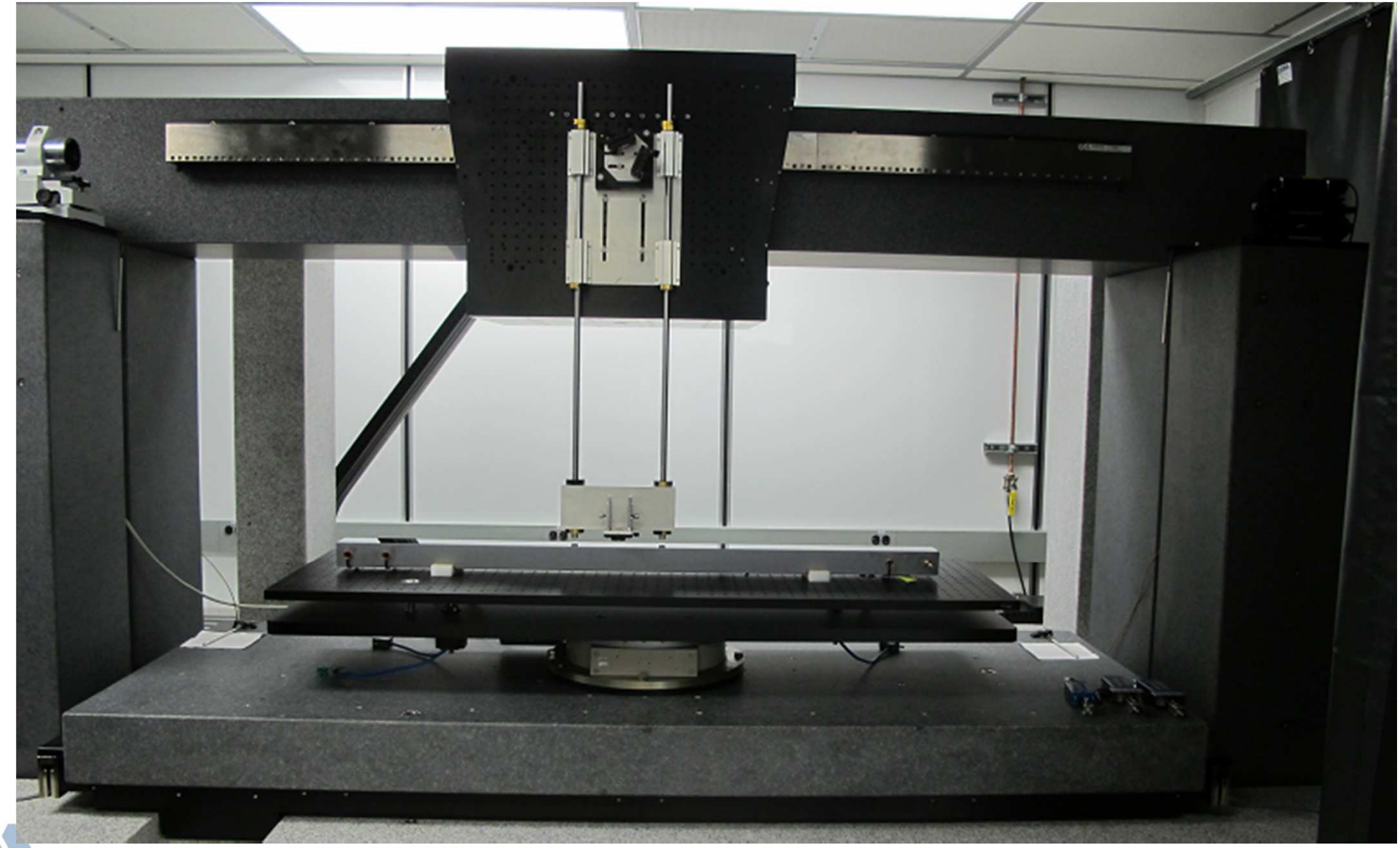
P.Z. Takacs, E.L. Church, C. Bresloff, and L. Assoufid, Appl. Optics, 38,(25) (1999), 5468-5479.

Enclosure

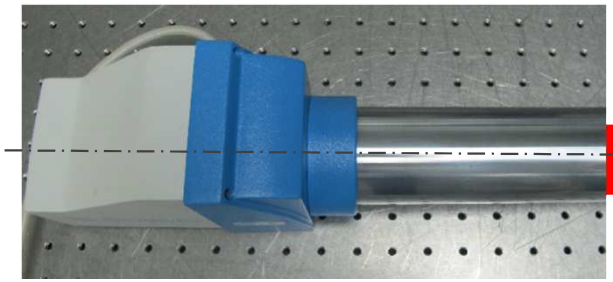
Completed November 2011



The APS Optical Slope Measuring System



The optics system of the APS OSMS



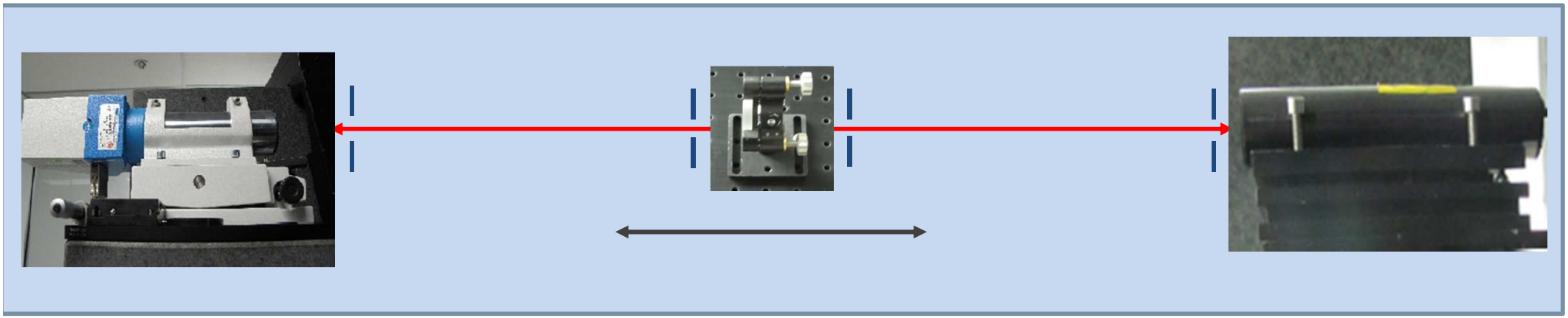
ELCOMAT 3000/8 Autocollimator
(from MÖLLER-WEDEL OPTICAL GmbH)

To align the OSMS properly for achieving high accuracy:

1. The axis of the autocollimator should be parallel to the axis of the scanning stage.
2. The beam shouldn't be twisted; needs to minimize roll, pitch, and yaw errors of individual optic.

*F. Siewert, H. Lammert, T. Zeschke, Modern Developments in X-ray and Neutron Optics, Springer 2008
*S. G. Alcock and K. J. S. Sawhney, Proc. SPIE 6704, 67040E (2007).

Alignment of the autocollimator parallel to the scanning stage



Fixed Autocollimator Mirror with polished backside on scanning stage Fixed He-Ne Laser

Procedure of the alignment:

1: Align the laser // scanning stage with the help of the pinholes -> fix the laser

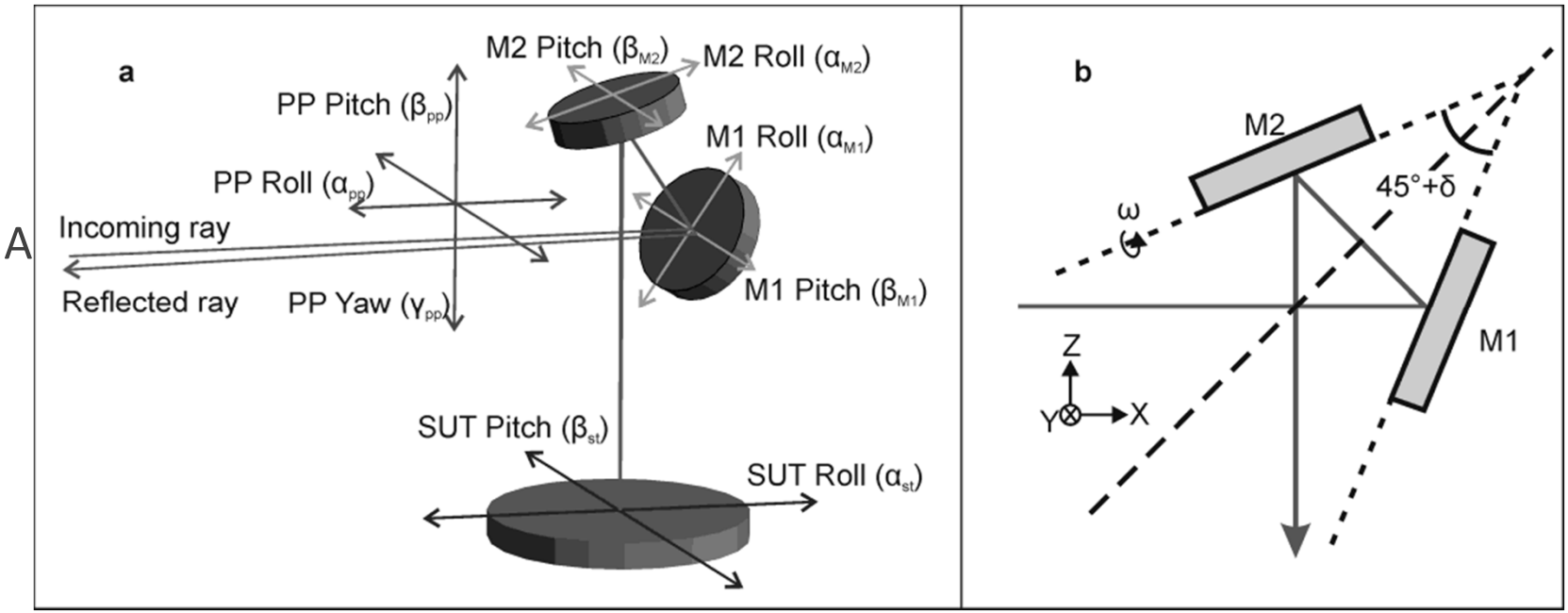
2: Align the mirror relative to the laser -> fix the mirror

3: Align the autocollimator relative to the mirror -> fix the autocollimator

4. Take measurement while scanning the mirror and then make fine corrections.

Goal: Autocollimator axis // to the axis of the scanning stage

Alignment of the mirror pentaprism relative to the SUT



Individual mirror: roll and pitch errors
Pentaprism unit: roll, pitch and yaw errors

M1 / M2 Parallel error
M1 / M2 45^{o} angular error

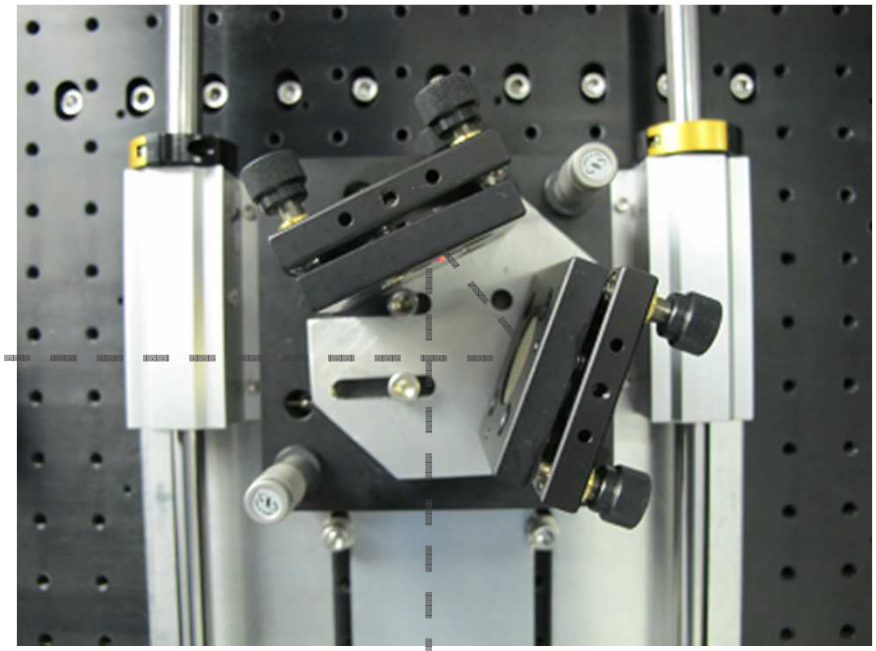
R. D. Geckeler, *Meas. Sci. Technol.* **18** 115-125 (2007).

Samuel K Barber, et al., Optical Engineering Vol. 50(5), May 2011

The mirror pentaprism design

- Individual mirror is on itself x-y axes adjustable mirror mount.
- Both mirror mounts are on the x y axes adjustable and rotatable mirror mount to form the mirror pentaprism unit.

Fixed autocollimator



SUT

Mirror pentaprism unit: roll, pitch and yaw errors
Need more careful alignment

Method: trail - and - error

Optimizing measurement conditions

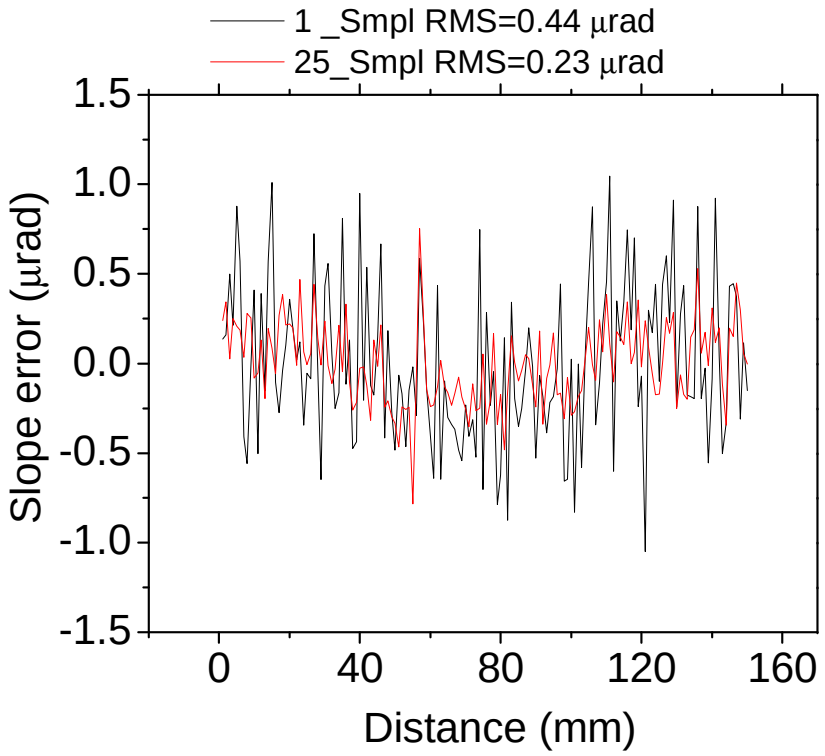
- Stability scan with enclosure close/open
- Stability scan with local air on/off
- Stability scan with a fixed mirror setting at different locations relative to the autocollimator
- Stability scan with a fixed mirror on moving stage
- Different size of aperture
- Sampling rate per data point
- Scan w/o delay after each data collection
- Orientation of the autocollimator (x_axis / y_axis)

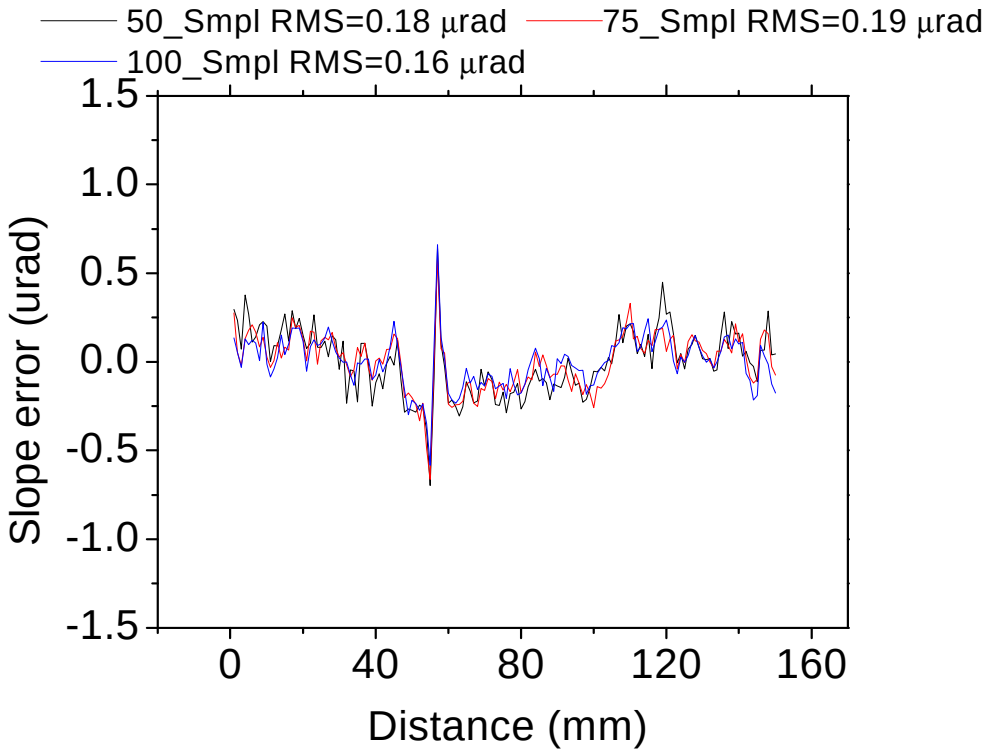
Finding optimal measurement conditions is essential to achieve the desired performance!

Example

How about sampling rate at each data point?

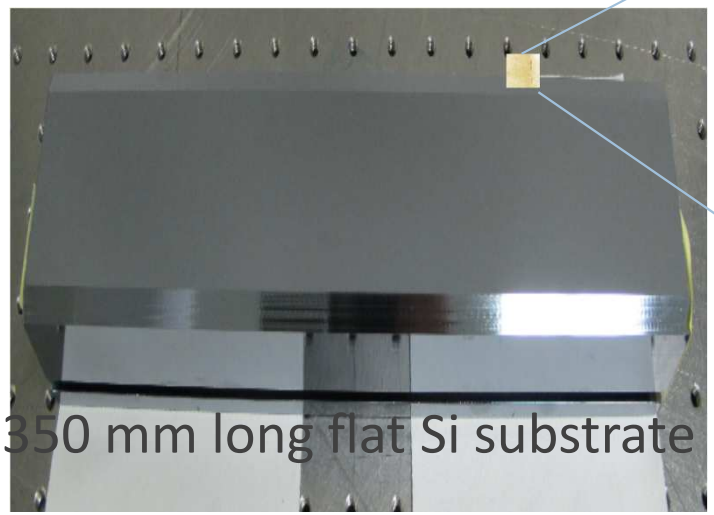
Sampling rate: # of samples per data point taken in the measurement.
We tried measurements with samples of 1, 25, 50, 75 and 100 per data point to see the difference of the S/N.





We decided from now on, we use sampling rate of 50/point for all of the normal measurements.

First mirror measurement with the APS OSMS was carried out in January 2012.

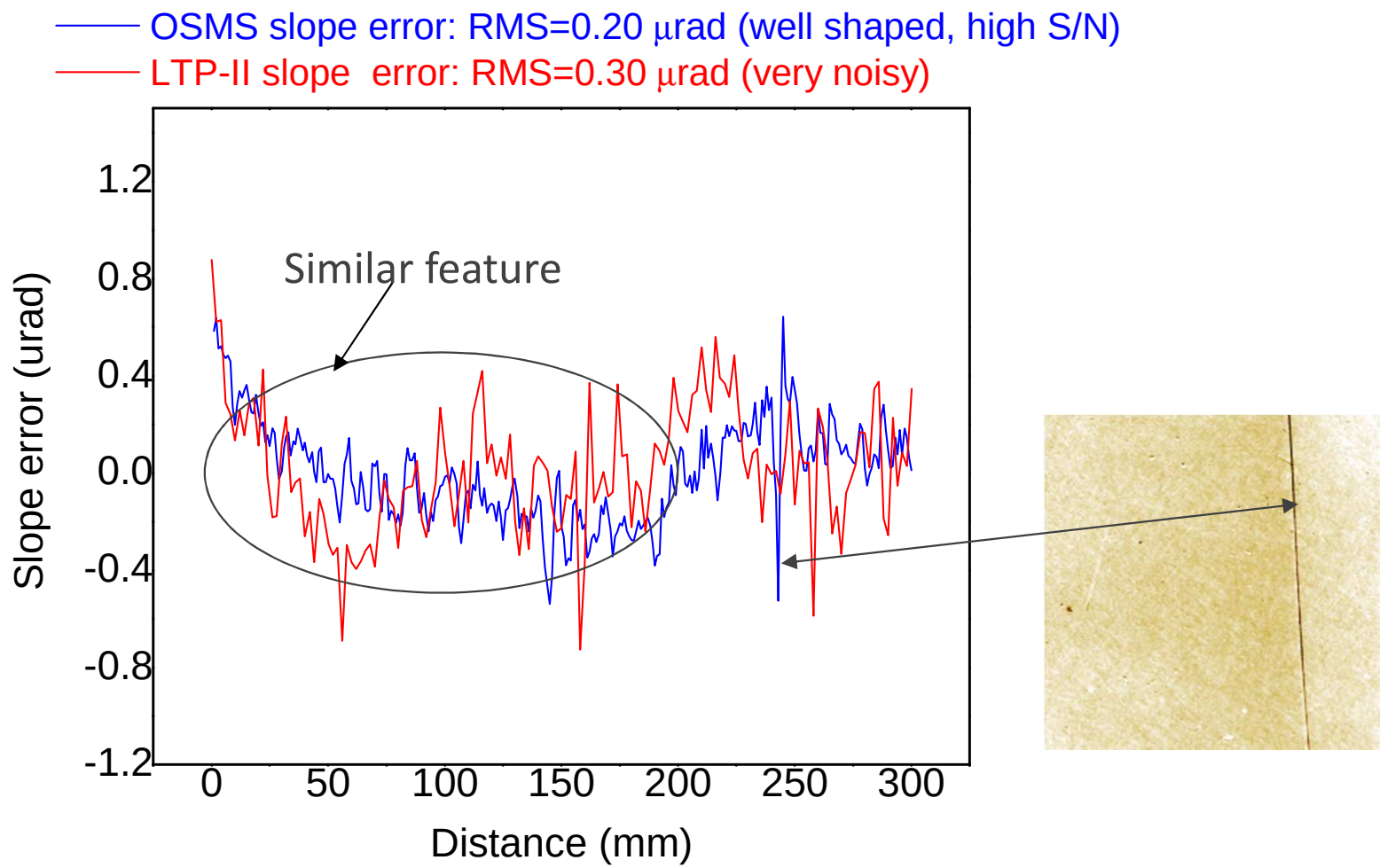


350 mm long flat Si substrate

Defect on surface (Identity)

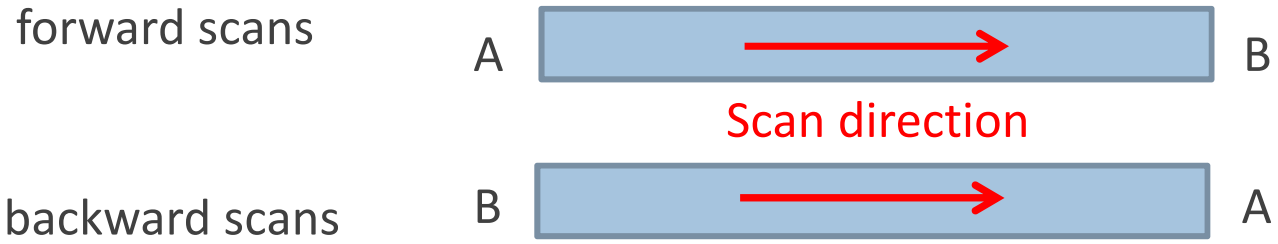
MicroXAM surface profiler

Data comparison of the 350 mm long flat mirror acquired with the OSMS and LTP-II

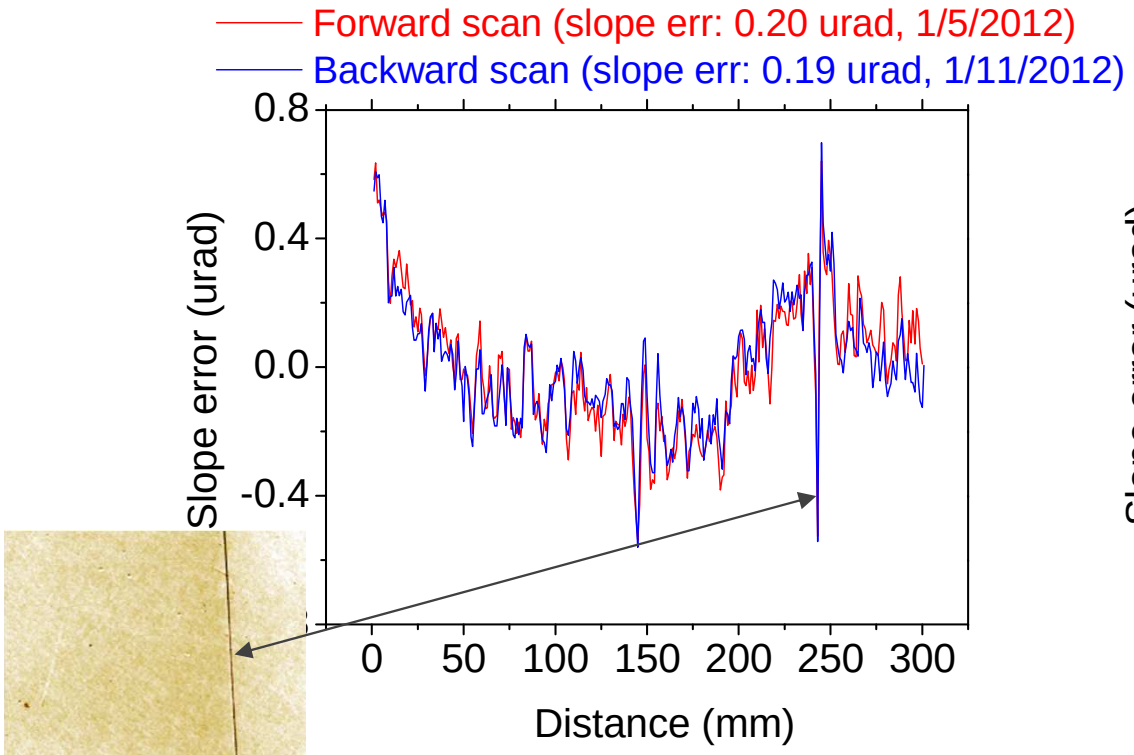


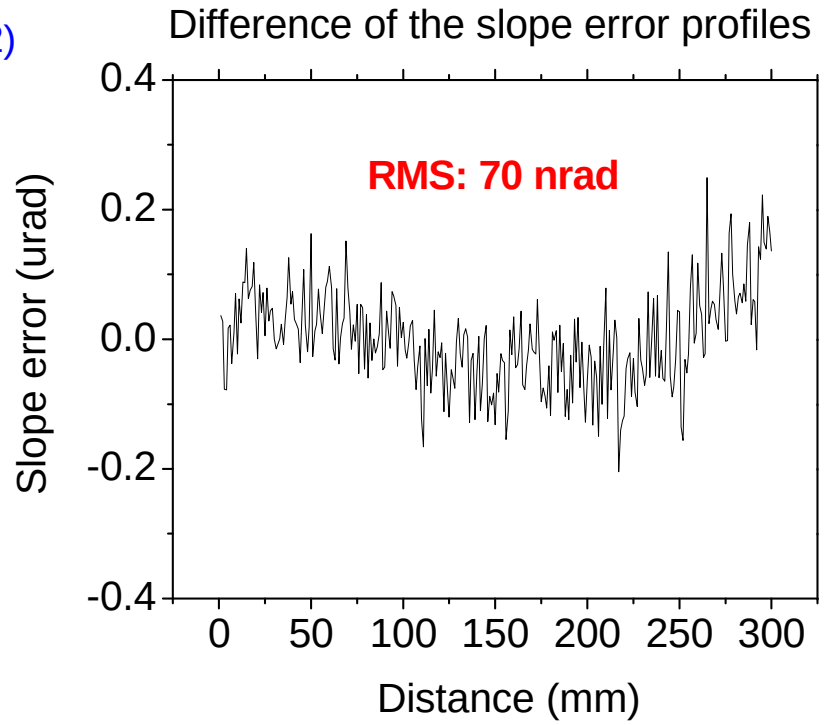
Systematic error of the APS OSMS < 70 nrad

(Method: Making forward and backward scans and comparing the profiles)



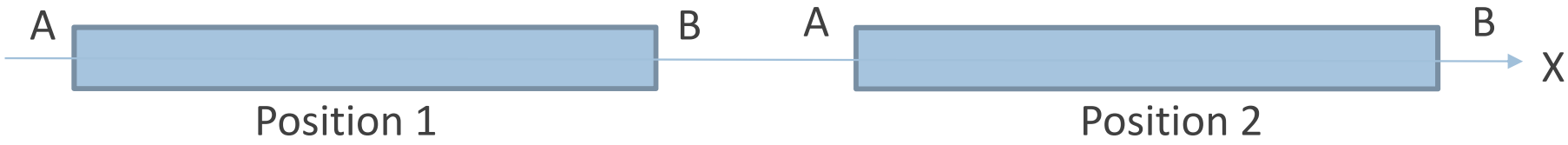
Measured in two different days



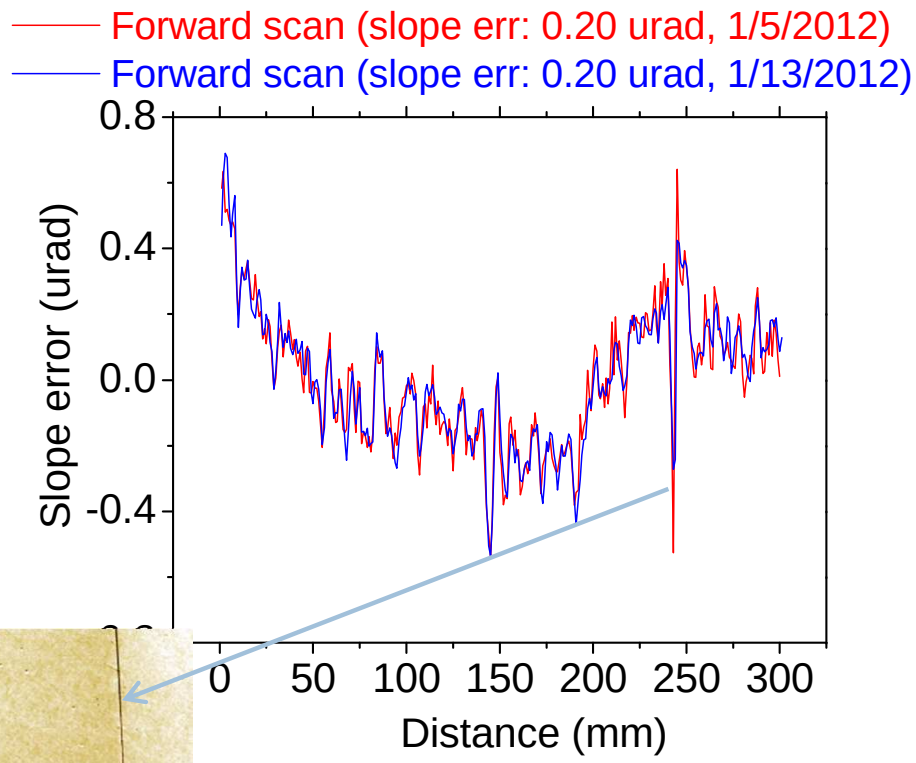


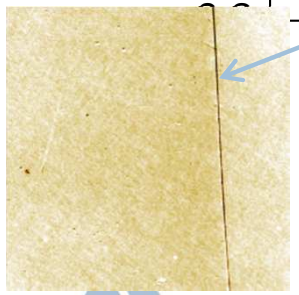
Reliability of the APS OSMS < 60 nrad

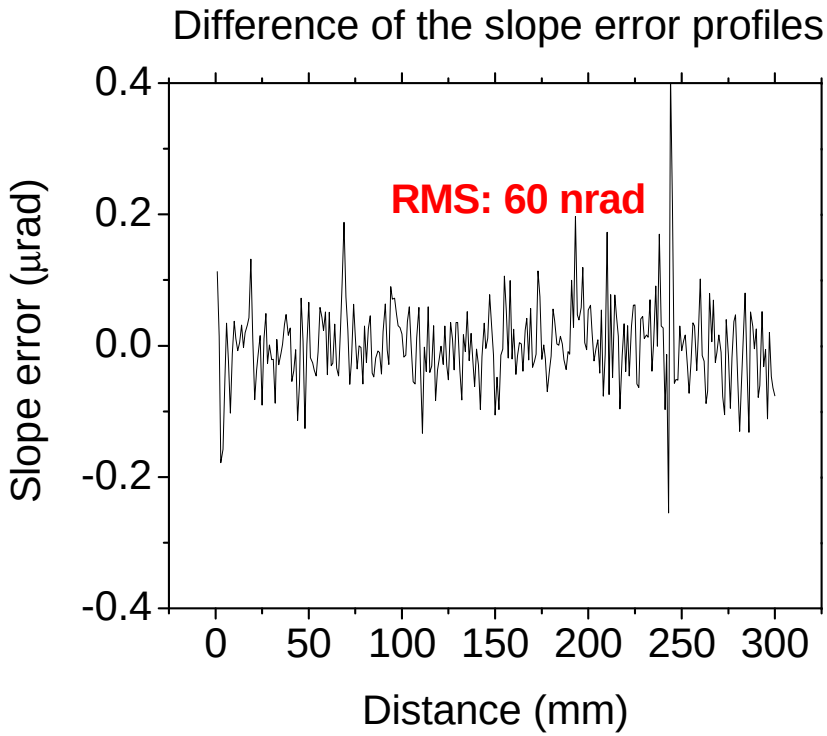
(Method: taking measurements with mirror at different locations)



Measured in two different days!

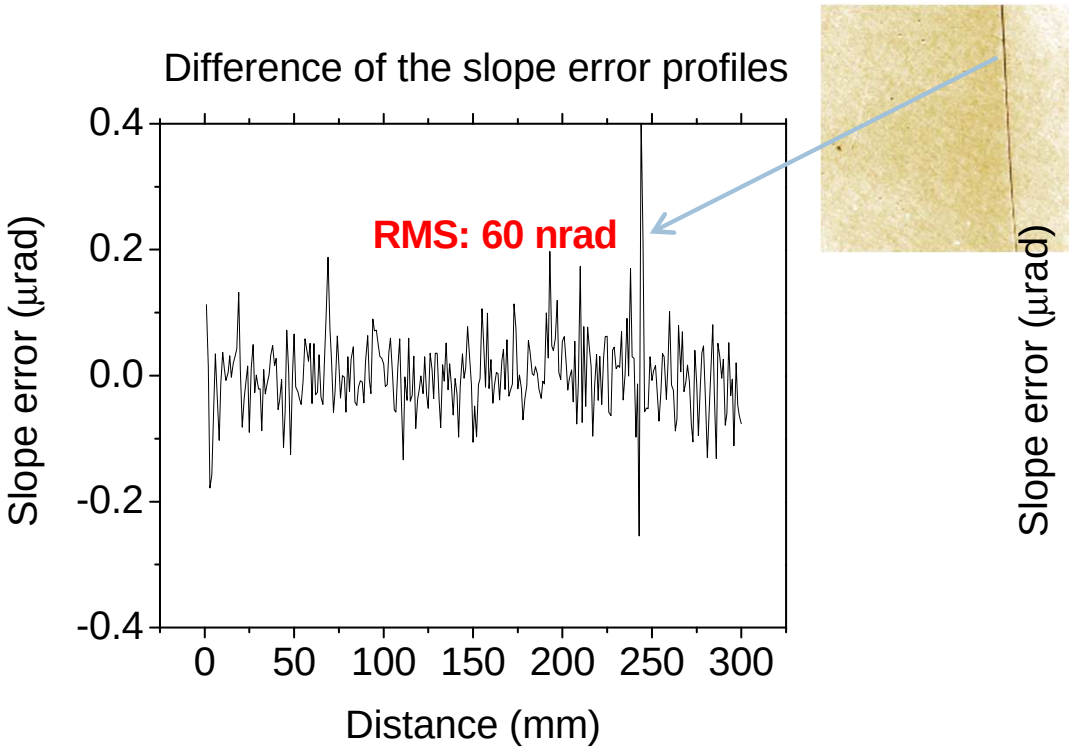


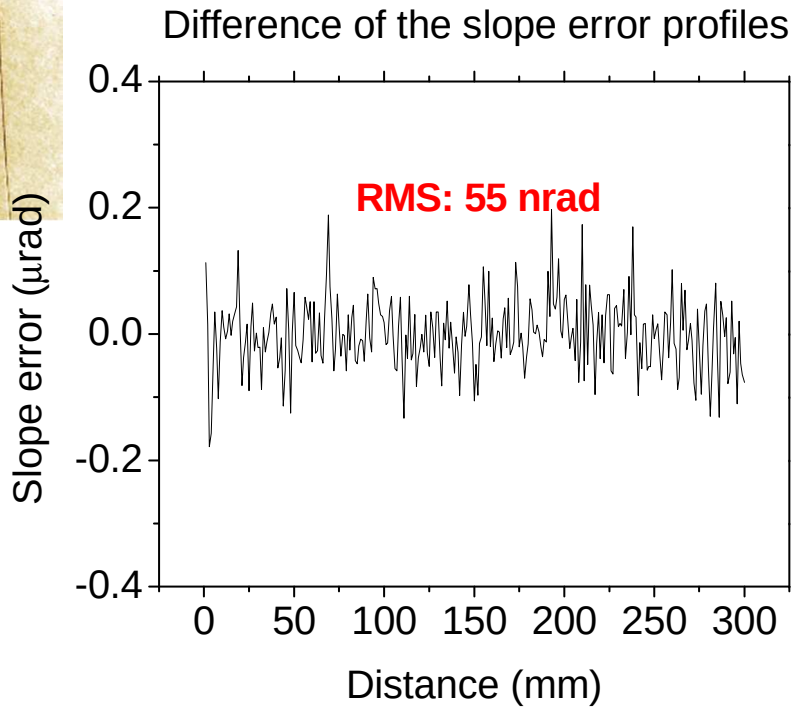




Measurements reliable and repeatable!

Is it possible to achieve less than 60 nrad rms?





~0.1 mm difference

Manually removed the big spike

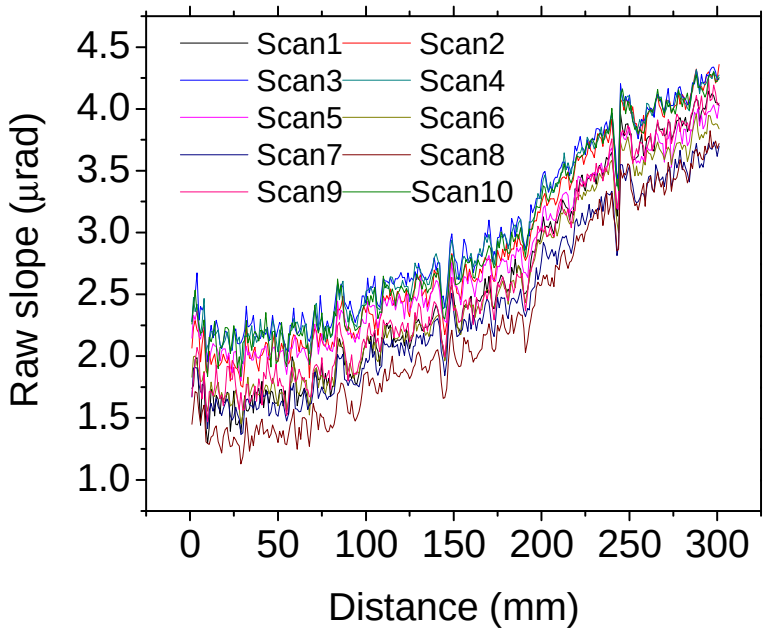
Most likely it is due to mirror positioning error in the two measurements

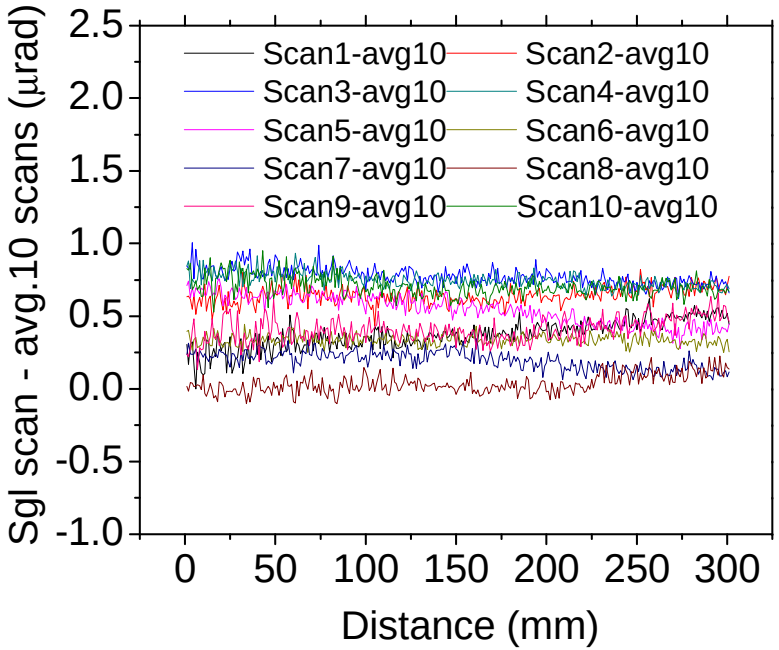
Further work

1. Positioning the mirror precisely.
2. Make measurement steps smaller. (Steps of the current data: 1 mm.)

Repeatability of the APS OSMS ~ 97.50%

(Method: Comparing 10 forward scans)





Scan	RMS of the raw slope (µrad)	Profile subtraction	RMS of the Slope Diff (µrad)
1	2.8527	Scan 1 - avg	0.0979
2	2.9849	Scan 2 - avg	0.0589
3	2.9560	Scan 3 - avg	0.0614
4	2.7562	Scan 4 - avg	0.0512
5	2.5456	Scan 5 - avg	0.0999
6	2.4062	Scan 6 - avg	0.0363
7	2.244	Scan 7 - avg	0.0617
8	2.6164	Scan 8 - avg	0.0635
9	2.9154	Scan 9 - avg	0.0832
10	2.869	Scan 10 - avg	0.0670
Average	**2.7146+/-0.0401**	**Average**	**0.0682+/-0.0185**

Deviation of the single scan to the average of 10 scans

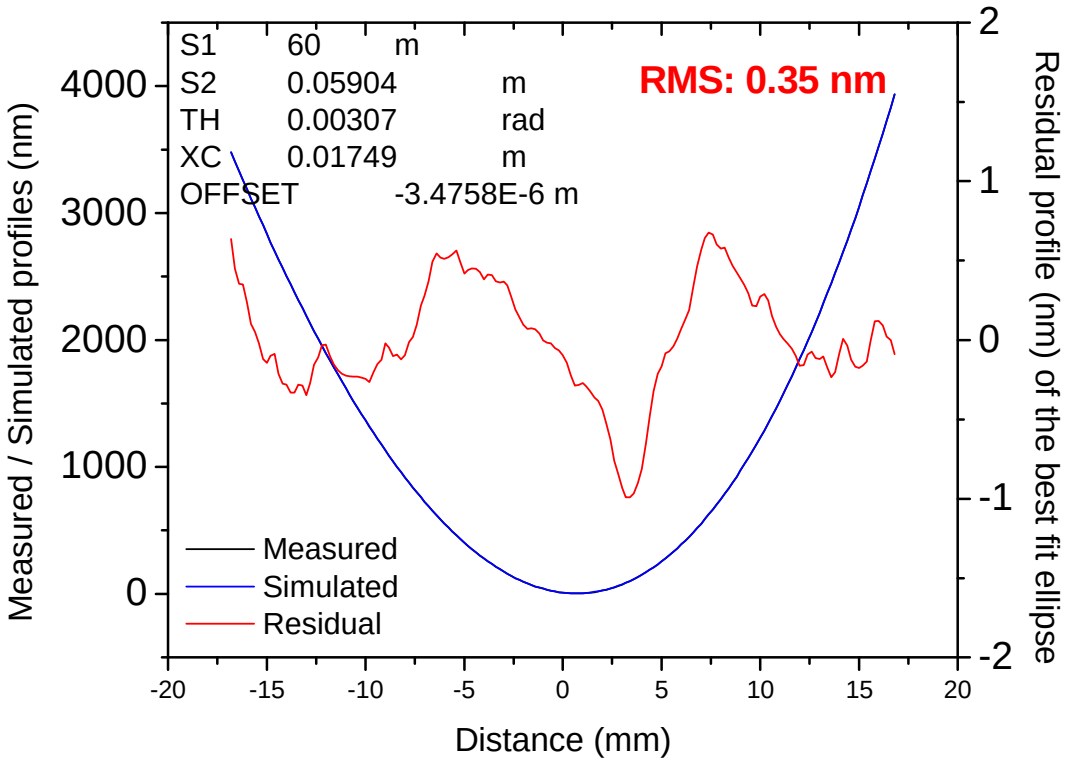
Ratio of the slope-diff to raw slope 0.0682 / 2.7146 = 0.0251 !

Measurement of an elliptical KB mirror for APS 34 ID beamline

Size: 40mm x 20mm x 20mm

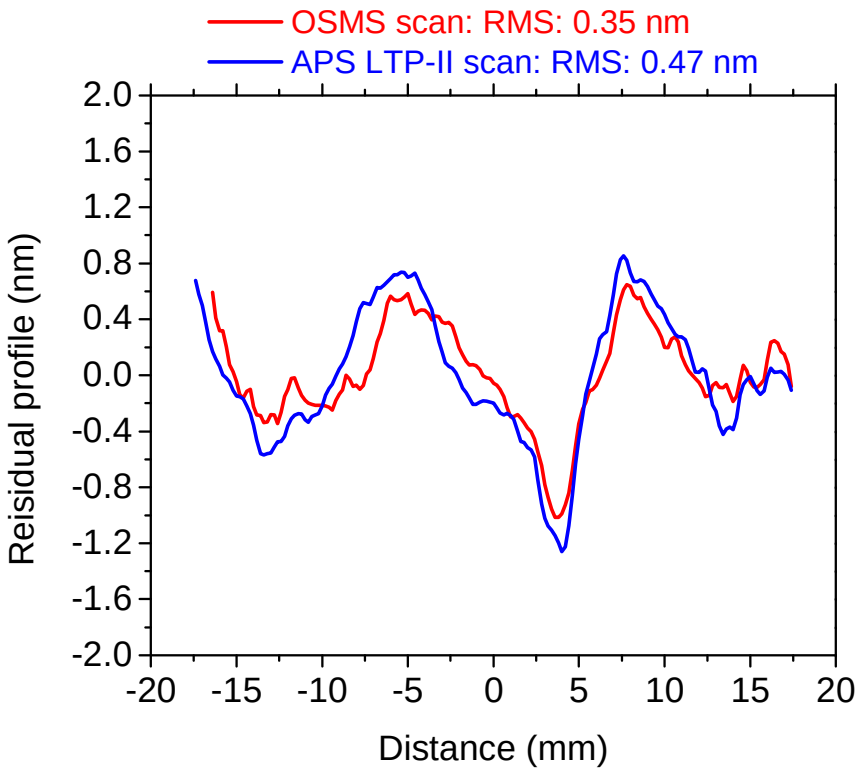
Shape: Elliptical (S1=60 m, S2=60 mm, Theta= 3 mrad, mean curvature: ~40 m)

Instrument: APS OSMS, APS LTP-II and APS MicroXAM surface profiler (stitching)

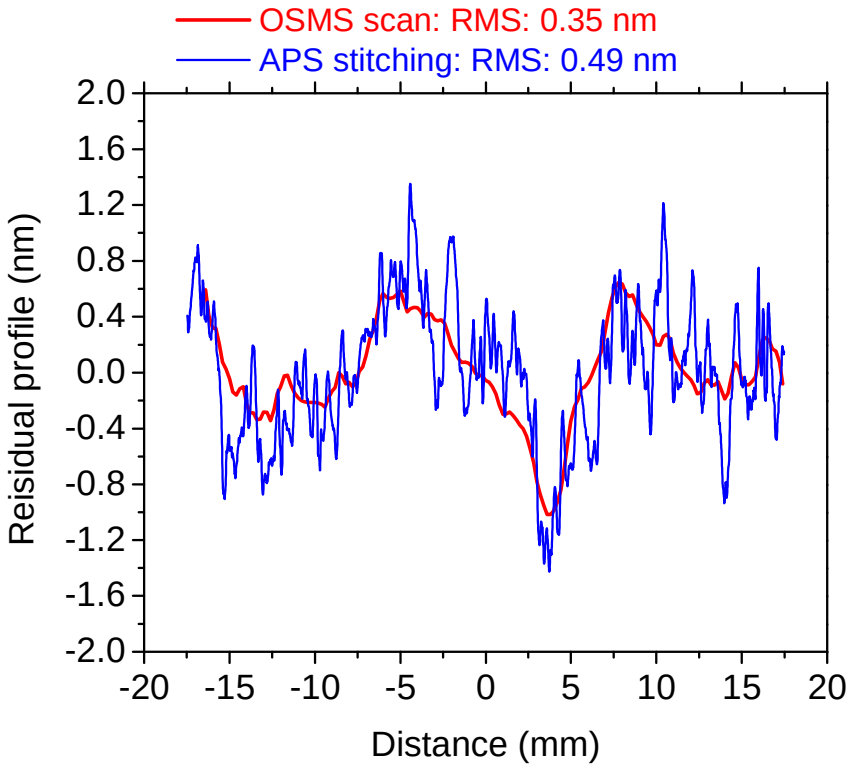


Simulation result (best fit ellipse) of the KB mirror height profile acquired with the APS OSMS

Residual profiles of the best ellipse fit of the KB mirrors data acquired with the OSMS, LTP-II and Stitching profiler



Data comparison
APS OSMS vs. APS LTP-II



Data comparison
APS OSMS vs. APS Stitching

Conclusion

1. We performed the preliminary tests of the APS OSMS for super flat mirrors and achieved our Phase I goal for < 100 nrad rms slope error system accuracy.

   Data summary:

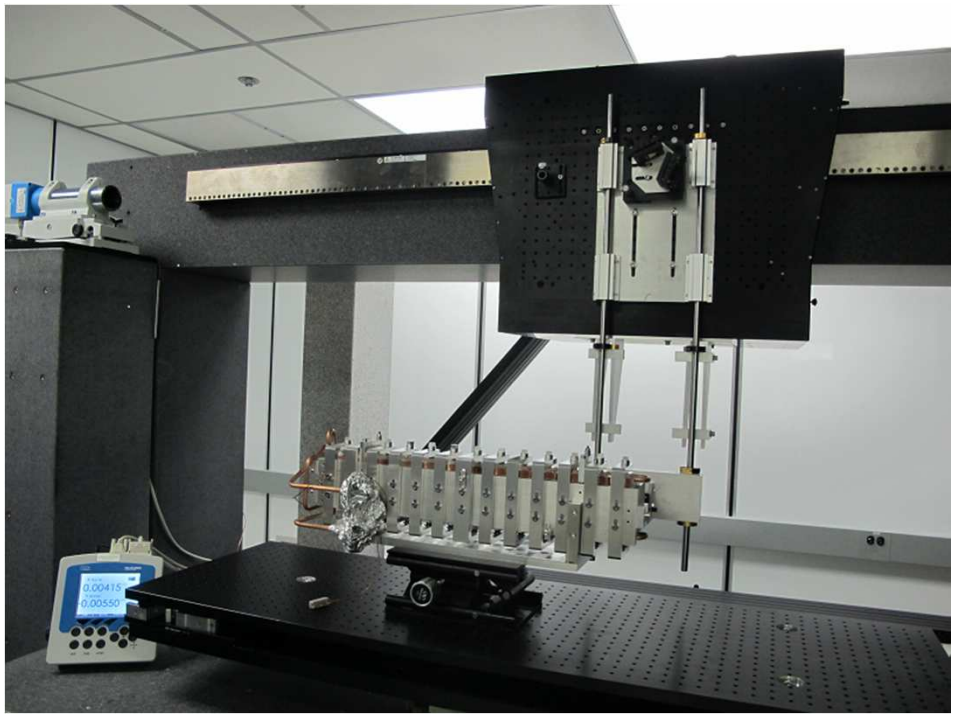
   - Systematic error < 70 nrad
   - Reliability error < 60 nrad
   - Repeatability error < 68 nrad
     or the repeatability ~97.5%

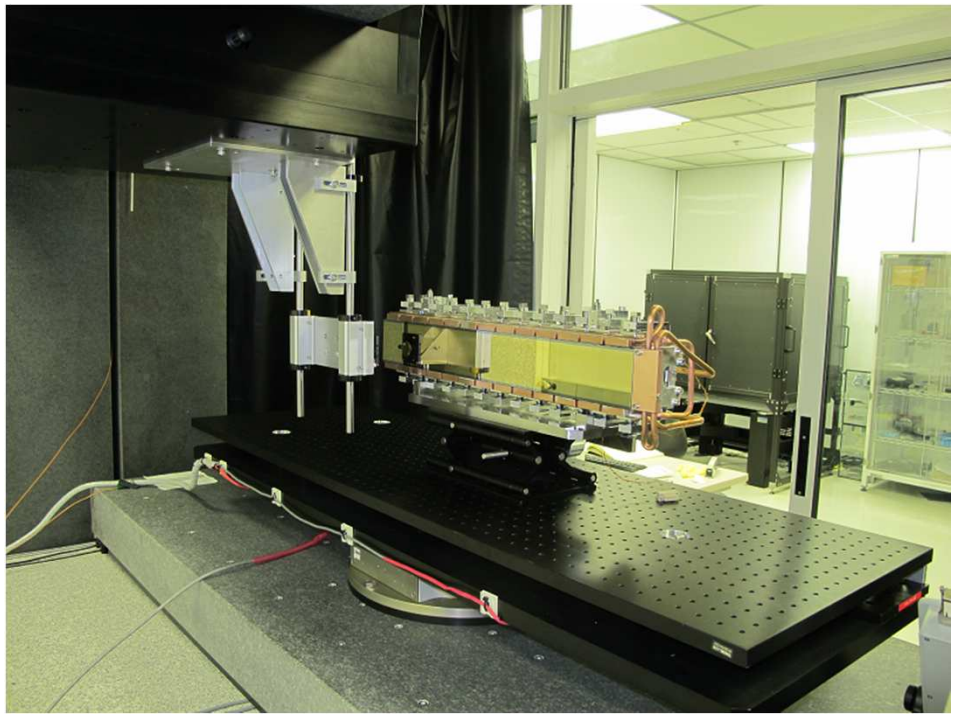
2. For curved KB mirror measurement, the APS OSMS data agrees with the data from the APS LTP-II and APS stitching interferometer.

3. Further works:

   - Curved mirror/correction with the calibration data of the autocollimator
   - Further measurement to evaluate performance
   - Environment control, software development

The APS OSMS has been joining the other instruments for measuring mirrors for APS users.





600 mm long clamped HFM for high heat load exp. , 29ID IEX beamline in the APS

Mirror was facing sideway.
Measurements were performed on June 29, 2012

Acknowledgements

- The authors would like to thank Valeriy V. Yashchuk, Nikolay A. Artemiev, Daniel J. Merthe from Lawrence Berkeley National Lab for their valuable efforts in the measurements with us and we are still looking forward for further collaboration works.

- We also would like to acknowledge Mark Erdmann for his Engineering support and John Attig for his technical support.

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Thanks for your attention!