Characterization of the error budget of the Alba-NOM

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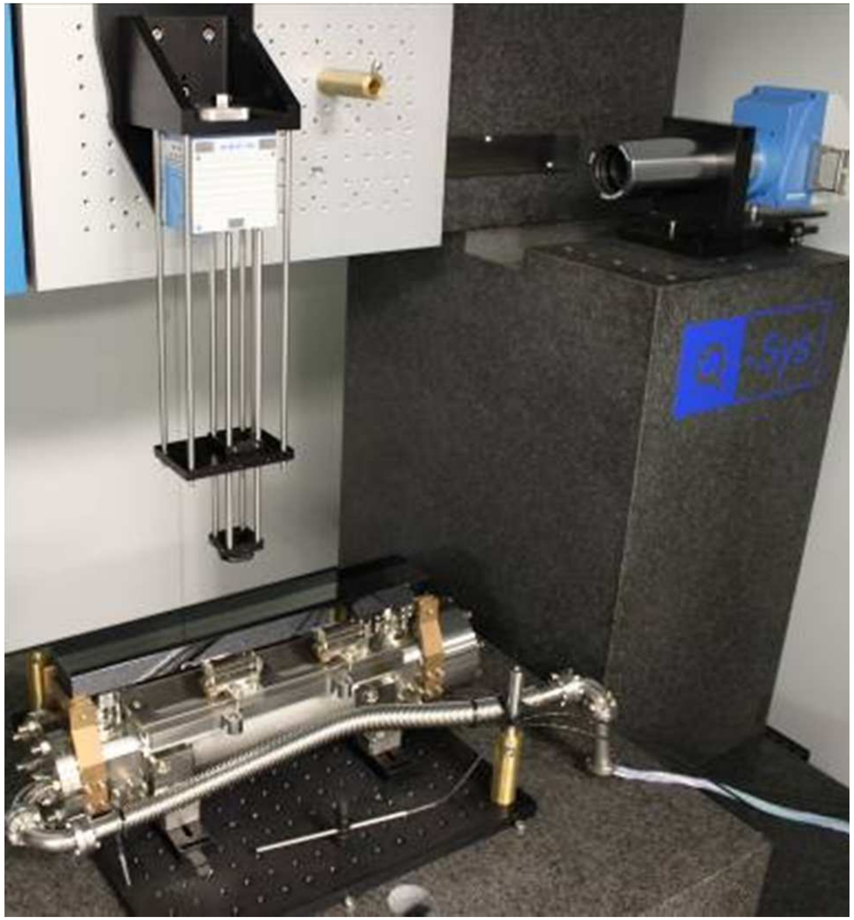
ALBA light source

Outline

We aim to characterize the uncertainty of slope measurements obtained by the Alba-NOM, contributed by stochastic effects and systematic errors:



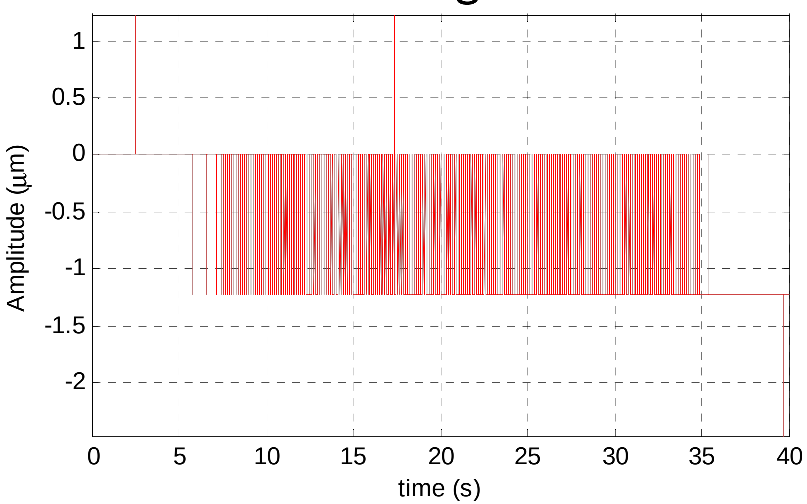
1. **The bench**
   a. Motion metrology
   b. Raytracing of the guidance induced error
   c. Vibrations, noise and stability
2. **The optics**
   a. Calibration using redundant-independent datasets.
   b. Optimization of the iris aperture.
3. **One application**
   a. surface correction using few point forces
   b. Exsitu vs Insitu

Motion performance

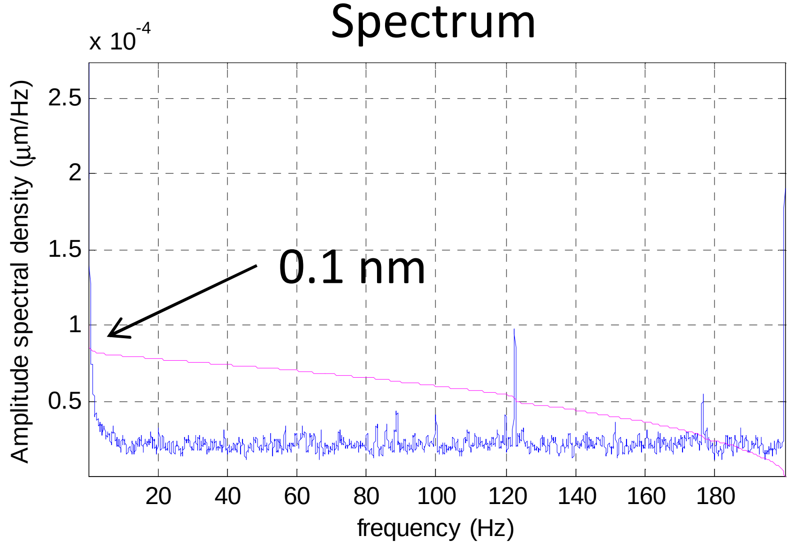
The use of a differential interferometer allows an accurate characterization of the motion performance of the bench

Resolution (linear)	1 nm
Resolution (angular)	41 nrad
Maximum sampling rate	5 kHz
Noise level	~0.1 nm RMS
Accuracy (linear)	±0.7p.p.m
Linearity (angular)	±0.5 µrad

Time signal



Spectrum

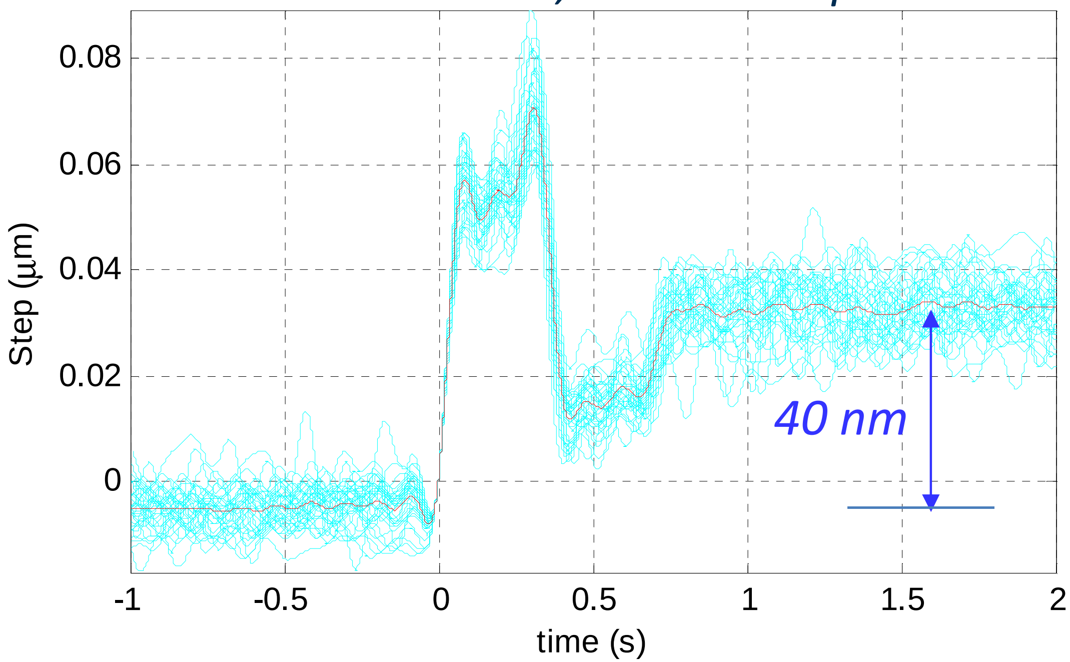


Motion performance

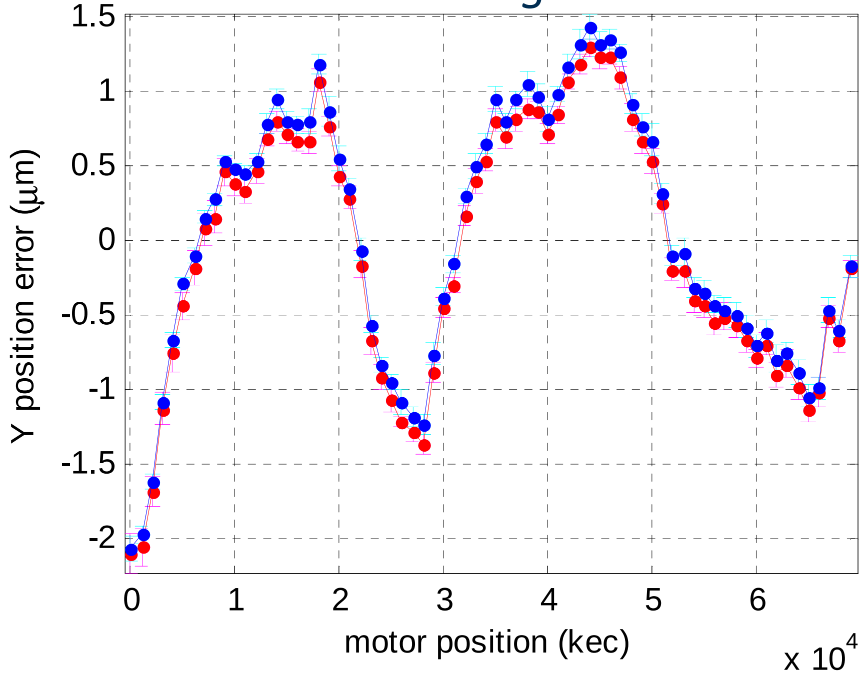
The use of a differential interferometer allows an accurate characterization of the motion performance of the bench

	Backlash	Accuracy	Repeatability	Resolution
Position	100 nm	3.5 um	77 nm	20 nm

Resolution, a 40 nm step

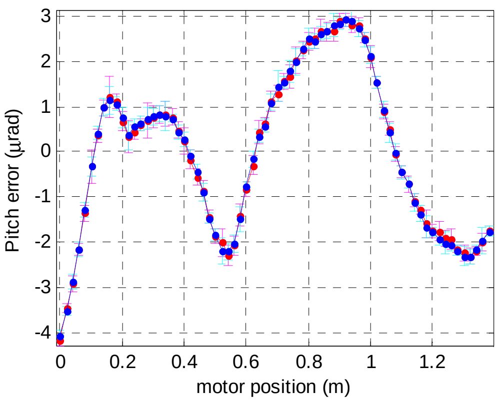


Positioning error

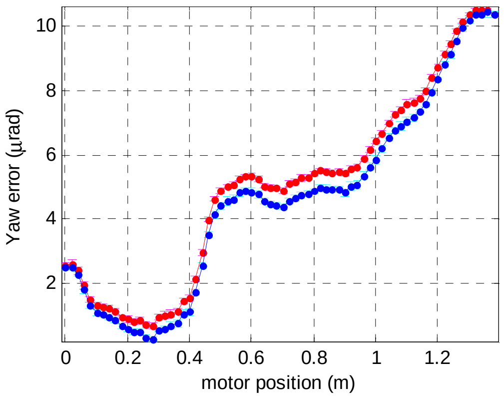


Guidance measurements

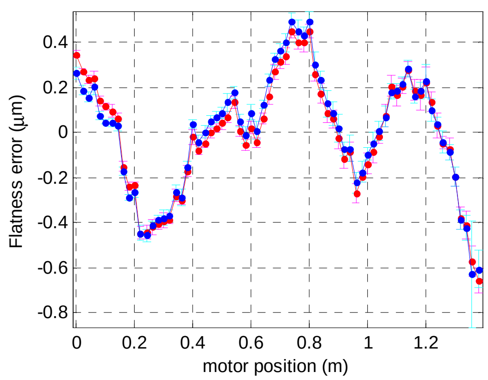
	Backlash	Accuracy	Repeatability
pitch	2 nrad	7.1 urad	200 nrad
yaw	390 nrad	10.1 urad	94 nrad
roll	<115 nrad	6.1 urad	<200 nrad
flatness	14 nm	1.1 um	42 nm
straightness	2 nm	2.1 um	47 nm



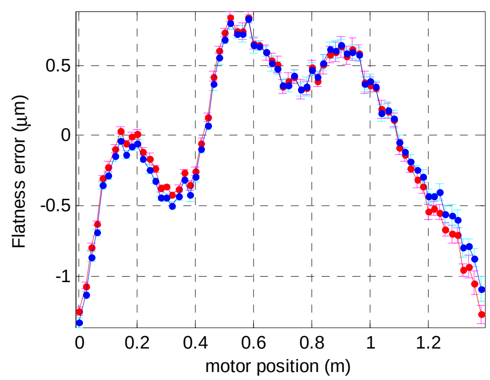
Pitch



Yaw

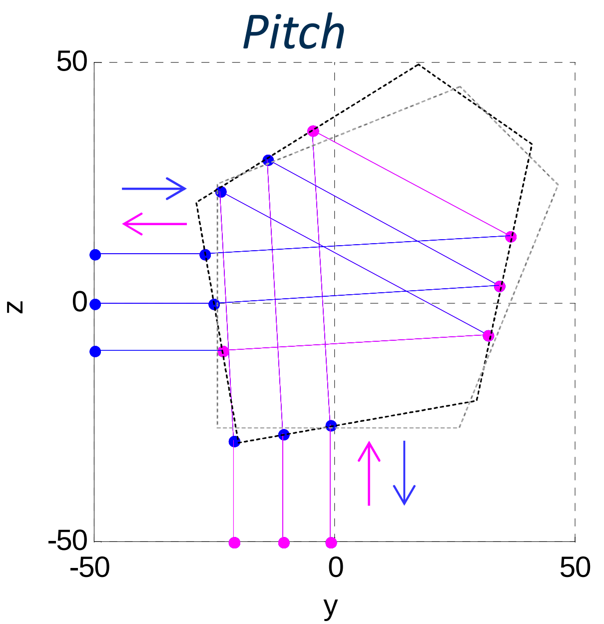


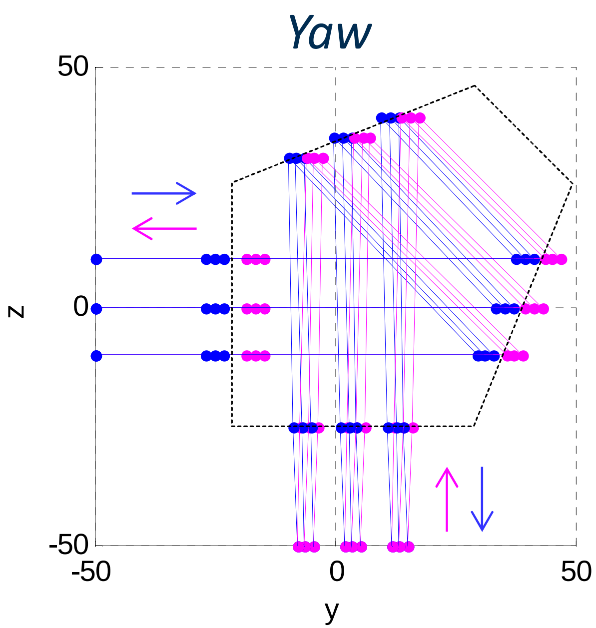
Flatness

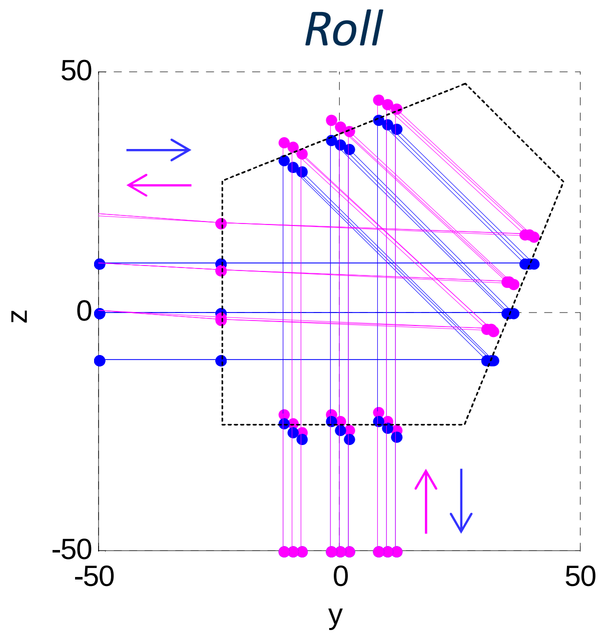


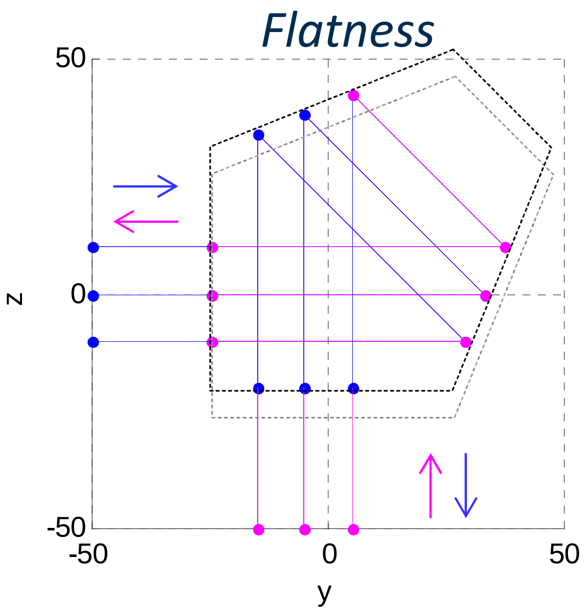
Straightness

Raytracing



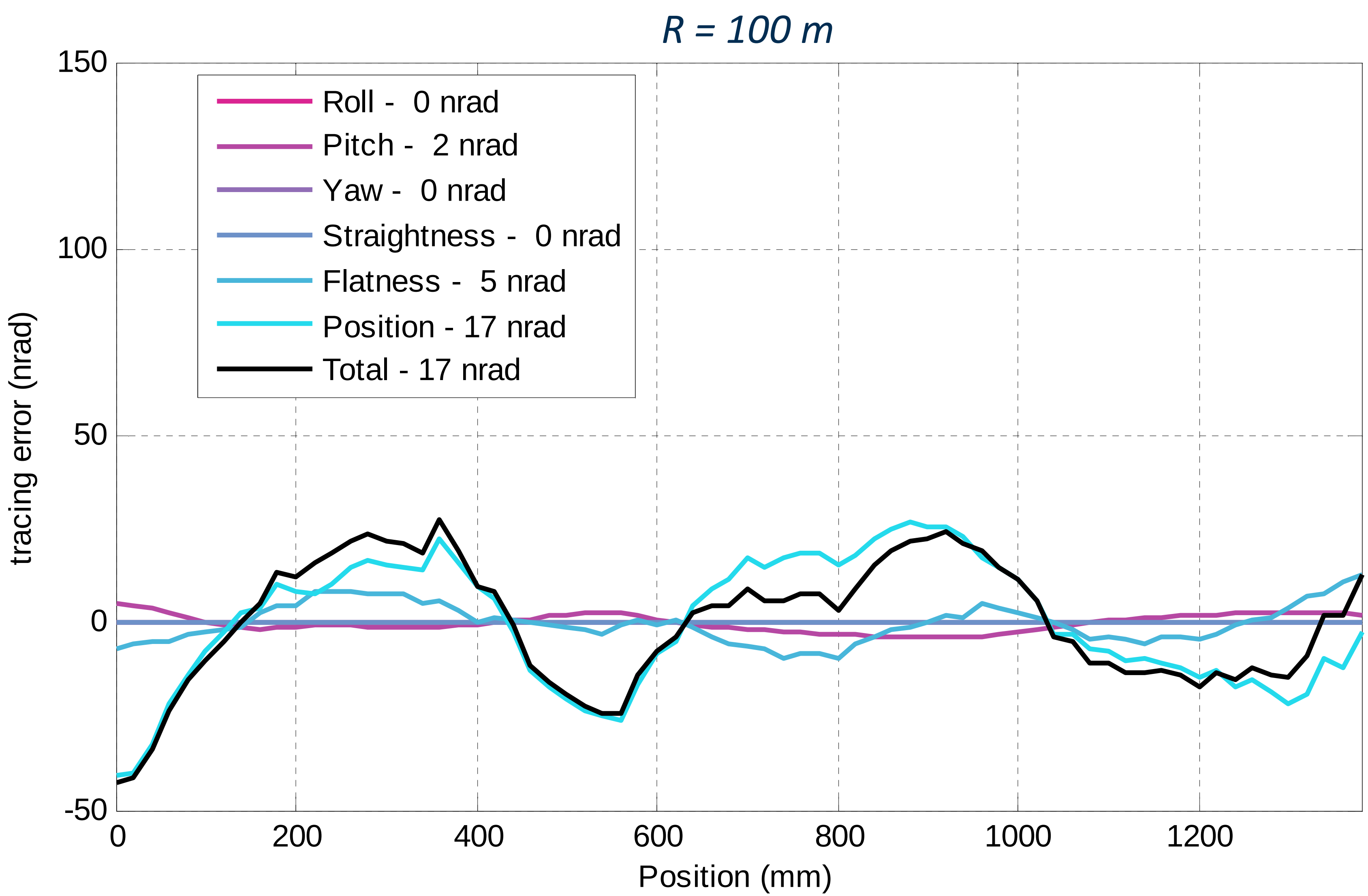






Double pass raytracing of the scanning pentaprism is used to determine the influence of guidance error on the measurement

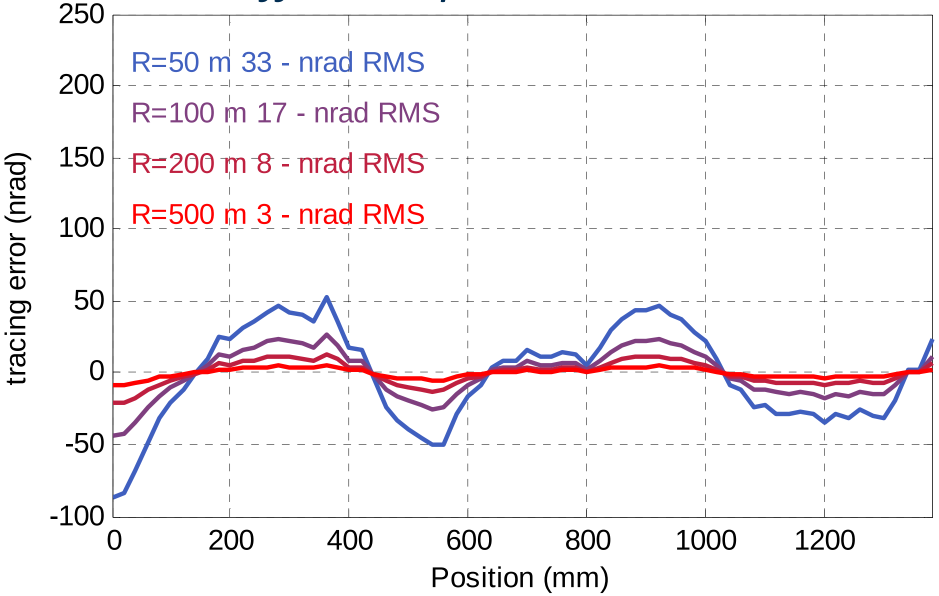
Guidance accuracy



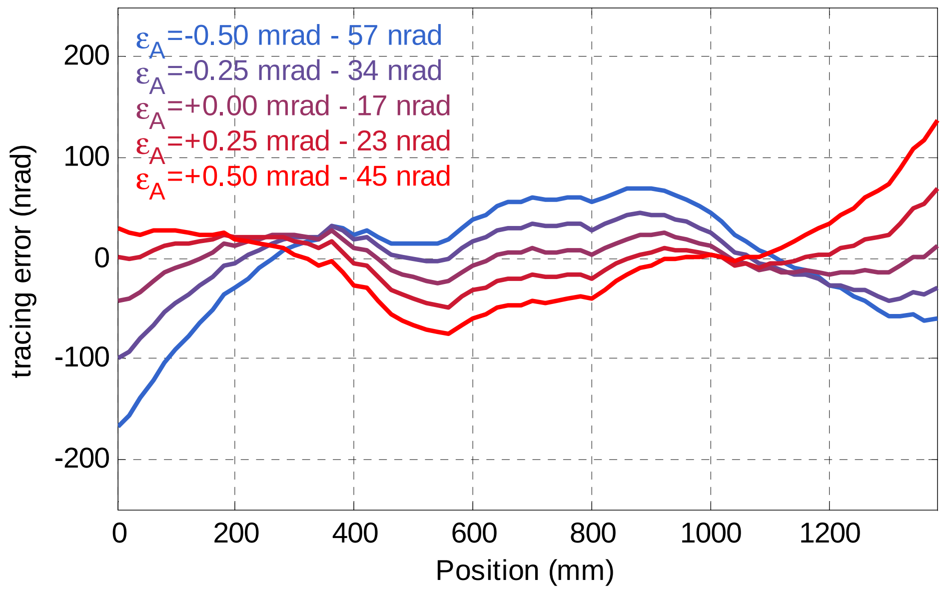
Contribution of the guidance error to the LTP error

Guidance accuracy

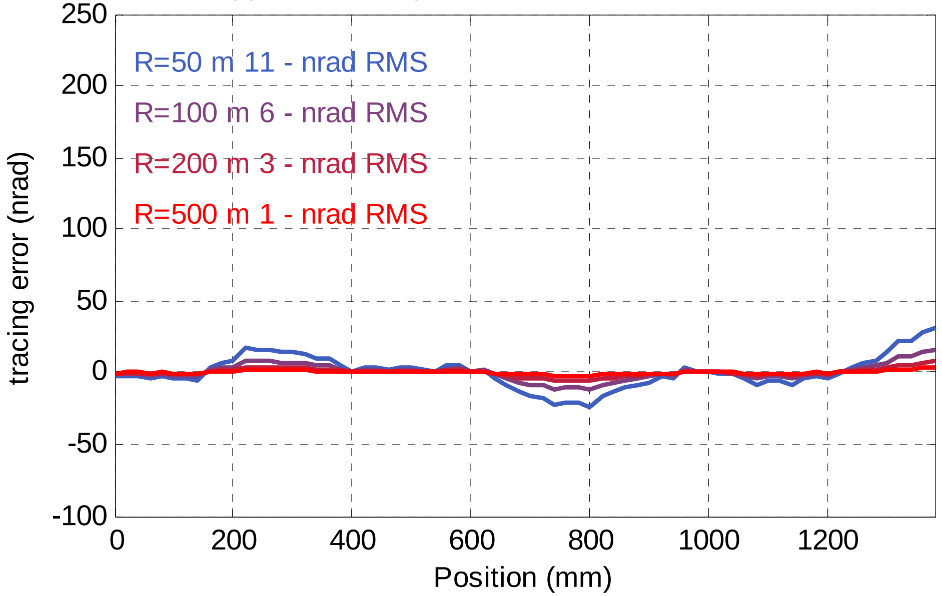
Different spheres



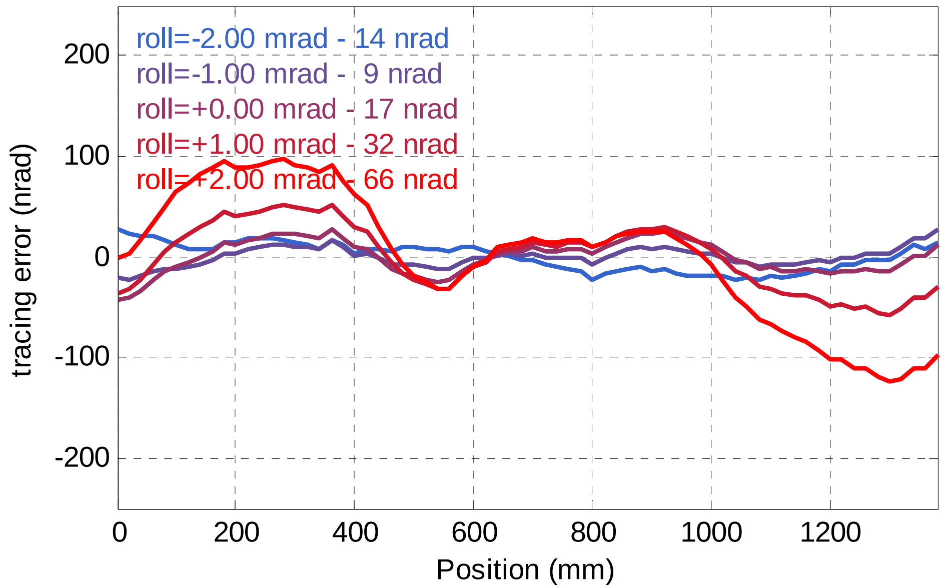
Pentaprism error – R=100 m



Different spheres – Position LUT

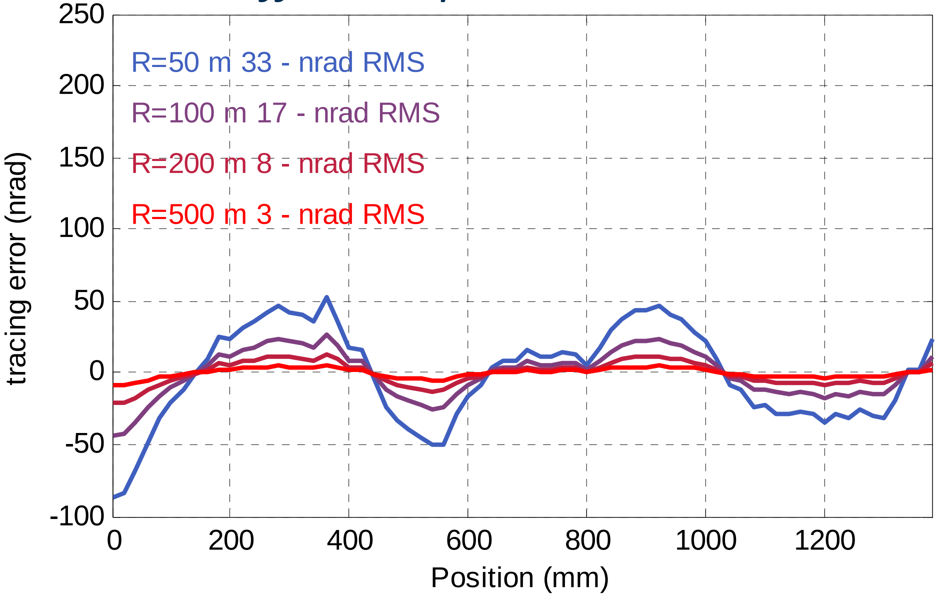


Pentaprism roll – R=100 m

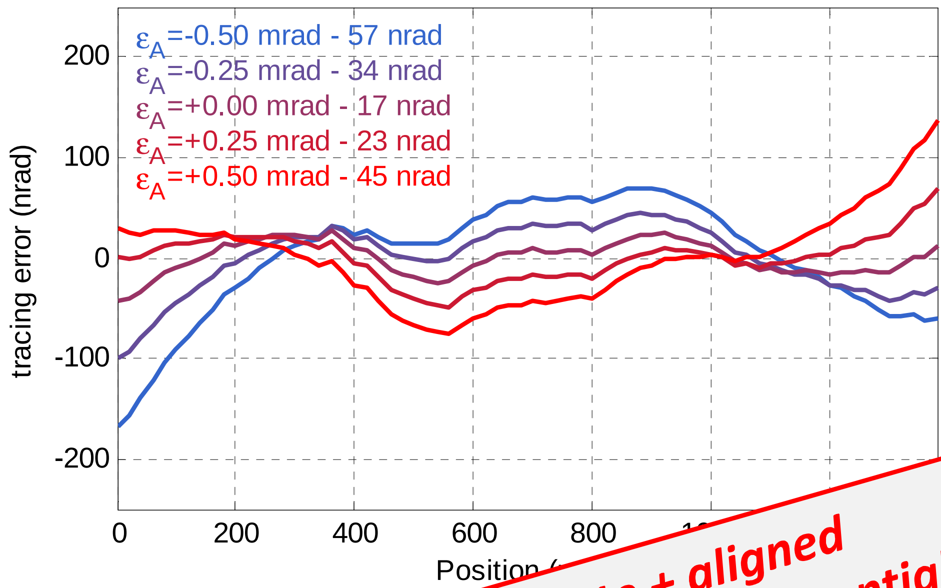


Guidance accuracy

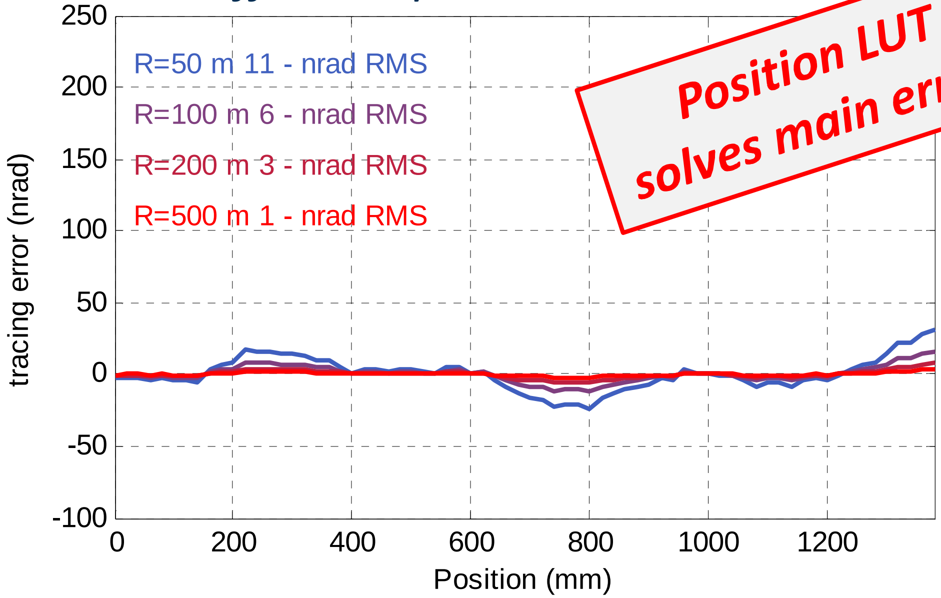
Different spheres



Pentaprism error – R=100 m

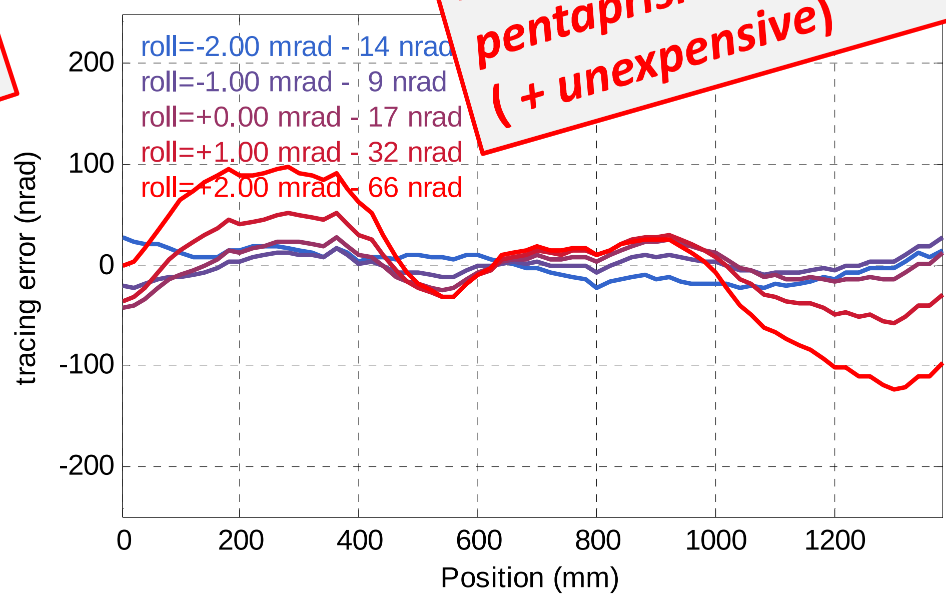


Different spheres – Position LUT



Position LUT solves main errors

Pentapris



Accurate + aligned pentaprism is essential (+ unexpensive)

Vibrations on top of the NOM

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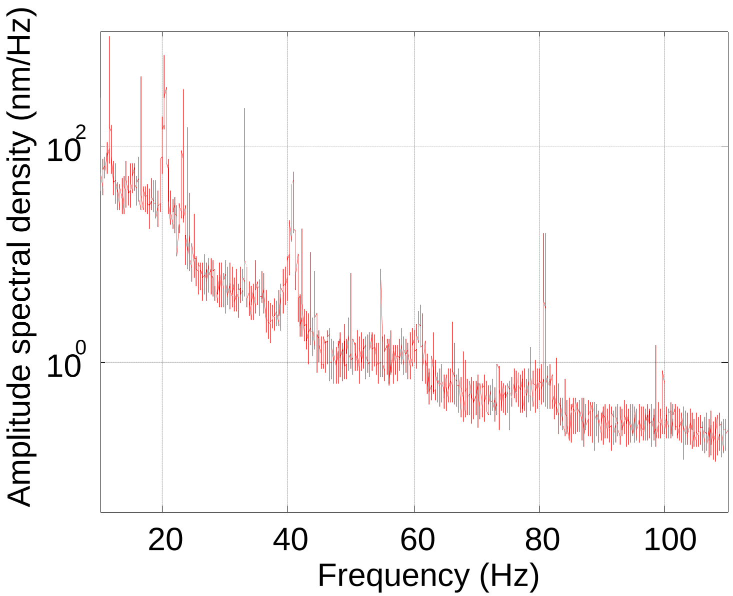
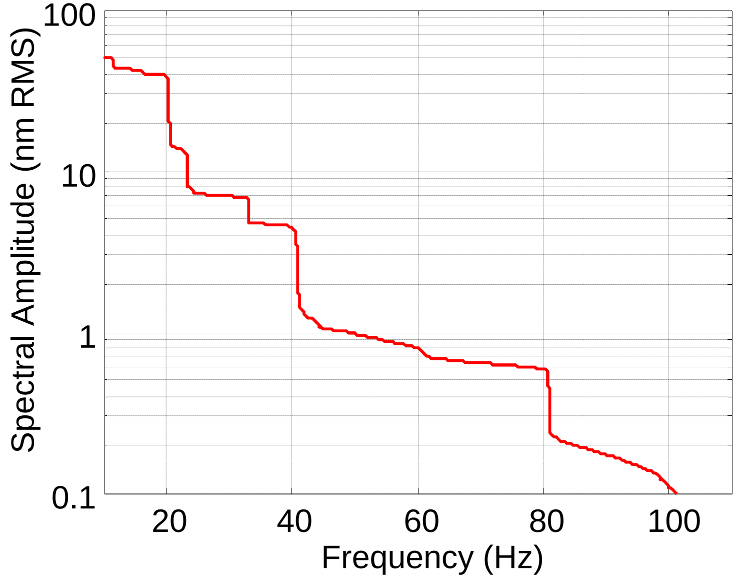
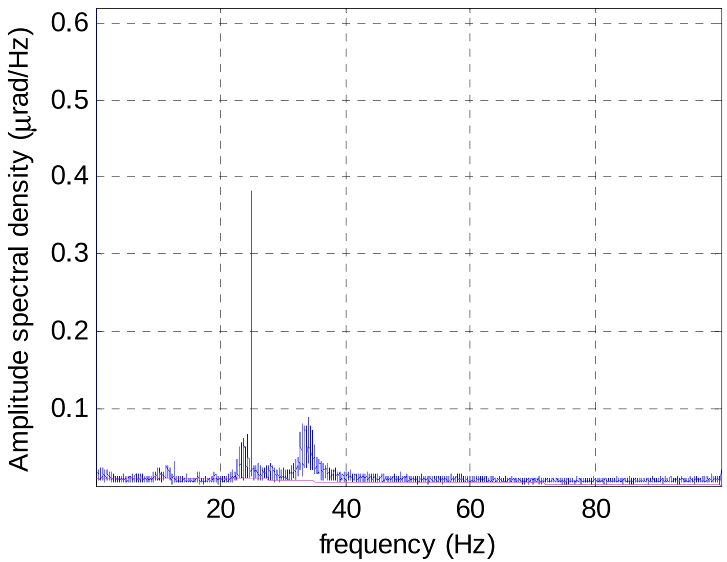
Although the amplitude of the vibration in the ground is ***50 nm RMS****, the measurement on top of the NOM is* ***13 nrad RMS***

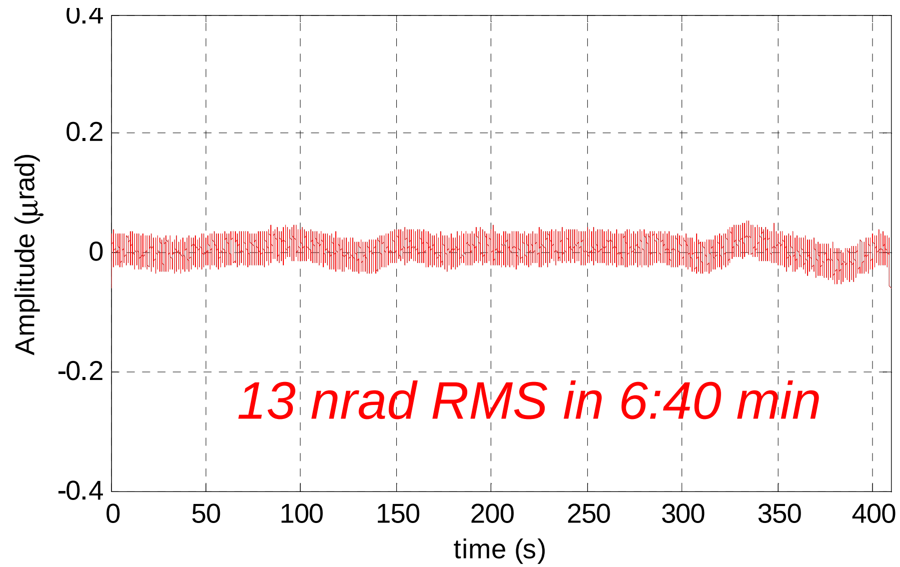


← *Ground vibration (vertical)* →





← *NOM (pitch between platforms)* →



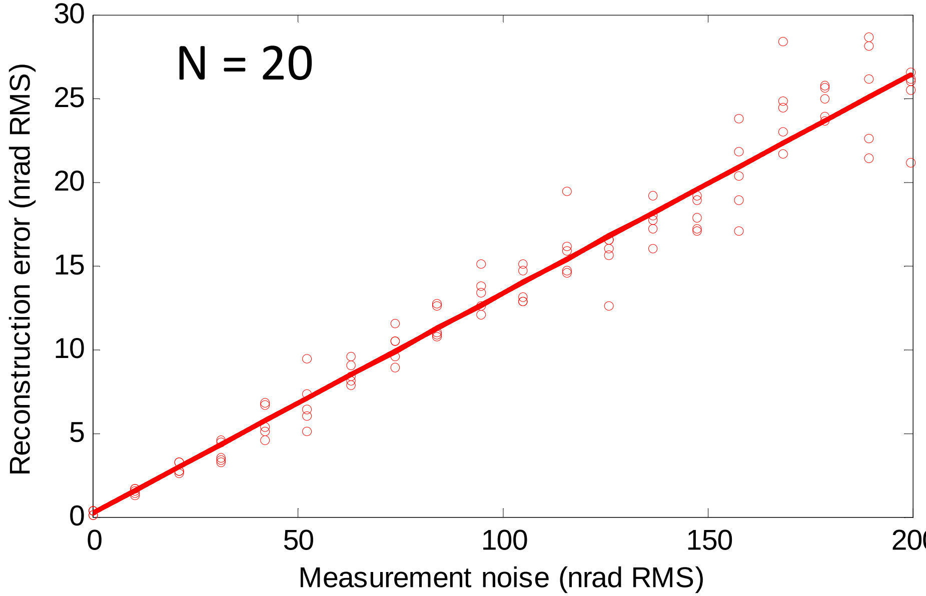
Redundant-independent datasets

The use of redundant-independent measurements of a mirror allows to estimate the slope error and the linearity error of the instrument

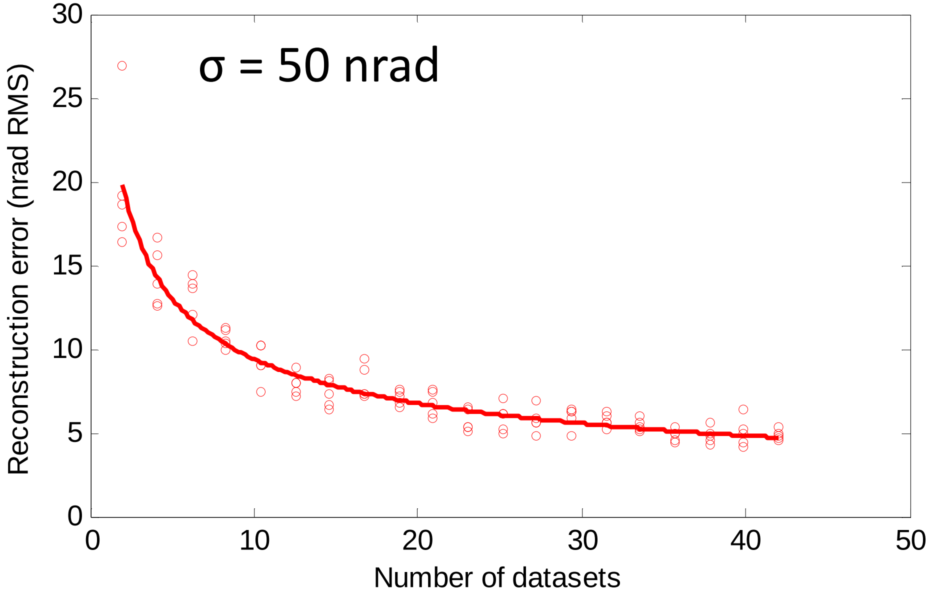
The resolution of the surface is limited

- *Validity of the error model → short mirrors vs long mirrors*
- *Noise of each measurement*
- *Number of measurements*

Simulation: accuracy dependence on noise



Simulation: accuracy dependence on number of datasets



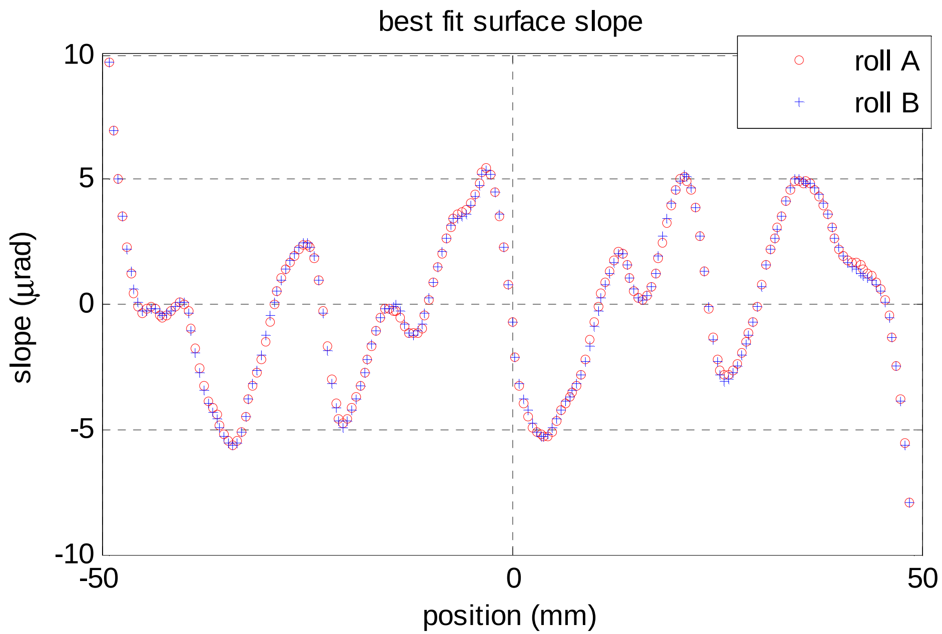
F. Polack, et al , *Nucl. Instrum. Meth. Phys. Res. A* **616** (2010) 207

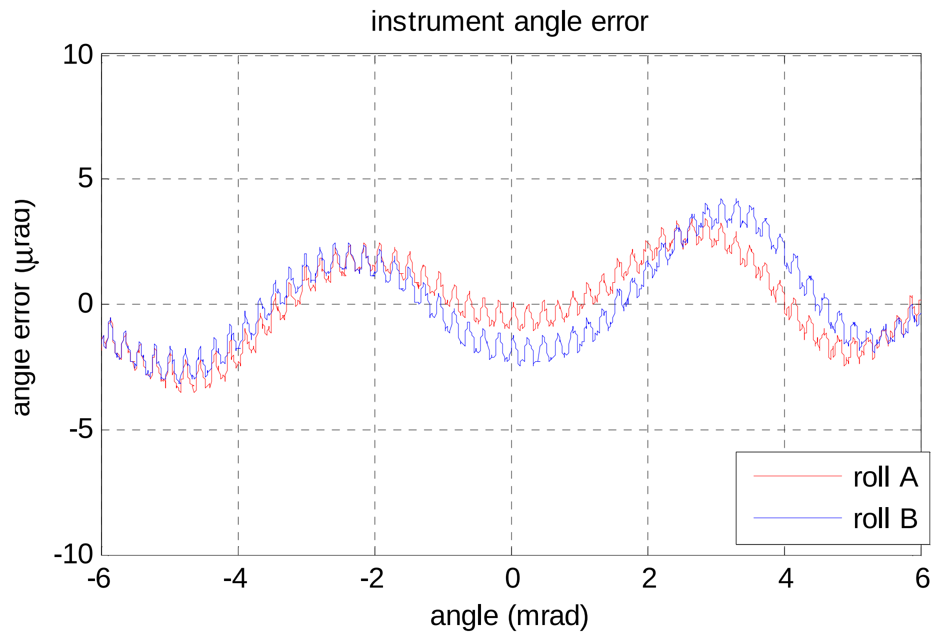
Redundant-independent datasets

A 100 mm, R=75 m sphere has been used to cover 12 mrad range of the NOM.

Each reconstruction is based on 54 scans

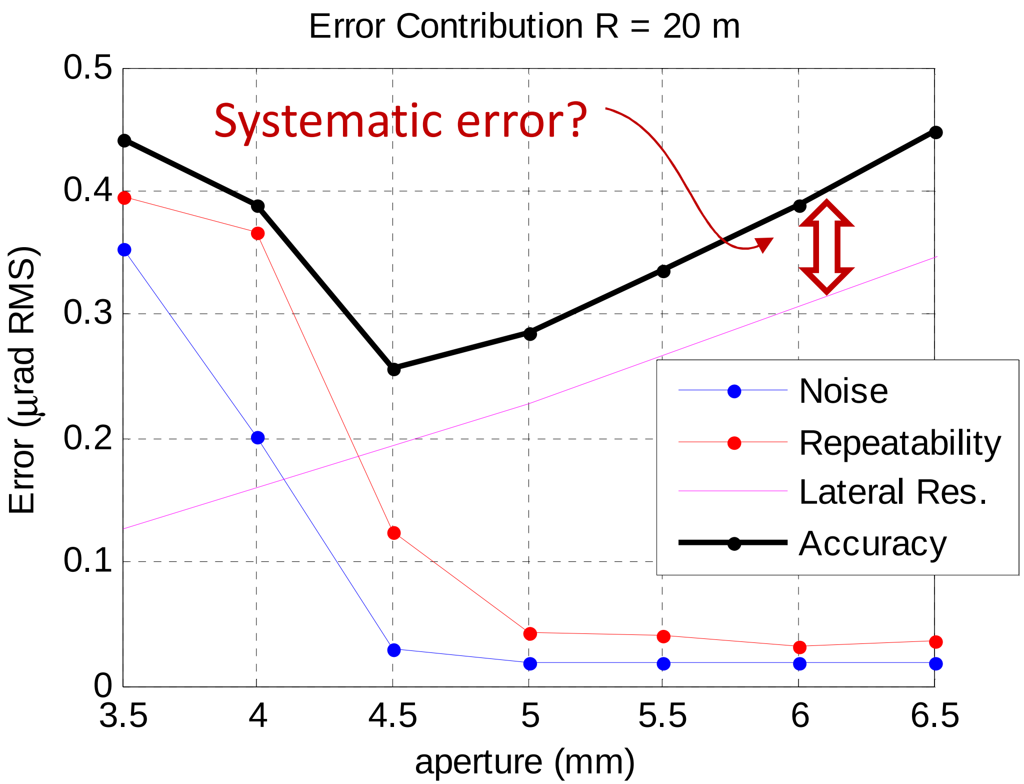
Residual aberration + periodic subpixel interpolation error found for two different roll positions of the pentaprism.

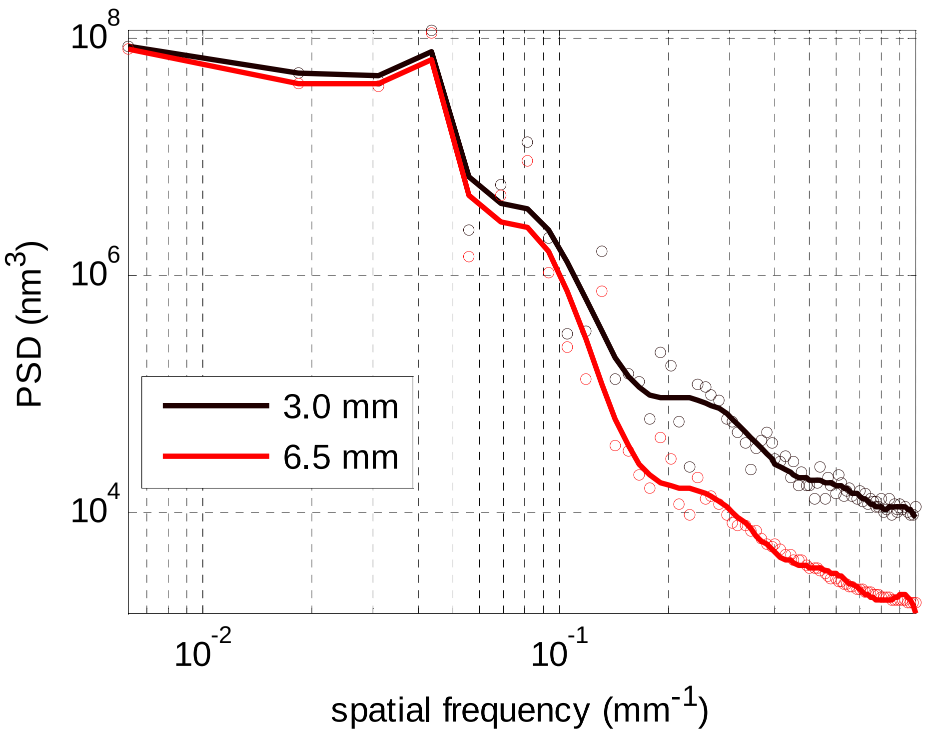




Accuracy vs spatial resolution

Measurements of the same mirror, using different iris apertures, all compared with a reference measurement at 3 mm iris





- *For small apertures uncertainty is limited by noise and repeatability*
- *For larger apertures, the error increases, mainly, due to the loss of lateral resolution*

Slope error optimization

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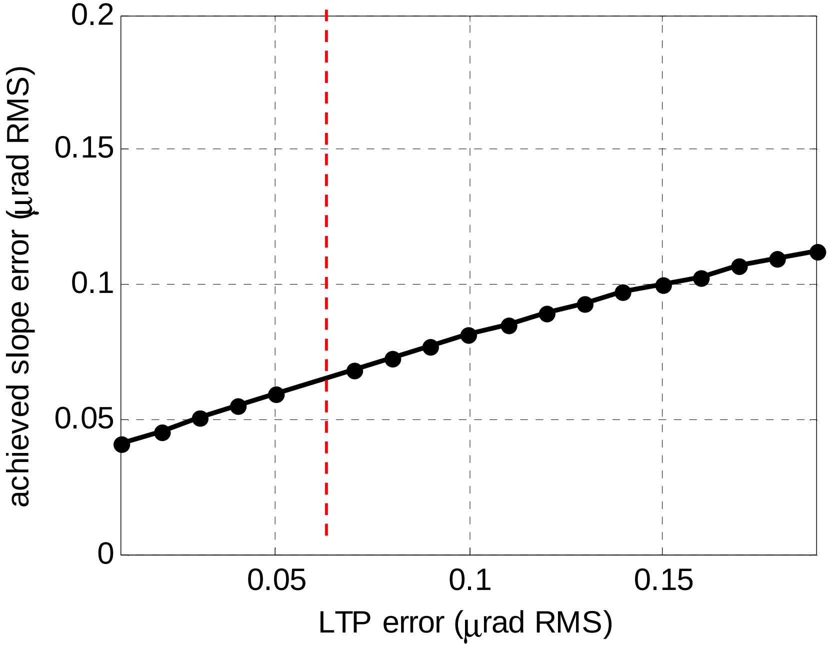
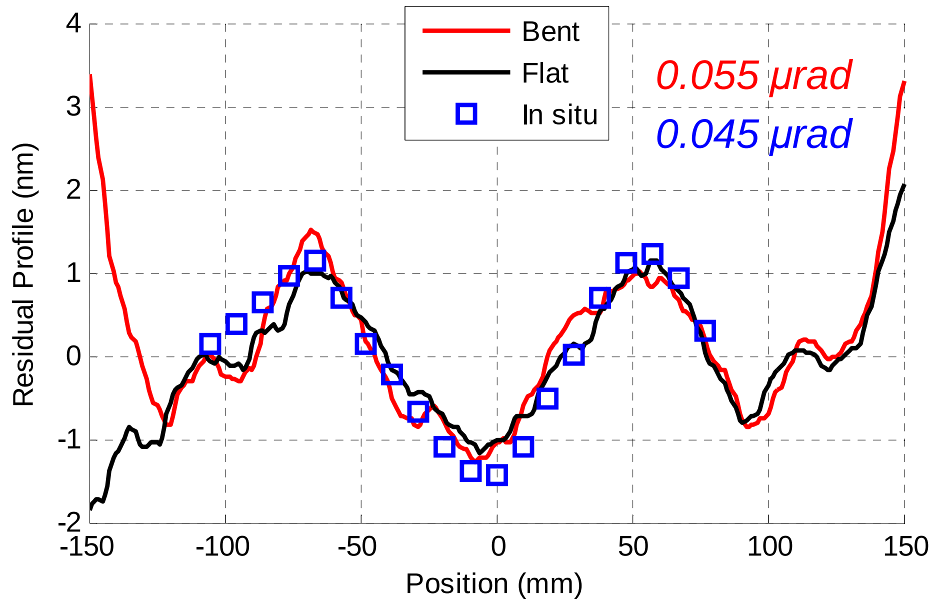
For whatever correction technique, accuracy of metrology is a limit to the achievable slope error



Simulation of the achievable slope error with 2 actuators, as a function of the measurement error.



Mirror figure measured by the pencil beam method matches the profile optimized to 55 nrad at the Alba-NOM 2 years ago.

Conclusions

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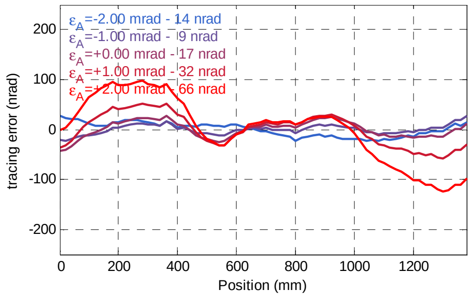
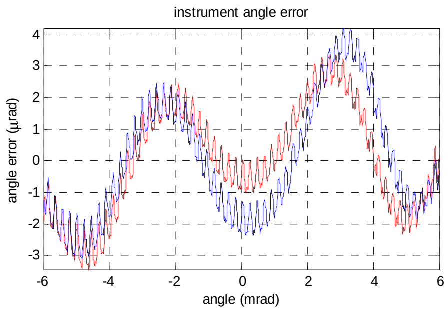
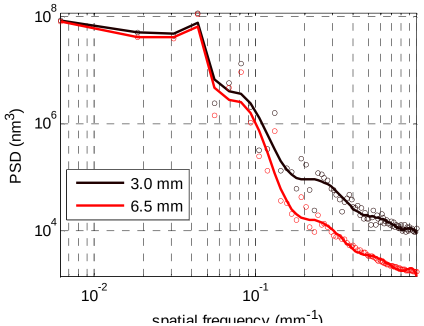


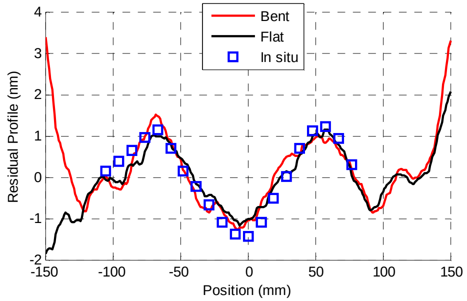
Positioning error correction (LUT) and accurate pentaprism allow reducing the bench induced error to the few nanoradian



The usage of redundant-independent datasets allow an accurate modeling of the optics induced error.



Using them, also allows reducing the iris aperture, to increase spatial resolution preserving accuracy.



The measurements provided by the NOM are accurate enough to optimize the mirror figure to nanometer accuracy

Acknowledgements

Computing and Controls	**Zbigniew Reszela**
	Sergi blanch
	Guifré Cuní
	Tiago Coutinho
	Sergi Pusó
Algorithms	**Juan Campos (UAB)**
Engineering	**Claude Ruget (CRC)**
	Carles Colldelram
	Ricardo Valcárcel
	Jordi Iglesias
Technicians	**José Ferrer**
	David Calderón
	Pablo Jiménez
Administration	**Laura Campos**
XALOC beamline	**Jordi Juanhuix**

Thank you for your attention