The Diamond-NOM: a non-contact profiler capable of characterizing optical figure error with sub-nanometre repeatability

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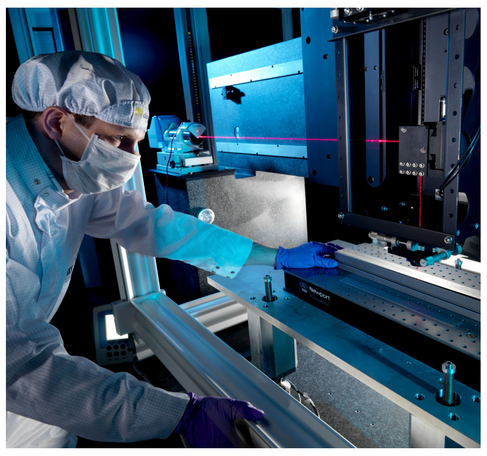
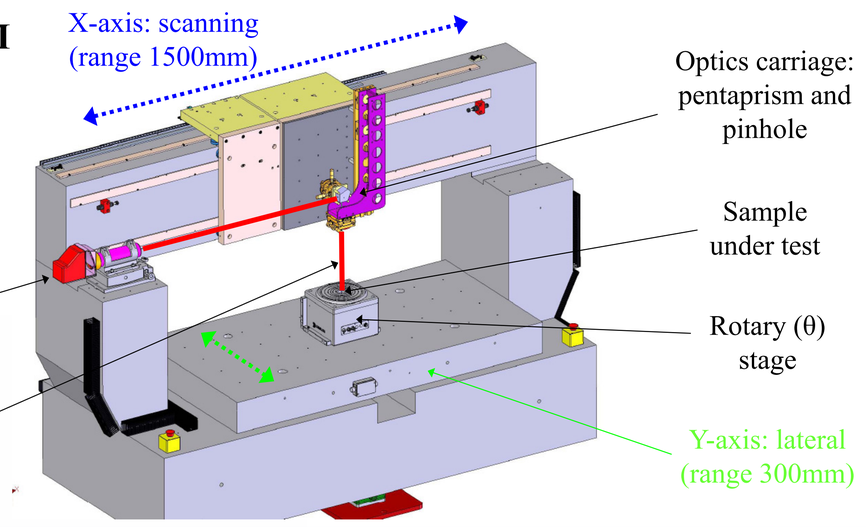
Introduction

Diamond-NOM (Nanometre Optical Metrology) [1]

- Non-contact, slope measuring profiler
- Slope error repeatability <50nrad rms
- Sub-nanometre (~0.25nm rms) height repeatability
- Scanning length 1500m
- Load capacity 150kg
- Thermal stability ~0.001°C over 5 hours
- BESSY-NOM concept [2] is robust & transferable



Diamond-NOM

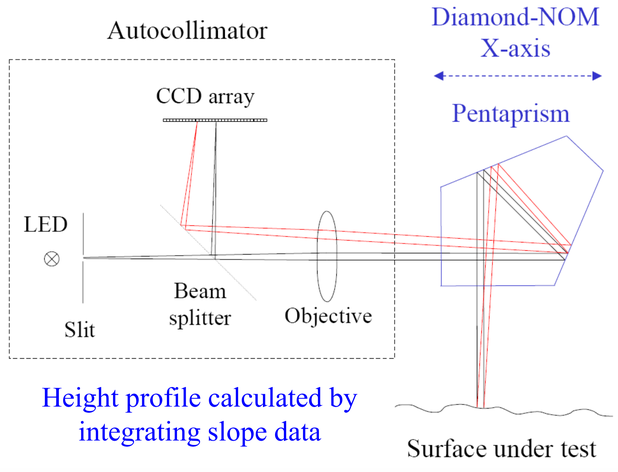


Deflectometry principle

- Autocollimator (AC) beam (~3mm) records local deflection angle of surface under test
- AC beam scanned using computer controlled stages & pentaprism to determine global slope profile

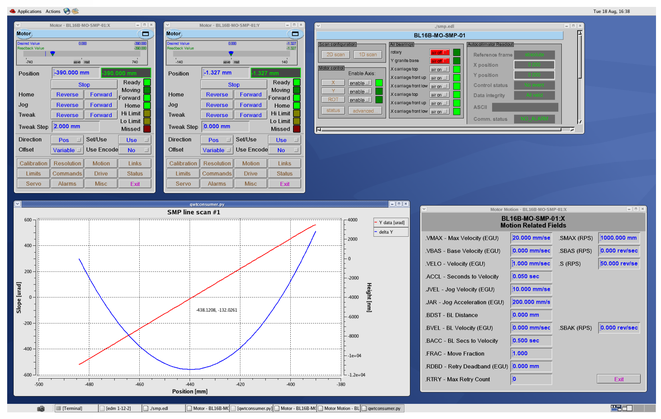
AC (Elcomat3000) specifications

- LED source (λ=660nm)
- Two, CCD-line arrays
- Angular range ±5mrad (2 axes)
- Resolution ~20nrad (multiple slits & sub-pixel interpolation)



Motion controls

- Three degrees of motion: X (scanning), Y & θ (lateral translation & rotation of optic under test)
- Linear servo motors (low heat output) on air-bearing stages with Heidenhein encoders
- Delta Tau Turbo PMAC "Clipper"
- EPICS interface to communicate with motors and AC
- 0D (point stability), 1D (line), or 2D (area) scans
- Data collection in discrete (step) or continuous (fly) modes
- Automated sequential scanning (Jython scripts) & stitching
- Data visualisation & analysis tools



Height / slope profiles Motor parameters

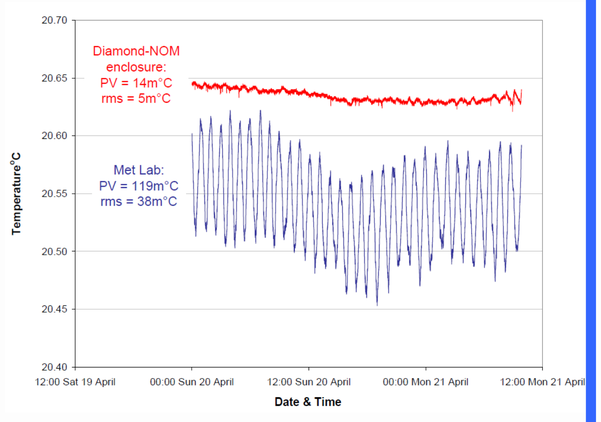
Experimental

- Excellent mechanical stability (granite ~5500kg)
- Located in Optics & Metrology cleanroom (class 10,000 - ISO7) [3]
- Active control of temperature in the cleanroom (<0.1°C rms), and housed in an insulating enclosure

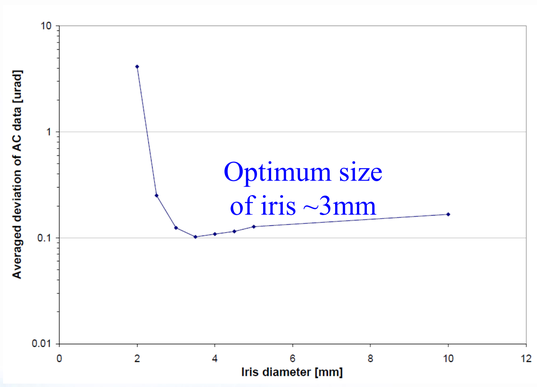
Temperature stability <10m°C required for sub-nanometre precision measurements

Diamond-NOM temperature stability:

- <5m°C rms over ~36hrs
- ~1m°C rms over ~5hrs



- Calibrated iris defines AC beam
- Measure standard deviation of 10 AC readings (data rate ~25Hz). Repeat 100 times and calculate average standard deviation. Repeat for range of iris diameters
- "Noise level" of each set of 10 AC readings ~100nrad rms
- Noise can be statistically reduced by collecting more AC readings at each scan point, or by averaging several scans



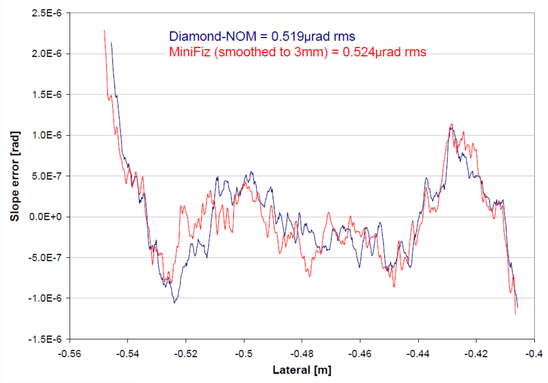
Results

The Diamond-NOM has characterised and optimised a wide variety of optics (including (piezo bimorphs and mechanically bent optics) prior to beamline installation.

Comparison with Fizeau interferometer

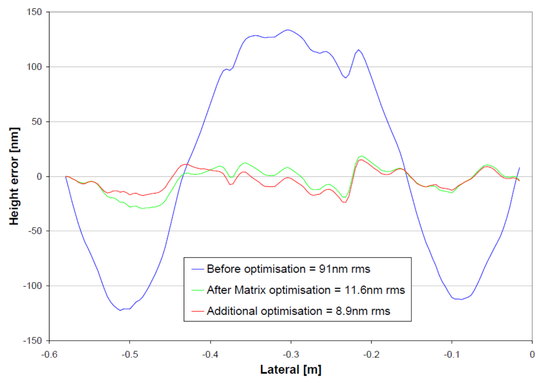
MiniFiz150 with λ/100 reference flat

~5nrad difference in optical slope error

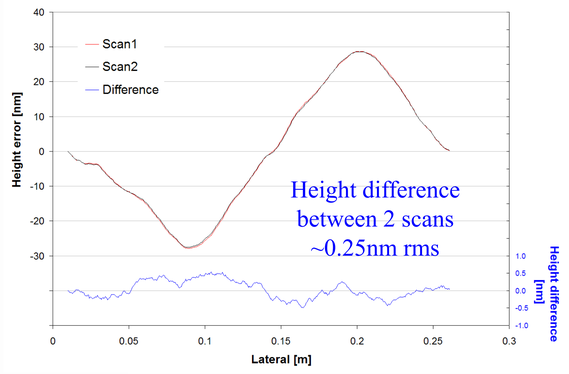


Optimising a 550mm long, bimorph optic

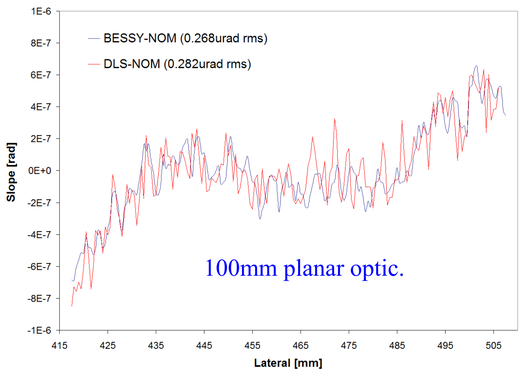
- Slope error: 1.7µrad → 0.66µrad rms
- Height error: 91nm → 9nm rms



Height repeatability of Diamond-NOM



Comparison with BESSY-NOM



[1] S. G. Alcock, K. J. S. Sawhney, S. Scott, U. Pedersen, R. Walton, F. Siewert, T. Zeschke, F. Senf, T. Noll, and H. Lammert, "*The Diamond-NOM: a non-contact profiler capable of characterizing optical figure error to sub-nanometre precision*", To be published in Nuclear Instrument and Method A, 2009

[2] F. Siewert, T. Noll, T. Schlegel, T. Zeschke and H. Lammert, AIP Conference Proceedings 705 (2004) 847-850.

[3] S. G. Alcock and K. J .S. Sawhney, Proceedings of SPIE: Advances in Metrology for X-Ray and EUV Optics II (2007) 6704.

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