Metrology testing of bimorph mirrors at Diamond Light Source

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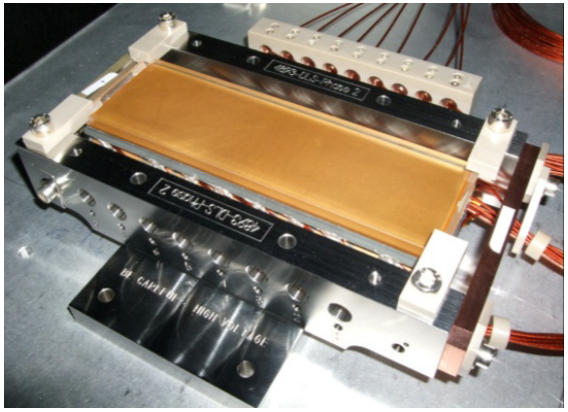
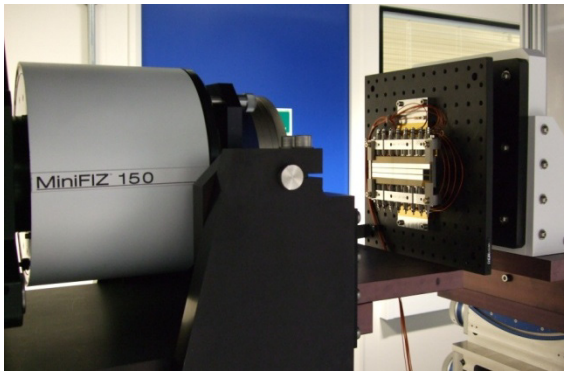
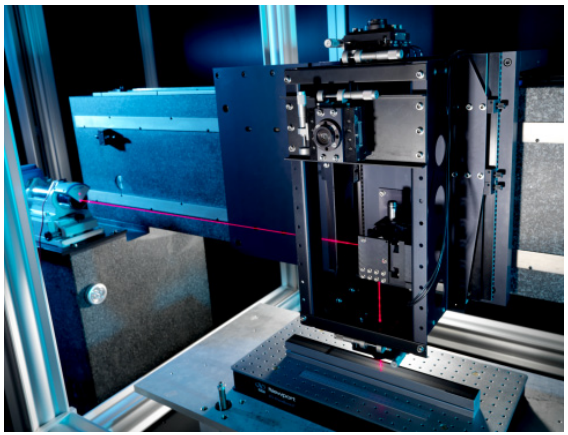
diamond





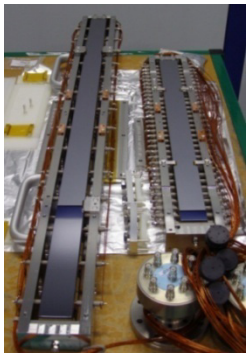


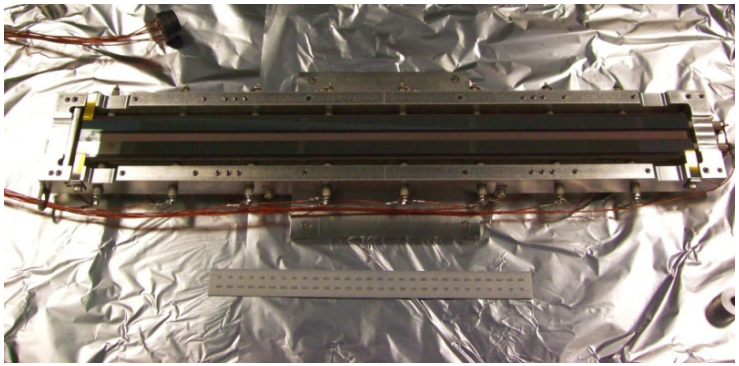
Overview

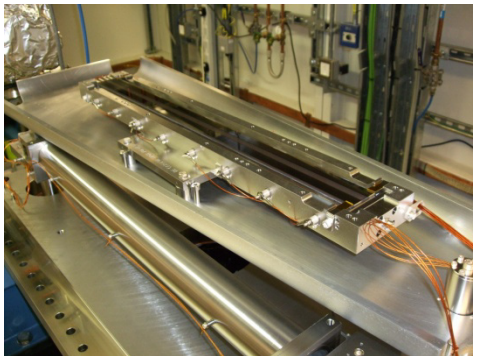
- Motivation
- Strategy
- Metrology instruments
- Results
- Conclusions

Motivation

- Mirror performance limited by figure errors (mm's → L):
  - Polishing defects
  - Gravitational sag
  - Mounting strains
  - Thermal bumps induced by high powered photon beams
- How can figure errors be reduced? Use bimorph technology!







Piezo power!

- By applying appropriate voltages to the bimorph piezos, overall figure and localised figure errors are dynamically corrected to create a well defined photon beam

Bimorph mirrors have exceptional potential
…but how can this be harnessed?

- Many degrees of freedom?
- How do the piezos behave?
- Quick & easy optimisation would be nice!

Metrology strategy at Diamond

Accurate measurement of surface topography is required as input to correct active optics

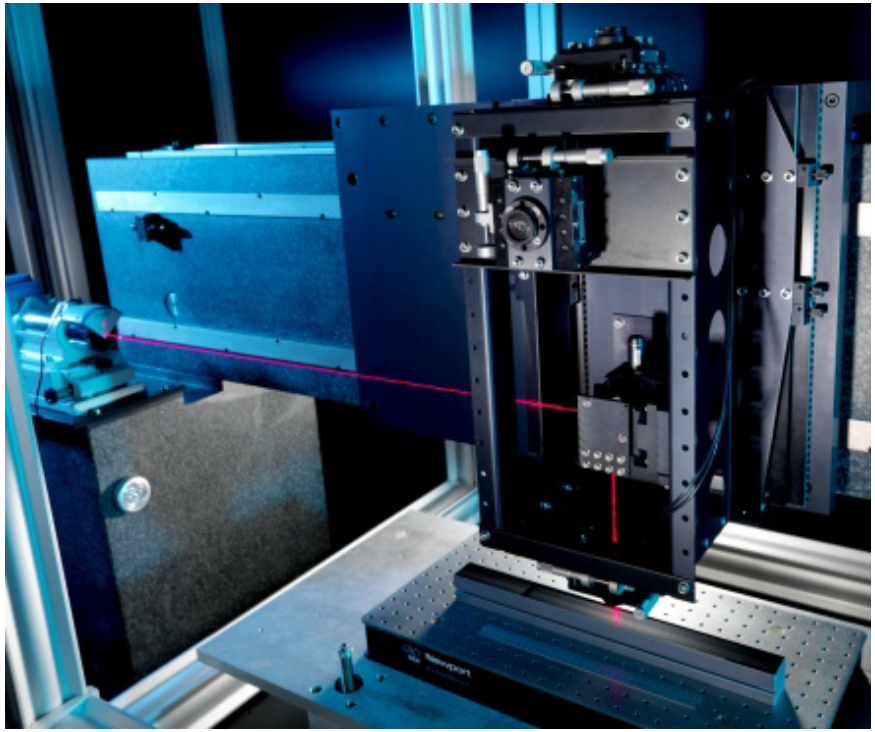
- **Ex-situ (metrology cleanroom)**
  - Diamond-NOM (slope error) [Simon Alcock - poster]
  - MiniFiz Fizeau (3D figure & dynamics) [Geoff Ludbrook - posters]
- **In-situ (beamline)**
  - Pencil beam method & X-ray eye camera [John Sutter - talk]
  - Shearing interferometry [Hongchang Wang – talk]
  - EEM bimorph & Test beamline (B16) [Kawal Sawhney – talk]

Ex-situ metrology

- Diamond-NOM and MiniFiz150 Fizeau interferometer optimise slope / figure errors of active, synchrotron mirrors
- With recent hardware upgrades, can accommodate fully mounted, optical assemblies in their intended beamline orientation
- Significant amounts of synchrotron beamtime can be saved by ex-situ optimisation of active optics, prior to beamline installation
- Sub-nm repeatability levels of Diamond-NOM provide information which is not easily measured at the beamline

Tour of Metrology cleanroom lab & B16 on Monday afternoon

Diamond-NOM



- Non-contact, slope measuring profiler
- Scan range: 1500mm x 300mm
- Slope errors <100nrad rms
- Sub-nm repeatability
- Upward or side facing acquisition
- Thermal stability <10m°C
- 1st replication of BESSY-NOM concept

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

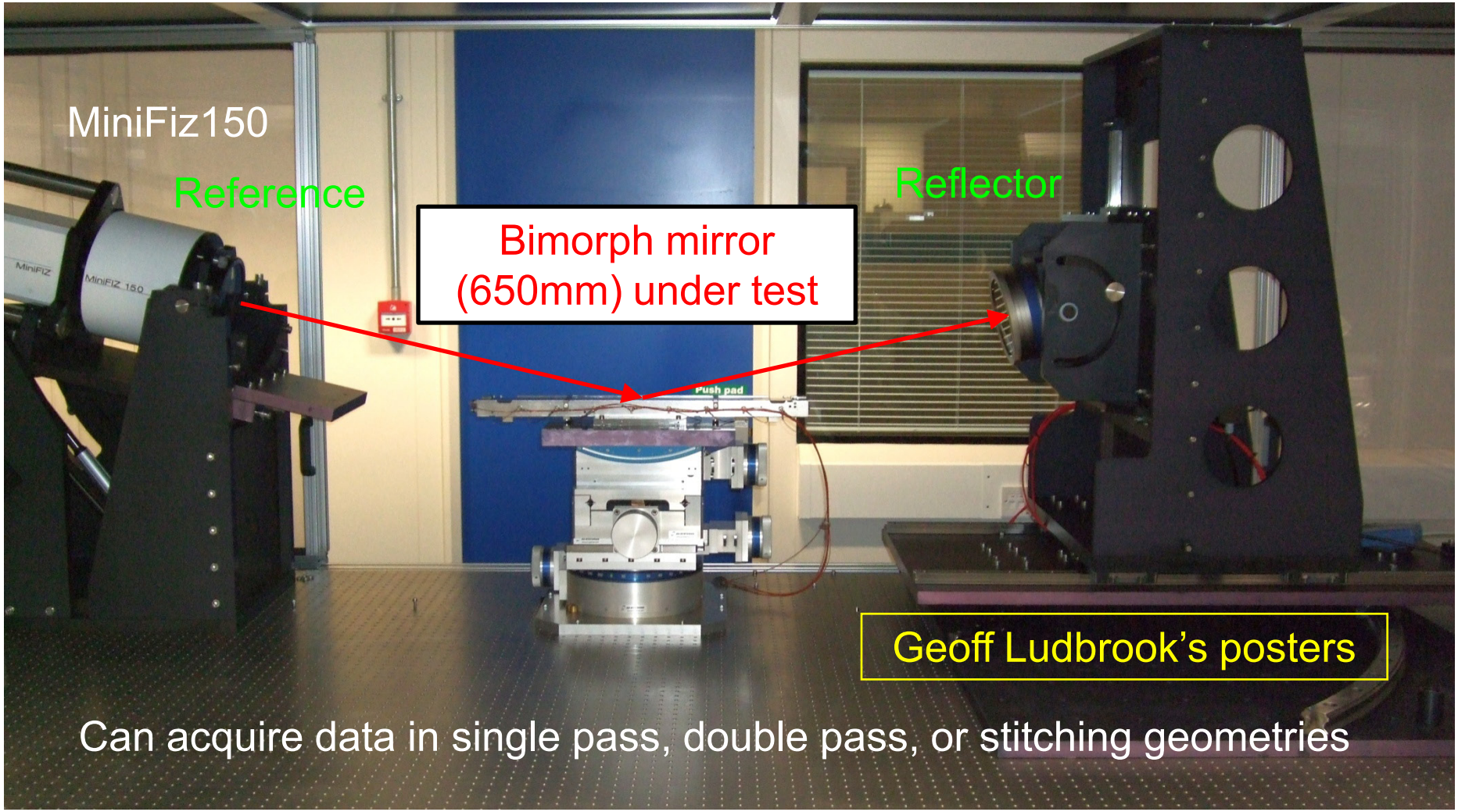
S. G. Alcock, K. J. S. Sawhney, S. Scott, U. Pedersen, R. Walton, F. Siewert, T. Zeschke, F. Senf, T. Noll, and H. Lammert.

Nucl. Instr. and Meth. A, Volume 616, Issue 2-3, p. 224-228 (2010)

“MiniFiz” Fizeau interferometer

“A double-pass Fizeau interferometer system for measuring the figure error of large synchrotron optics”

G. D. Ludbrook, S. G. Alcock, S. Scott, Proc. SPIE 7801 (2010).



Results

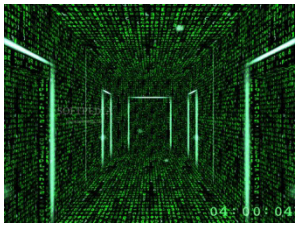
Diamond-NOM & MiniFiz

- Super-polished (EEM) VFM, 150mm
- Re-polished VFM (I04), 600mm
- HFM (I18),150mm

- Piezo response functions & matrix correction method
- Dynamic evolution of surface in response to piezo voltage changes
- Stability & reproducibility of curvature

High quality metrology → better optical performance!

Enter the Matrix!

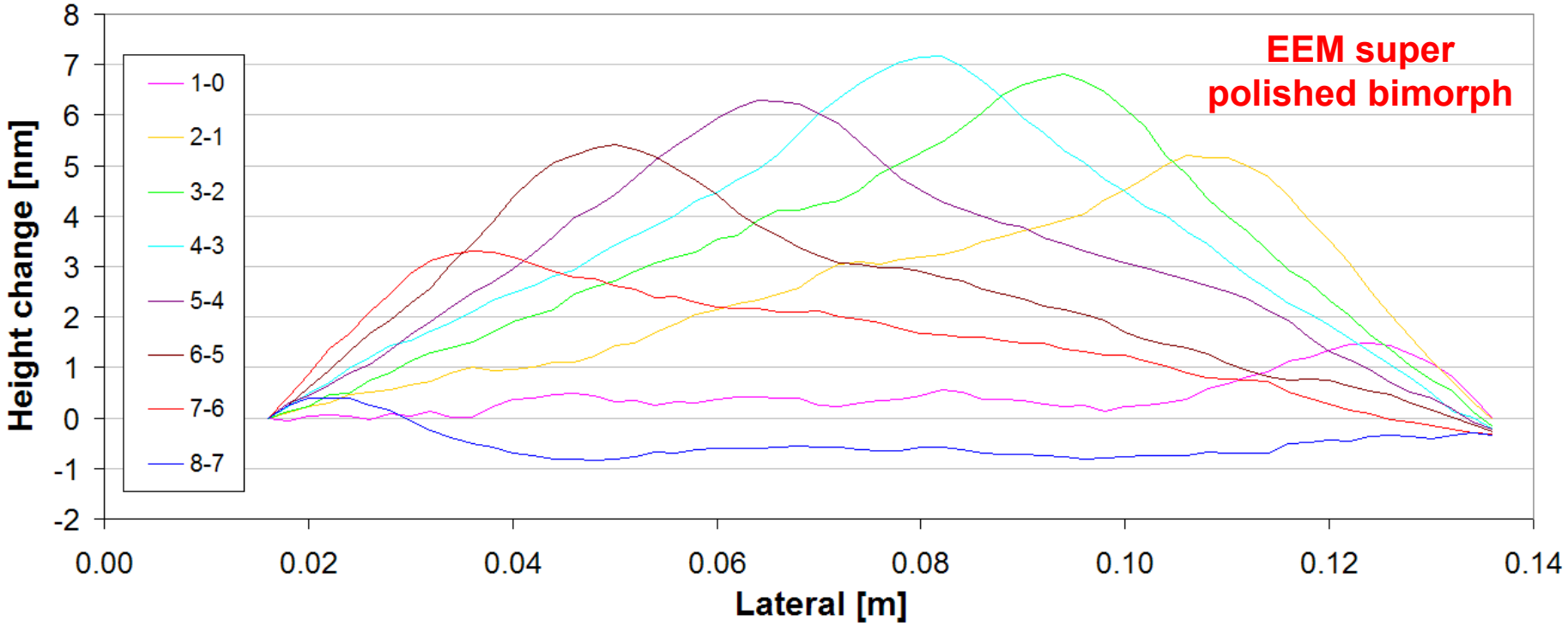


- Piezo response functions gives complete control over bimorph
- Matrix inversion method predicts required voltage corrections

Piezo response functions

- Assess how piezos respond to applied voltage (+25V)

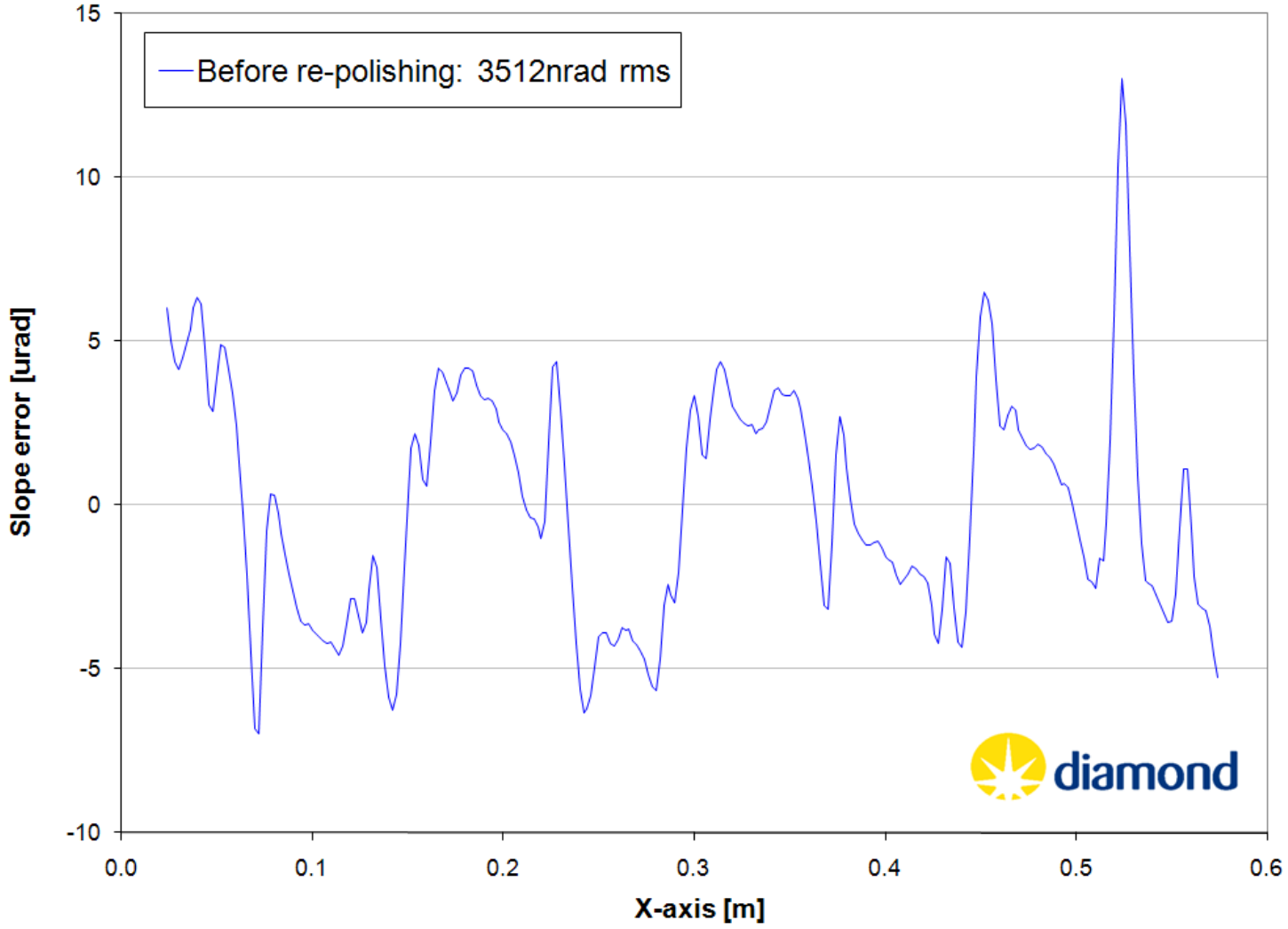
→ Matrix gives figure corrections & bend parameters



Sub-nanometre figure control using Diamond-NOM

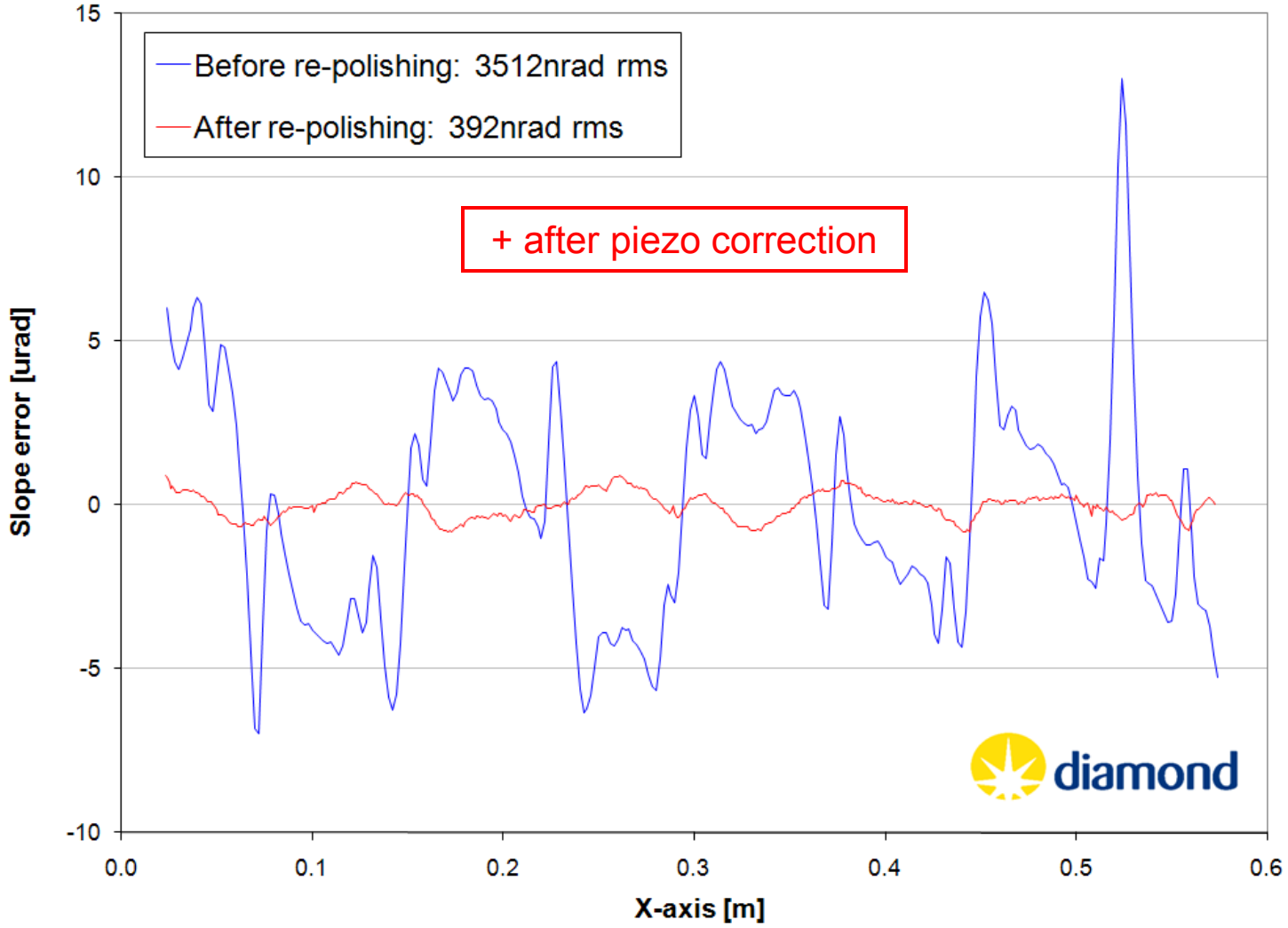
Repolished bimorph mirror

- Large slope “spikes” (>10urad PV) at interface between piezos



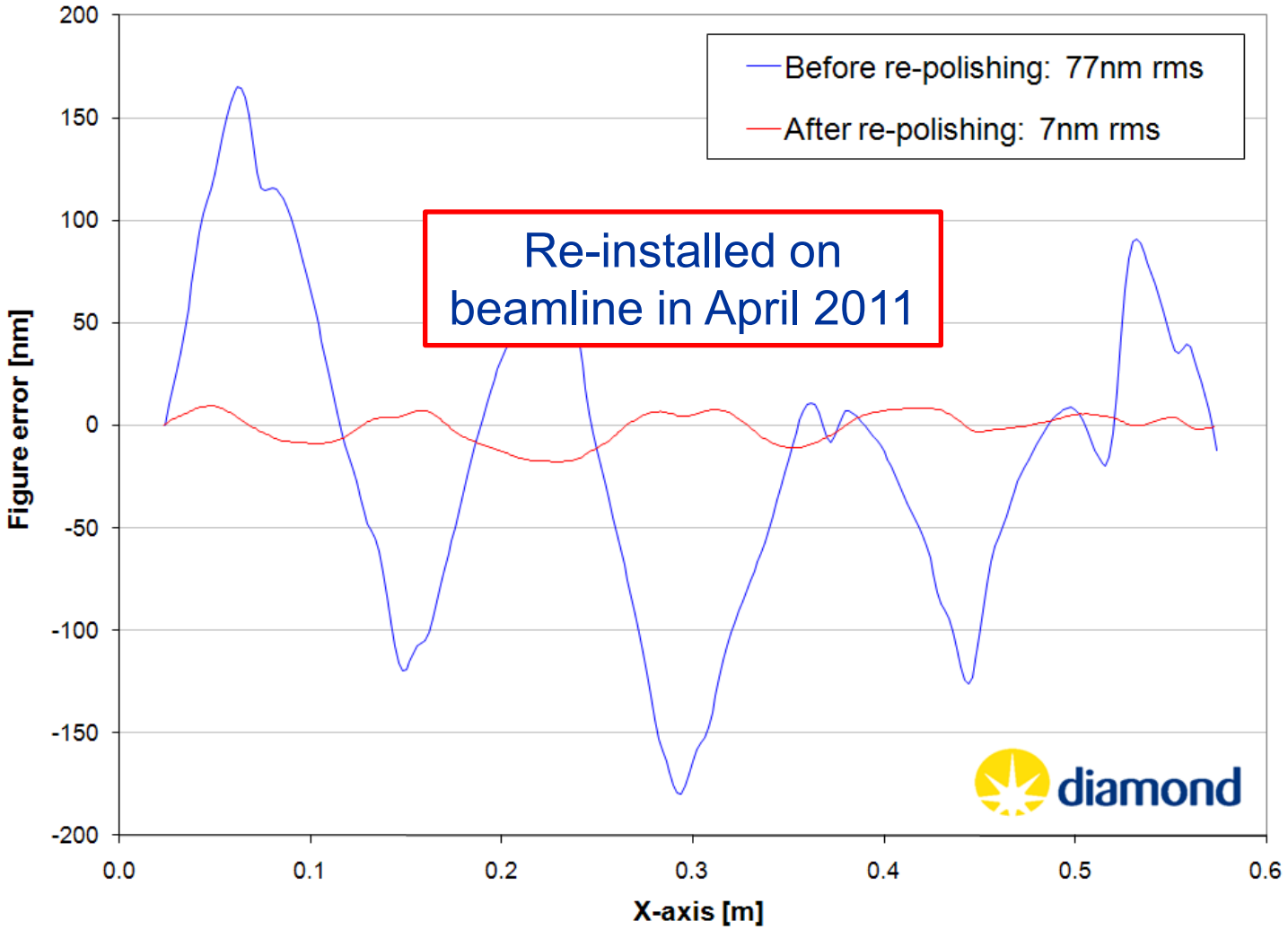
Repolished bimorph mirror

- After repolishing at SESO, slope error = 3512nrad → 392nrad rms



Repolished bimorph mirror

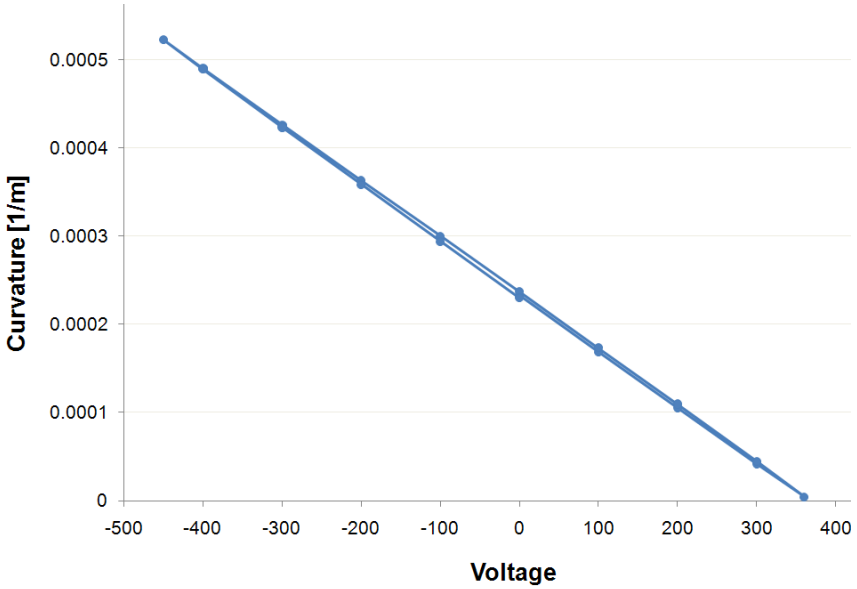
- "Saw tooth" figure errors removed by repolishing



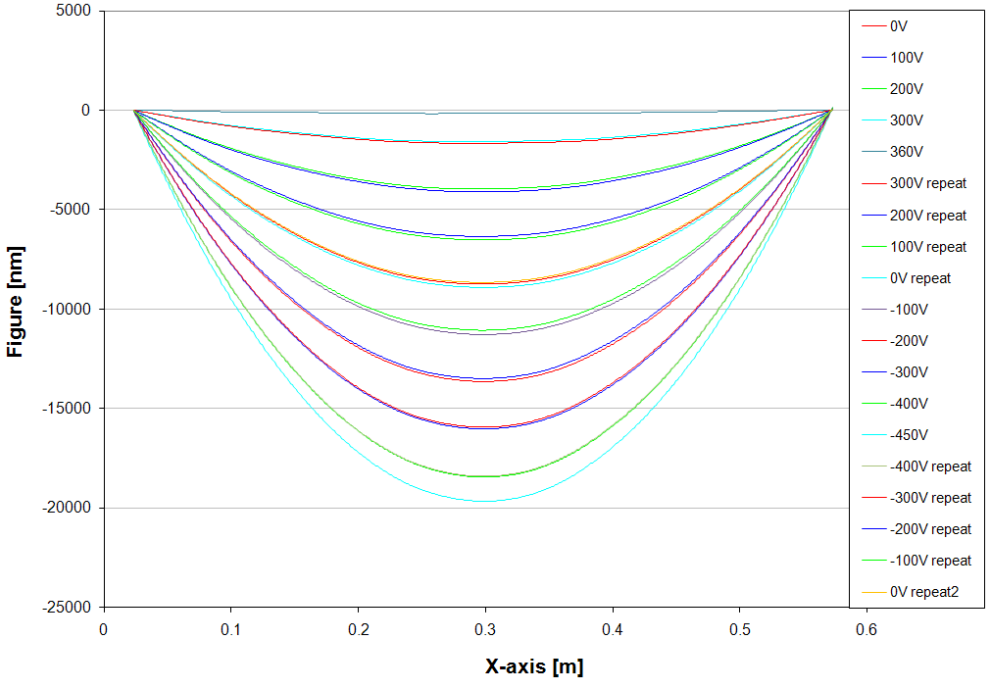
Bend performance

- Use Diamond-NOM to measure figure and curvature as a function of applied voltages

Very low hysteresis

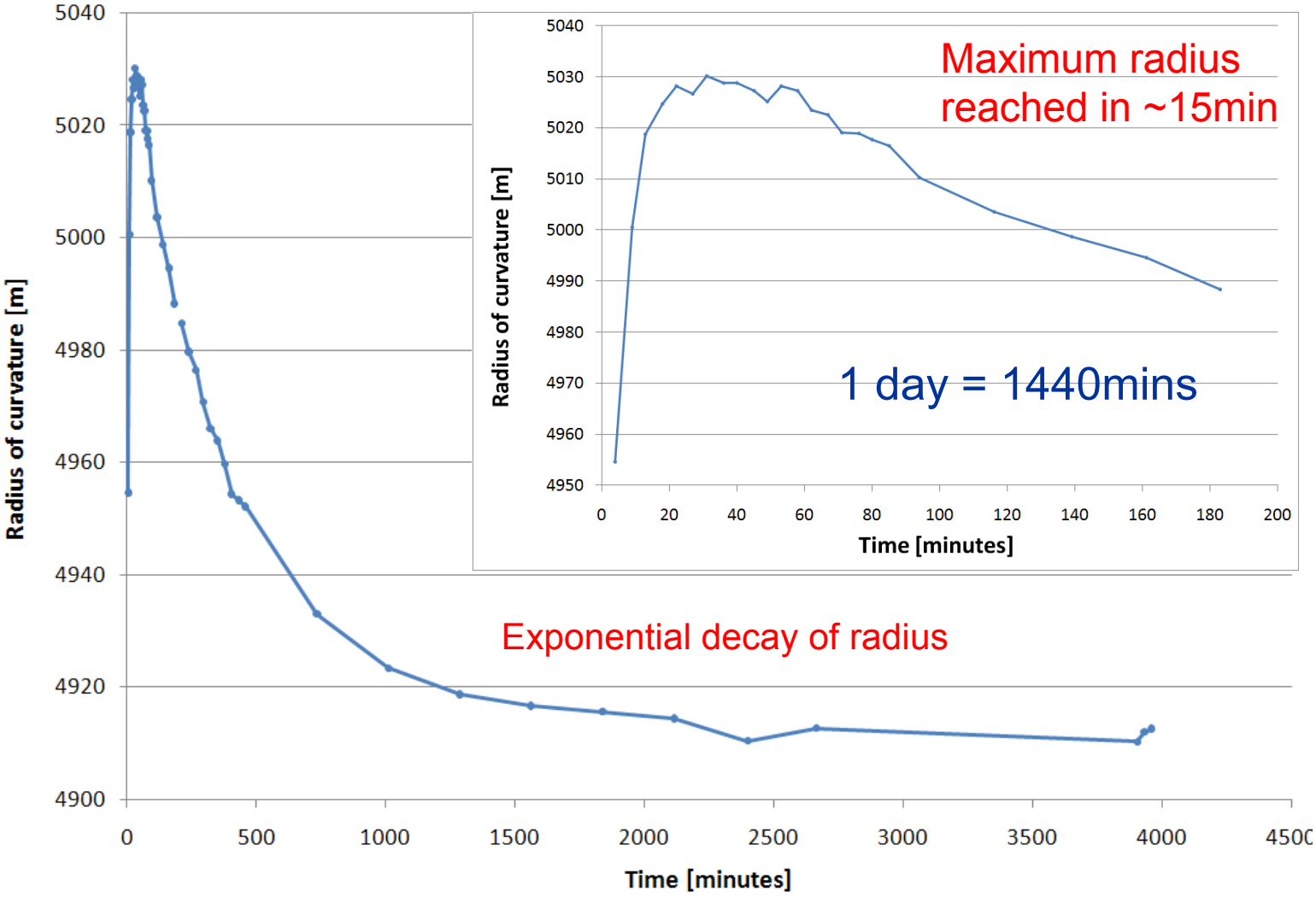


Reproducible figure



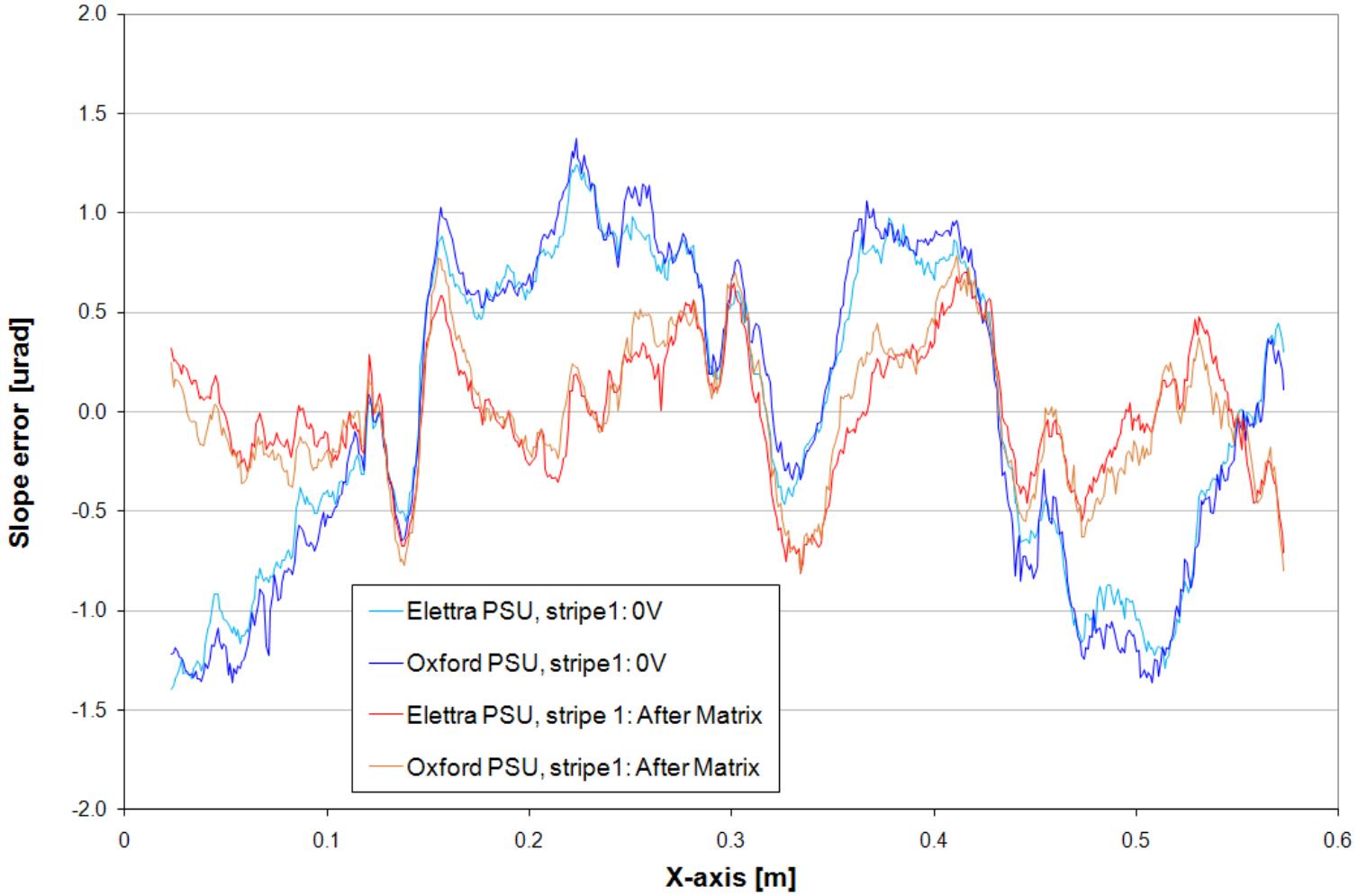
Dynamics of bimorphs

- Apply voltages and record curvature (4min for each Diamond-NOM scan)



Power supply comparison

- Two different power supplies give very similar slope errors



MiniFiz: 2D topography

- Capture 2D topography of mirror surface in <1minute

  → Dynamic effects & enables rapid iterations of modifications

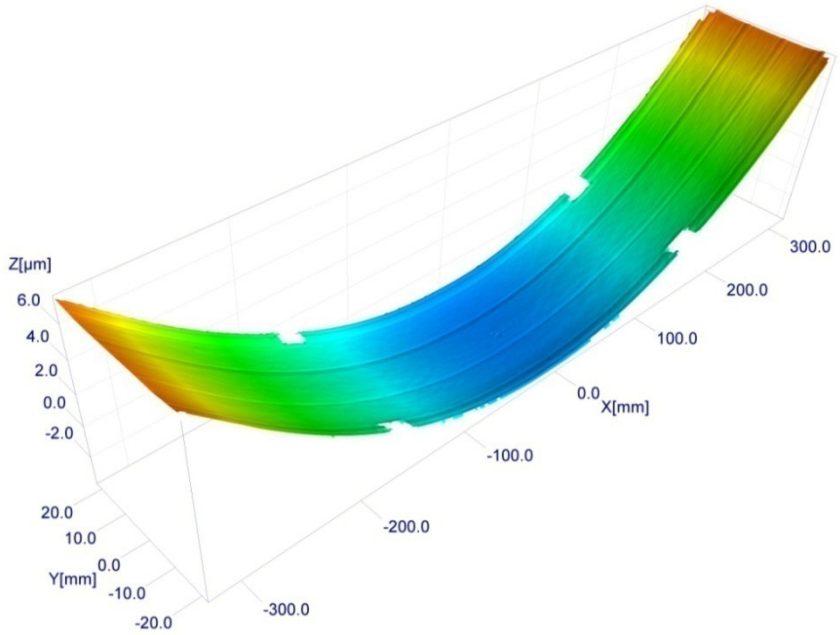


Figure of I04 VFM
(over full surface 650mm)

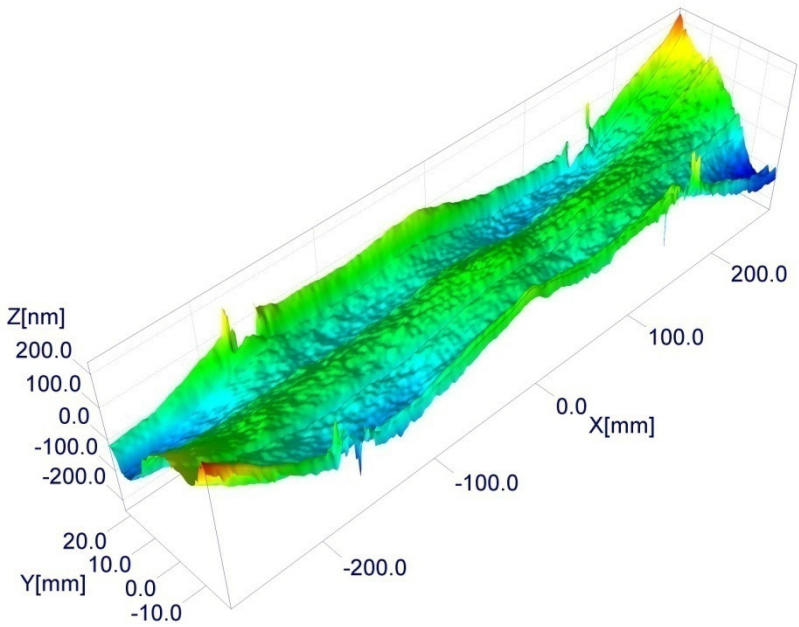
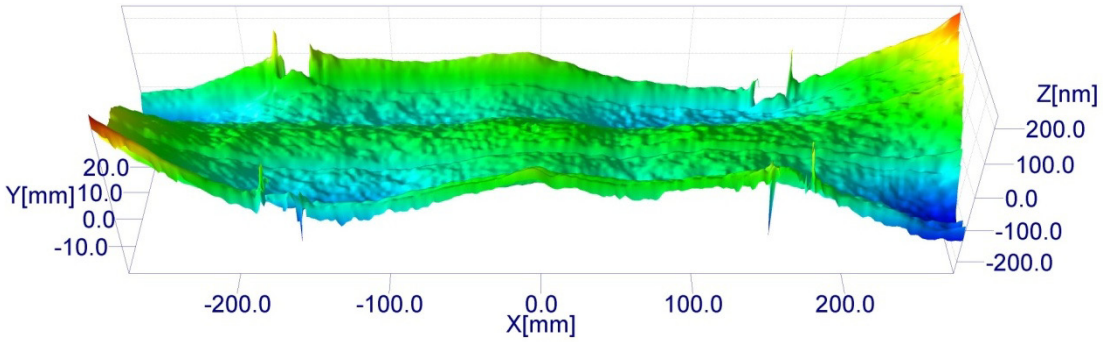
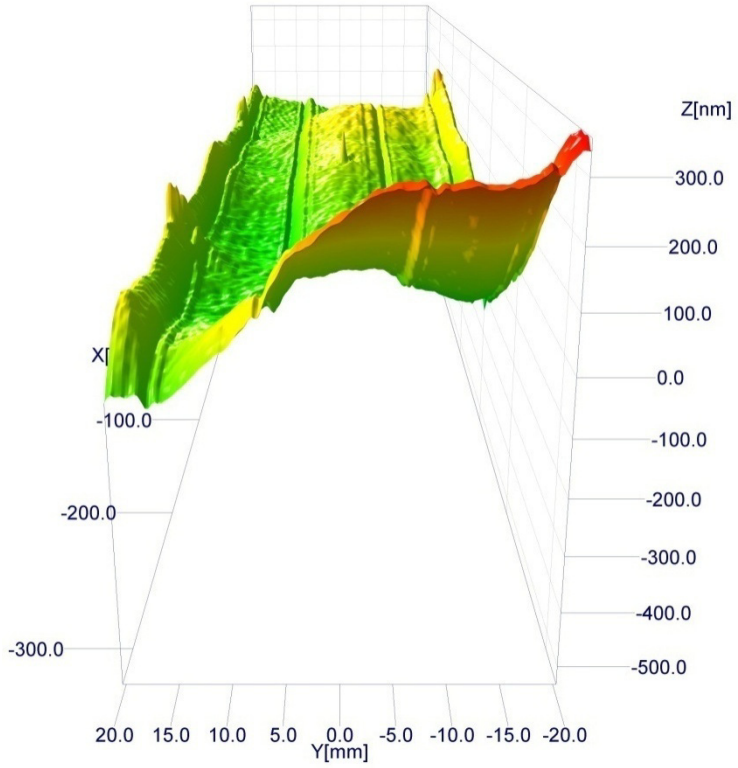


Figure error of I04 VFM
(over active surface 550mm)

MiniFiz: 2D topography

Movies





- MiniFiz scans reveal I04 bimorph mirror is slightly twisted
- Voltages found from Diamond-NOM shown to optimise figure error of each coating stripe

Conclusions

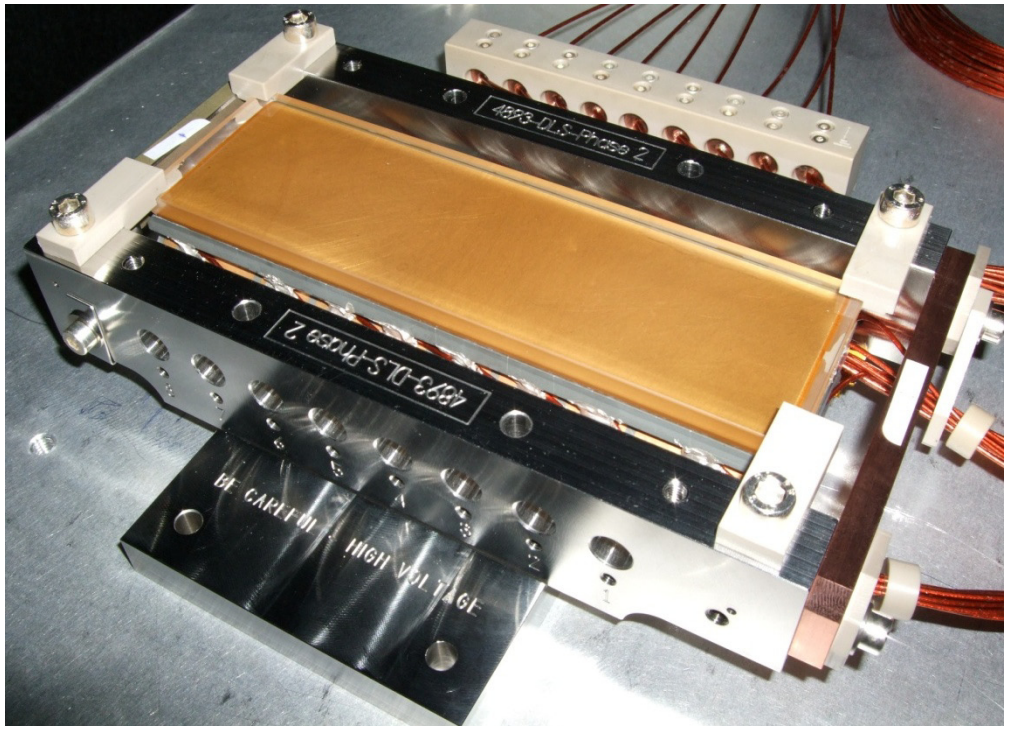
- Comprehensive programme of ex-situ & in-situ methods to investigate active optics
- Suite of ex-situ metrology instruments and protocols to quickly and easily optimise bimorph mirrors
- Metrology instruments can accommodate fully mounted, optical assemblies in their intended beamline geometry

→ *Develop collaborations to push novel active optics to their limits!*

Thank you for your attention! ☺

Super-polished (EEM) bimorph mirror

- 8 piezo bimorph (SESO), 150mm long, silica substrate
- EEM treatment (JTEC) on central ~120mm
- Elliptical pre-figure (p=41.5m, q=0.4m, θ=3mrad)



World's 1st super-polished bimorph mirror

Super-polished (EEM) bimorph mirror

Figure error
<1nm rms

Diamond-NOM

Slope error
~154nrad rms