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MEADOW

MEtrology, Astronomy, Diagnostics and Optics Workshop

Investigation of a Next Generation Piezo Bimorph Mirror

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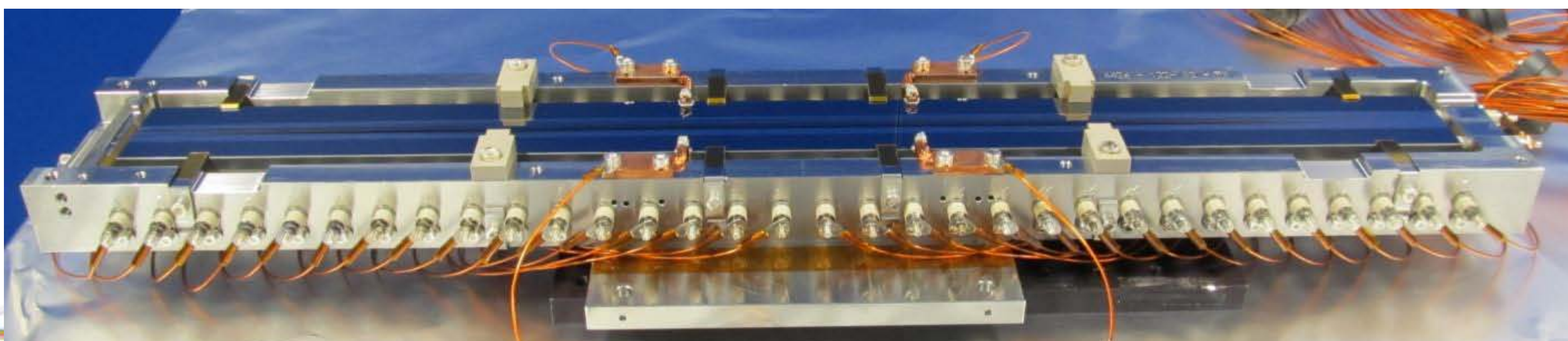
Advantages of bimorph mirrors

- Versatility: can be bent to a range of ellipses to provide variable focal distance or X-ray spot size / shape
- Remove distortions:
  - Polishing
  - Clamping
  - Heat bump
- Correct wavefront errors introduced by other optics or source



Bimorph control and analysis

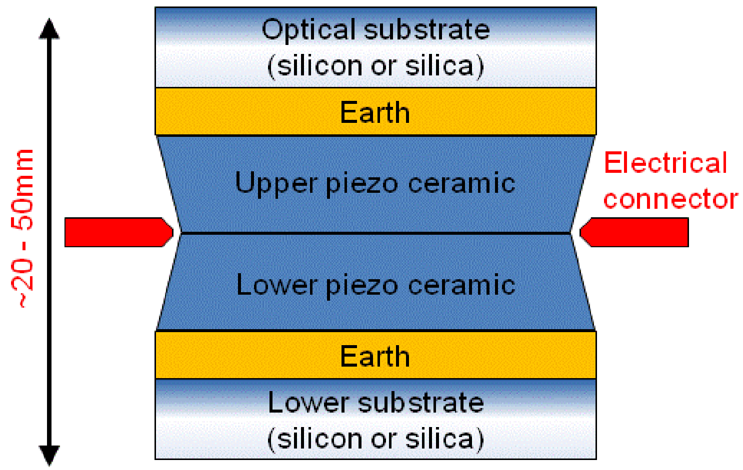
- In-house developed software (EPICS) used routinely at all bimorph beamlines:
  - control of voltages
  - automatic correction (minimise figure / slope errors)
  - defocus beam to given size / shape

- Active research:
  - bend mirror to given ellipse
  - create non-Gaussian beam profile (e.g. top-hat intensity)

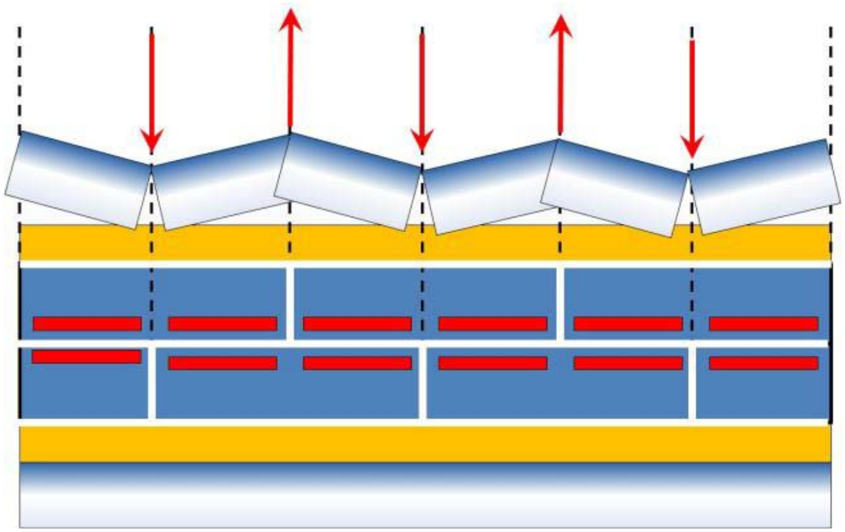
→ Ease of use for beamline teams and users

Old type bimorph mirrors

- Complicated internal structure
- Major problems caused by junction effect [1]



End view

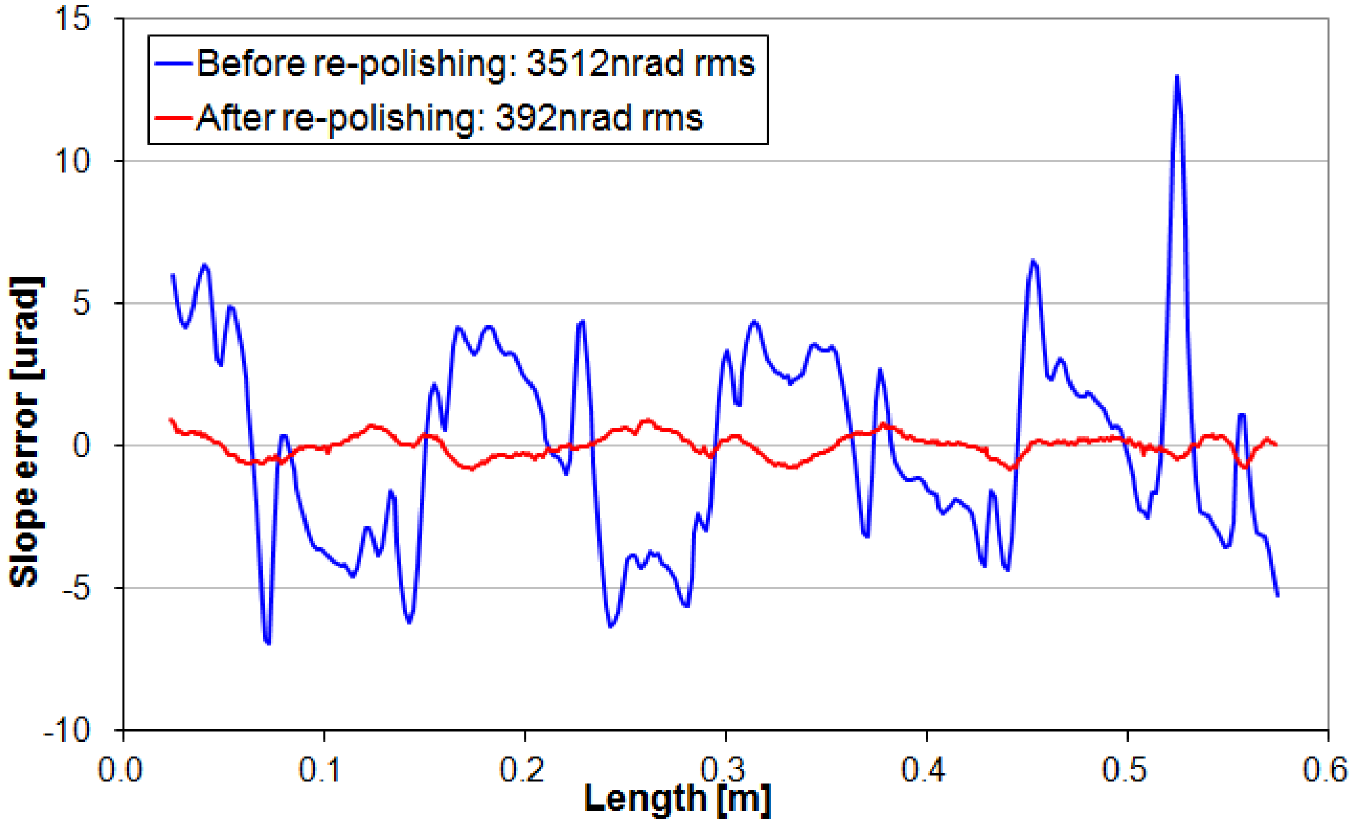


Side view

[1] S. G. Alcock, J. P. Sutter, K. J. S. Sawhney, D. R. Hall, K. McAuley, and T. Sorensen, "Bimorph mirrors: The Good, the Bad, and the Ugly," Nuclear Instruments and Methods A, vol. 710, pp. 87–92, May 2013

Junction effect

- Junction effect removed by repolishing
  - 6 bimorphs successfully repolished + 1 being repolished
  - Much improved slope errors (factor of 10) to below 500nrad
  - Significantly improved size & profile of reflected X-ray beam



Next generation bimorph mirrors

- New design: piezo ceramics glued to side of substrate [2]

✓ Eliminates junction effect

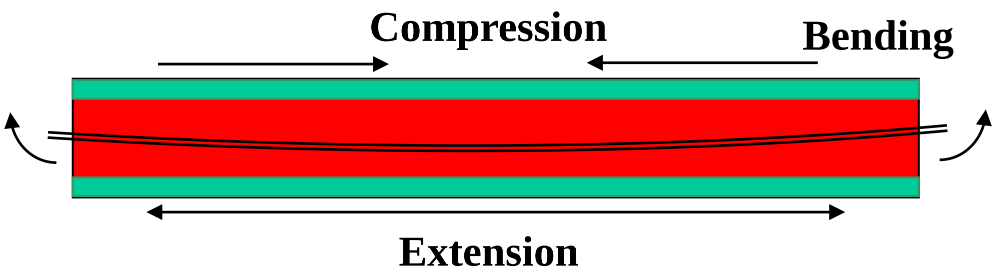
✓ Less expensive

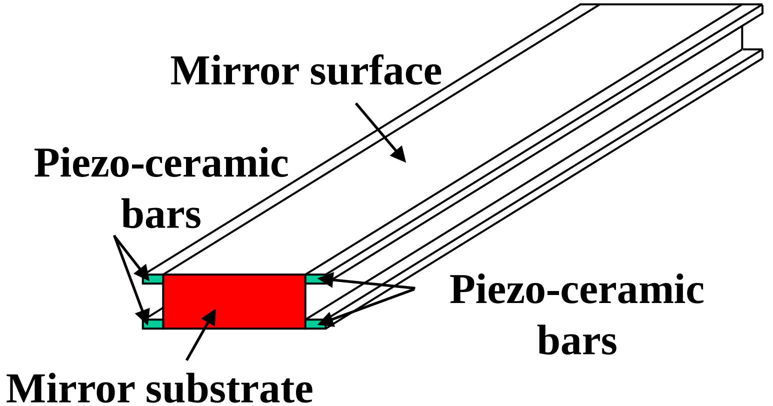
✓ Simpler design

✓ Can be super-polished / ion beam figured

✓ Simple substrate can be ‘bimorphized’

✗ Less responsive → reduced range of bending (?)



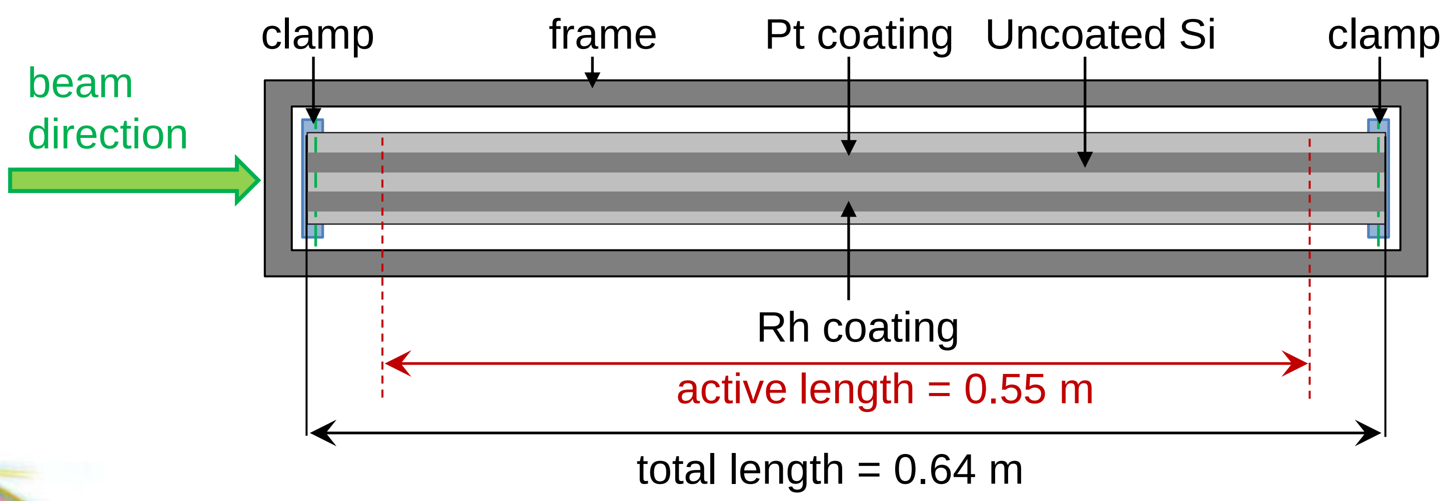


[2] Patent 1000471-05/02/2010

Diagrams courtesy of Thales -SESO

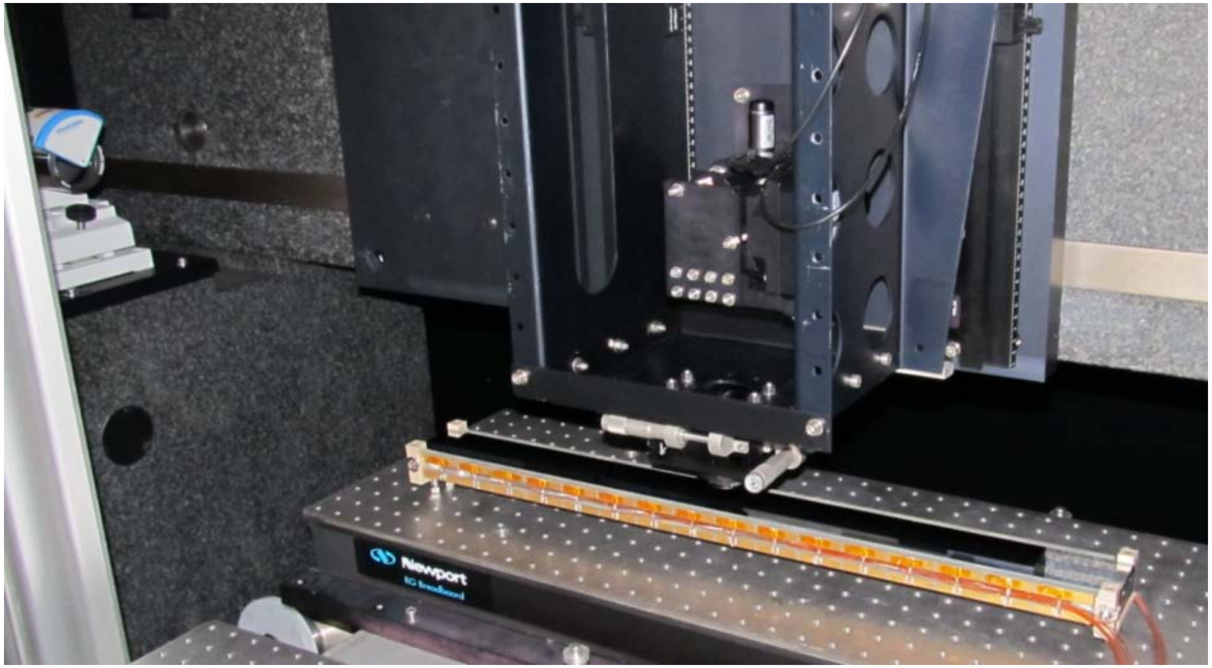
DLS Next Generation bimorph mirror

- Manufacturer: Thales-SESO
- Characteristics:
  - Designed to be used on a range of beamlines
  - Versatile mounting (facing up, down and sideways)
  - 3 active regions: Rh & Pt coating + uncoated Si (central)
  - 16 electrodes



Ex-situ metrology

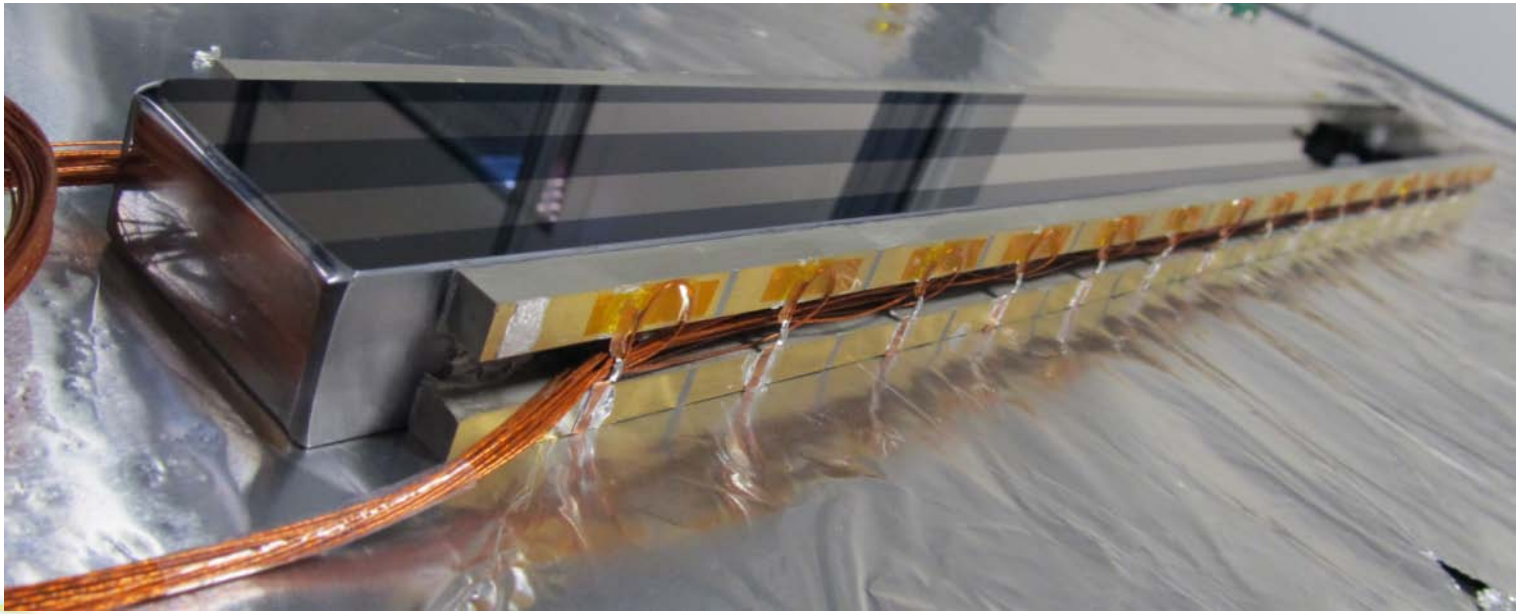
- Diamond-NOM: non contact, slope measuring profiler [3]
- Optical surface facing upwards
- Automated & integrated voltage control & Diamond-NOM scans (EPICS)



[3] 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 with sub-nm repeatability", Nucl. Instr. and Meth. A, Volume 616, Issue 2-3, p. 224-228 (2010)

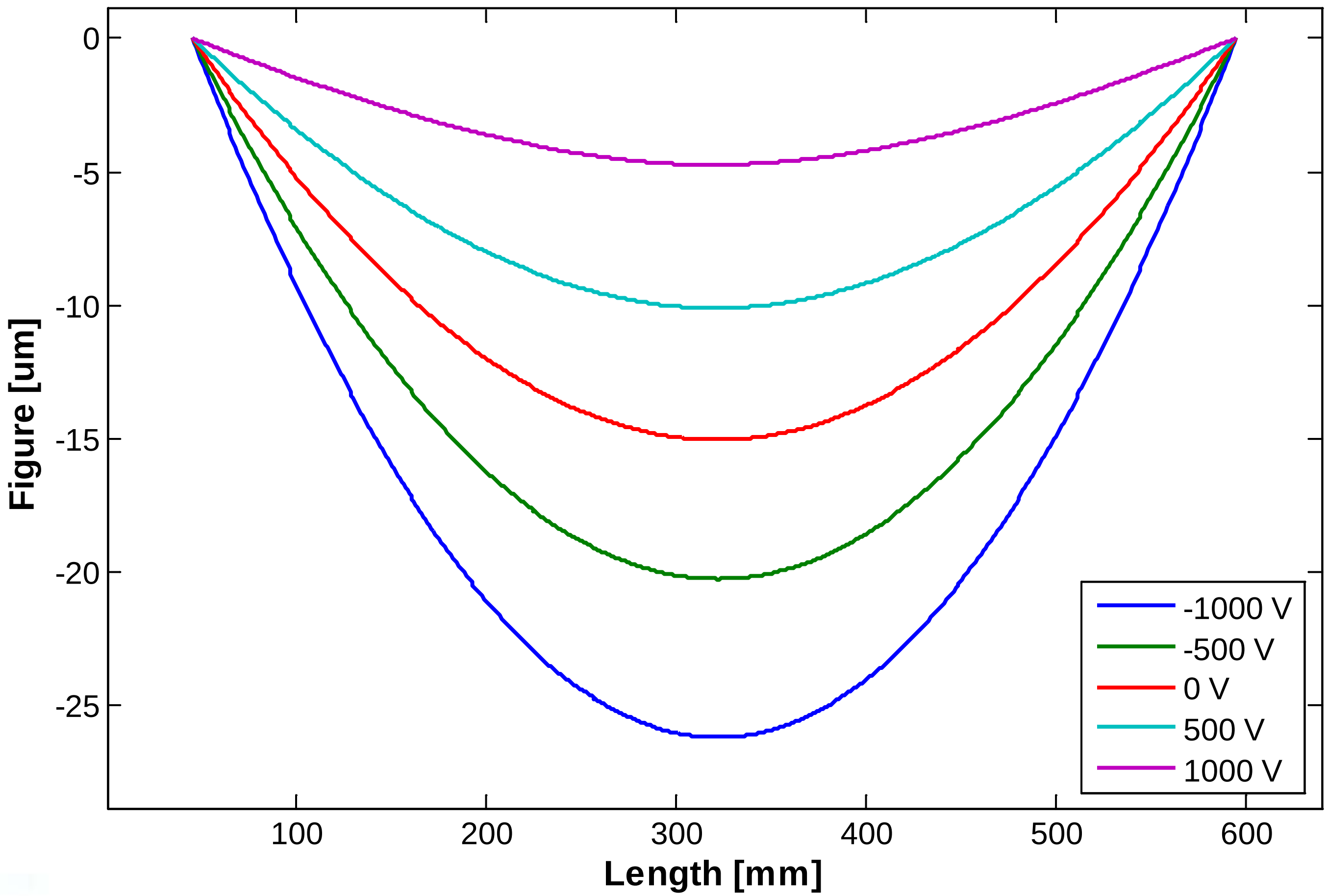
Metrology characterisation

- Bending range of mirror
- Stability of curvature
- Piezo response functions (PRFs)
- Optimisation of slope error using matrix correction method



Bending tests

- Radius of curvature: flat (+1300V) to ~1430 m (-1000 V)



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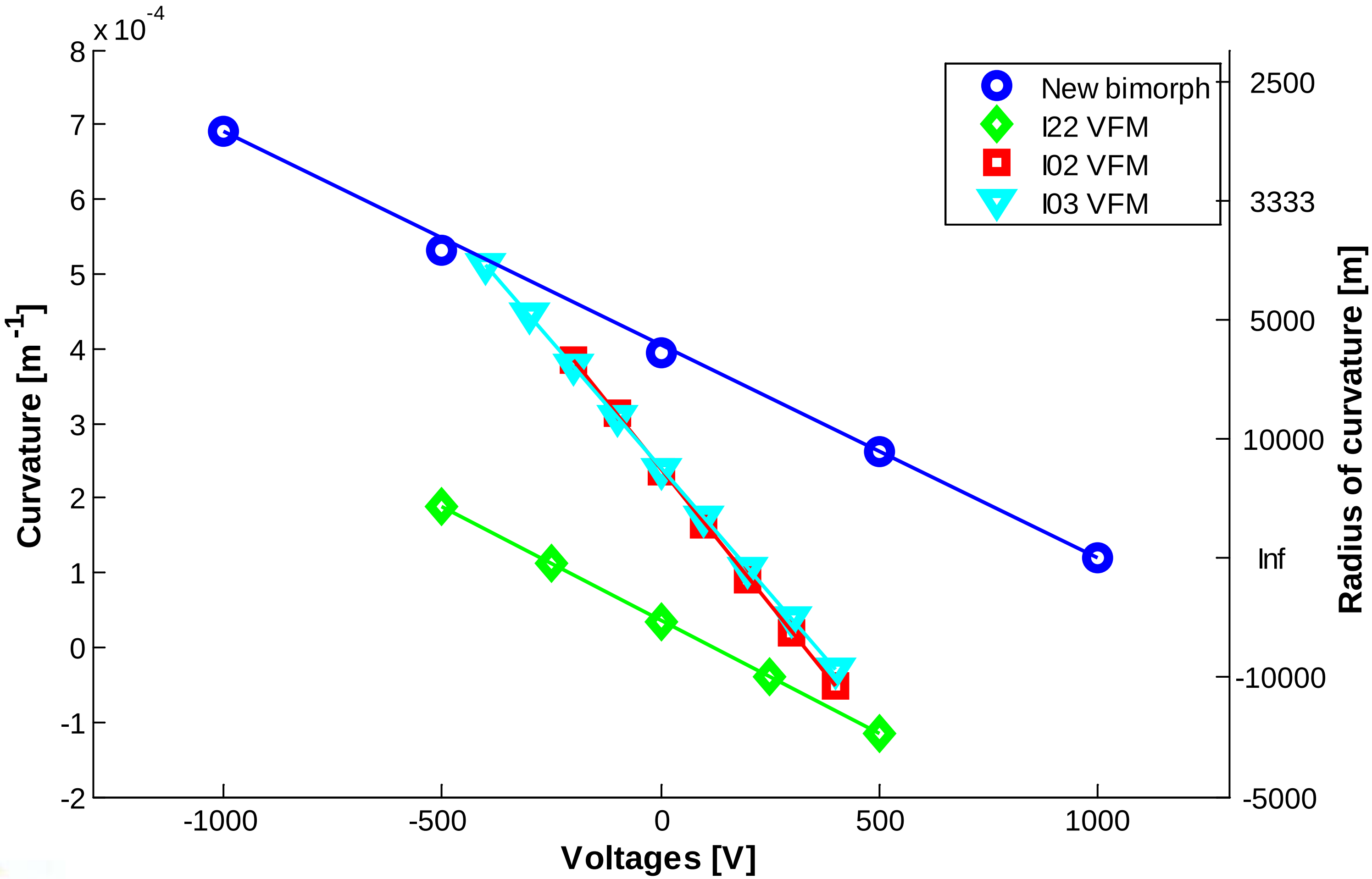
Dynamic range of bending

- Range of bending comparable to thicker, old type bimorphs



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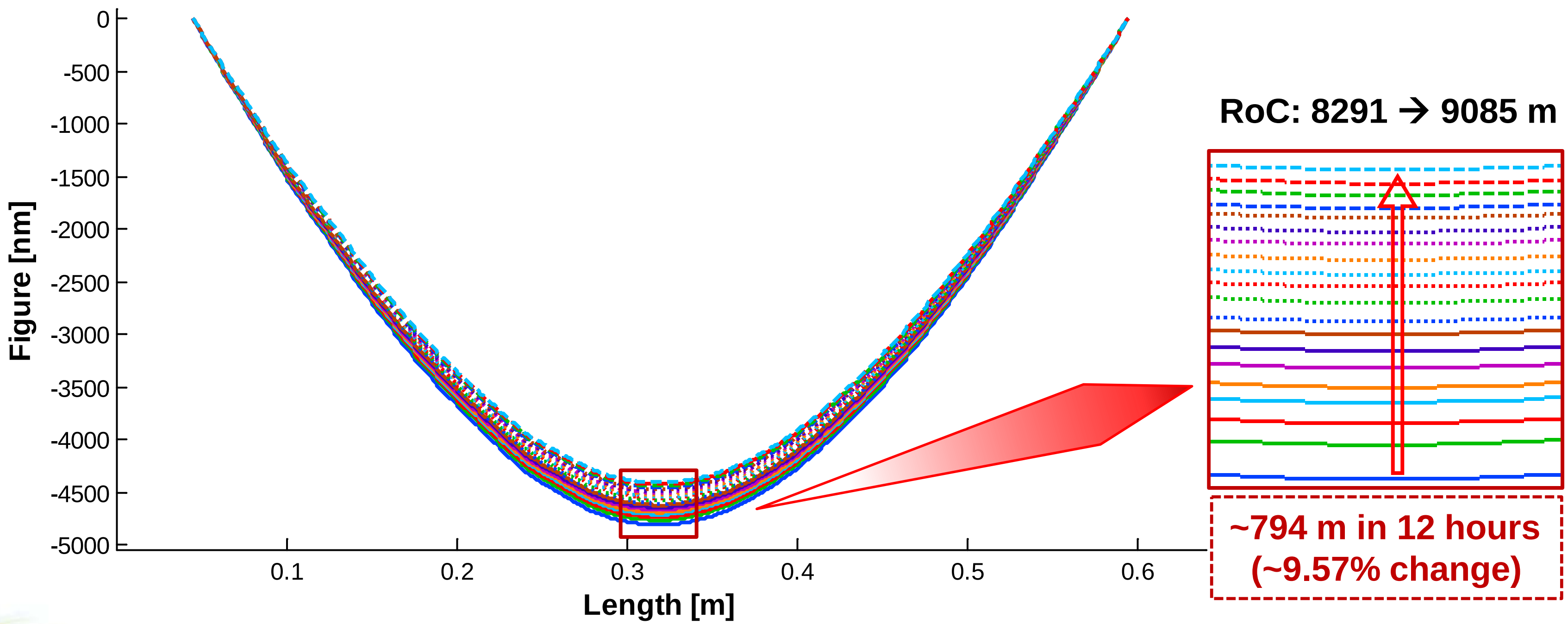
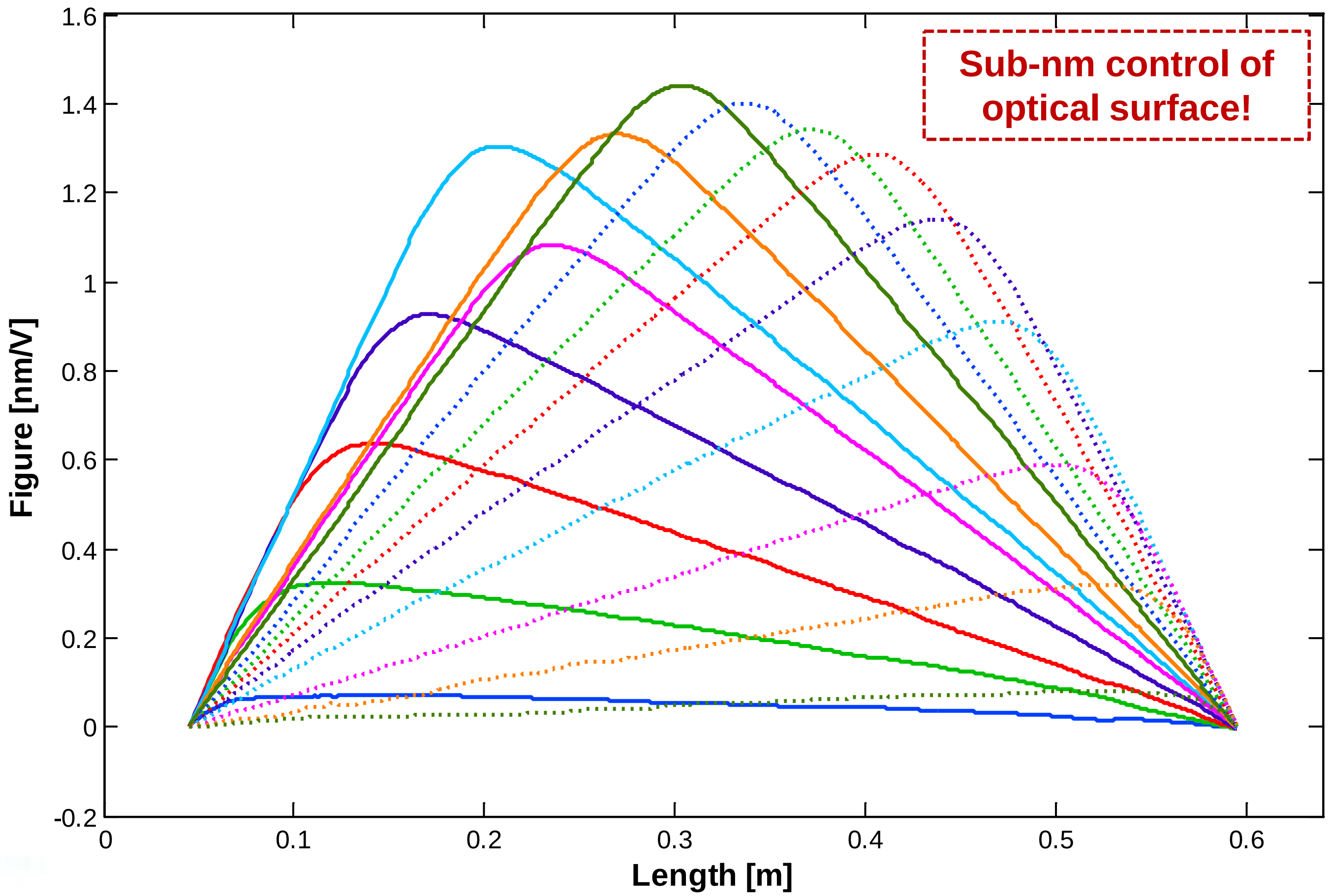
Stability tests

- Monitor curvature over several days at flattest (+1000 V) & most concave situations (-1000 V)
- Significant drift (~10%): piezos overcoming friction from holder



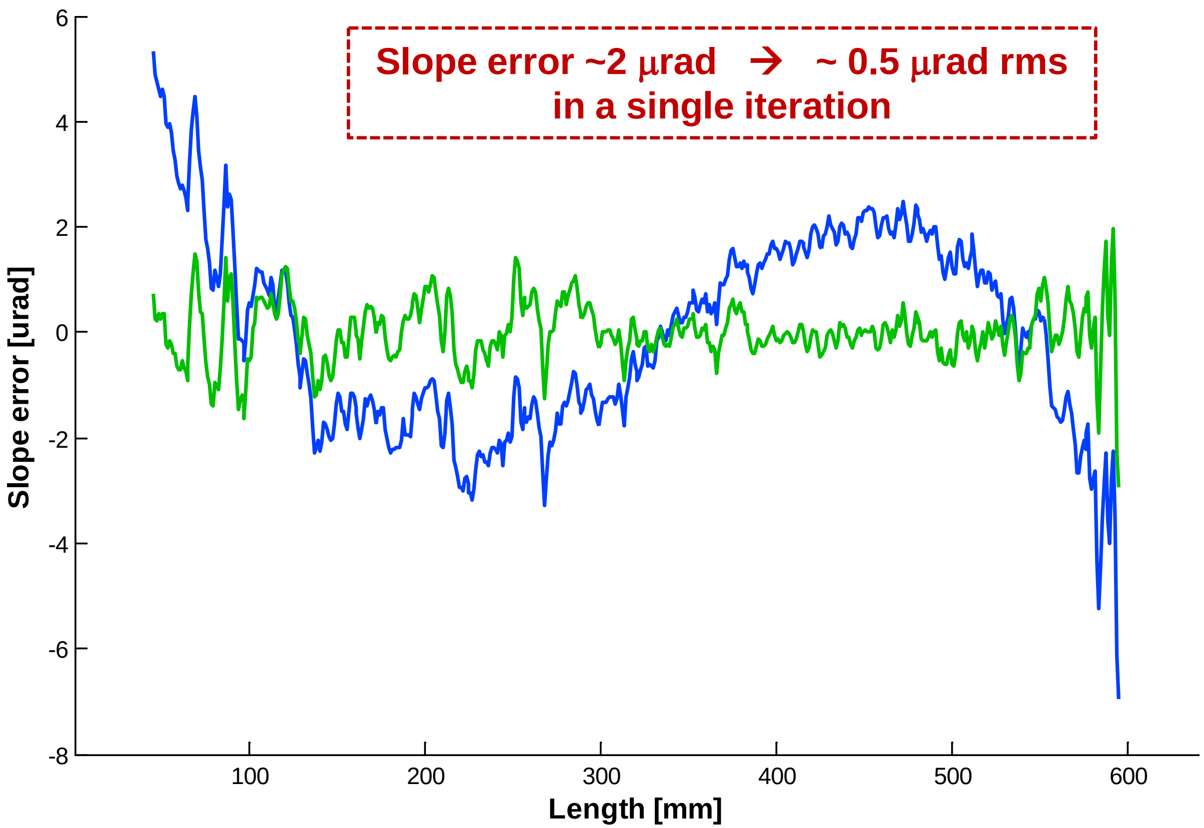
Piezo response functions

- Characterize how individual piezos respond to applied voltage



Matrix optimisation

- Correction voltages obtained by inverse matrix method
- Remaining slope error due to polishing defects



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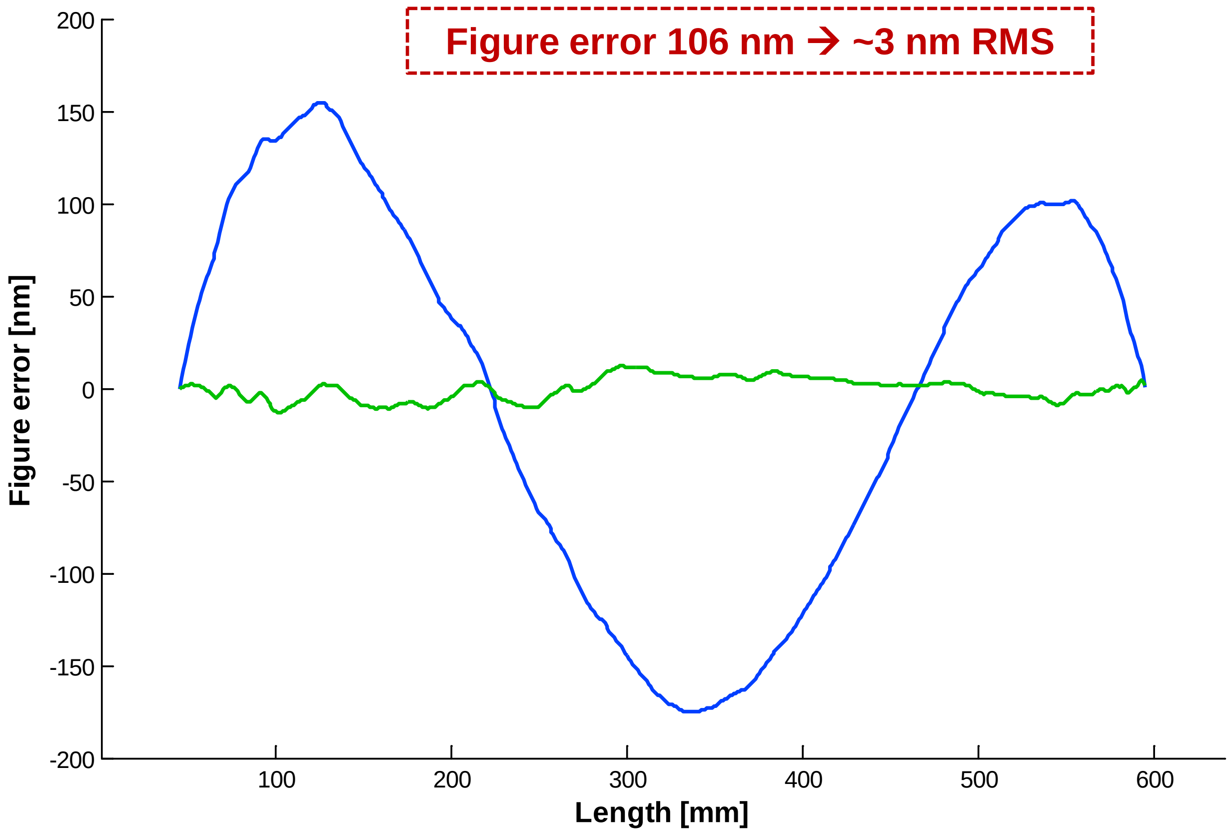
Matrix optimisation

- Improvement to figure error over central, uncoated Si stripe



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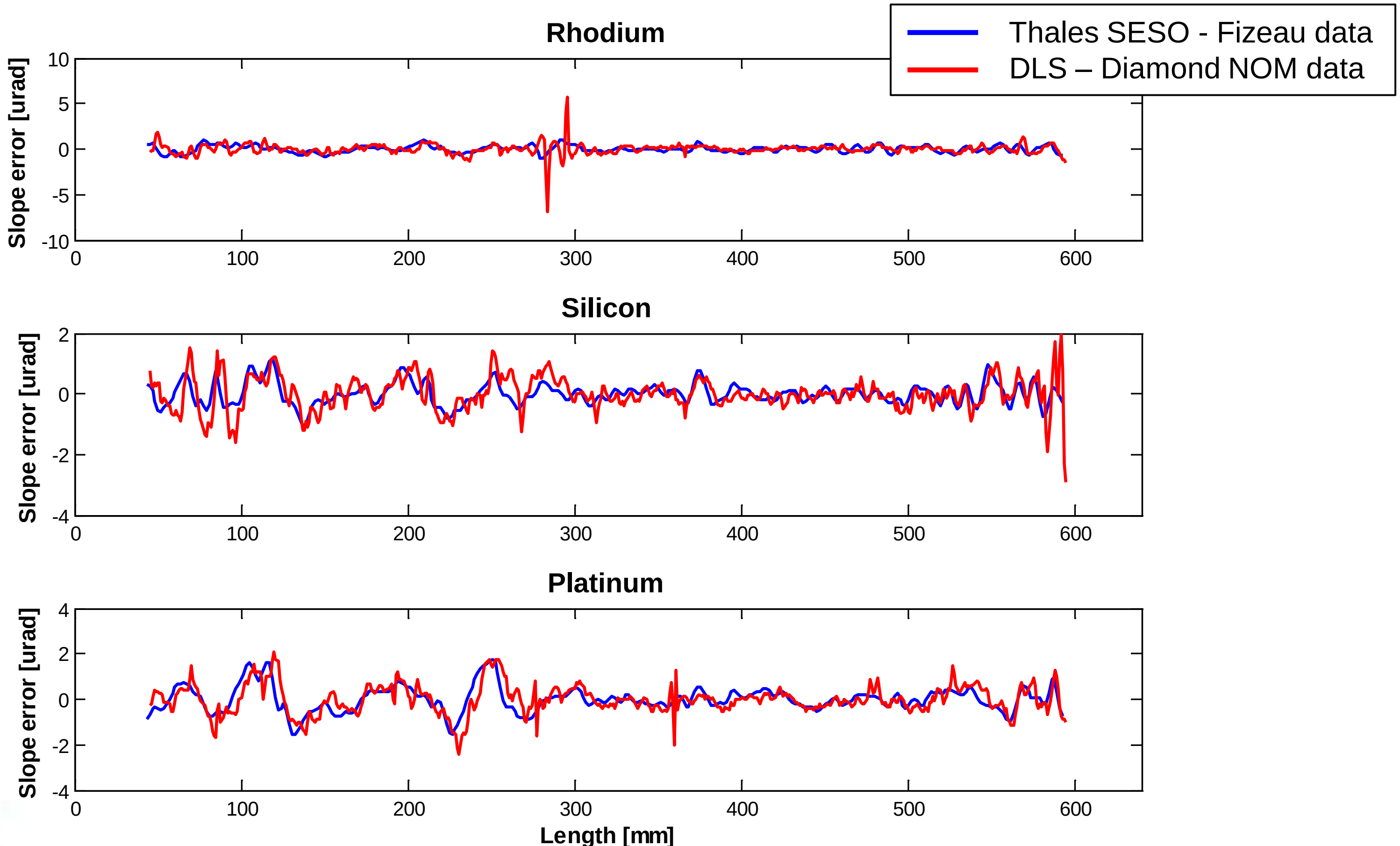
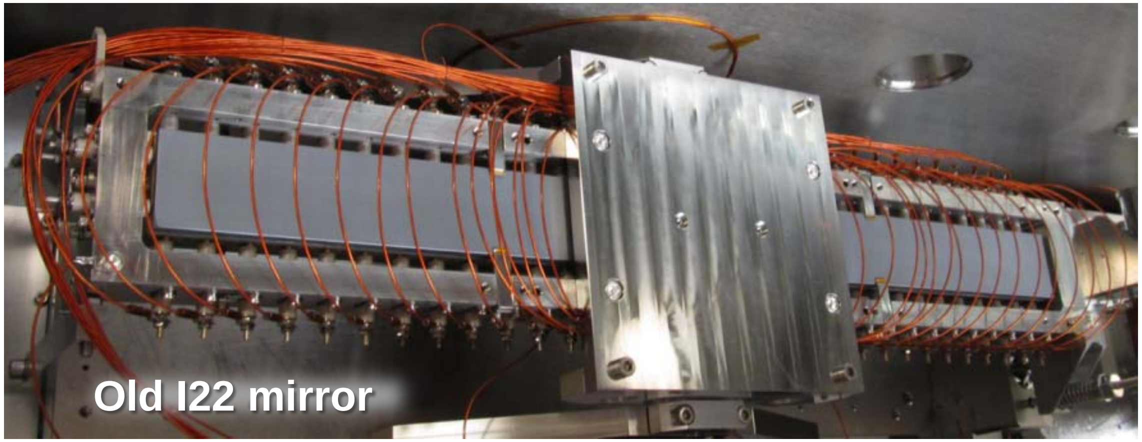
Agreement with Thales-SESO data

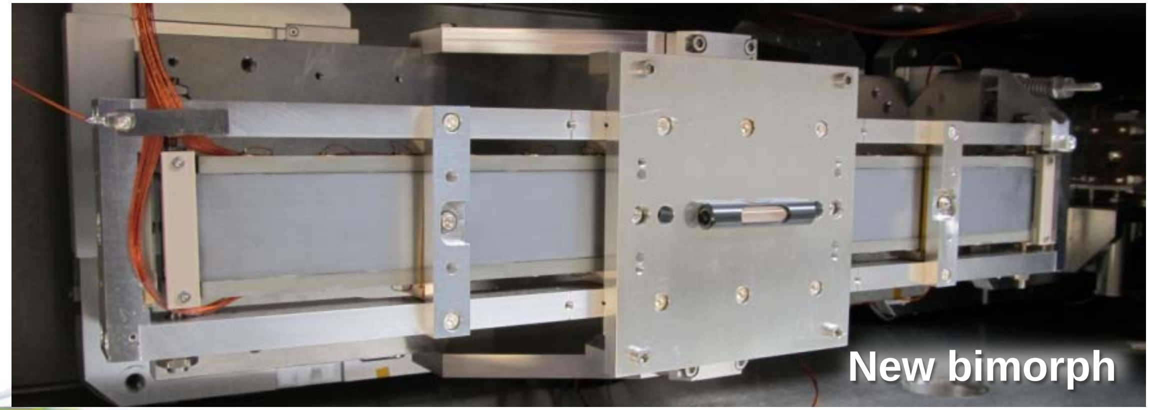
- Diamond-NOM optimised slope error vs. Thales SESO slope error (high order polynomial removed)



Beamline installation

- New type bimorph mirror installed on I22 (June 2013)





Acknowledgements to I22 team: Nick Terrill, Lee Davidson, Marc Malfois, Olga Shebanova & Andy Smith

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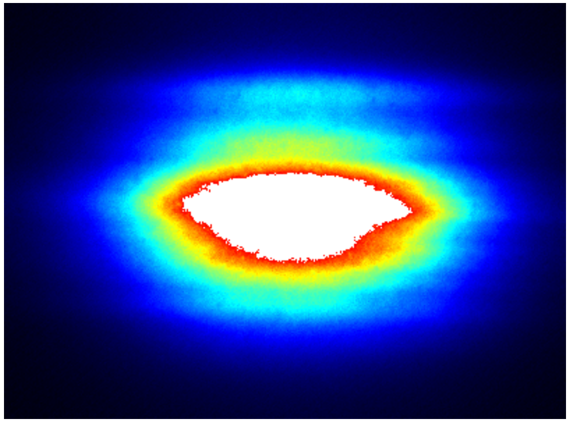
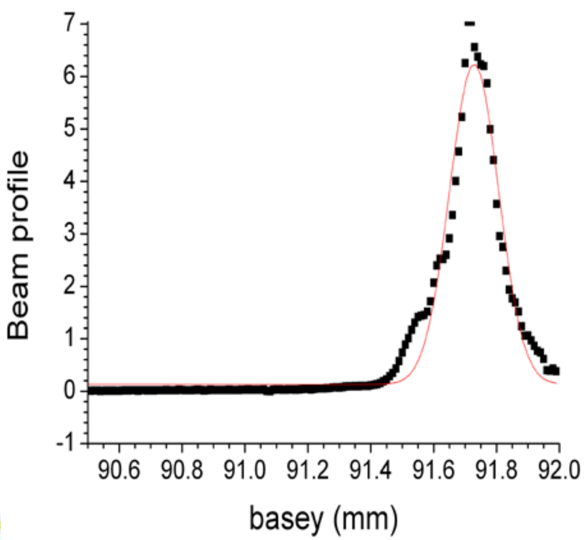
In-situ X-ray metrology

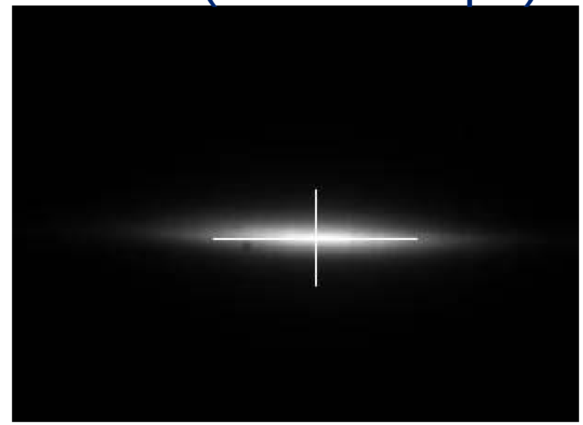
‘Before’ (old I22 mirror)



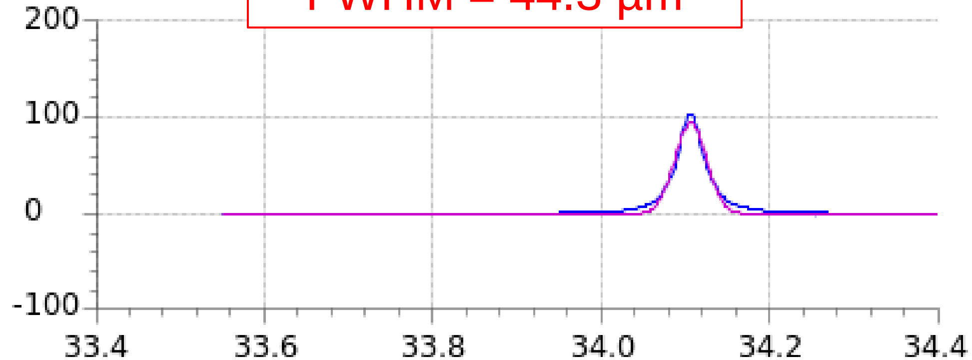
FWHM = 183 µm



‘After’ (new bimorph)



FWHM = 44.3 µm



- Focusing performance hasn’t degraded over 4 months of beamline operation

Data courtesy of John Sutter (Optics Group) and I22 team

Conclusions

- DLS Next Generation bimorph mirror achieves ~0.5 urad slope error over a bending range of flat to 1.4 km (concave)
- Problems with holder, and ultimate performance limited by polishing issues (damage during fabrication)
- Successfully replaced old type bimorph mirror on beamline → significant improvement to beamline performance
- Perspectives:
  - New design needed for holder
  - Possibility of super-polishing substrates

Thank you for your attention

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