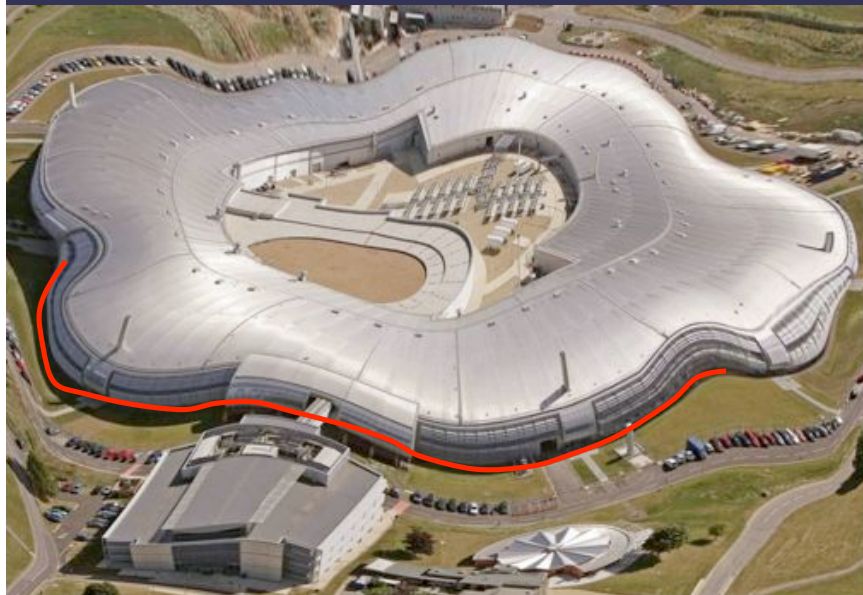
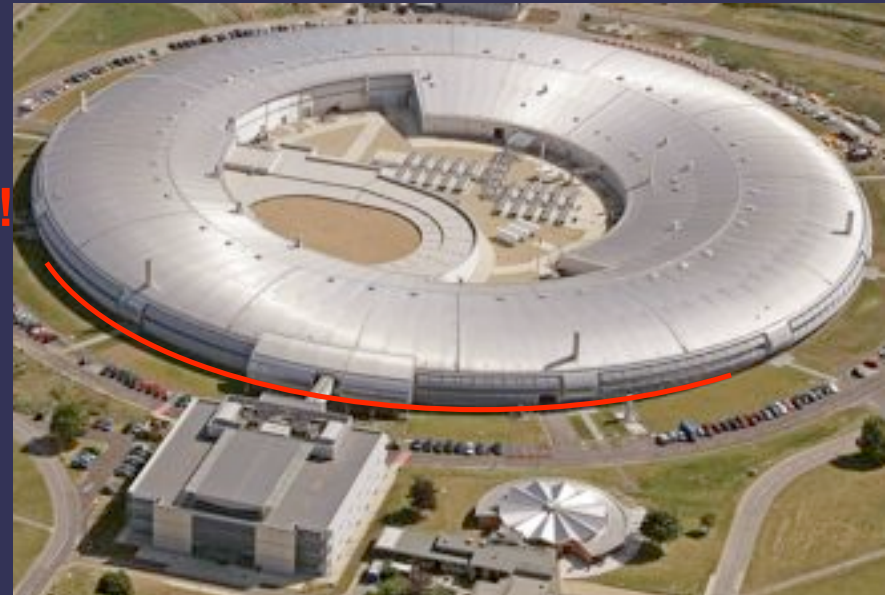


Using the SMP to optimize the shape of adaptive bimorph optics



**BIG
piezos!**



Dr. Simon Alcock, Diamond Light Source

simon.alcock@diamond.ac.uk



DLS Optics & Metrology

Group leader:

☀ Kawal. J. S. Sawhney

Ex-situ, optic testing (cleanroom)

☀ Simon Alcock

☀ Geoff Ludbrook

In-situ, bimorph testing (beamline)

☀ John Sutter

Ray tracing & nano-focussing

☀ Lucia Alianelli

Optics technician:

☀ Hiten Patel

Metrology cleanroom lab, physical metrology lab, & peripheral lab (x-ray source & diffractometer)



www.diamond.ac.uk

Location:

[Home](#) > [Jobs](#) > [Current vacancies](#) > [Scientific vacancies](#) > [DIA0458/SB - Optics Scientist](#)

Job Reference & Title	DIA0458/SB - Optics Scientist
Type of post	Scientific
Post details	Full Time / Permanent
Division	Science
Salary information	Circa £32k; a higher salary will be available for experienced candidates, see essential criteria below.
Application deadline	7th November 2008

Duties

- Contribute to the optical design and commissioning of beamlines, working in close collaboration with beamline scientists;
- Support beamline scientists in specifying, procuring and testing of beamline optics;
- Work on one or more of the following: soft x-ray polarimetry, nano-focusing optics for hard x-rays, nano-instrumentation;
- Undertake research in the field of X-ray optics;
- Publish work in peer-reviewed journals.

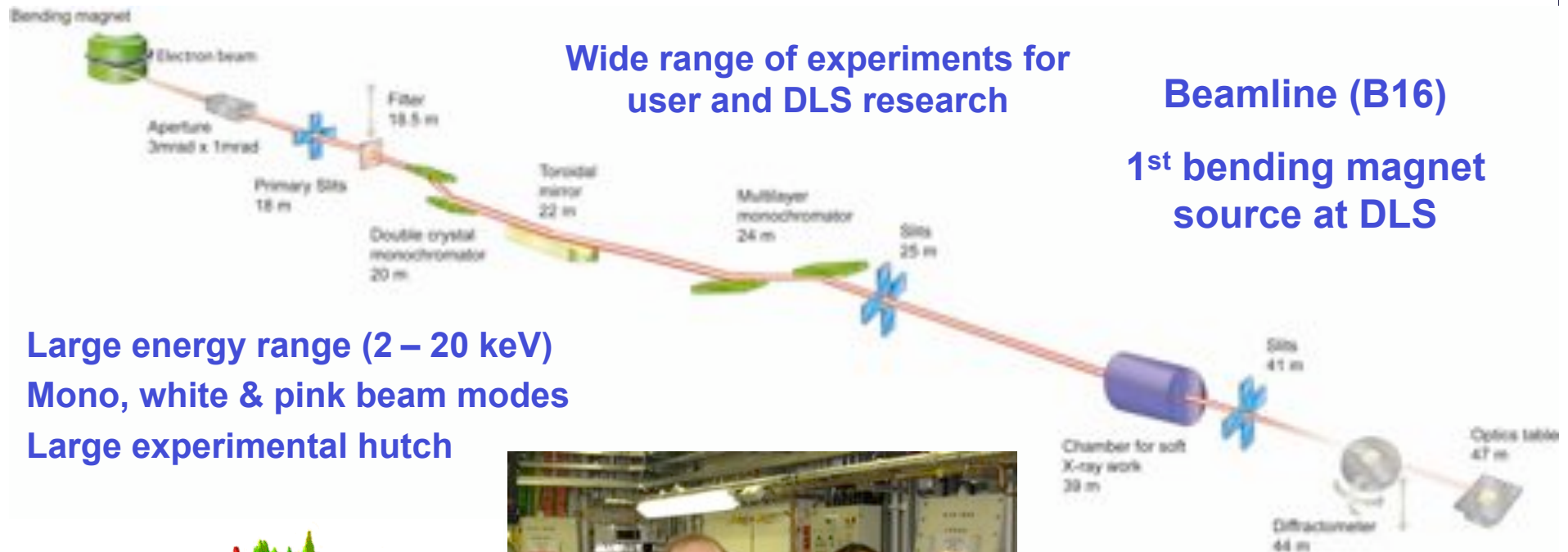
Qualifications and Experience: Essential

- PhD in physics, material science, applied optics or related disciplines; or equivalent qualification or experience;
- Experience in one or more of the following : beamline design, beamline instrumentation, synchrotron optics or metrology of beamline optics;
- Ability and initiative to get to the heart of the problem and take it effectively through to completion;
- Good interpersonal, communication and presentational skills;
- Ability to work as part of a multi-disciplinary team;
- Self motivated;
- Must be available to travel occasionally in UK and overseas including overnight absences;

Synergy with “Test” beamline

- Testing optics, detectors, and controls
- Development of novel experiments & techniques

**Further information:
Kawal Sawhney**

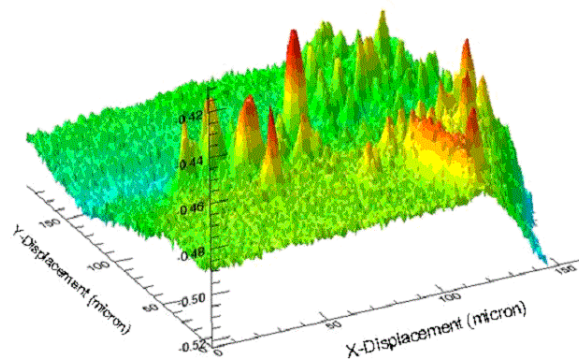


Wide range of experiments for
user and DLS research

Beamline (B16)

**1st bending magnet
source at DLS**

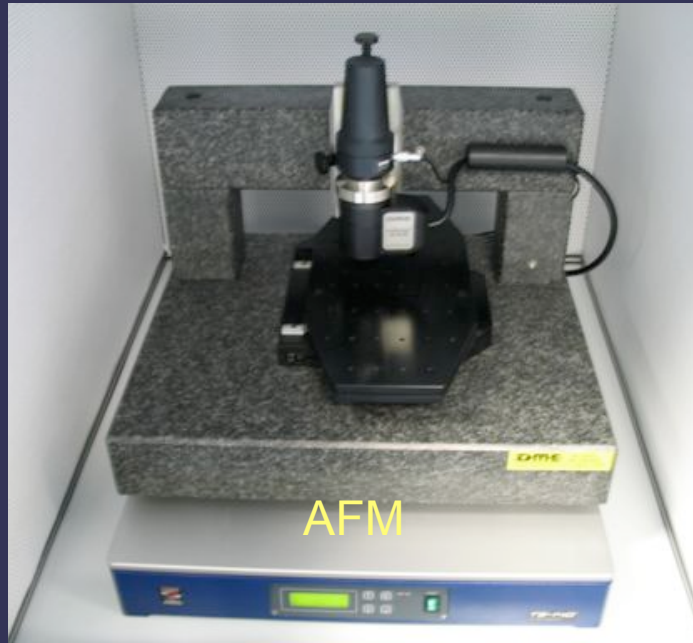
**Large energy range (2 – 20 keV)
Mono, white & pink beam modes
Large experimental hutch**



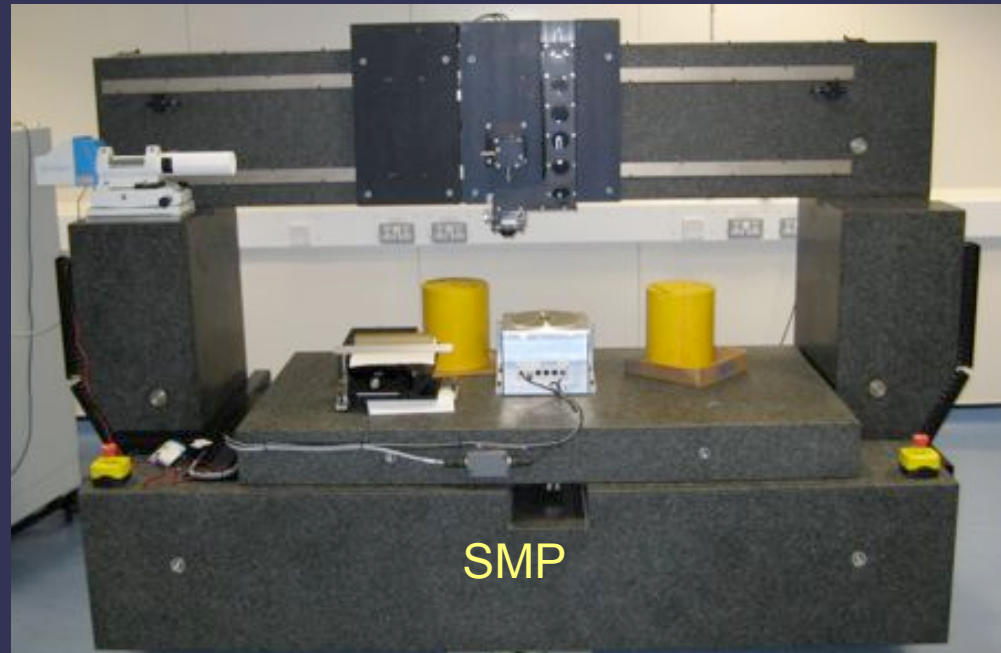
First users Jan 2008.

M. Moore et al

**Nano-collimator study of
metal inclusions in artificial
diamond**



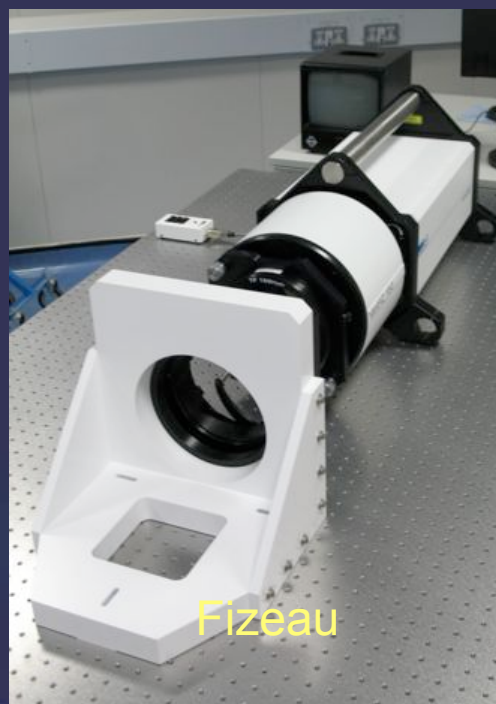
AFM



SMP



Optics & Metrology cleanroom
Class 10k (ISO7)



Fizeau



Micro interferometer

Metrology instruments

Atomic defects

Atomic Force Microscope (AFM)

- Atomic surface defects
- Lateral scan size: 50 μ m x 50 μ m
- Lateral resolution: <1nm
- Vertical accuracy: 0.01nm

Surface roughness

Phase shifting micro-interferometer

- Micro-topography
- Lateral scan size: 60 μ m – 10mm (+ stitching)
- Lateral resolution: 0.1 μ m – 9 μ m
- Vertical accuracy: 0.05nm (rms)

Shape / Slope errors

Fizeau interferometer

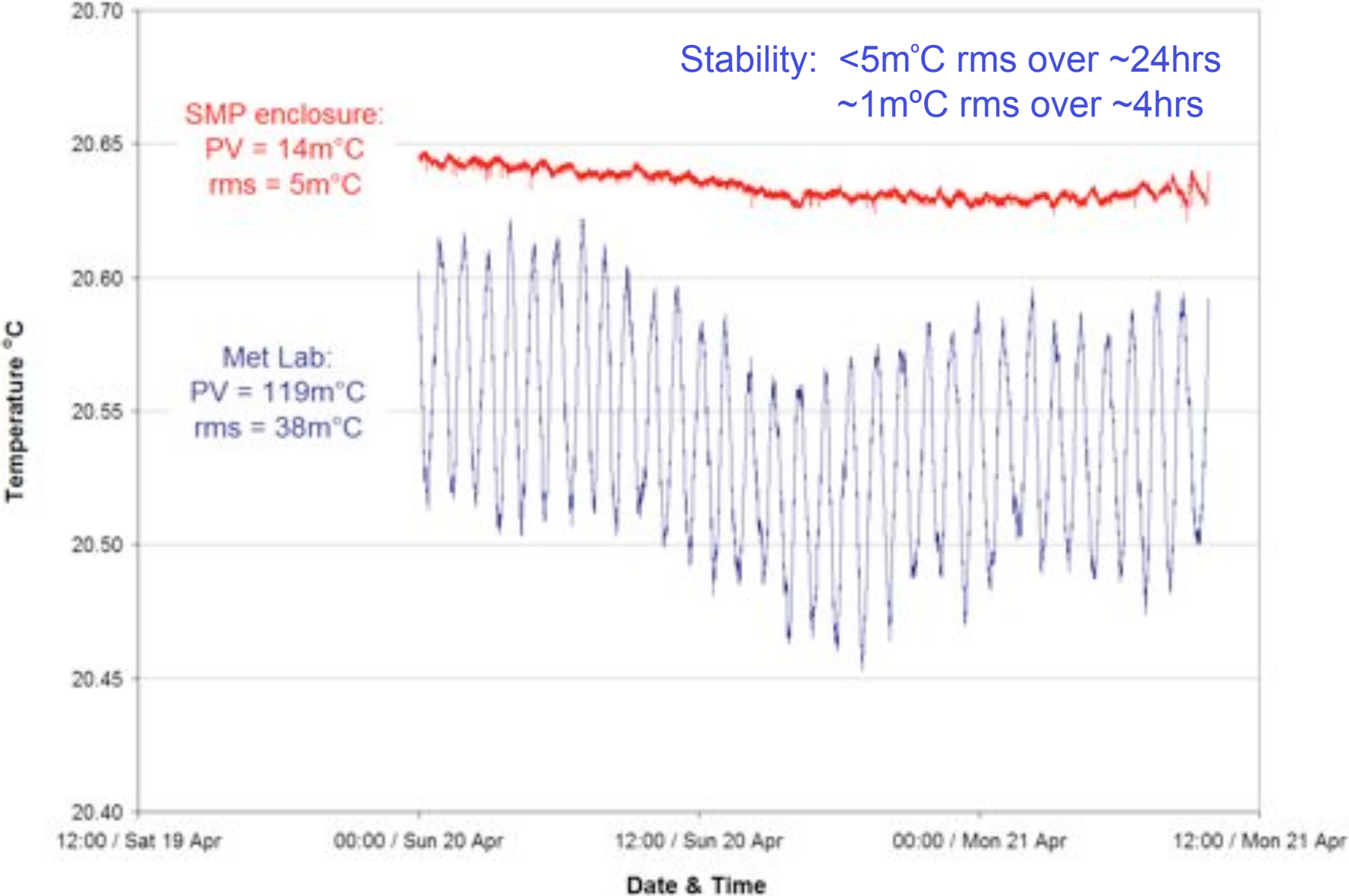
- 3-D height measurement
- Beam diameter: 150mm
- Lateral scan size: 150mm – 1500mm
- Accuracy: <1nm rms (λ /100 PV)

Slope measuring profiler (SMP)

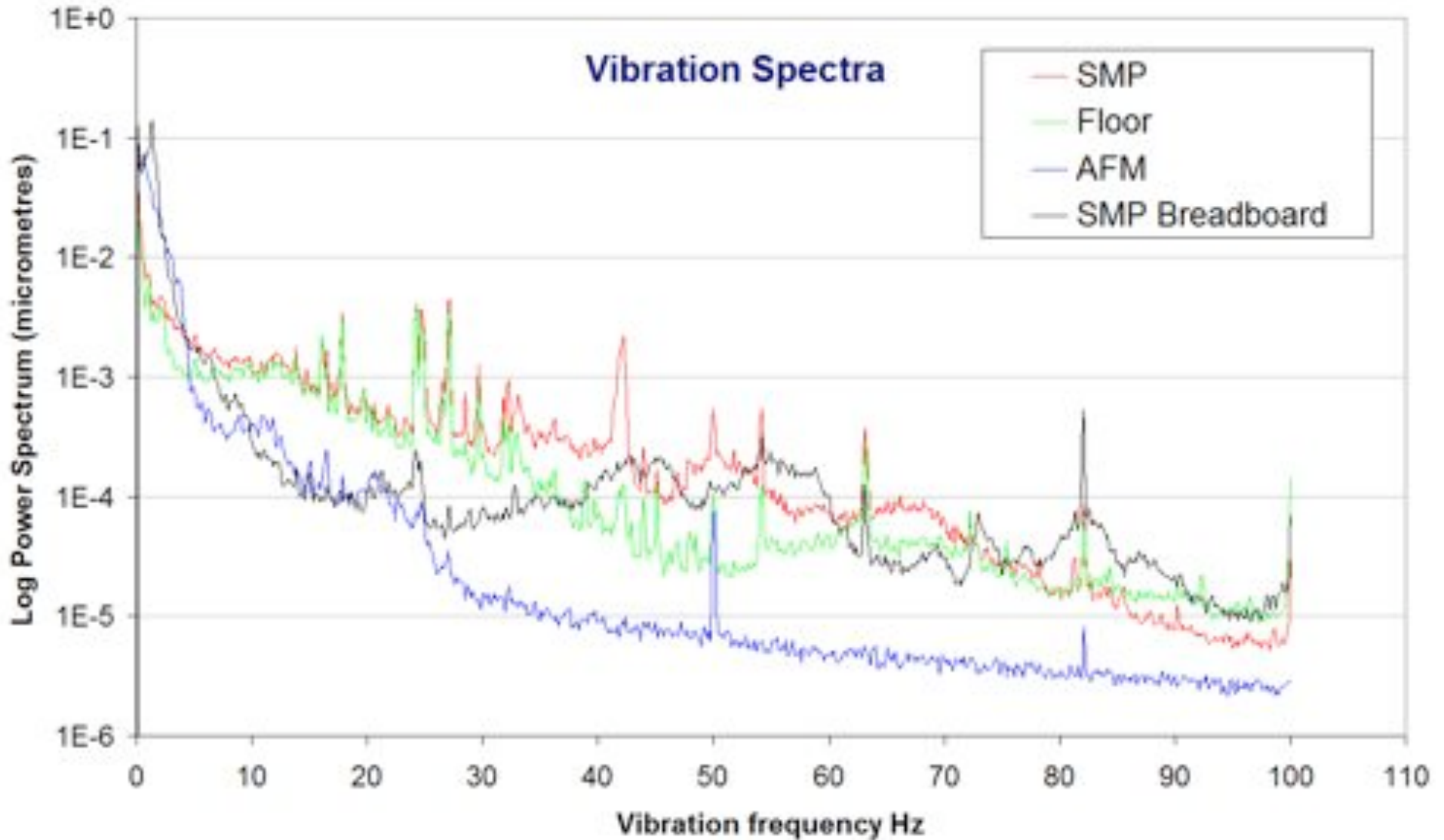
- 3-D slope measurement
- Lateral scan size: 1500mm x 300mm
- Lateral resolution: <0.5mm
- Repeatability <100nrad



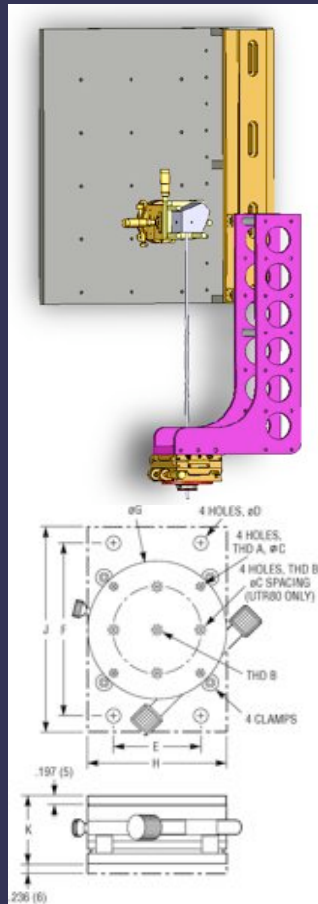
Cleanroom temperature stability



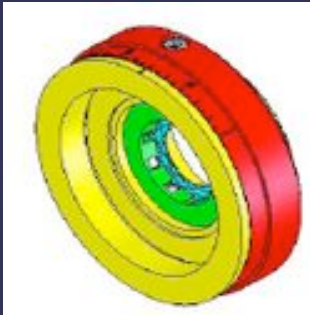
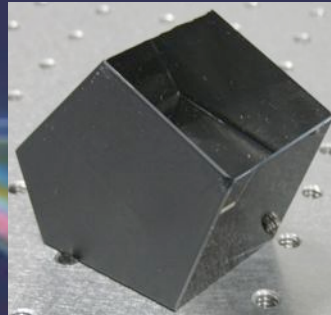
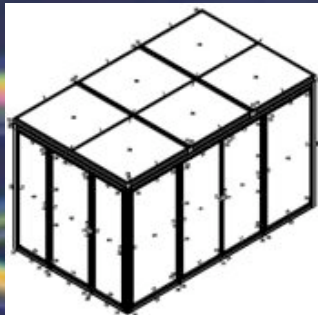
Vibrational stability



Slope Measuring Profiler (SMP)



Inspired by the BESSY-NOM



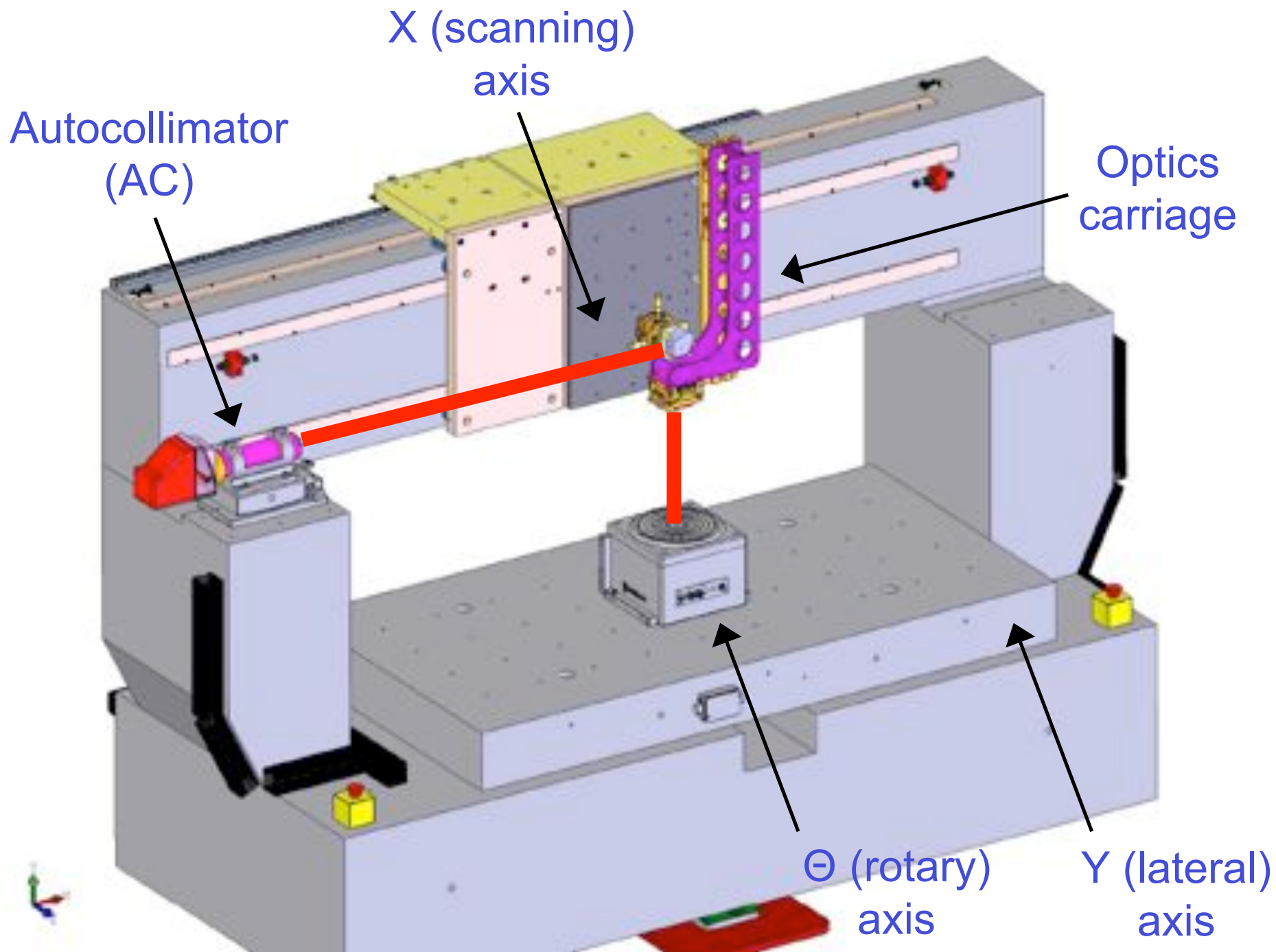
DLS / BESSY Collaboration

DLS team: Simon Alcock, Stewart Scott (Engineering), Ulrik Pedersen (Controls), Rob Walton (Software), and Kawal Sawhney.

Thanks and acknowledgement to Frank Siewert, Thomas Zeschke, Fred Senf, and associated staff at BESSY, for their expert knowledge and support in helping to develop the SMP.

F. Siewert, T. Noll, T. Schlegel, T. Zeschke, and H. Lammert, "*The Nanometer Optical Component Measuring machine: a new Sub-nm Topography Measuring Device for X-ray Optics at BESSY*", AIP Conference Proceedings 705, American Institute of Physics (2004) 847-850





SMP specifications II

Specifications [3]		
Axis	Rotary: _ axis	
Model	RT200	
Motor t ype	DC + belt	
Feedback system	RE36.000 lines/revolution 25X interpolation	
Travel	360	[°]
Resolution [4]	0,36	[Arcsec]
Repeatability (3 _)	± 1	[Arcsec]
Positioning accuracy including repeatability (3 _)	± 2	[Arcsec]
Concentricity	± 0,2	[µm]
Flatness of rotation	± 0,2	[µm]
Maximum velocity	3	[RPM]
Axial load capacity	100	[kg]

[3] Specifications valid per axis, without external load, and measured at 25 mm height above the table surface

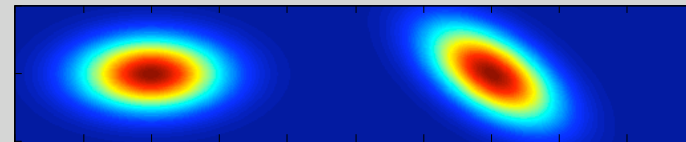
[4] With additional 25X interpolation, and 4X interpolation in the controller

SMP Controls & Analysis

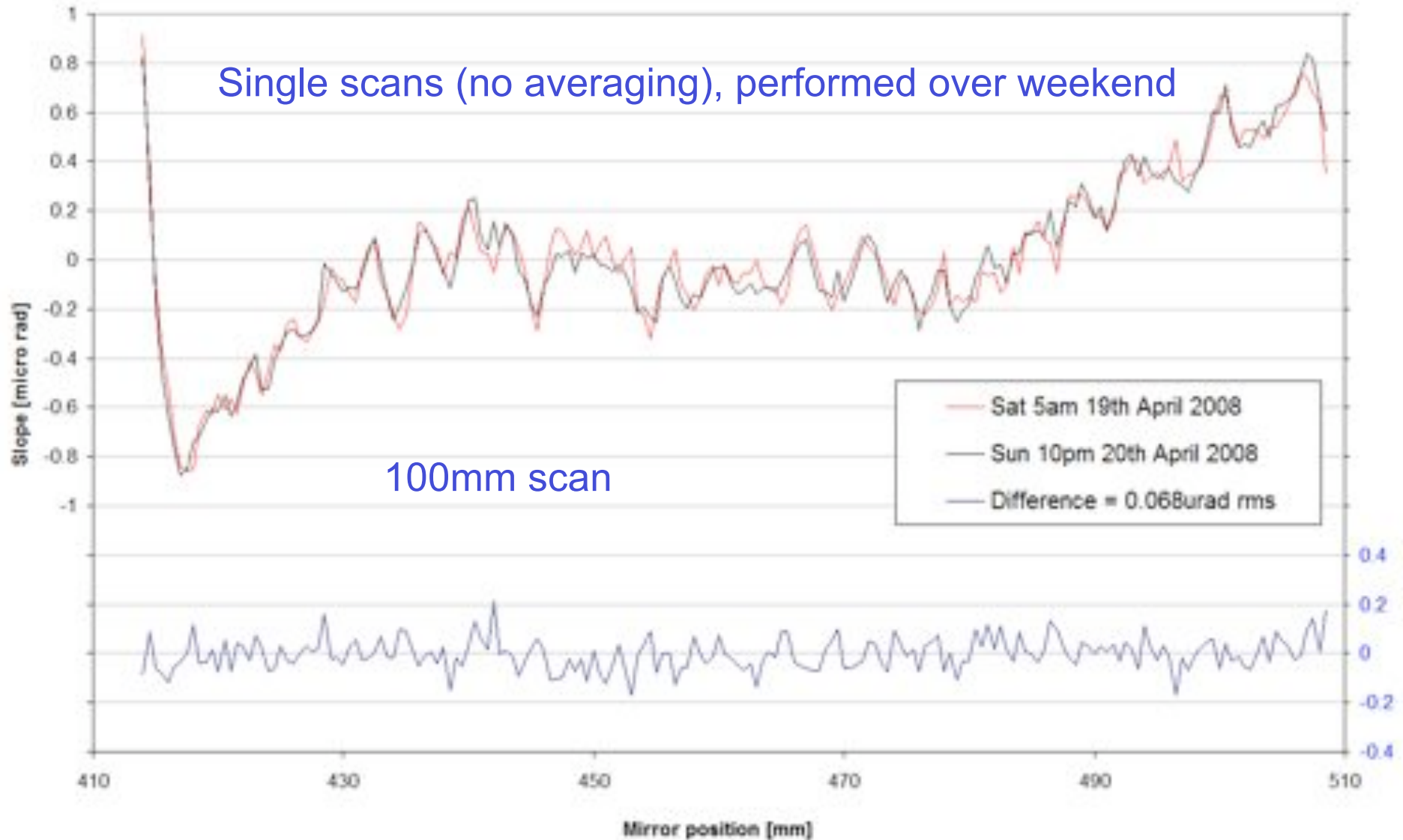
- ☀ Scan types: step (discrete), flyscans (continuous), and stability
- ☀ EPICS interface (via PMAC controller) to SMP & A.C
- ☀ Python command scripts for sequential scans & waiting
- ☀ Automatic data analysis and error flagging
- ☀ Matlab with LabCA interface to EPICS
- ☀ Delta-Tau (PC104, “Turbo” PMAC “Clipper”) with Ethernet/RS232

The screenshot displays the SMP control software interface. It features three main windows: two motor status windows on the left and a scan configuration window on the right. The motor status windows show position, home, jog, tweak, and tweak step values for two motors. The scan configuration window shows scan configuration and autocalibrator settings. A data table is visible at the bottom left.

ID	Dir	Scan	Reference	Start	Stop	Step	Unit	Y Pos	Y Pos
1	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
2	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
3	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
4	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
5	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
6	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
7	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
8	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
9	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
10	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
11	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
12	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
13	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
14	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
15	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
16	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
17	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
18	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
19	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
20	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
21	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
22	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
23	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
24	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
25	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
26	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
27	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
28	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
29	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
30	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
31	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
32	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
33	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
34	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
35	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
36	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
37	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
38	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
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42	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
43	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
44	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
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46	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
47	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
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49	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
50	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
51	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
52	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
53	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
54	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
55	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
56	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
57	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
58	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
59	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
60	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
61	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
62	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
63	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
64	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
65	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
66	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
67	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
68	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
69	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
70	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
71	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
72	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
73	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
74	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
75	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
76	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
77	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
78	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
79	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
80	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
81	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
82	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
83	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
84	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
85	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
86	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
87	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
88	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
89	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
90	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
91	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
92	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
93	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
94	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
95	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
96	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
97	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
98	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
99	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000
100	+	+	0.0000	0.0000	0.0000	0.0000	mm	0.0000	0.0000



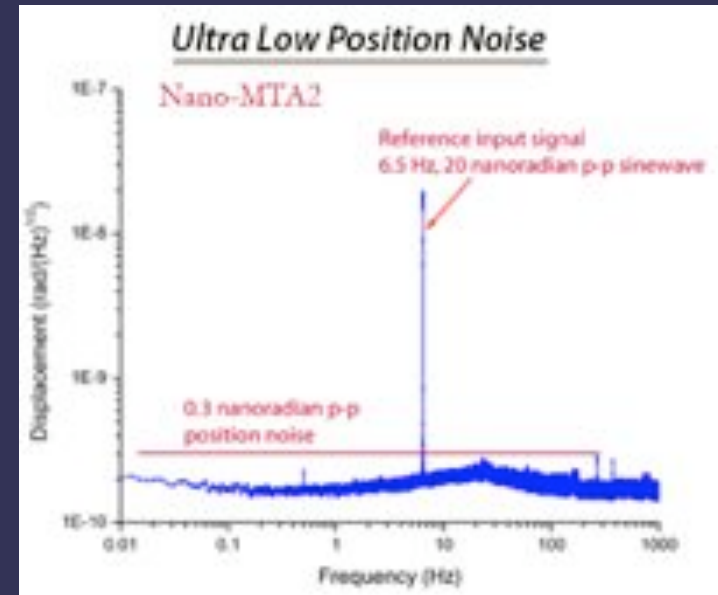
SMP repeatability $\sim 68\text{nrad}$



Piezo tip / tilt stage (angle calibration)

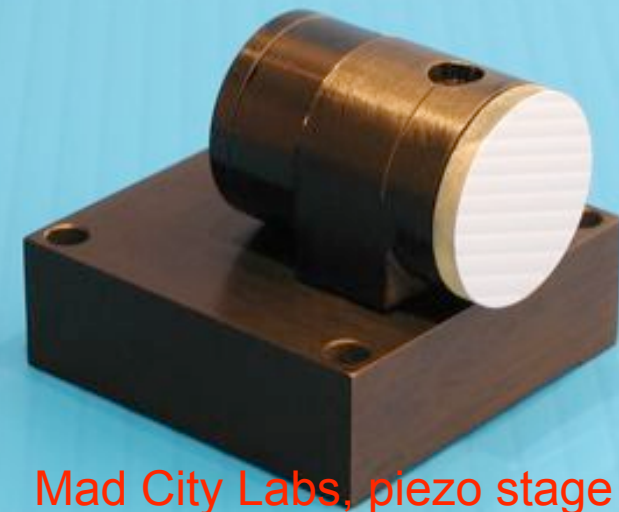
- ☀ Generate a certified tip / tilt angle to calibrate angle measuring systems.
- ☀ Range of motion: up to 10 milliradian
- ☀ Resolution ~ 10 nrad (with 20bit interface)
- ☀ Open or closed loop

Demonstration stage to be tested (Autumn 08).



Technical Specifications

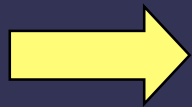
Range of motion (per axis)	2.0 mradian
Resolution	4.0 nradian
Range of motion (extended)	5.0 mradian
Resolution	10 nradian
Resonant Frequency (unloaded)	5 kHz $\pm 20\%$
Scanning Speed (full amplitude)	up to 400 Hz
Optics	1" diameter mirror mounting area
Body Material	Al or Invar and Titanium
Controller	Nano-Drive™/Nano-Drive™85



Mad City Labs, piezo stage (for 1 inch optics)

SMP projects

- ☀ Investigating the MCL piezo tip / tilt stage
- ☀ Calibrating the AC against a recognised, angular standard
- ☀ Actively participating in the “Round Robin” project
- ☀ Further development and automation of controls and visualisation software, including ex-situ test procedures



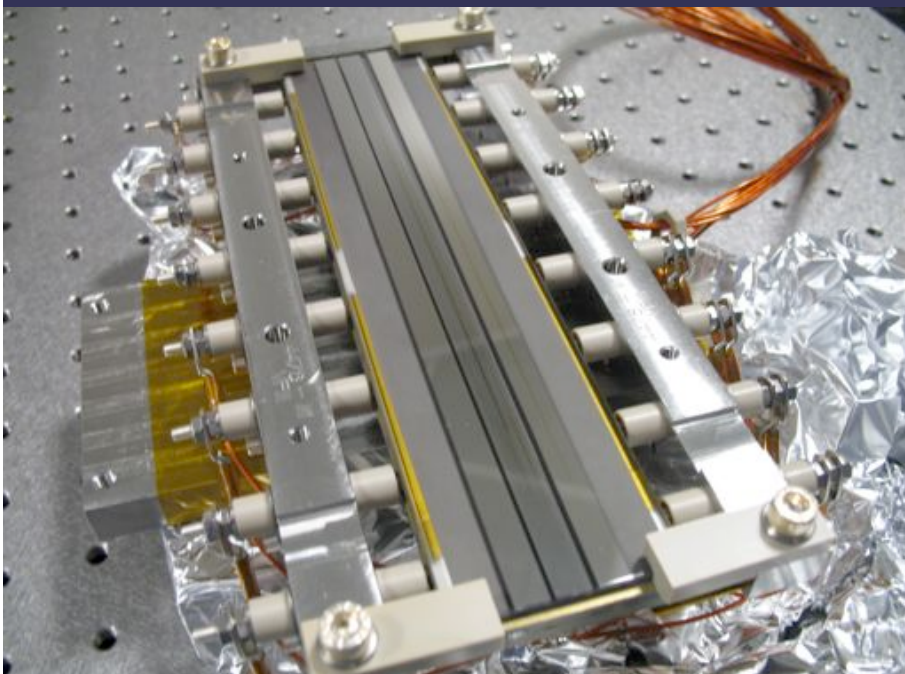
Pushing the SMP to its performance limits!



Pushing optics to their limits!

Bimorph optics at DLS

- ☀ Earlier presentations by Andy Dent & Paul Quinn
- ☀ Wide variety of length, piezo spacing, coatings, & geometry
- ☀ Slope / height scans using SMP & Fizeau interferometer
- ☀ Micro-topography using micro-interferometer & AFM
- ☀ In-situ beamline testing (John Sutter)



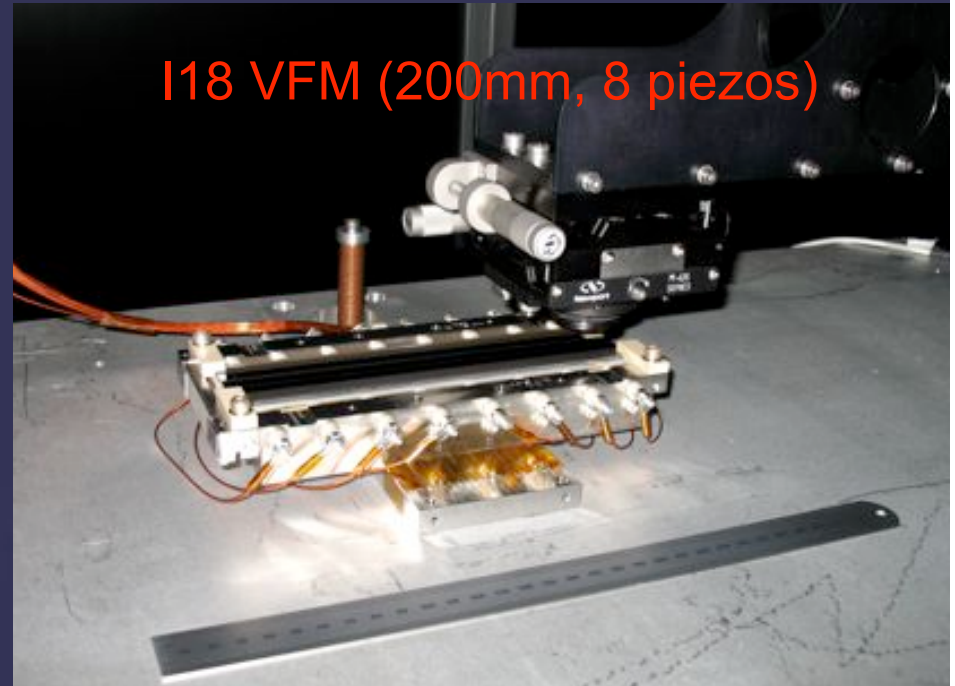
Recent SMP results

- ☀ I18 VFM: 3 days of testing (27th – 29th Aug 08).
- ☀ I07 HFM & VFM: 2 weeks of testing (end July 08)
- ☀ Scans along different coating stripes.
- ☀ Matrix scans and slope / height optimisation.
- ☀ “Hysteresis” (backlash) of piezo response.
- ☀ Stability (overnight).
- ☀ Temporal behaviour of piezos (voltage change).

I07 VFM (550mm, 32 piezos)

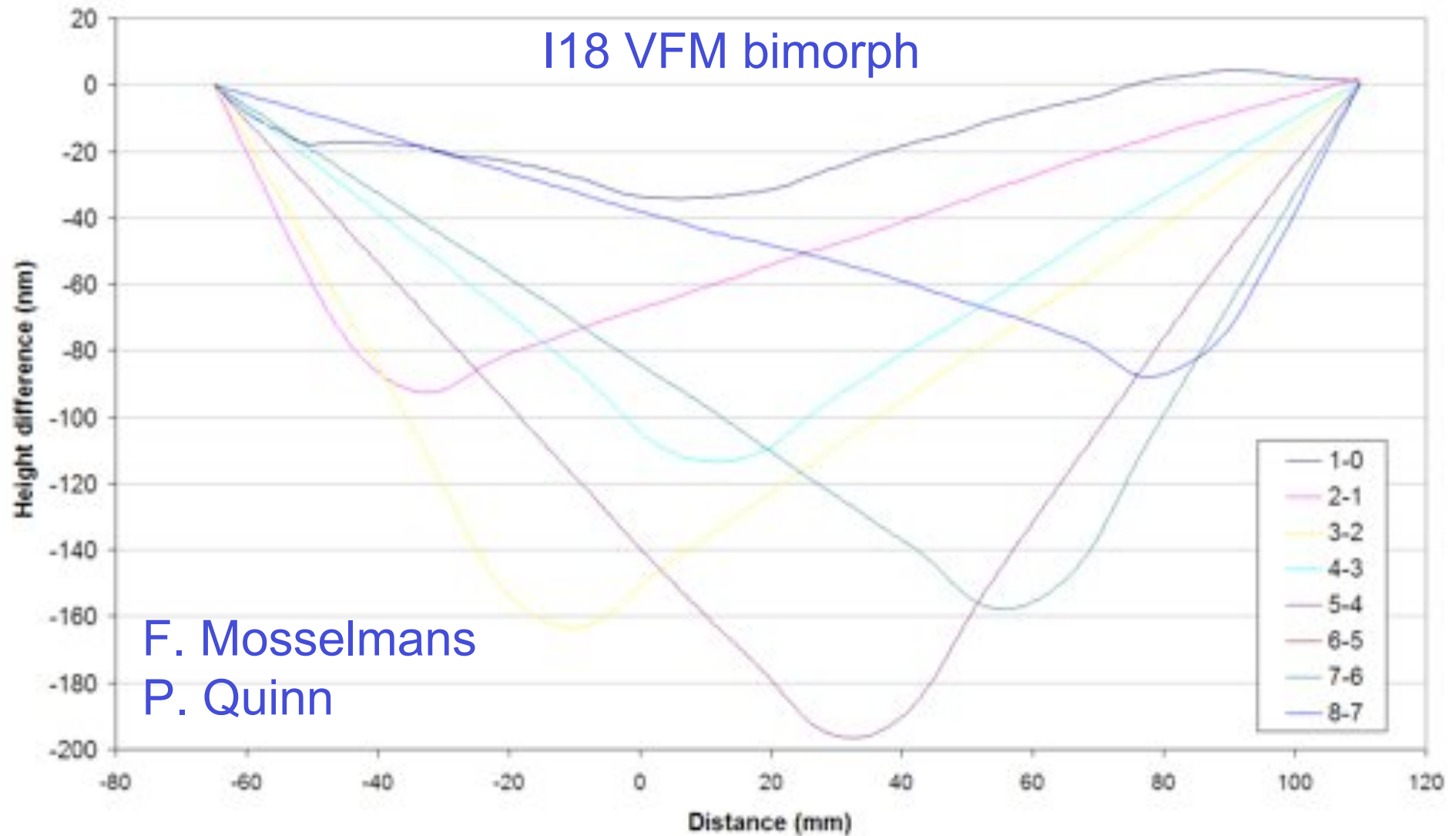


I18 VFM (200mm, 8 piezos)



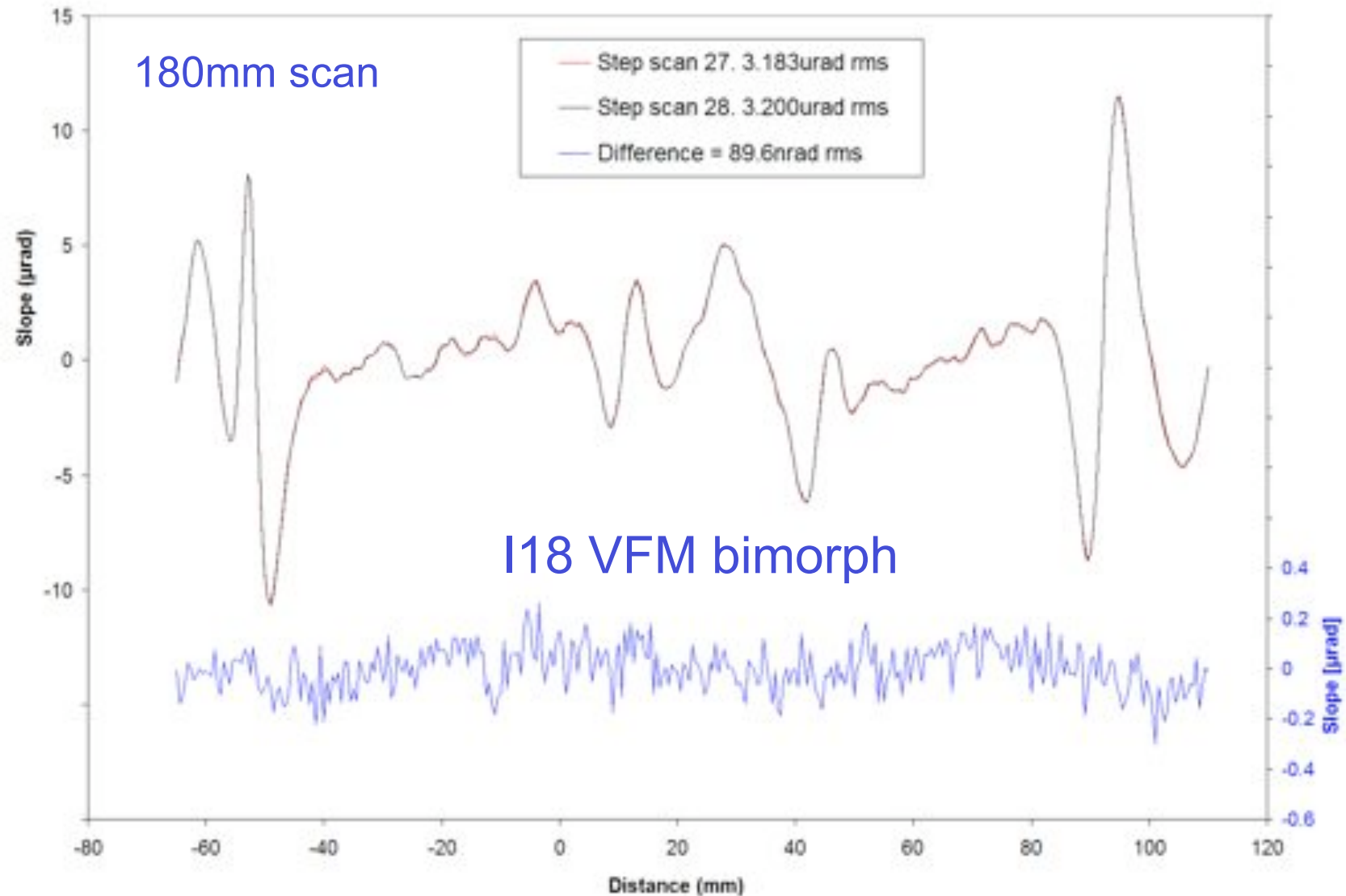
Matrix scans (R. Signorato *et al.*)

☀️ Single scans (no averaging), “work hours”, scientists in lab.

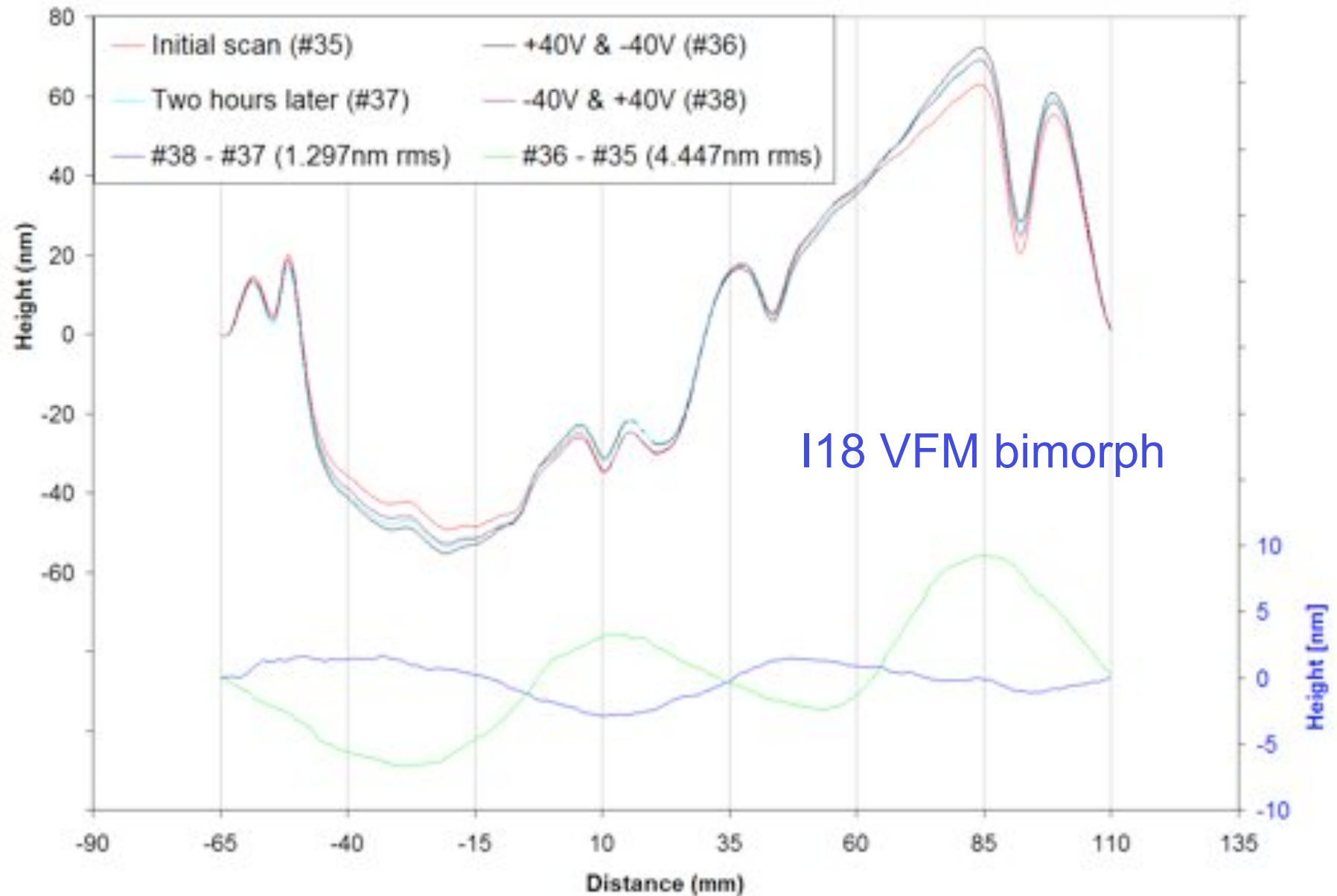


Repeatability of the SMP

☀ Single scans (no averaging), “work hours”, scientists in lab.

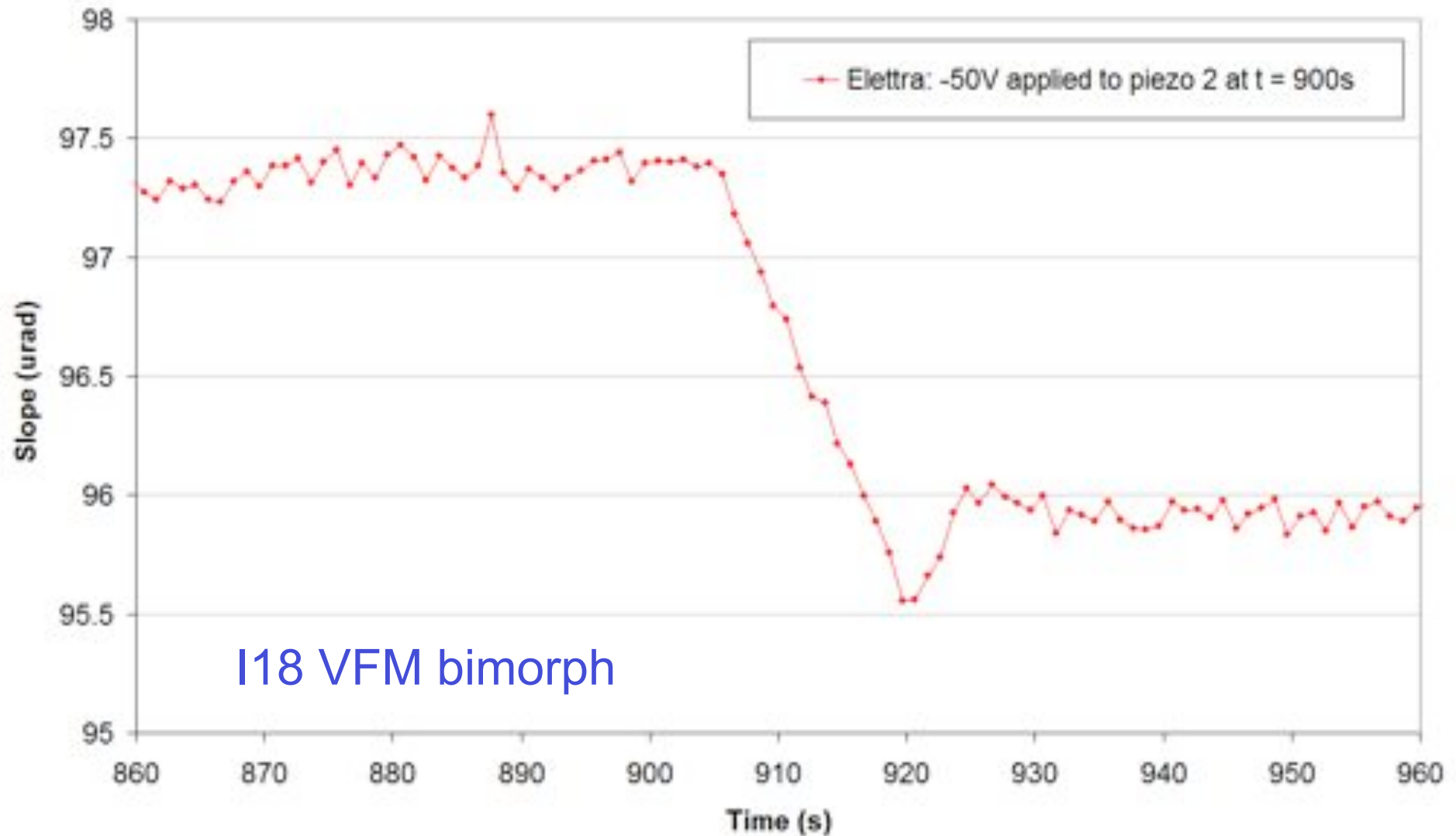


Piezo hysteresis



I18 VFM bimorph

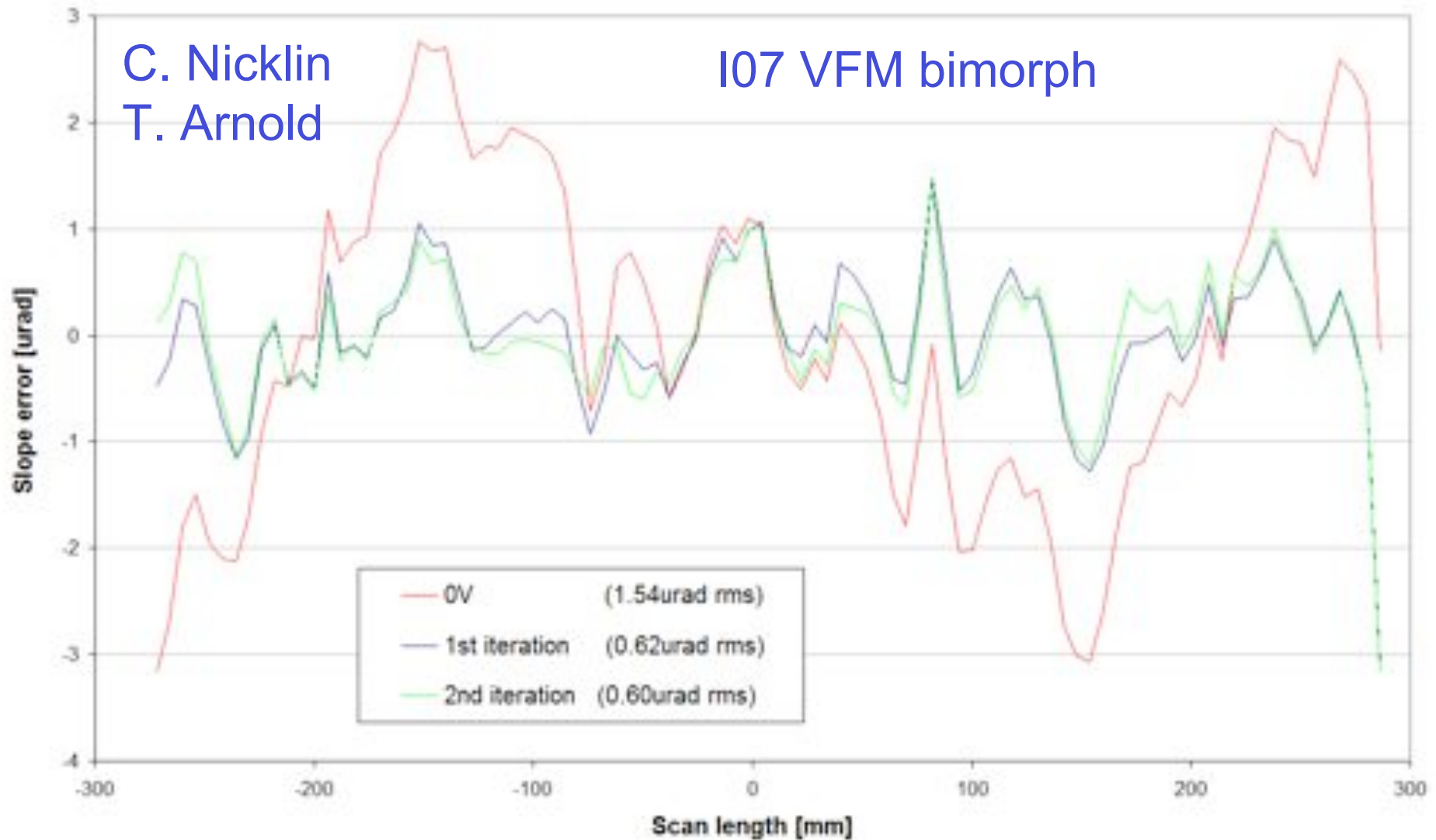
Temporal behaviour of single piezo in response to voltage change



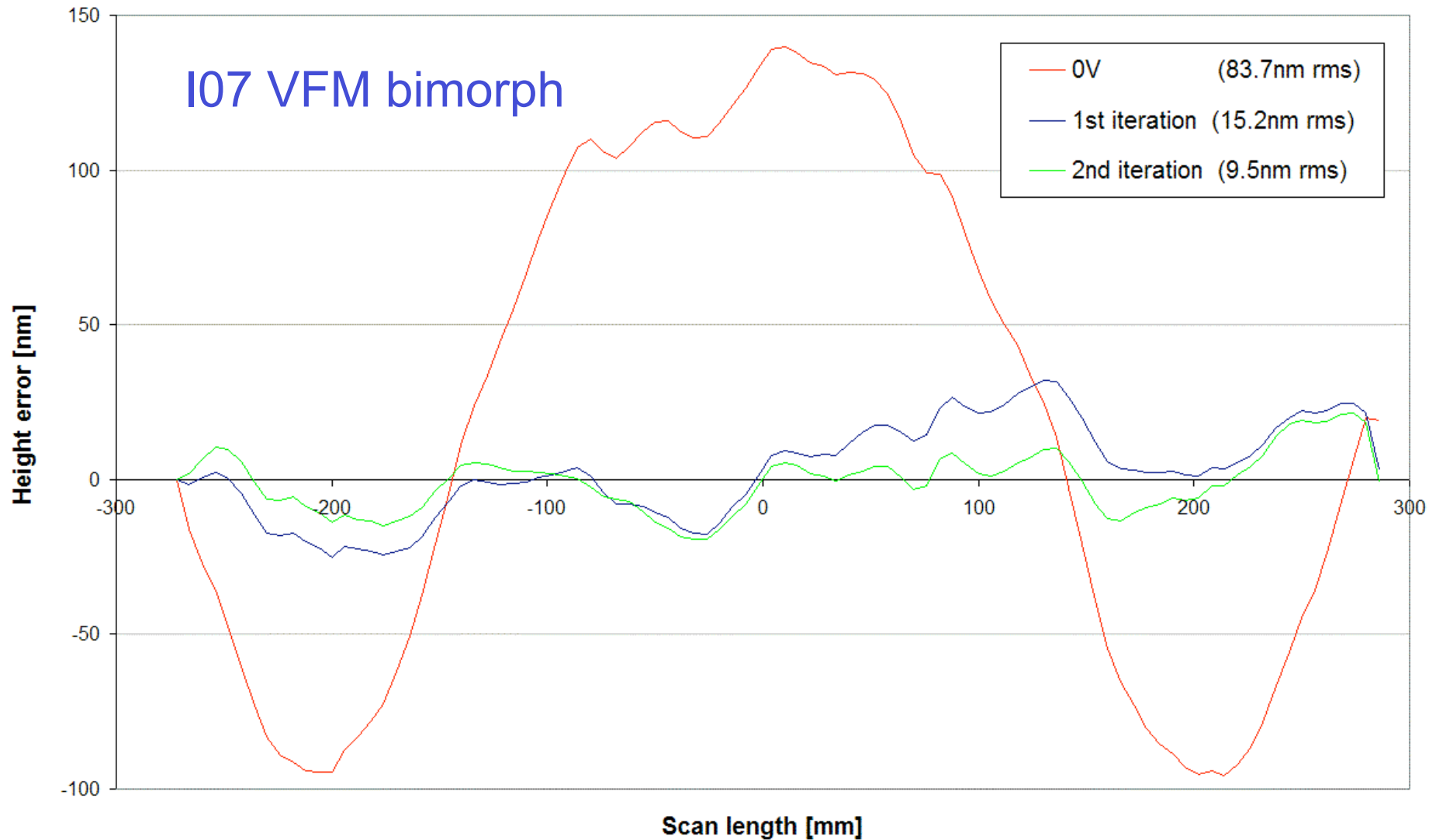
Slope error reduction (using Matrix method of Signorato *et al.*)

C. Nicklin
T. Arnold

I07 VFM bimorph



Height error reduction



Summary & Future

- ❁ Established a cleanroom laboratory, with exceptional temperature & vibrational stability, required for high grade metrology.
- ❁ Suite of complementary metrology instruments, capable of high accuracy, micro-topography and slope / height measurements.
- ❁ On-going metrology development & research
- ❁ ...and most importantly, **Lots of Collaborations!**

simon.alcock@diamond.ac.uk

