On-machine Measurement for Precision Corrective-polishing of Aspheres and Freeform Surfaces

David Walker, Christopher King

University College London

Zeeko Ltd & Zeeko Research Ltd

Based at the OpTIC Technium, North Wales

Sub-title

An update on an on-going product development

Acknowledgements

- Funding from PPARC (now STFC) PIPSS scheme
- Collaboration between UCL, Zeeko Ltd and the OpTIC Technium

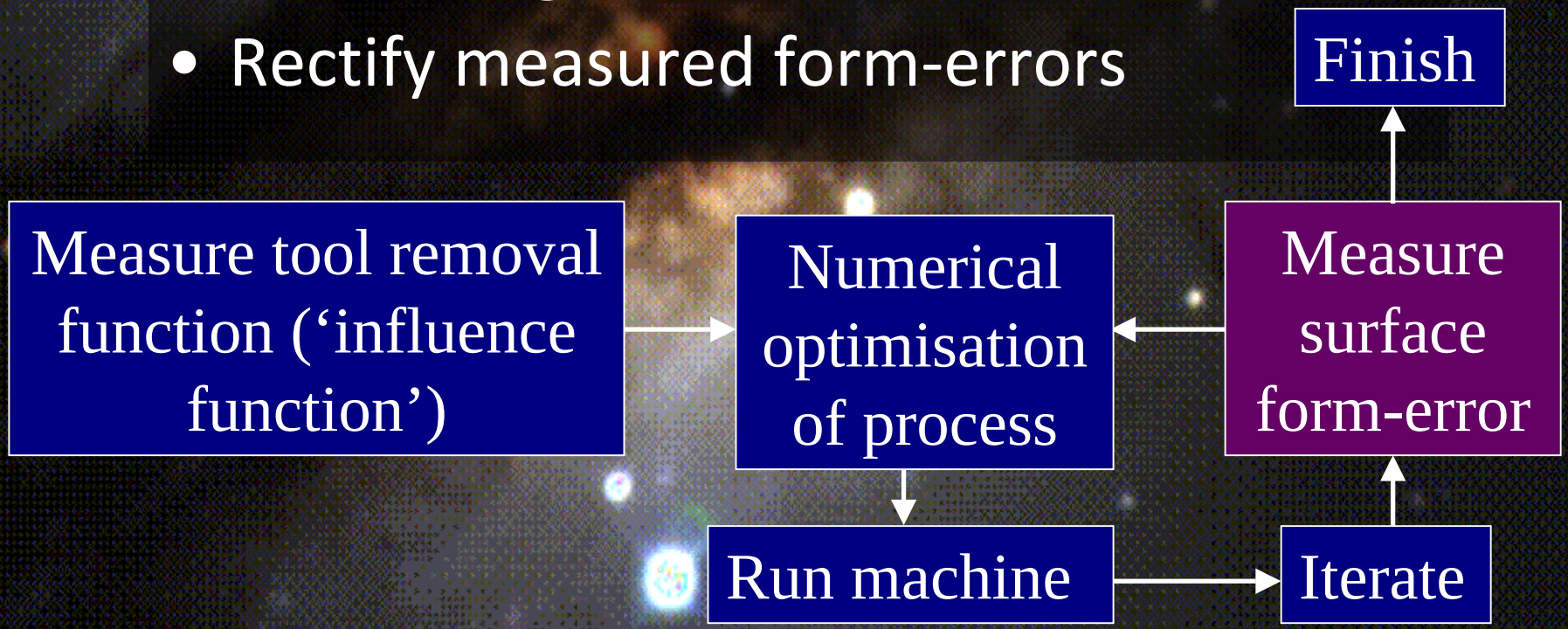
Areas of interest include …

- Optical lenses and mirrors
  - Head-up displays
  - Defence and space optics
  - Telescope and instrumentation optics
- Hip and knee joint implants
- Turbine blades
- Moulds and dies
- Mandrels for X-ray mirrors

- But, we'll address larger components for now!

The polishing technology

- Range of CNC polishing machines
  - Zeeko-Classic inflated bonnet tools
  - Fluid-jet polishing
- Polish rough surfaces
- Rectify measured form-errors

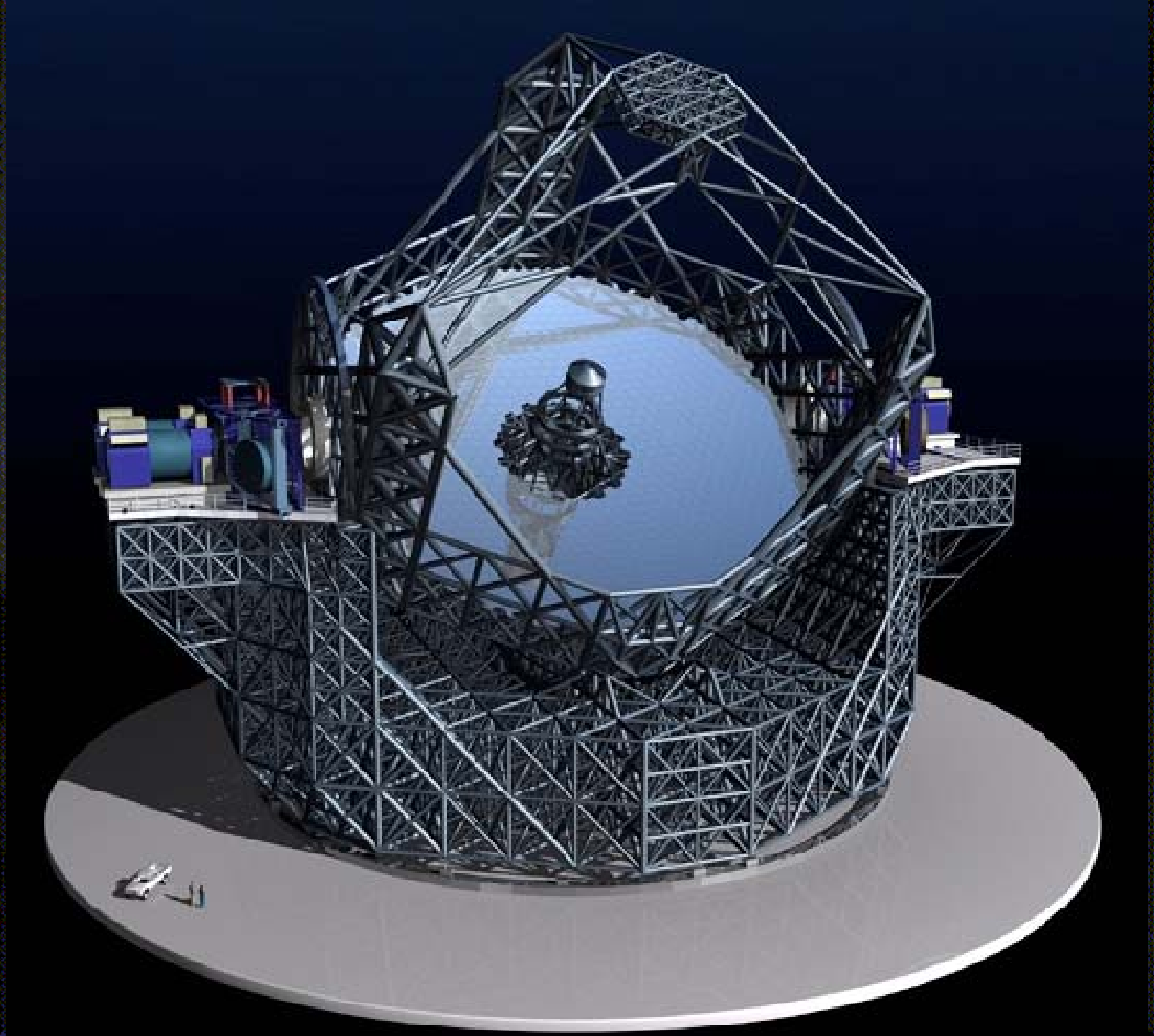


Aspheres & free-form surfaces

- Measurement dynamic range
- Need for null (‘corrective’) optics
  - The Hubble Space telescope problem!

For large parts

- Risk of damage in handling
- Substantial down-time measuring off-machine,
  - moving the component
  - re-adjusting at test setup and back on machine
  - thermal stabilization



On-machine metrology

- Demountable interferometer module to fit tool-chuck of the larger Zeeko machines
- Overlapping sub-aperture measurements
  - Sub-apertures cover pupil optimally
  - Sub-apertures are stitched in software
  - Residuals in overlap-regions => estimate of uncertainty of stitched results

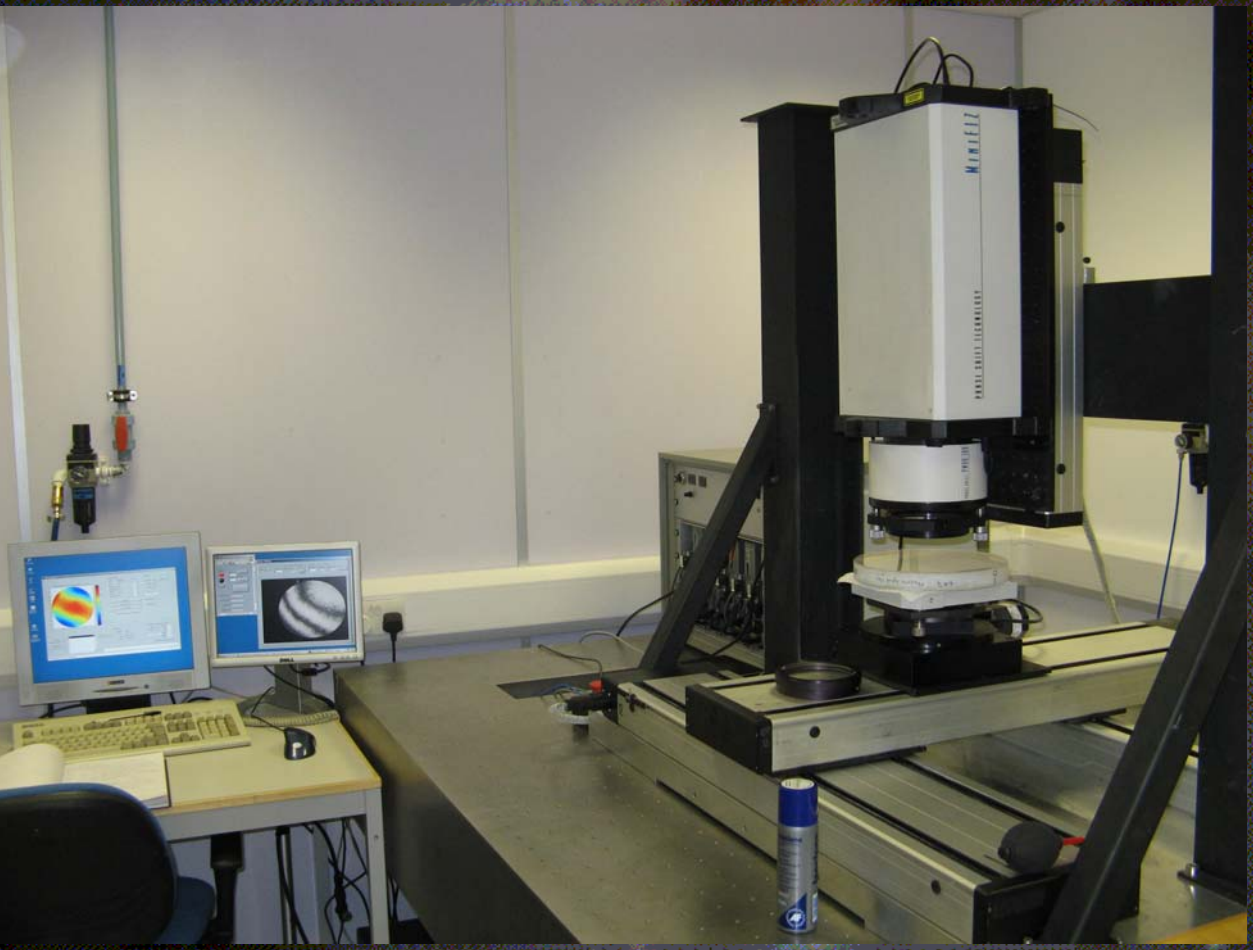
Advantages

- Increased dynamic range for on- and off- axis aspheres
- Close-up test reduces effects of air-turbulence
- Increased spatial resolution (more pixels)
- Handle large parts
- Handle steeply convex parts
- Possible application to convex/concave parts (e.g. saddles)

Key issues

- Size-envelope of module
- Environmental conditions
  - Vibration:- ambient, machine servos
  - Heat-load from machine and process
- Effectiveness of stitching software

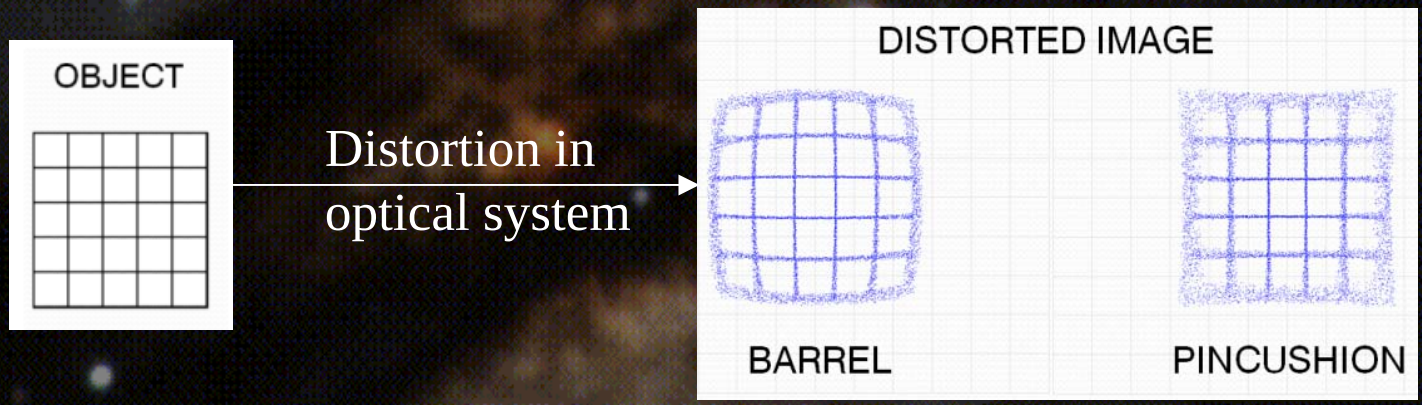
Test-rig for software development



- Stepper-motor rolling-element slide-ways
- Old Zygo PTI interferometer with Vidicon
- Vibration-isolated bench

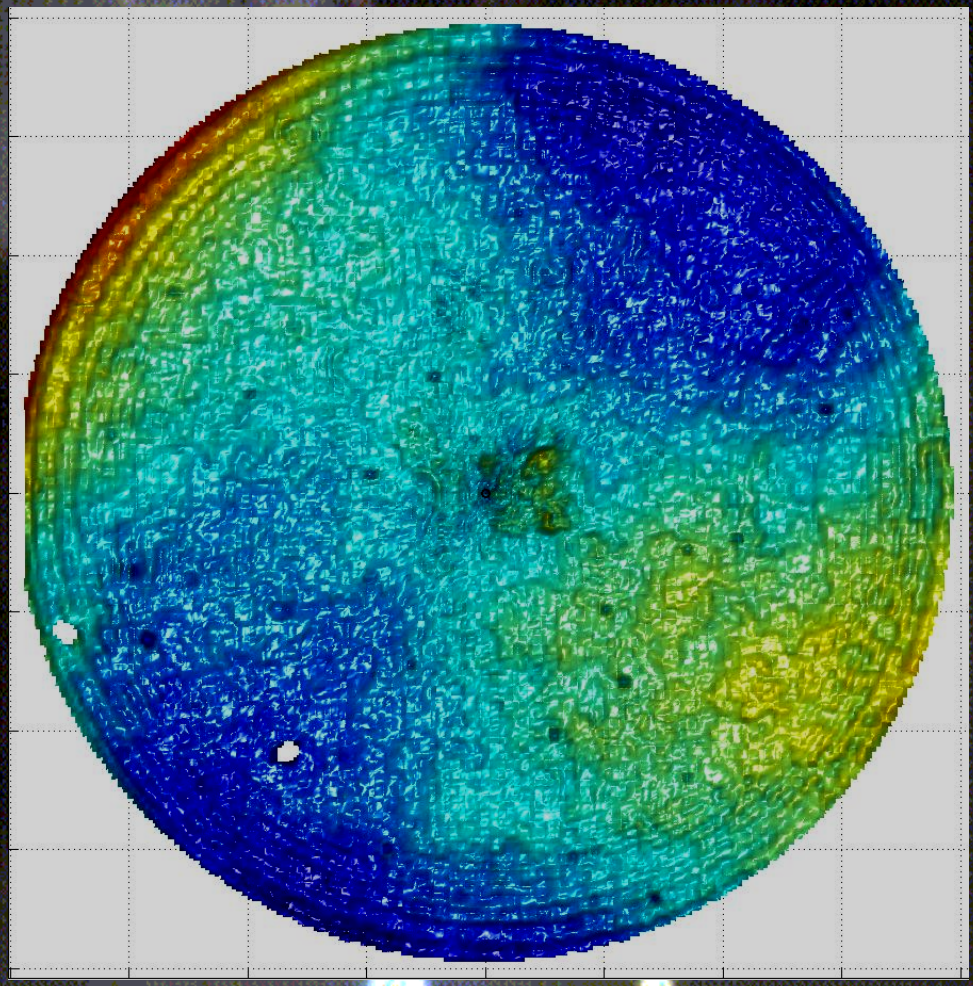
Stitching

- Individual phase-maps require correction for geometric distortion



- In the general case, stitching will not work well without distortion correction, especially on strongly-curved surfaces.

Effect of distortion

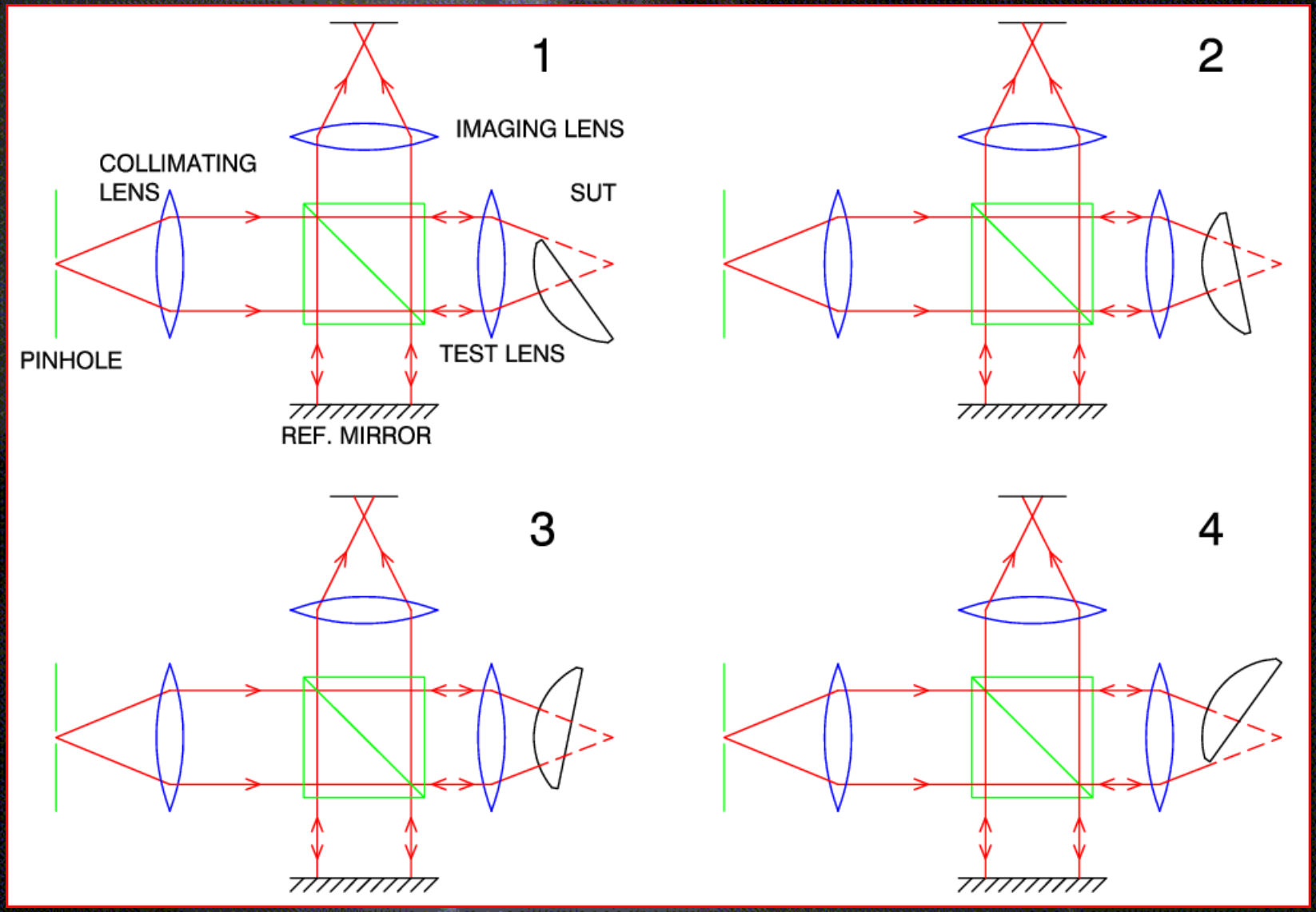


Stitching

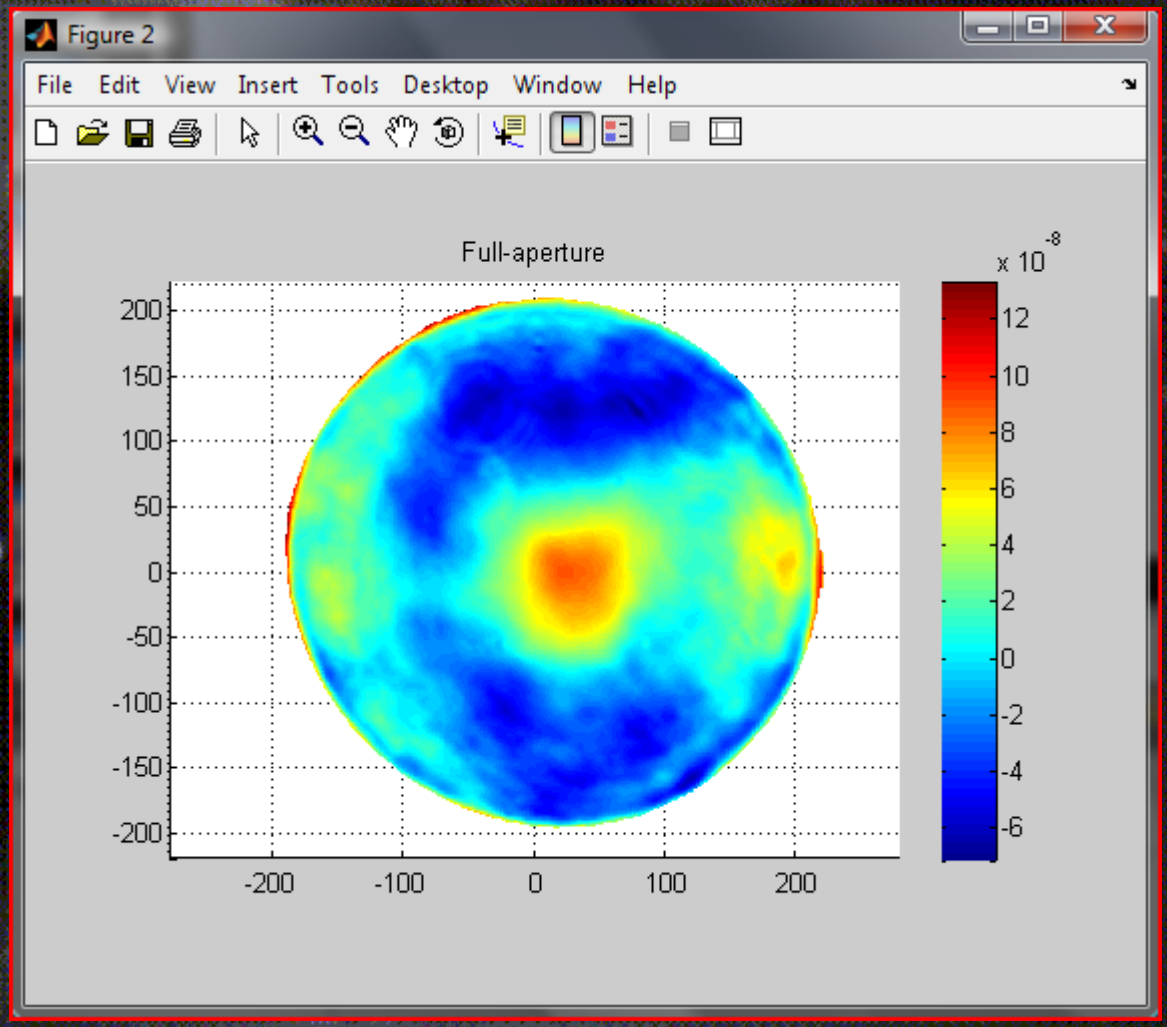
- Stitching then proceeds by optimization of the residuals in the overlap areas.

- The stitching error is estimated from residual noise, merit function and analysing data in the sub-aperture overlap areas.

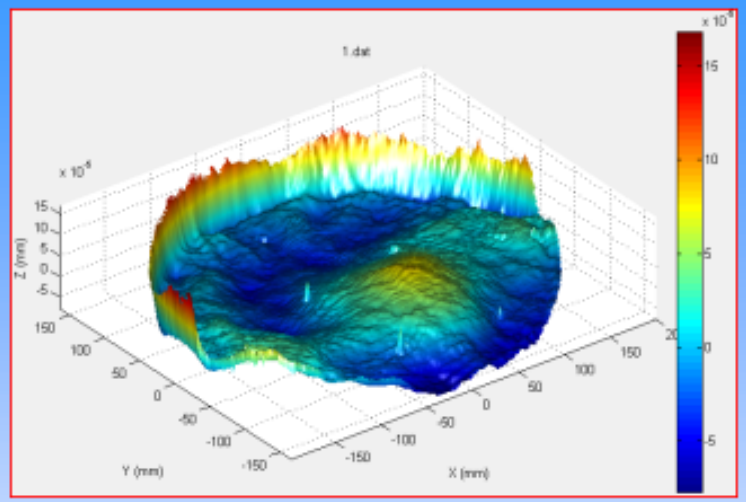
Example stitching a convex part

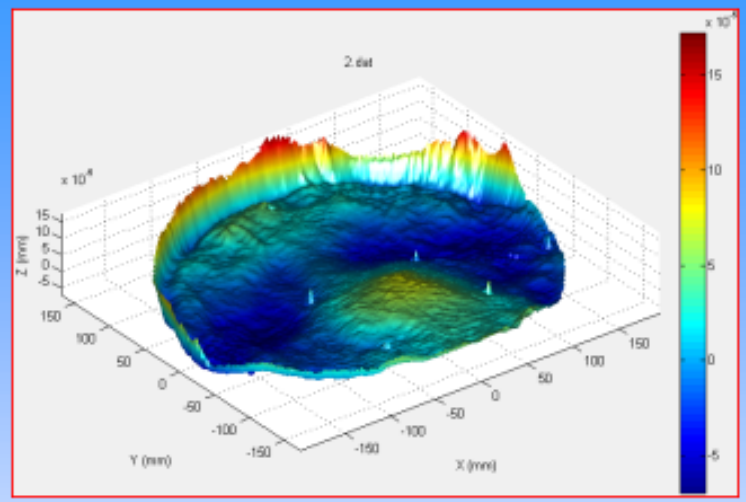


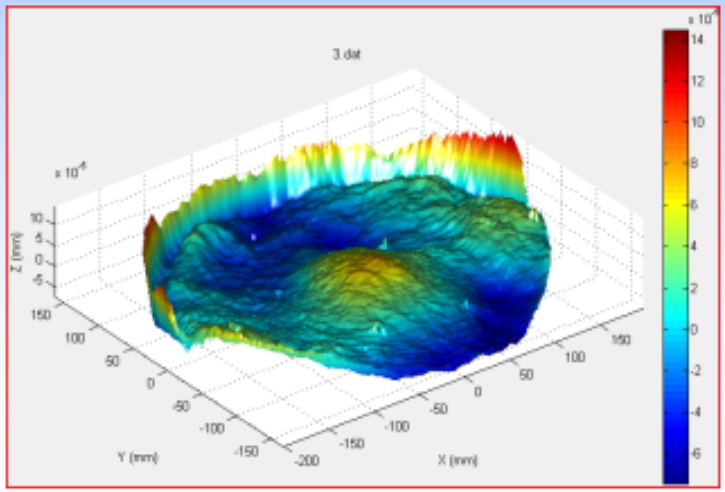
First results
1. Full aperture measurement

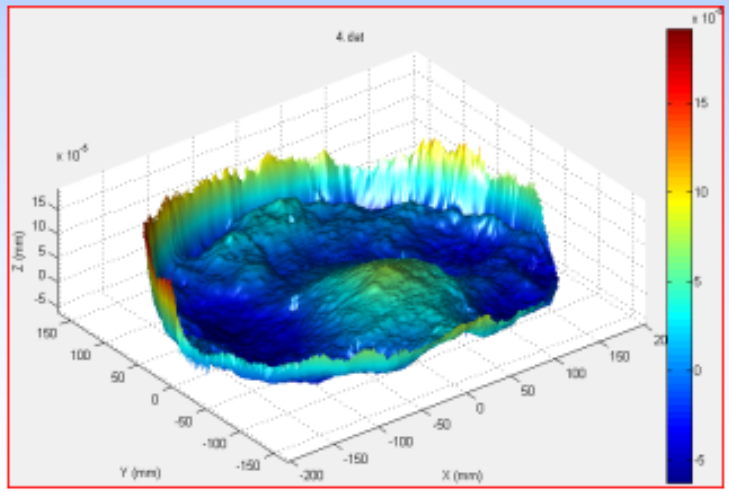


2. Raw sub-aperture measurements

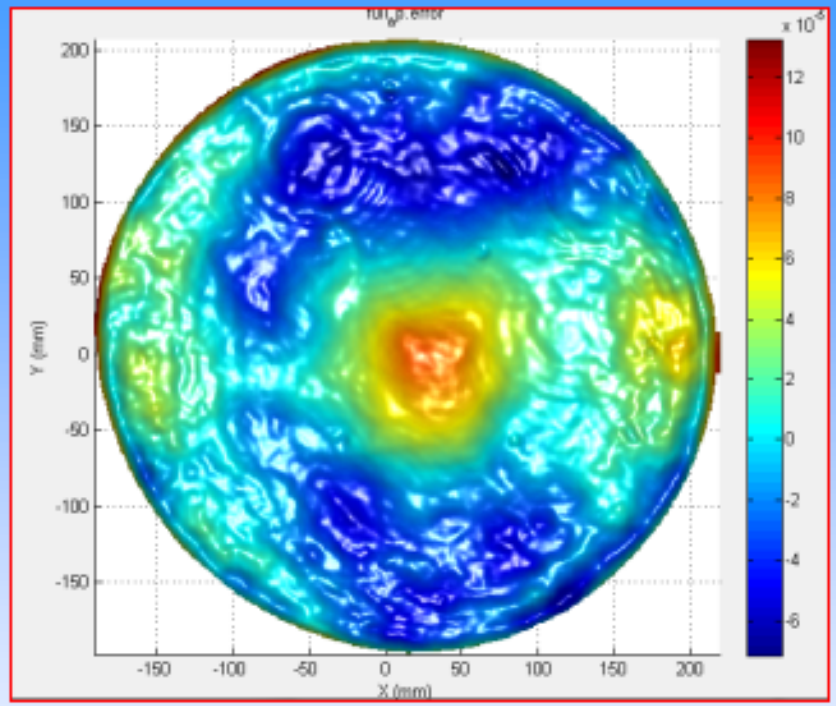




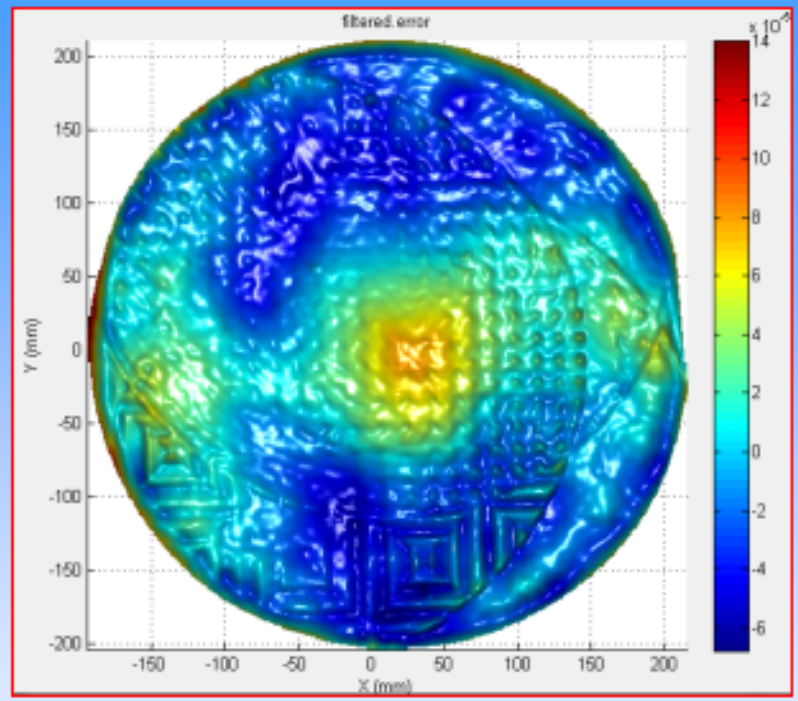




3. Comparison



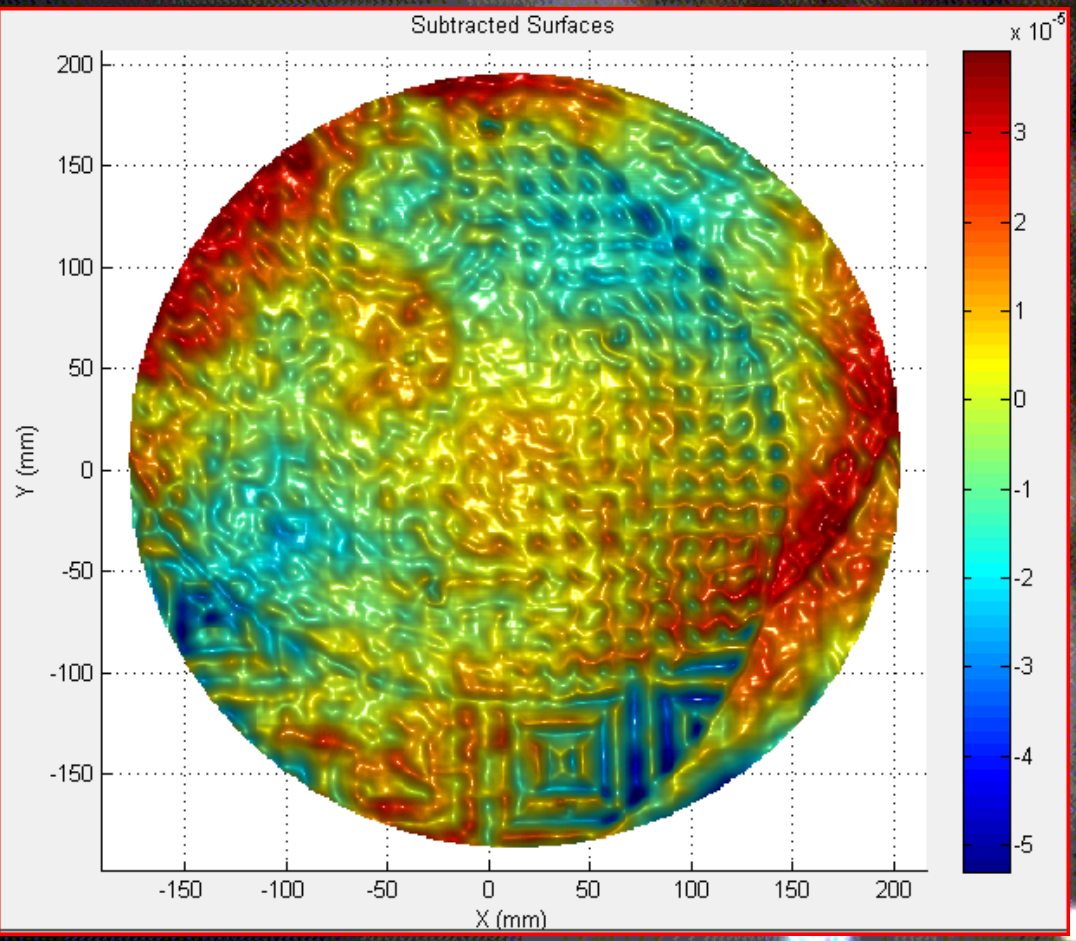
Full-aperture



Stitched

	RMS	PV
Full-aperture	32.0 nm	204 nm
Stitched	29.2 nm	208 nm

4. Difference
full-aperture & stitched



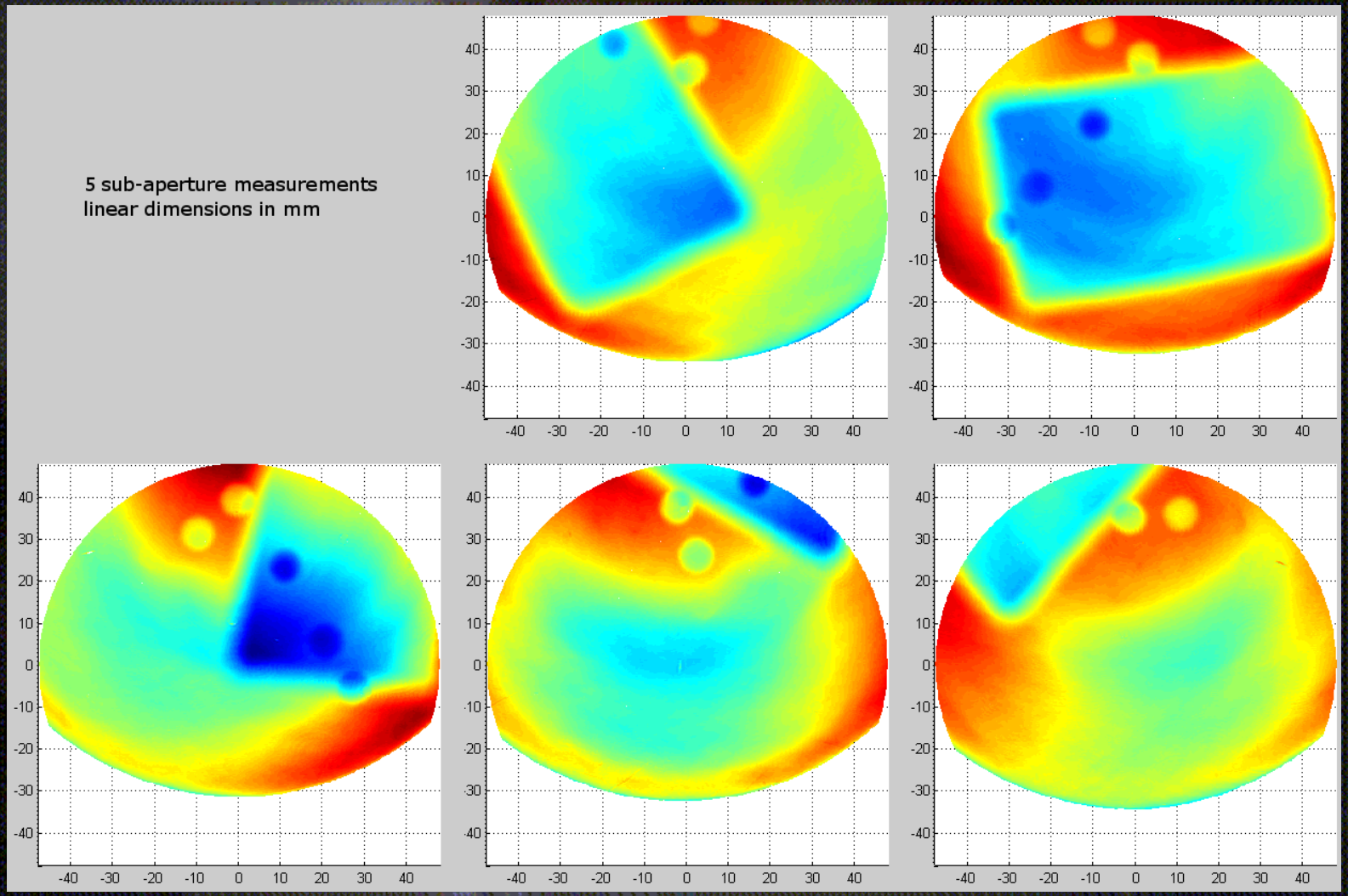
PV=92 nm
RMS 11 nm

Much of the residual error is systematic. Calibration is predicted to leave a few nm residual.

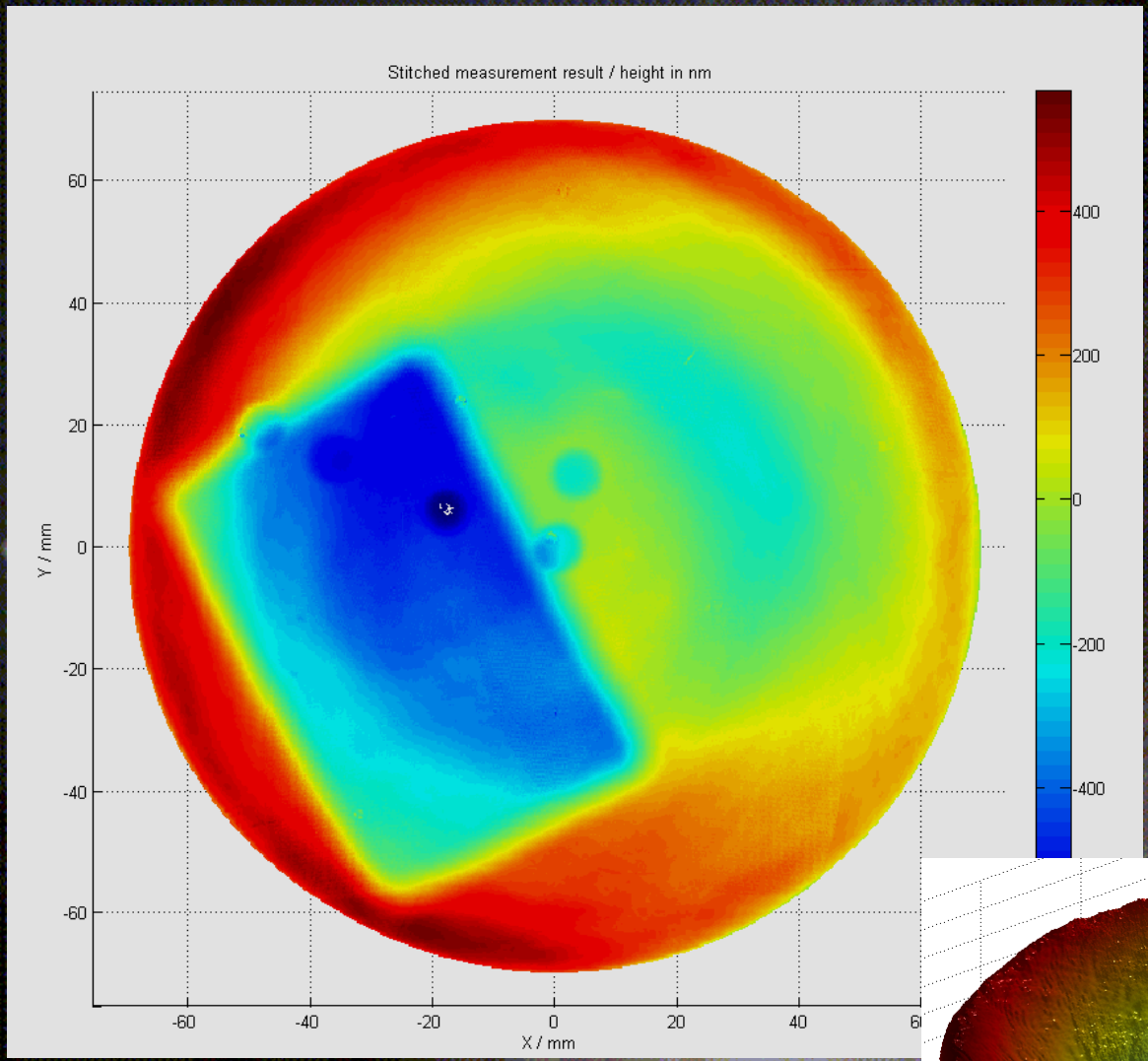
Expect residuals ~ X10 improvement after calibration

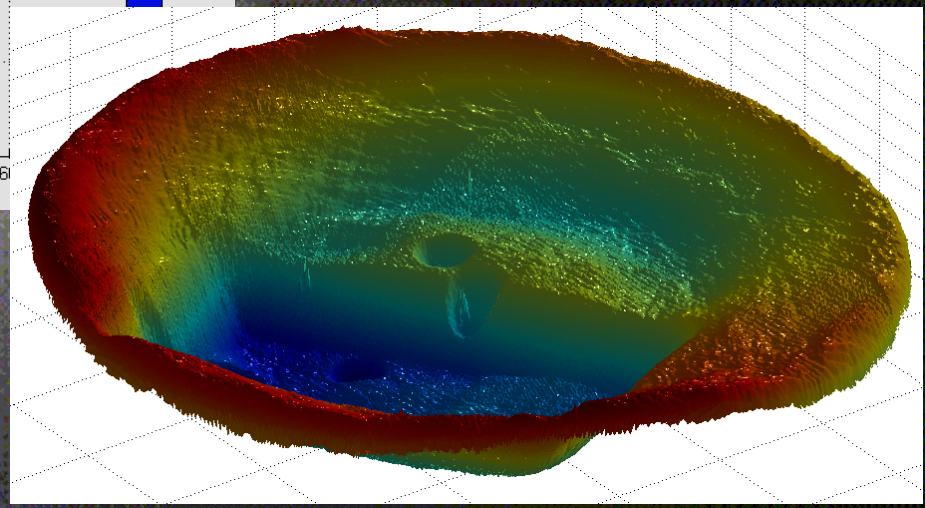
Stitching a part with complex features (140mm diameter)

5 sub-aperture measurements
linear dimensions in mm



Stitched result

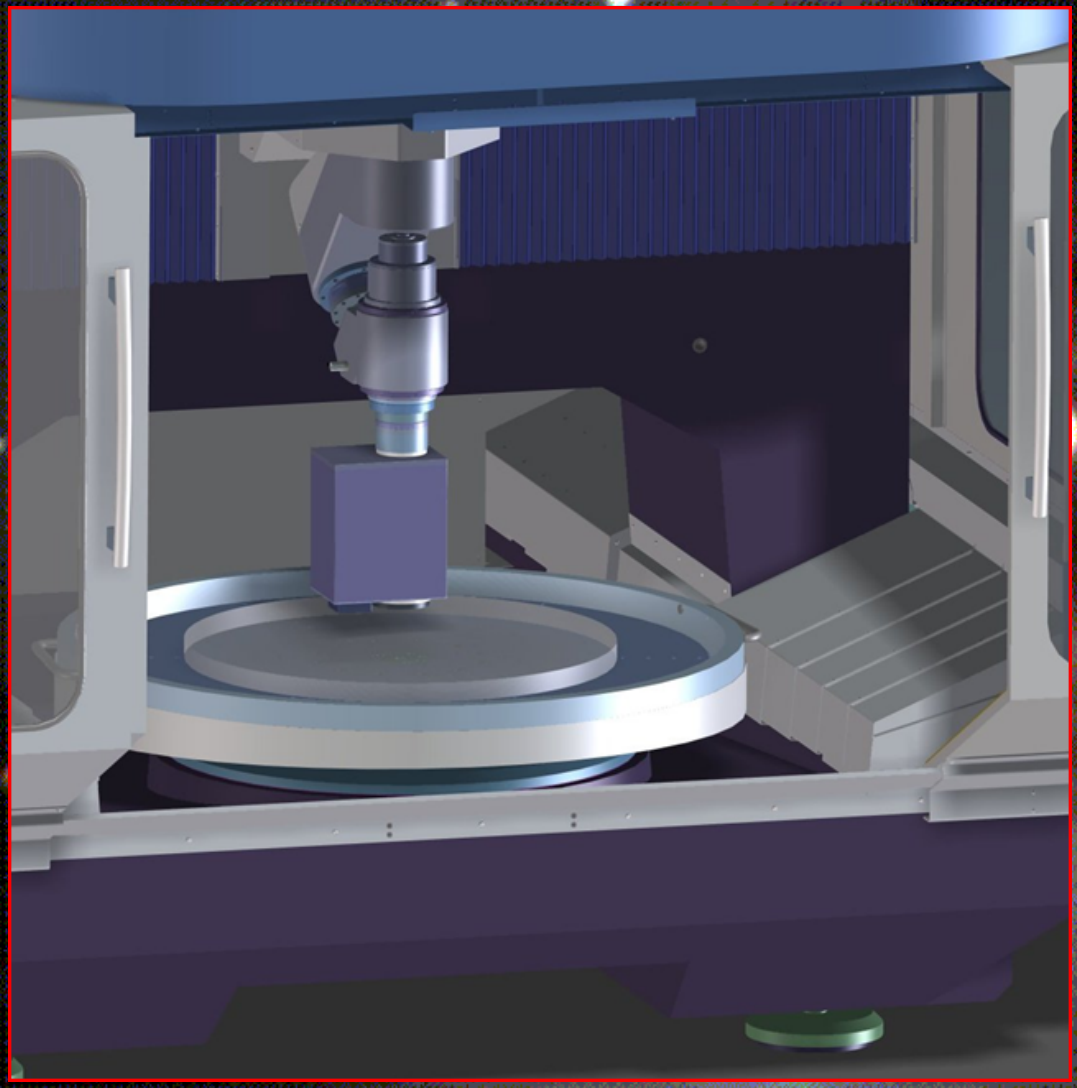




Module design: vibration and thermal

- Collaboration with 4D Technologies Corp.
  - 4D are developing a compact version of their simultaneous phase-shift interferometers
  - Short exposures freeze vibration

- Interferometer tests in machine environment confirm suitability for metrology
  - Polishing environment is flooded with polishing slurry at constant temperature when in use.



Module concept in polishing machine

X,Y,Z,A,B motions

Next stages

- Validate stitching on aspheres
- Evaluate prototype 4D compact interferometer
- Integrate optics and interferometer into on-machine module
- Formal consideration of uncertainty of measurement
- Delivery of first commercial system


Thank you!