Advances in traceable nanoscale metrology

Institute of Physics
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Professor Richard Leach FInstP FIoN
Mass & Dimensional

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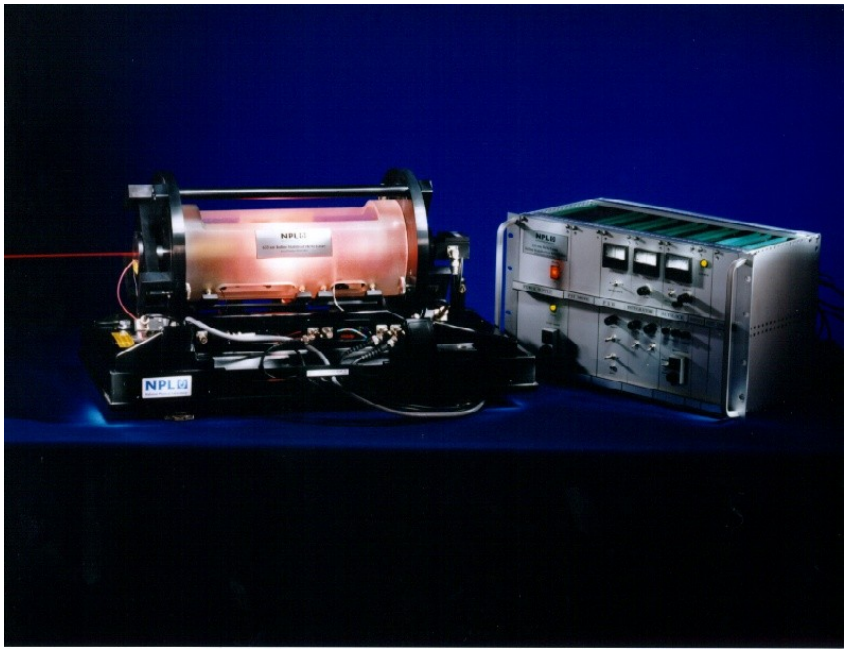
Talk structure

- A gentle reminder…
- Need for MNT metrology
- Surface topography measurement
- Atomic force microscopy
- Micro-co-ordinate metrology
- Some optical trickery
- Low force measurement

An important concept - traceability

"property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons **all having stated uncertainties**"

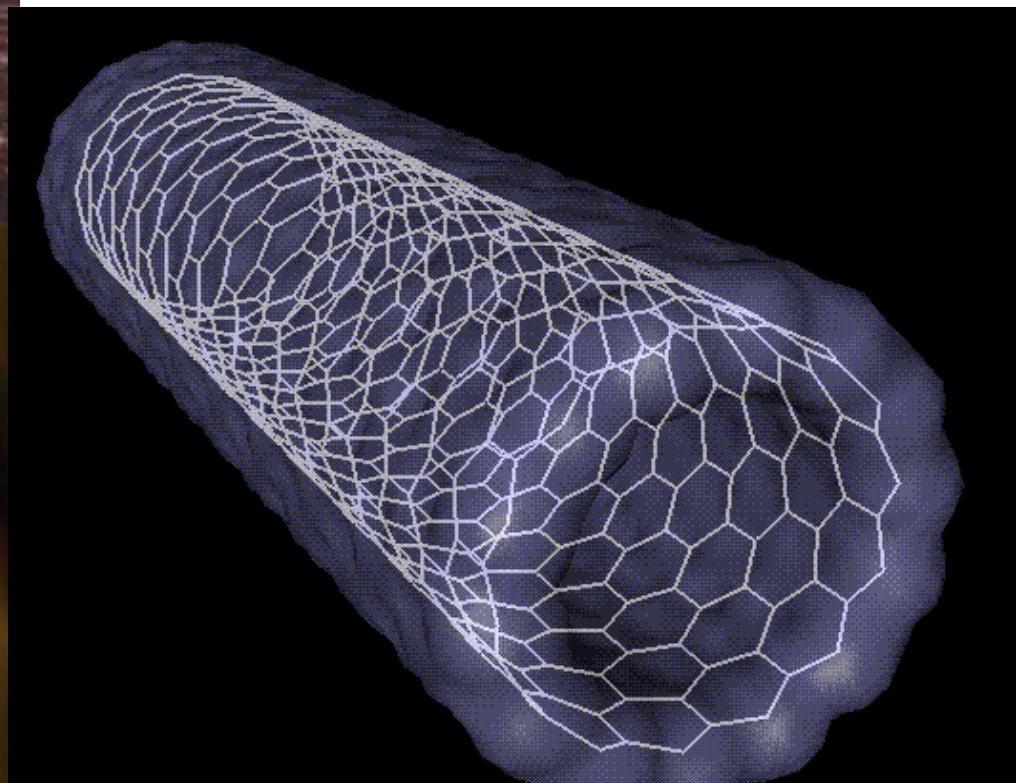


Iodine-Stabilised He-Ne laser

Micro/nano-structures – nature and man-made

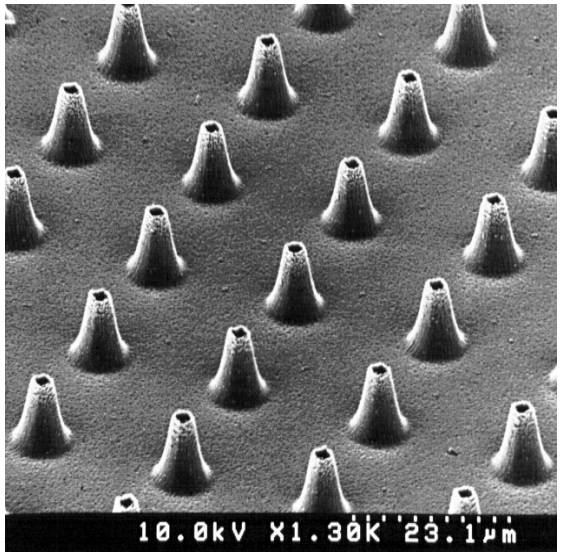
Carbon Nanotube Arrays with Strong Shear Binding-On and Easy Normal Lifting-Off

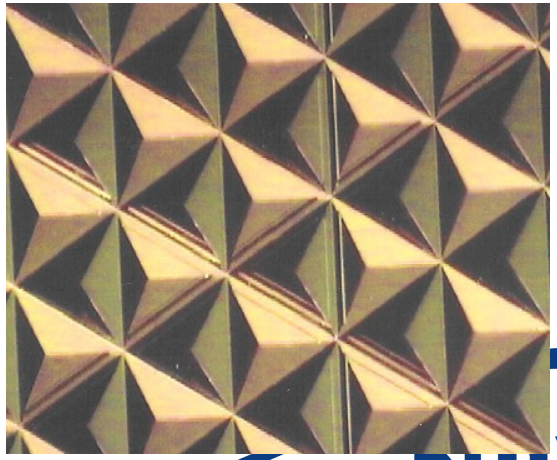
Qu et. al. *Science* Oct 2008



The importance of MNT metrology

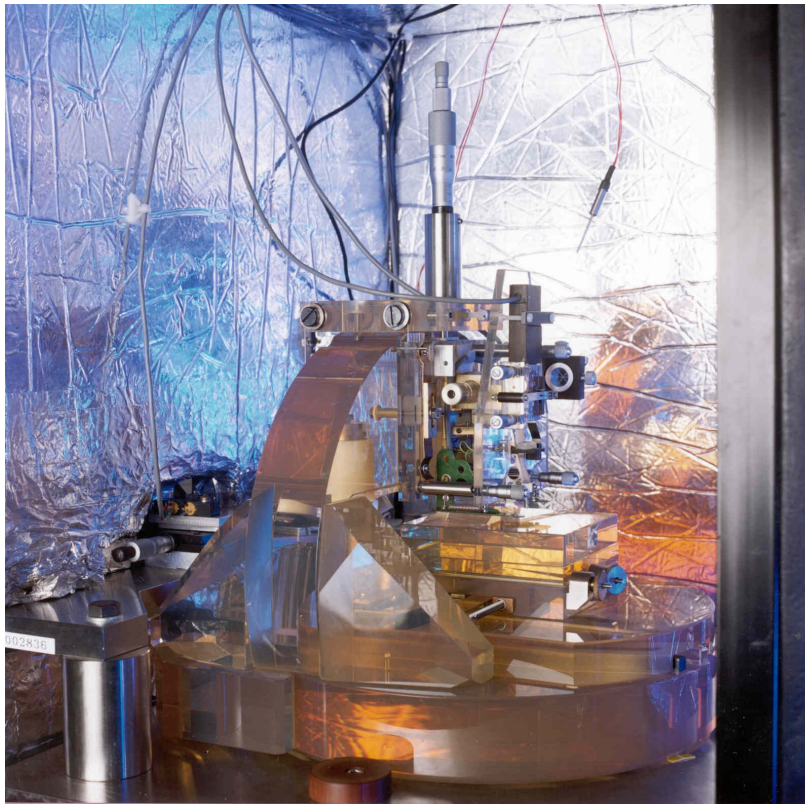
- Modern trend is towards miniaturisation – leads to lighter weight, better portability, less energy consumption, more functionality in same space, *etc.*
- But, as parts shrink and integration becomes complex, true 3D metrology becomes difficult or impossible
- Can no longer simply "measure from above"





Surface profile traceability – NanoSurf IV

- 10 μm *z* range, 50 mm *x* range
- 1 nm uncertainty
- Measures ISO 5436-1 transfer artefacts
- Dry-bearing slideway
- Interferometry leads to traceability
- Zerodur metrology frame



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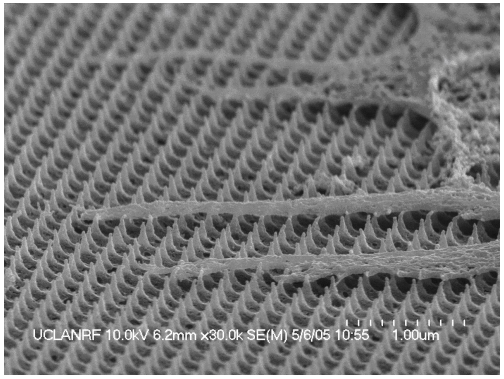
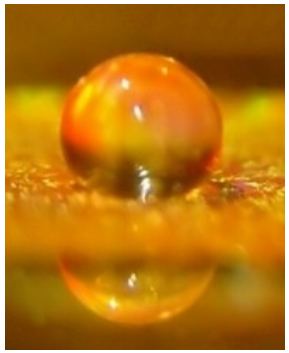
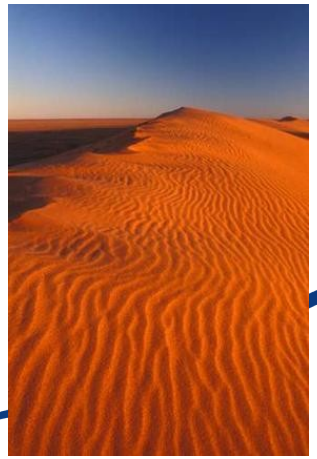
Areal surface texture – why?

- Allows structuring of a surface to enhance its functional capabilities
- Profile measurement not sufficient in many circumstances
- Areal measurement has more statistical relevance
- Less chance of missing significant features







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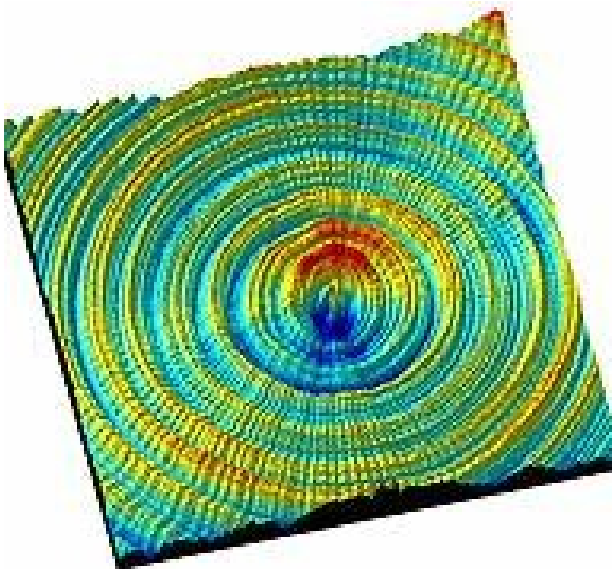
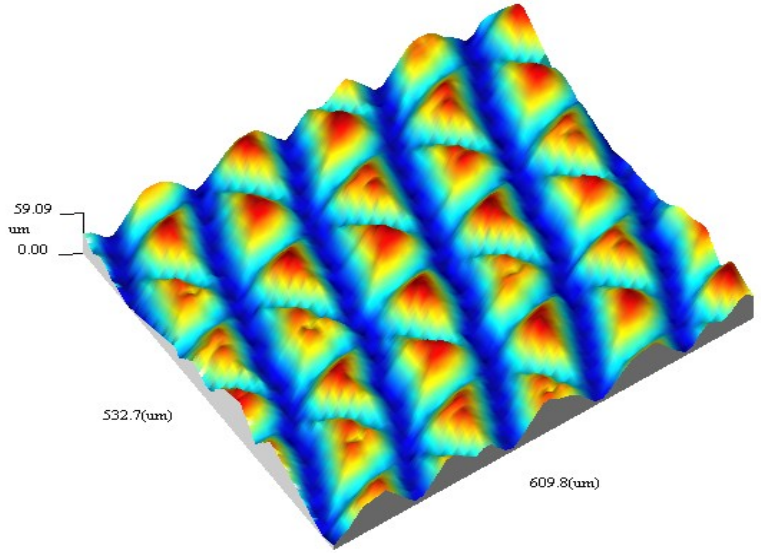
Traceability for areal surface texture measurements

- Drive in industry to impart functionality into a product by engineering or structuring the surface. This requires 3D or areal surface metrology
- There are stylus and optical instruments on the market but no direct route to traceability





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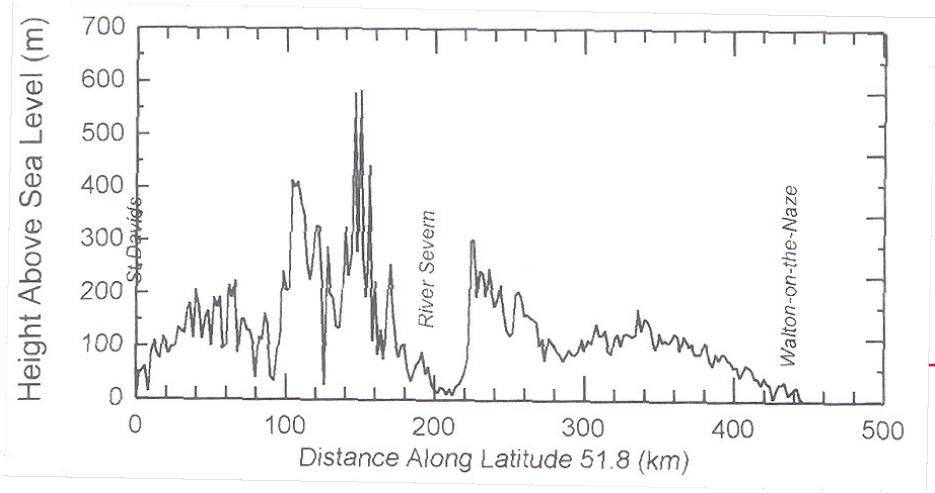
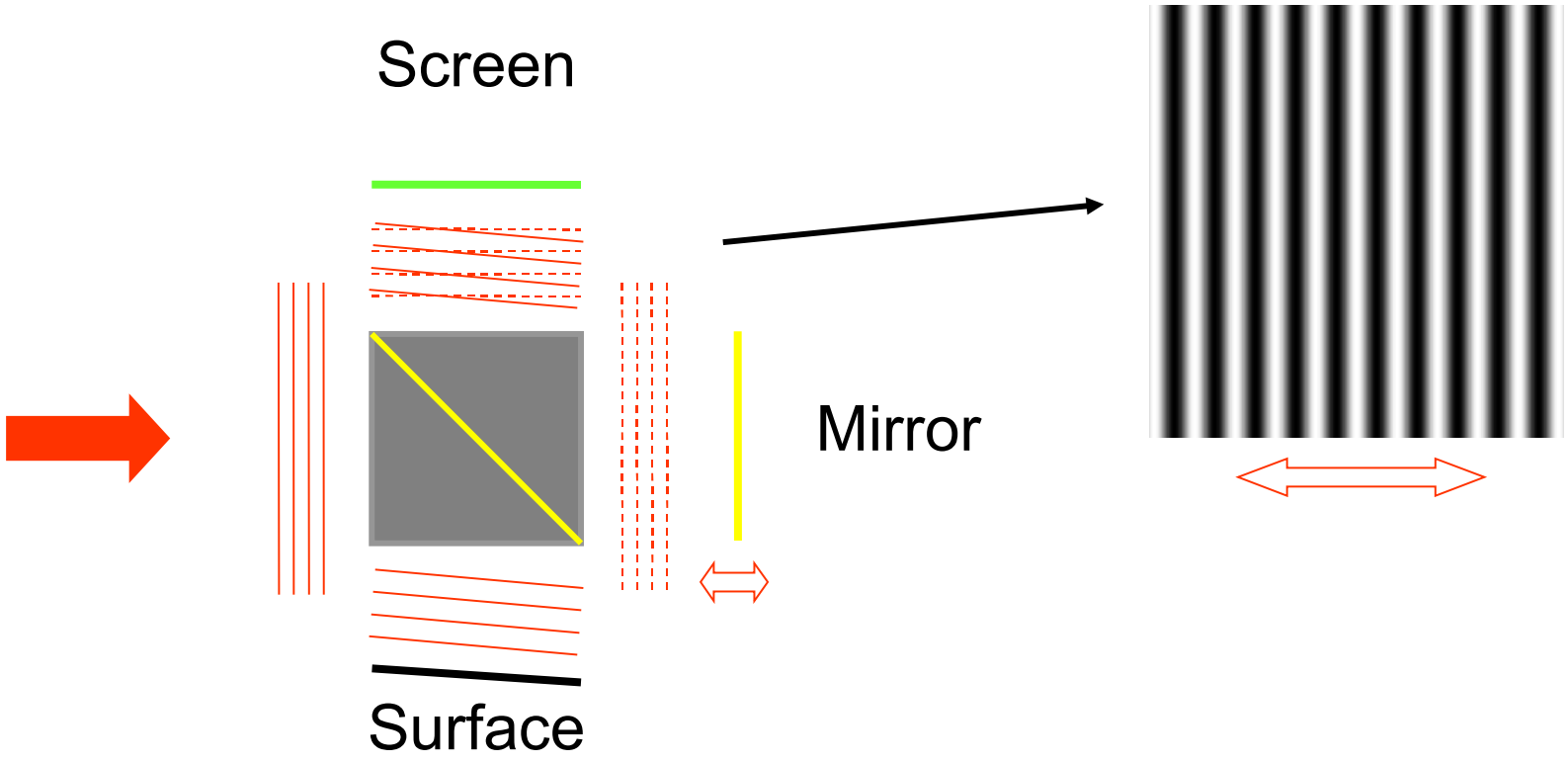
Describing a surface using a single profile!



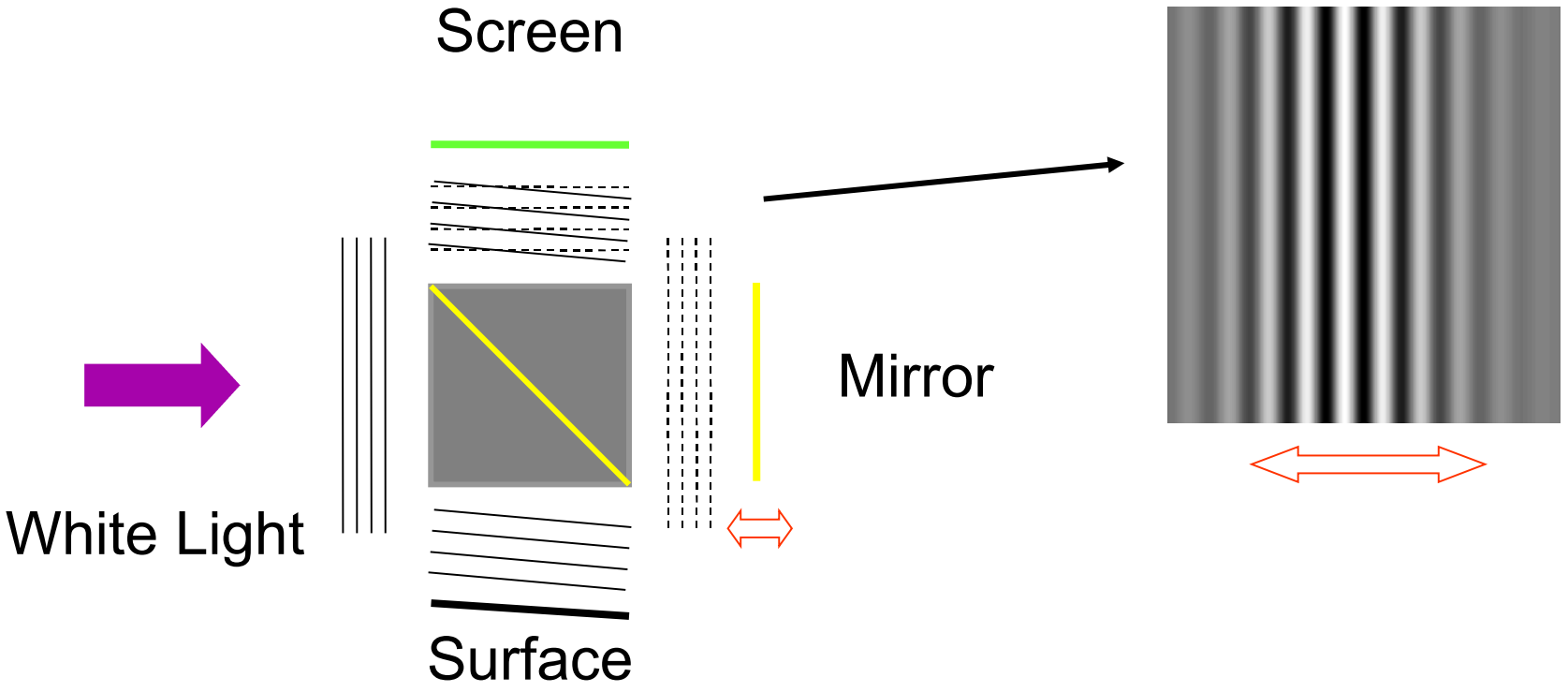
Stylus v's optical – the old battle!

- Stylus slow, optical fast
- Stylus has more predictable fidelity?
- Optical instruments are subject to NA and other optical effects
- Stylus instruments have finite stylus and can cause damage
- There will be no victors!

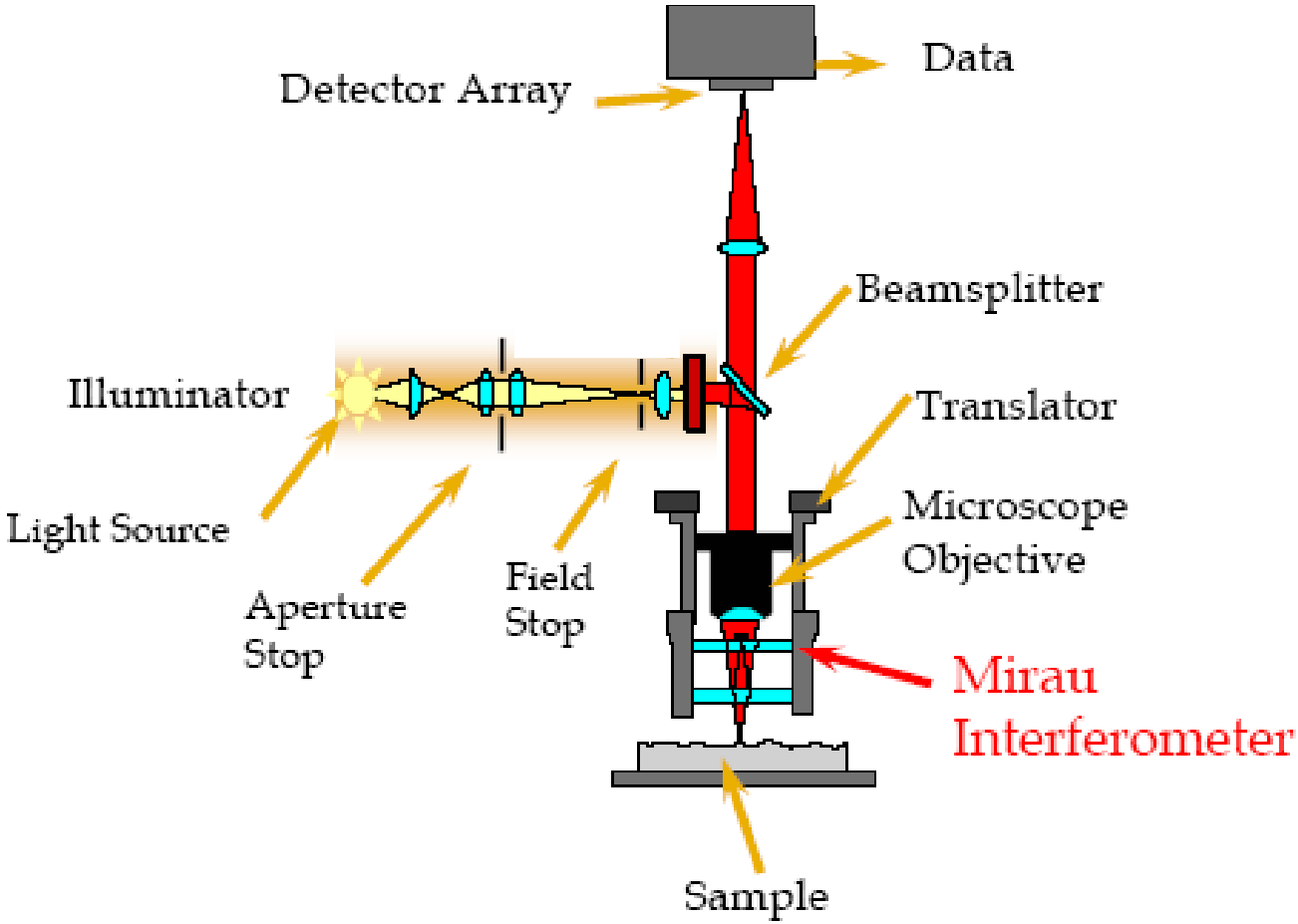
Michelson interferometer – laser illumination



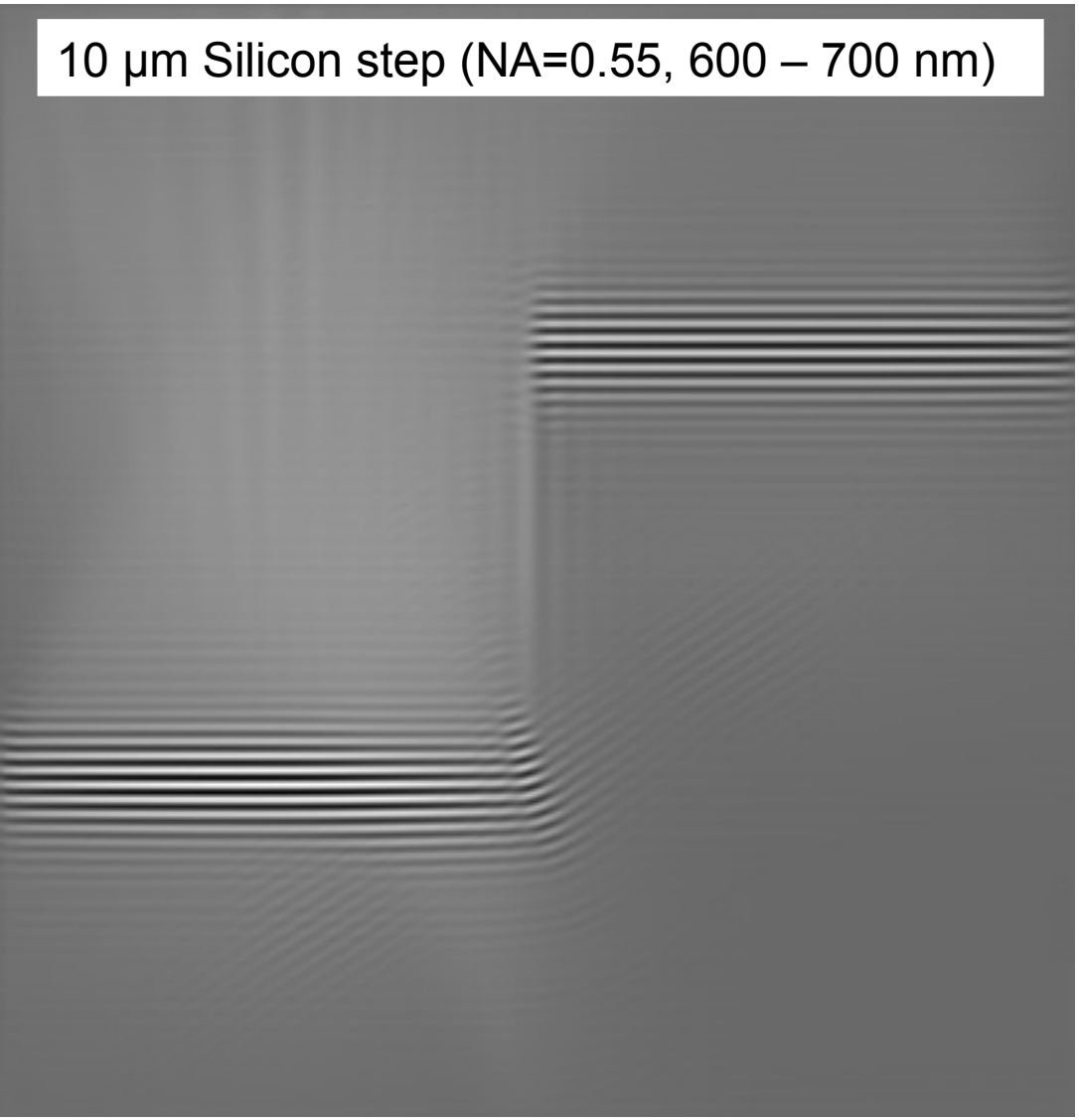
Michelson interferometer – white light illumination



Optical example – scanning white light interferometer



Step Interferogram



The information present in the interferogram is related to the step height by estimating the position of peak visibility (called vertical scanning interferometry (VSI) mode), and/or the phase of the interference fringes (called phase shifting inteferometry (PSI) mode).

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Some SWLI limitations

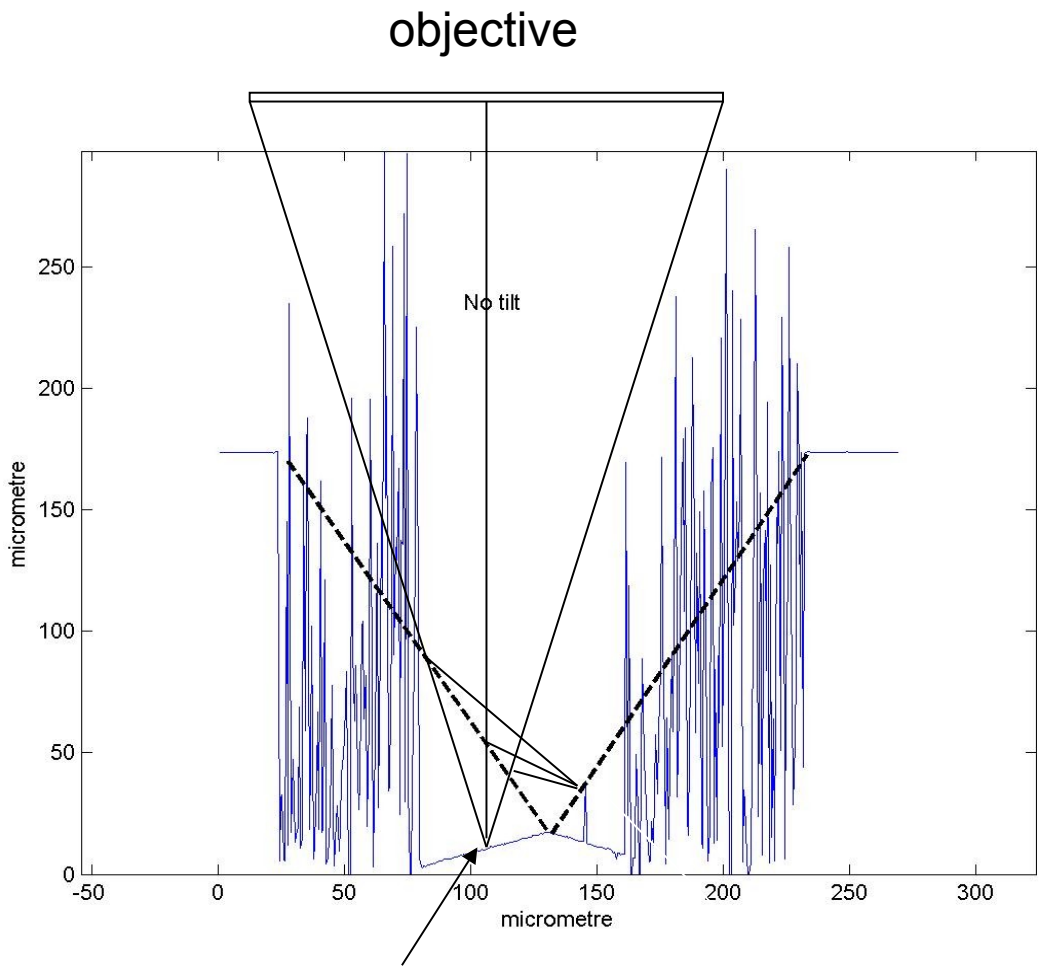
- Edge Artefacts – The Bat Wing Effect
- Ghost Steps – Dispersion Effects
- Material Effects
- Multiple Scattering / Surface Roughness Measurement

Gao F, Leach R K, Petzing J,Coupland M 2008 Surface measurement errors using commercial scanning white light interferometers *Meas. Sci. Technol*. **19**

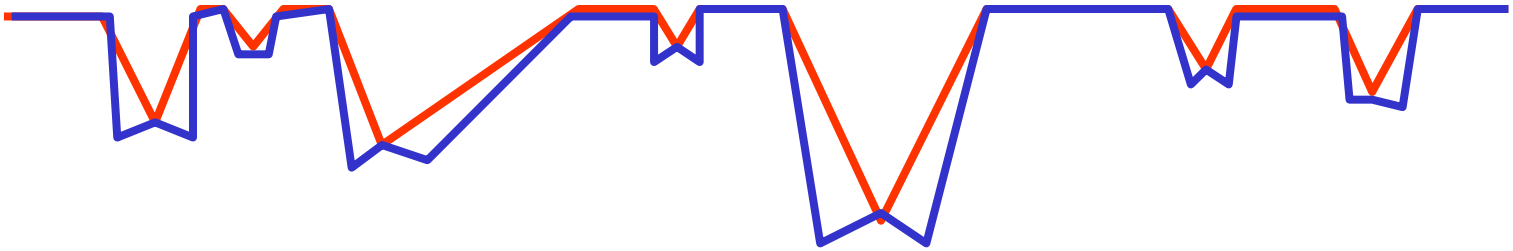
Optical limitations – vee-groove example

A basic ray analysis shows this type of error is due to multiple reflection

Note the error is approximately 100 μm here!



Surface Roughness Over-estimation



Actual Surface

Measured Surface