Limitations of vertical scanning white light interferometers

EMAN/Zygo event

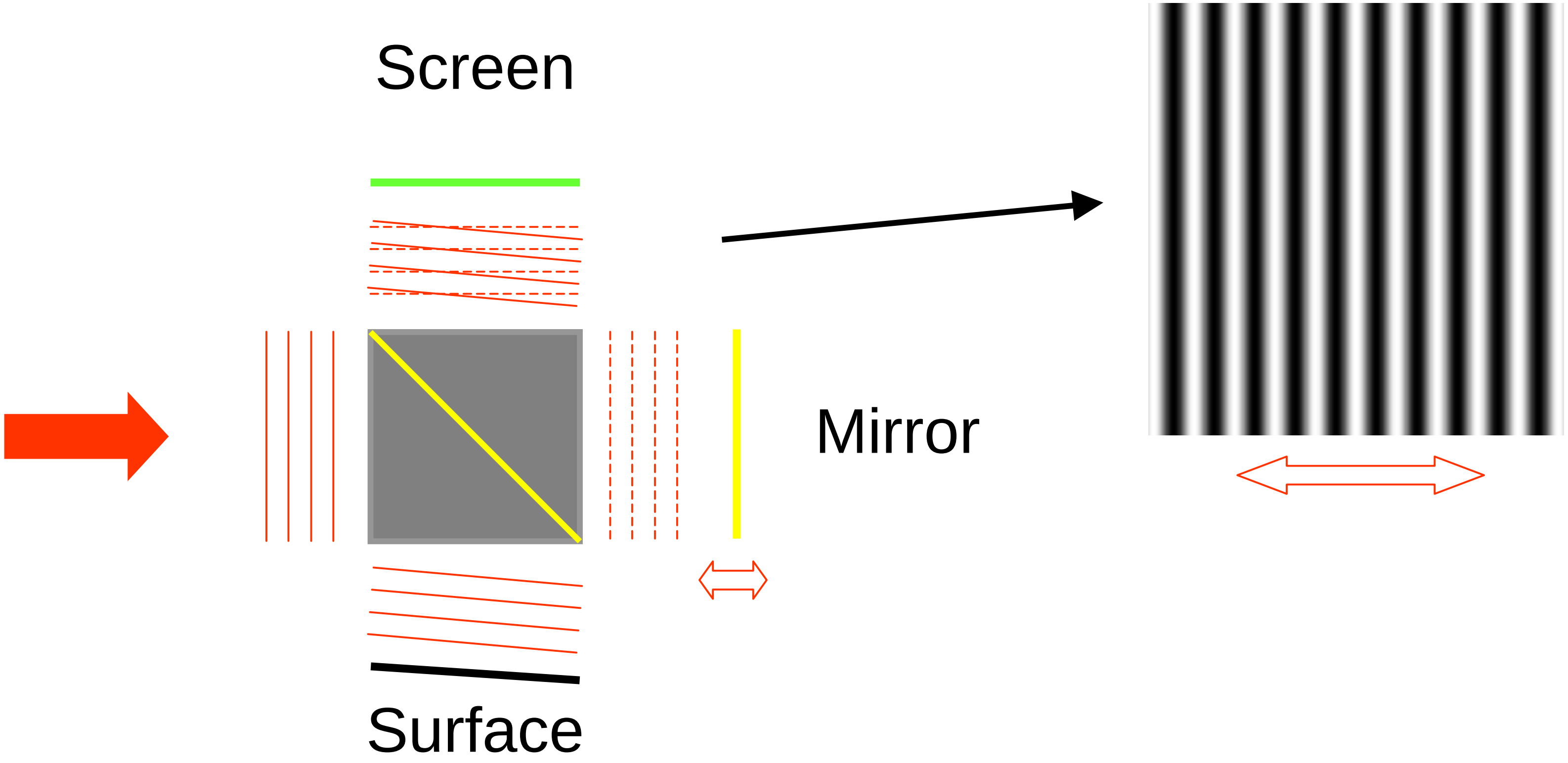
February 2007

Richard Leach (NPL)

Jeremy Coupland (Loughborough University)

National Physical Laboratory

Michelson interferometer – laser illumination

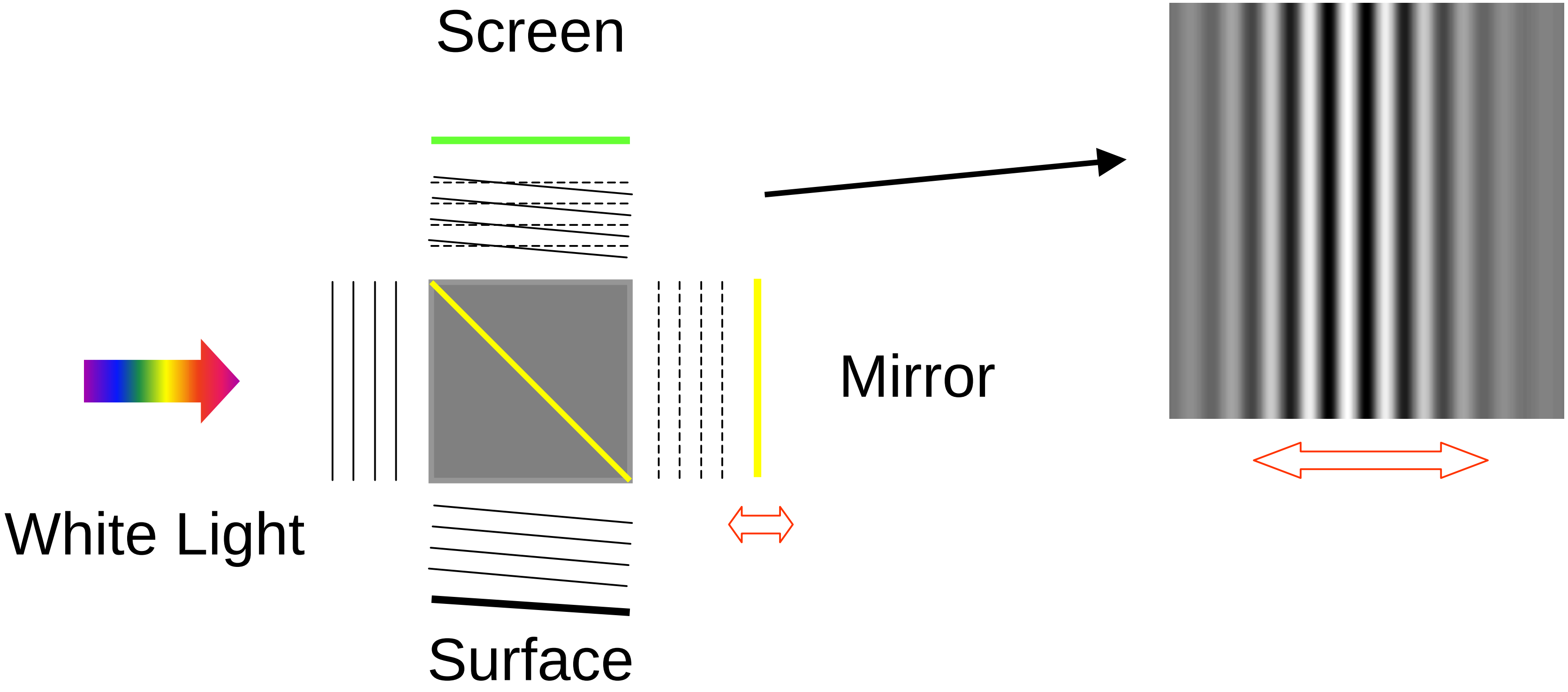


Screen

Mirror

Surface

Michelson interferometer – white light illumination

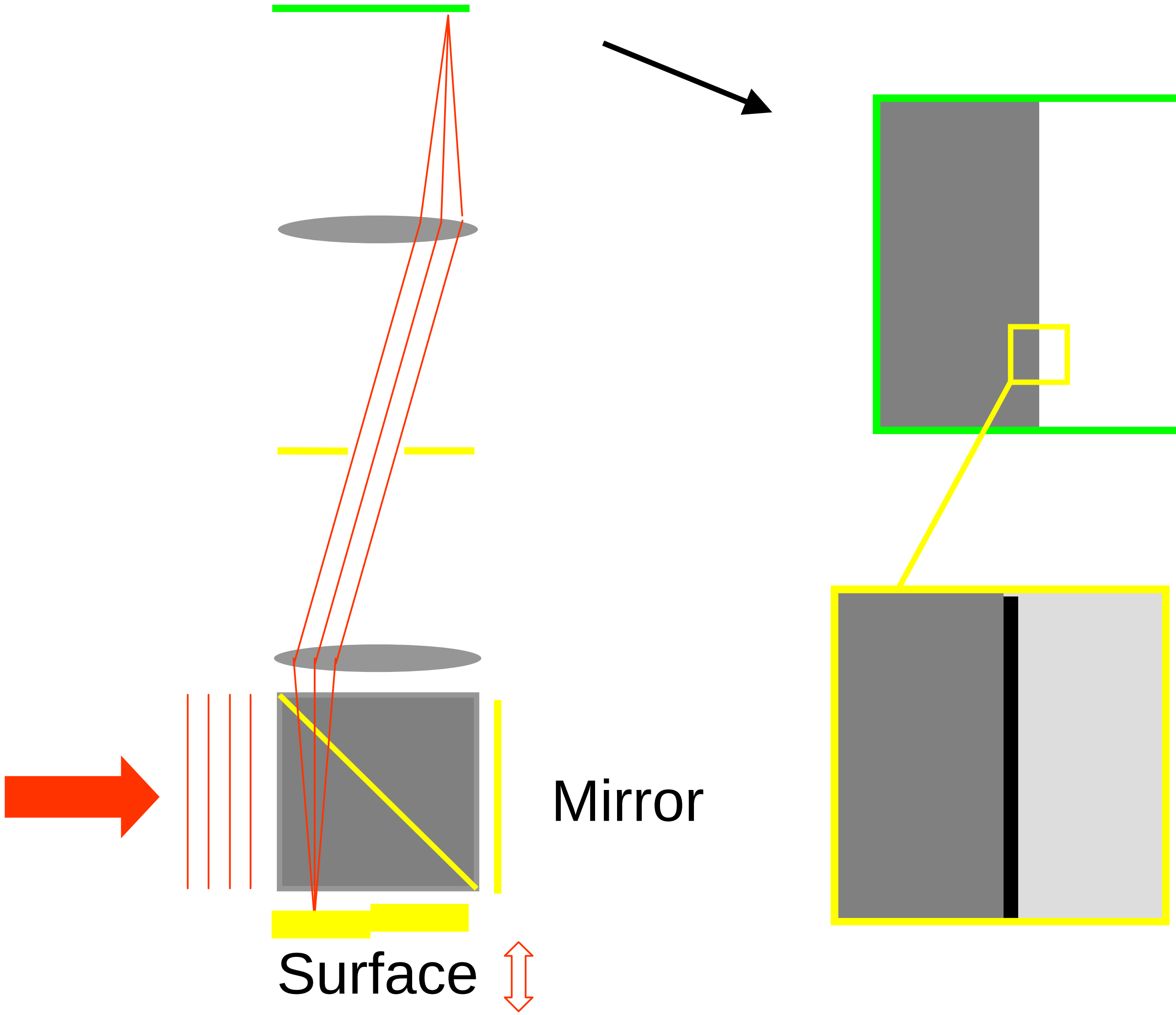


Screen

Mirror

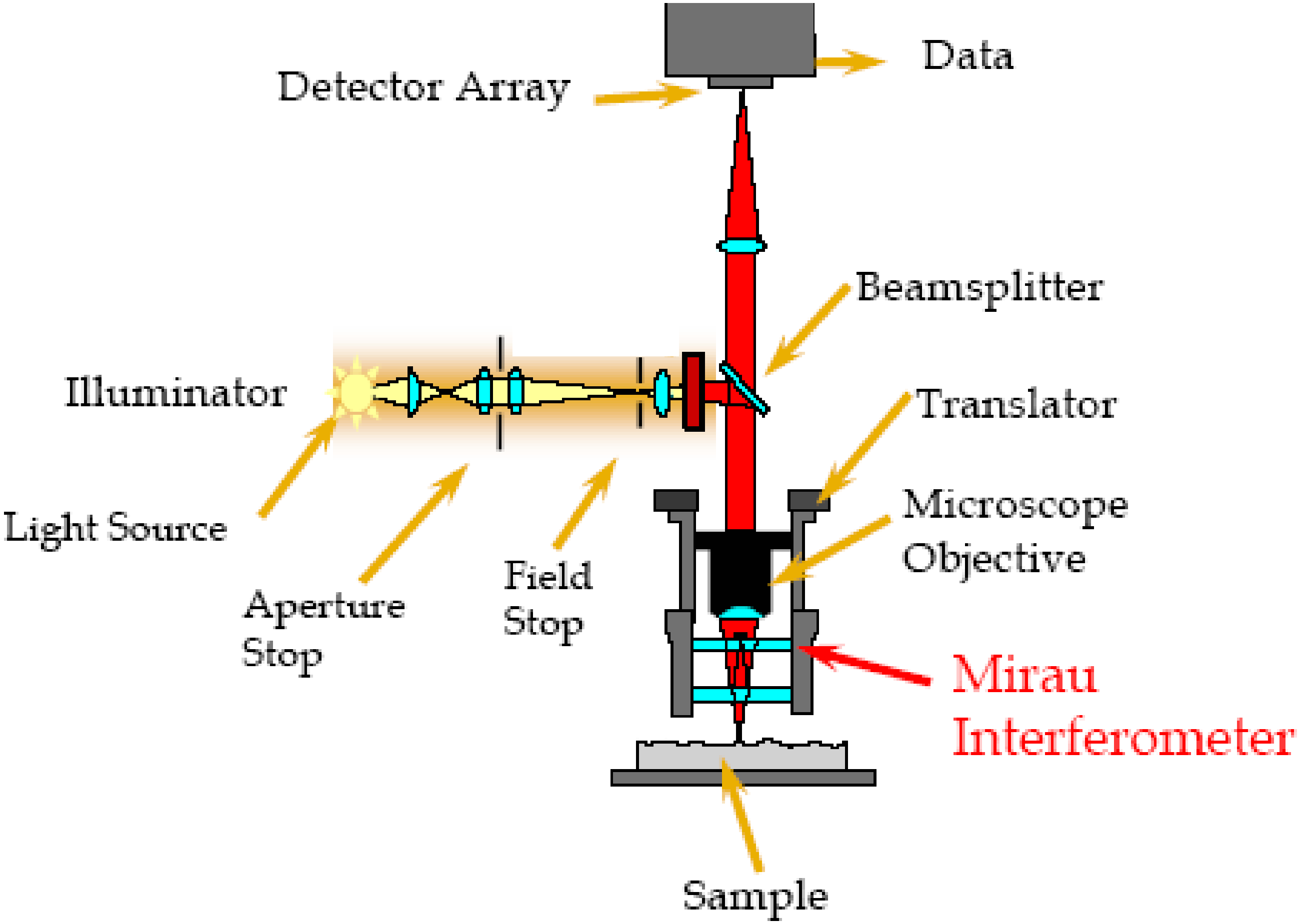
White Light

Surface

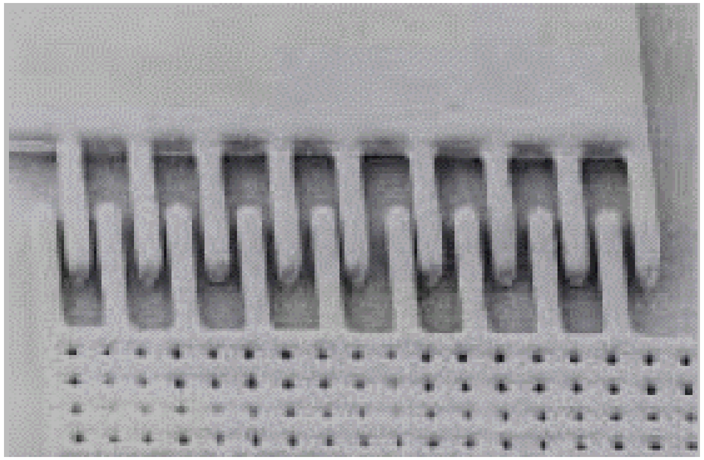


Scan surface rather than reference – object always in focus at point of maximum fringe contrast

SWLI schematic

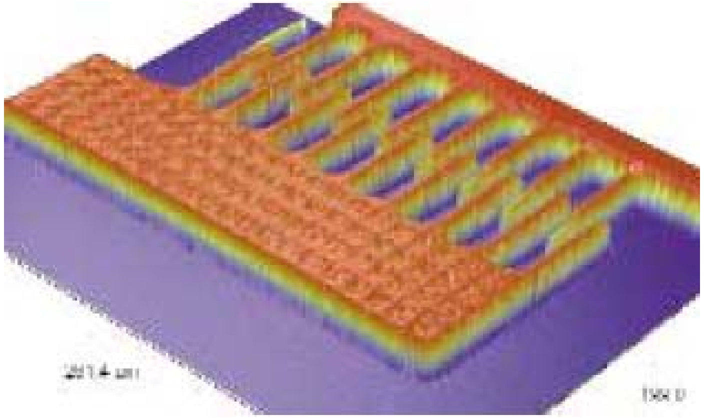


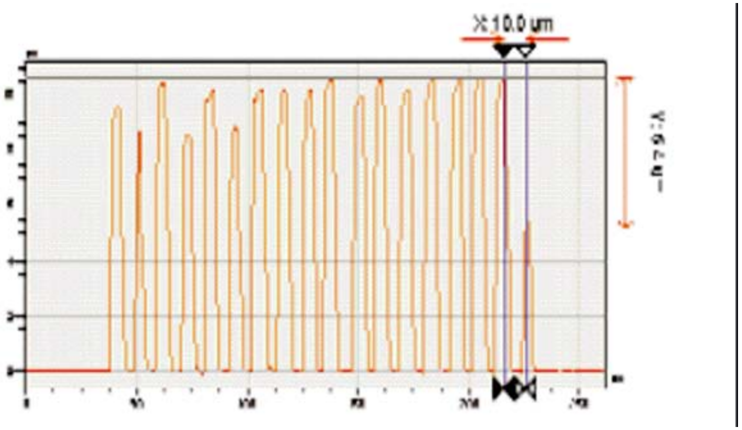
Commercial SWLIs



SEM (650X)

Optical Profilometry gives quantitative measurements that in the past would require destructive sectioning using SEM



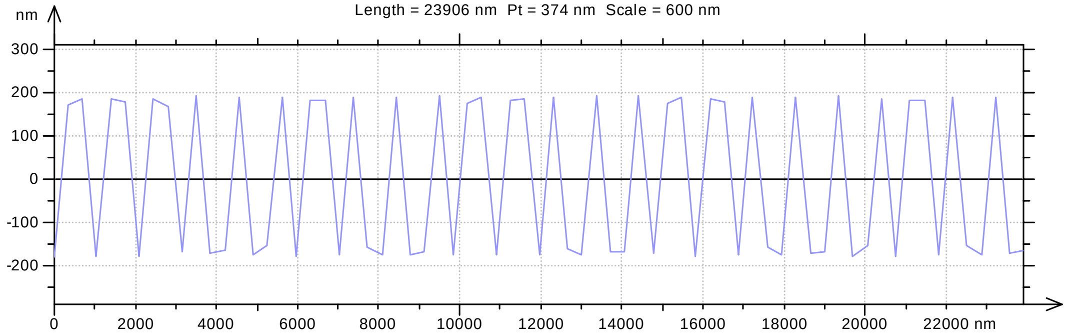


But there are some problems….

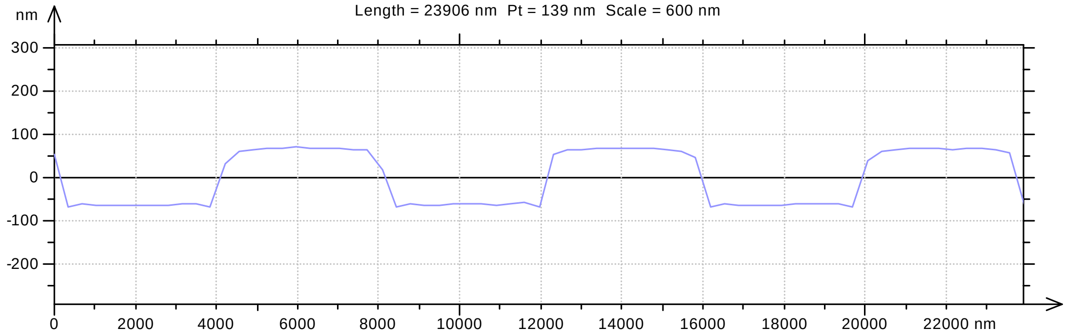
Objective lens limitations

Objective	NA	Optical resolution/μm	Pixel size/ μm
X10	0.3	1.12	1.76
X20	0.4	0.84	0.88
X50	0.5	0.61	0.35

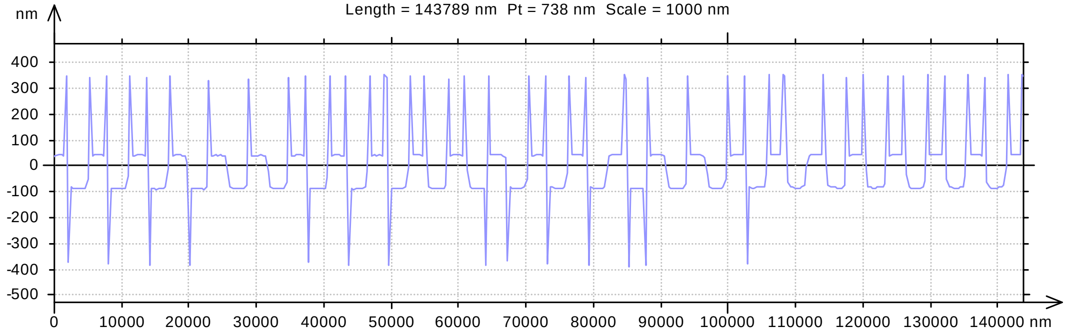
- Note that the optical resolution does not take into account the ability to measure depth, only the lateral intensity

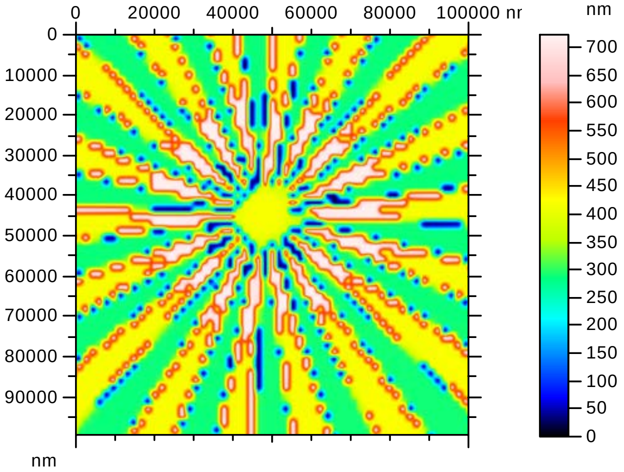


1 µm pitch, X50

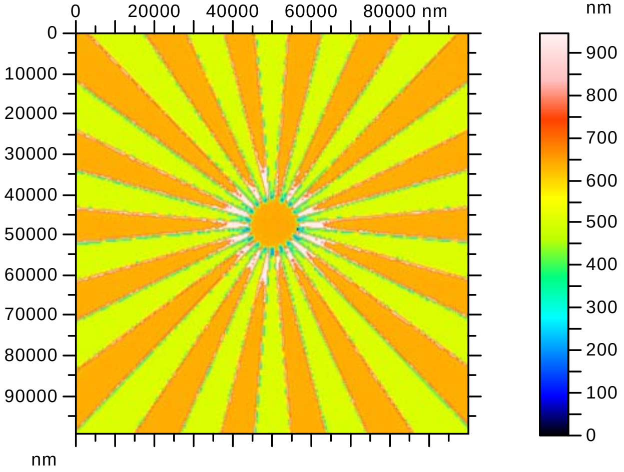


8 µm pitch, X50





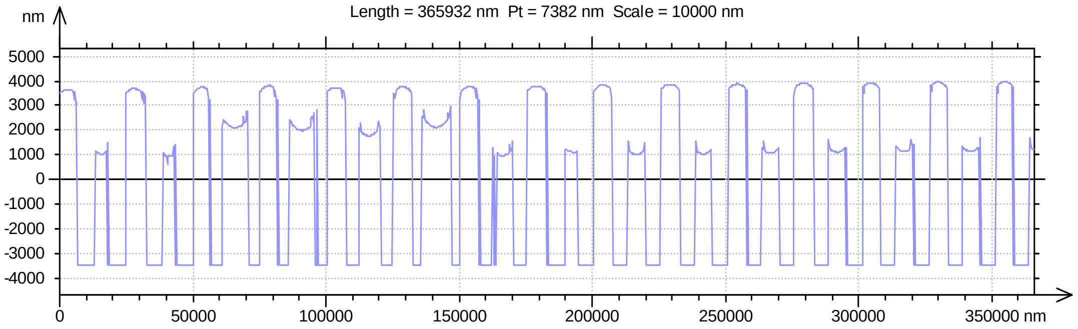
X10



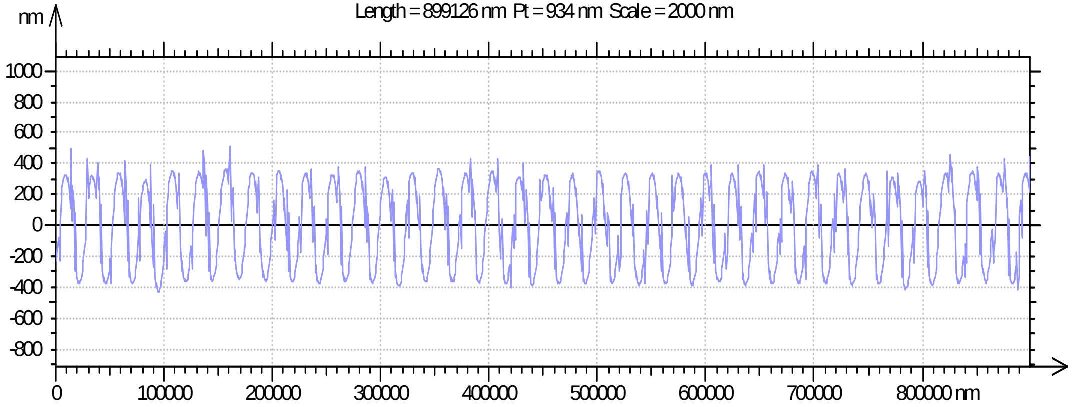
X50

Slope limitation

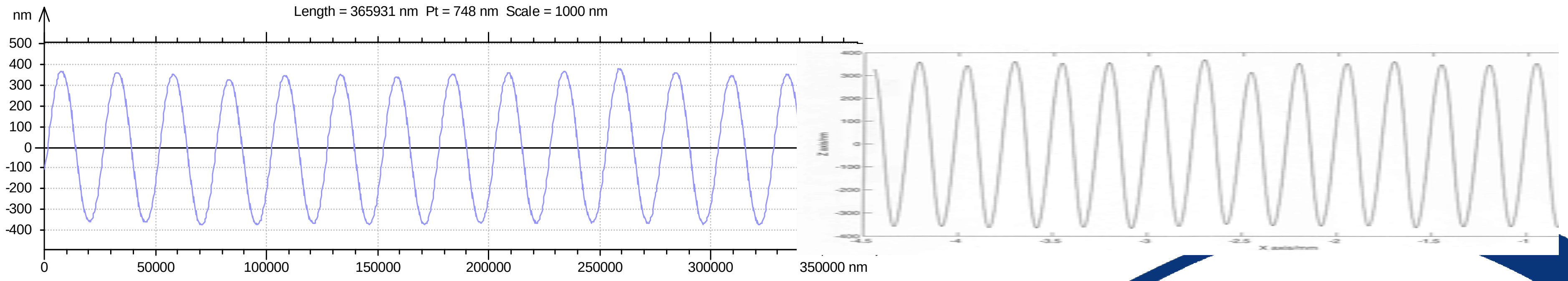
Objective	Max slope/°
X10	8.9
X20	17.4
X50	38.0



25 µm, 18.9 ° slope, X50

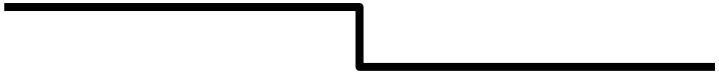


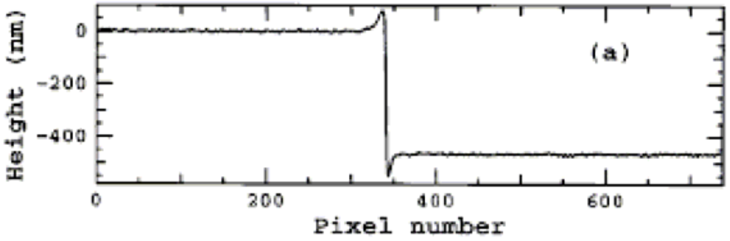
25 µm, 5.2 ° slope, X20

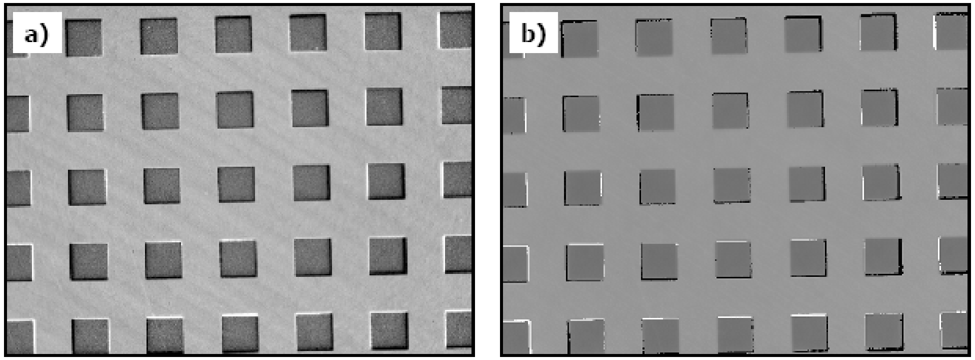


25 µm, 5.2 ° slope, X50

The batwing effect



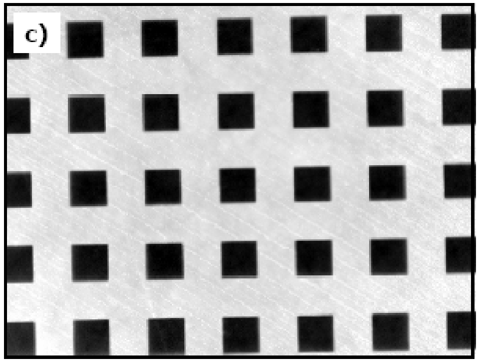




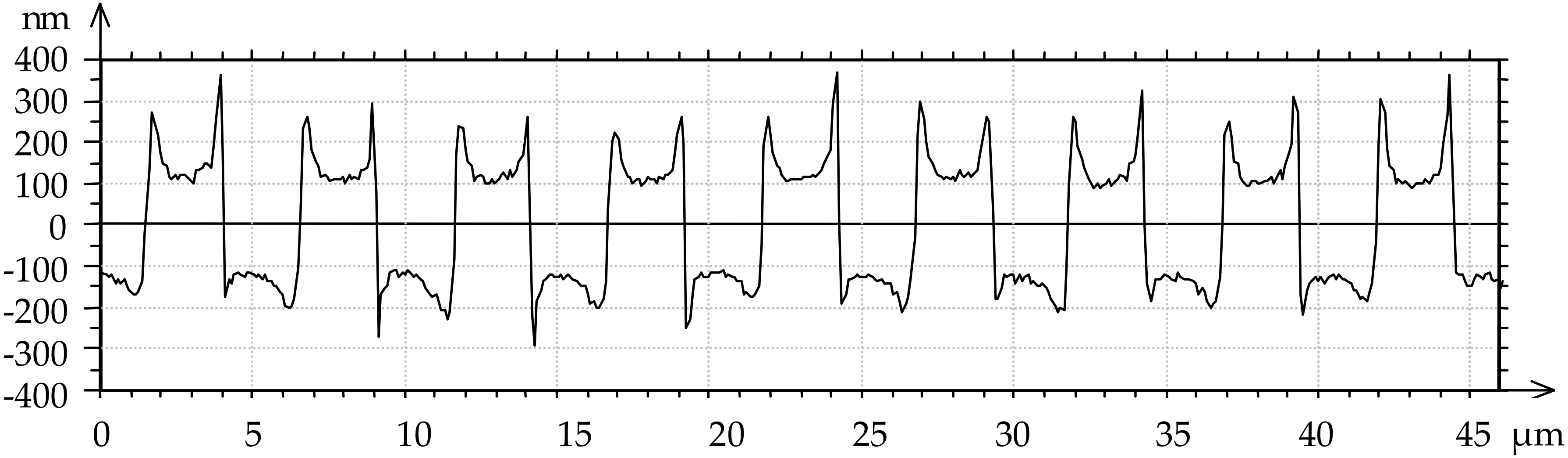
a) Coherence Peak Evaluation
Height Range: 0.42 µm

b) Phase Evaluation
Height Range: 0.51 µm

c) Phase Evaluation, Unwrapped
Height Range: 0.10 µm

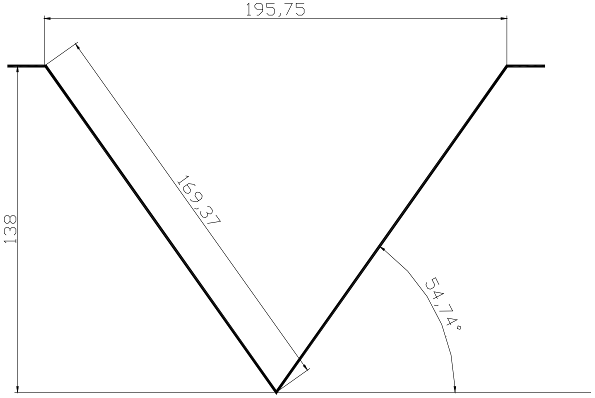


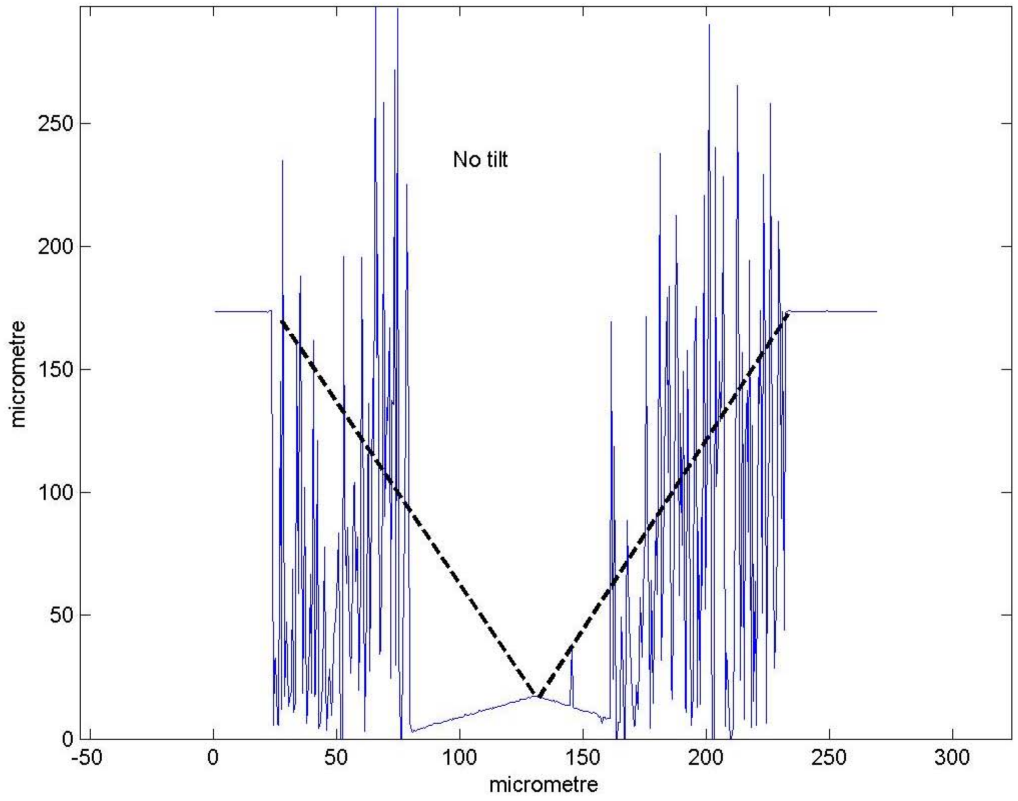
A square wave grating?



V-grooves

Measurement shows false information for the surface profiles of a 70 degree silicon V-groove





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The depth is 138 μm
The width is 195.74μm
The side length is 169.37μm
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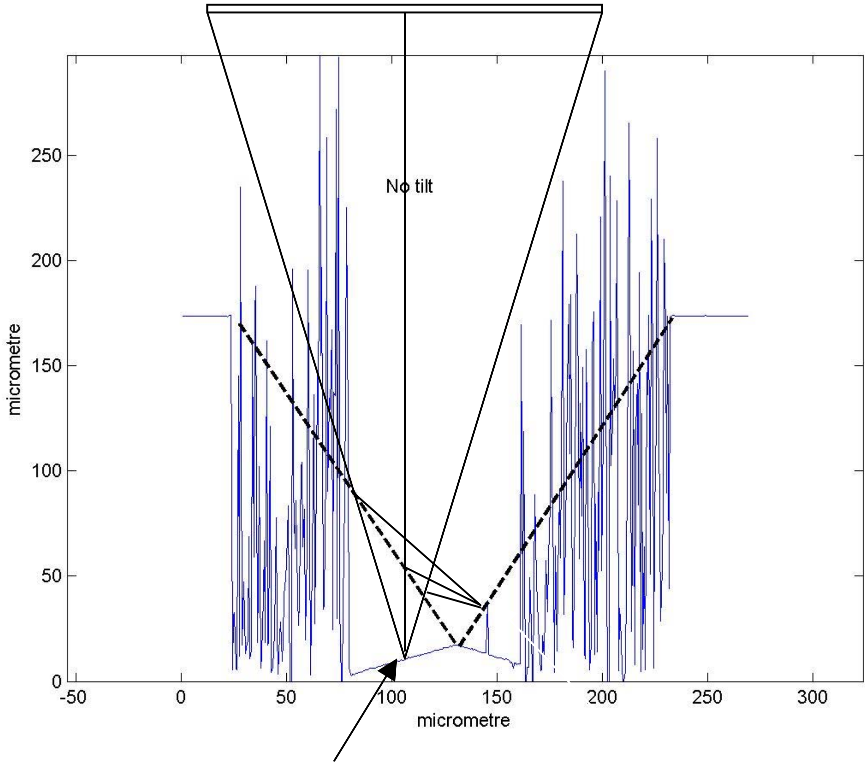
Multiple Reflections/Scattering

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

Note the error is approximately 100 μm here!

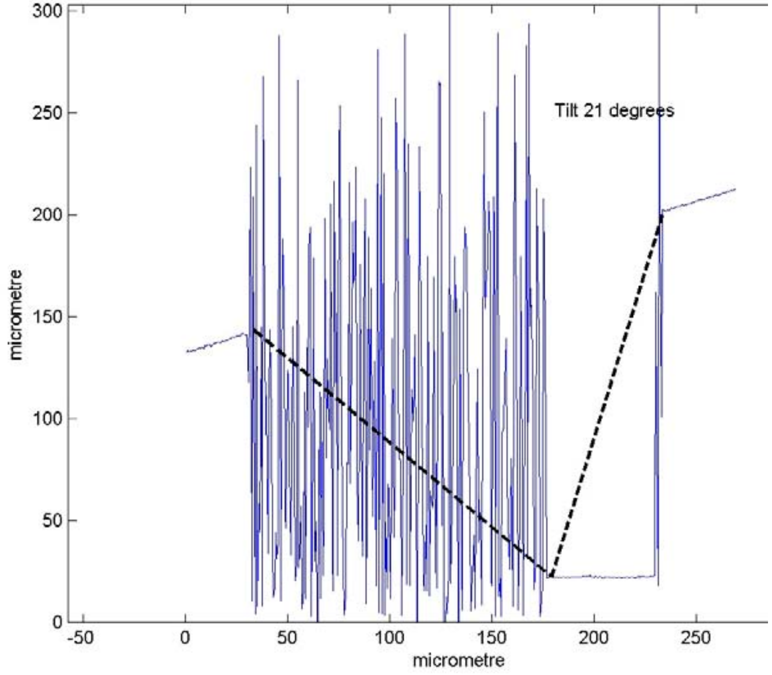


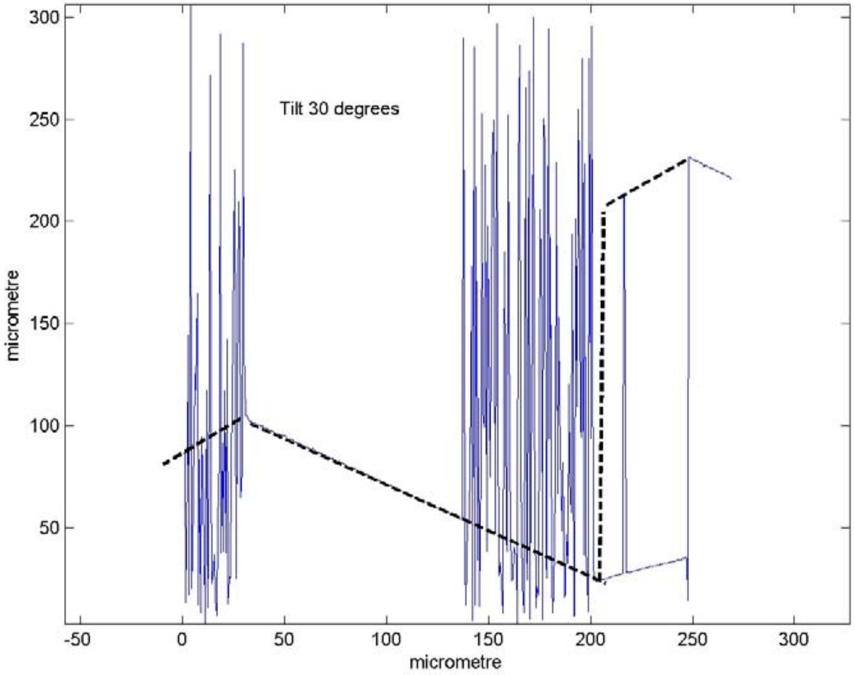
objective

apparent image point

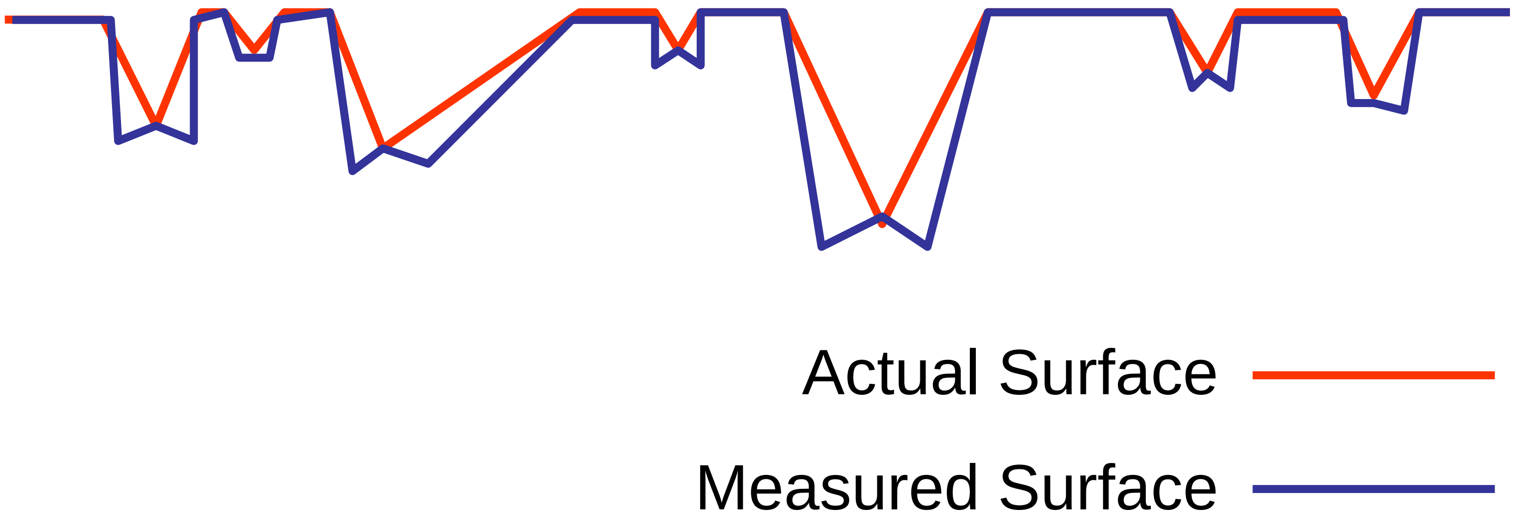
real image point

Measured profiles change as the V-groove is tilted



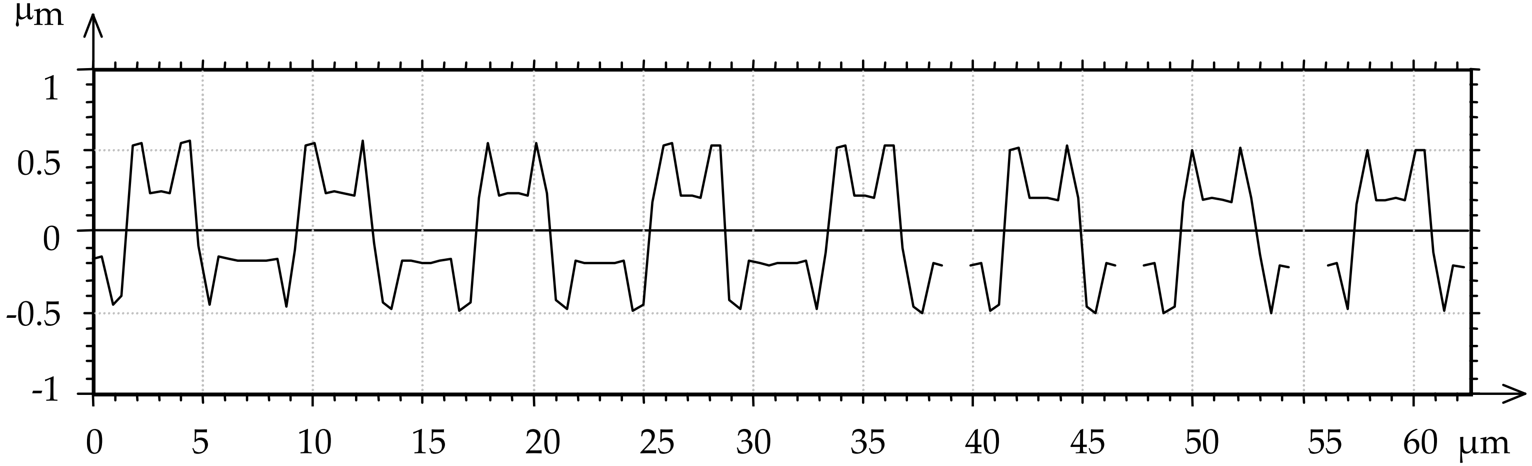


Surface roughness over-estimation



Ghost steps and dispersion

- Phase jumps of half a fringe or “2p” errors
- Usually found as spikes on a flat surface
- Caused by field dependent dispersion due to the SWLI optics or slope dependence



Phase change on reflection – chrome on glass step

NS4 height/nm	VSWLI height/nm	NS4 – VSWLI/nm	Expected phase shift/nm
60.8	37.3	23.5	19.5

$$\tan\delta = \frac{2n_1k_2}{n_1{}^2 - n_2{}^2 - k_2{}^2}$$

Conclusions

- VSWLI (and PSI) can be an excellent tool but it is difficult to assess when a measurement has gone wrong
- There are a number of issues that can be experimentally investigated that highlight the weak areas of an instrument
- It is, at this stage, not possible to draft a full uncertainty analysis, but best practice and a best measurement capability could be investigated in certain circumstances
- Good practice guide being produced…