Wavelength Scanning Interferometry for Thin Film Analysis of Fusion Targets

F. Gao, X. Jiang, H. Muhamedsalih and H. Martin

Centre for precision technologies

University of Huddersfield

Huddersfield, UK

3rd European Target Fabrication Workshop, 20th September -1st October 2010 Oxford, UK

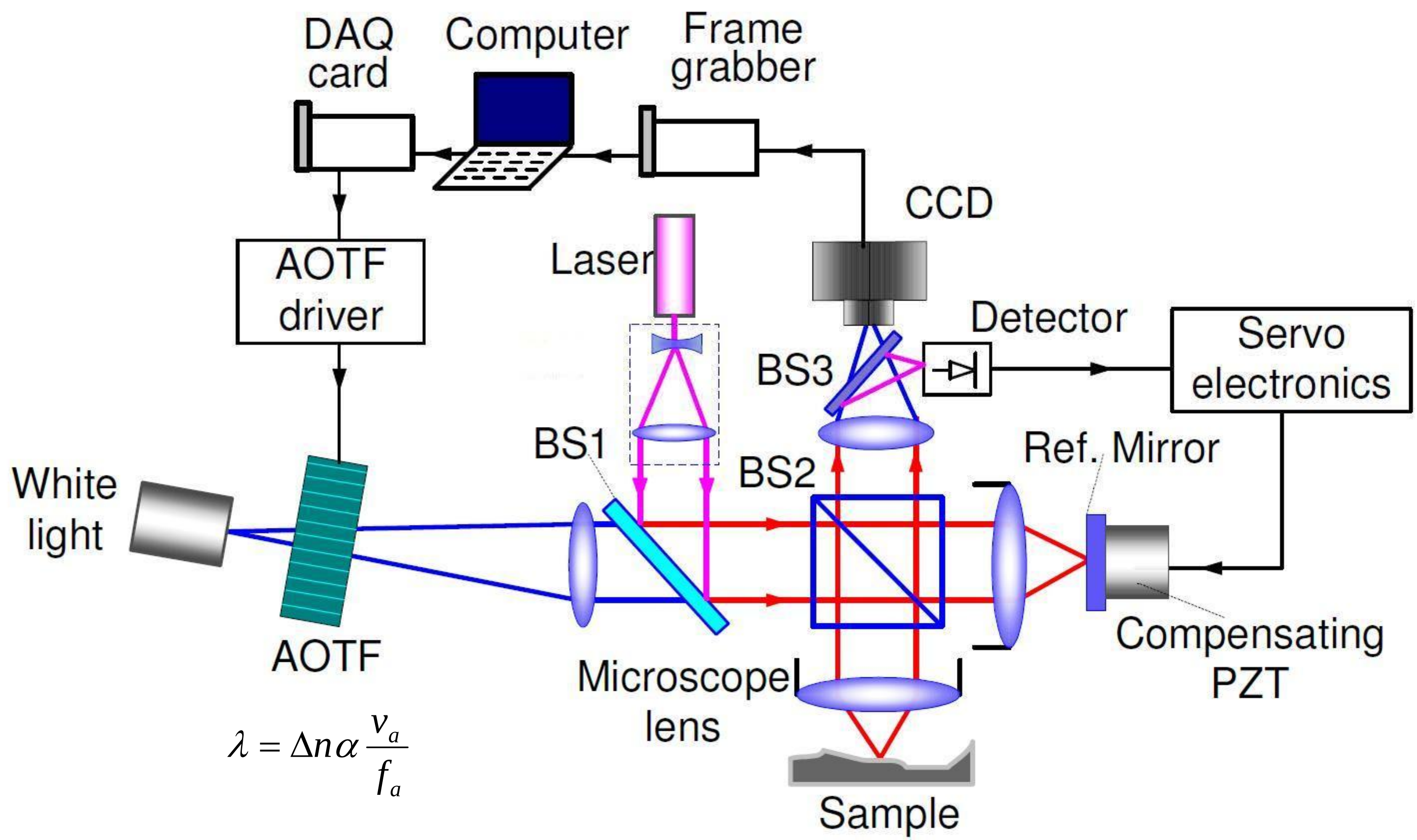
Outline

- Review on thin film measurement
- Introduction to Scanning Wavelength Interferometry (SWI)
- Scanning Wavelength Interferometry for thin film measurement
- Experiments on films of fusion target
- Measurement results comparison
- Looking forward

Review of thin film measurement

- Methods and instruments used for thin film measurements
  - Established methods
    - Spectrophotometry
    - Ellipsometry
    - Scanning White Light Interferometry
  - Methods used in research
    - Wavelength Scanning Interferometry
    - Thermal-wave detection with laser beam deflection
    - Prism coupler
    - SEM for measuring metal film

Wavelength scanning interferometry

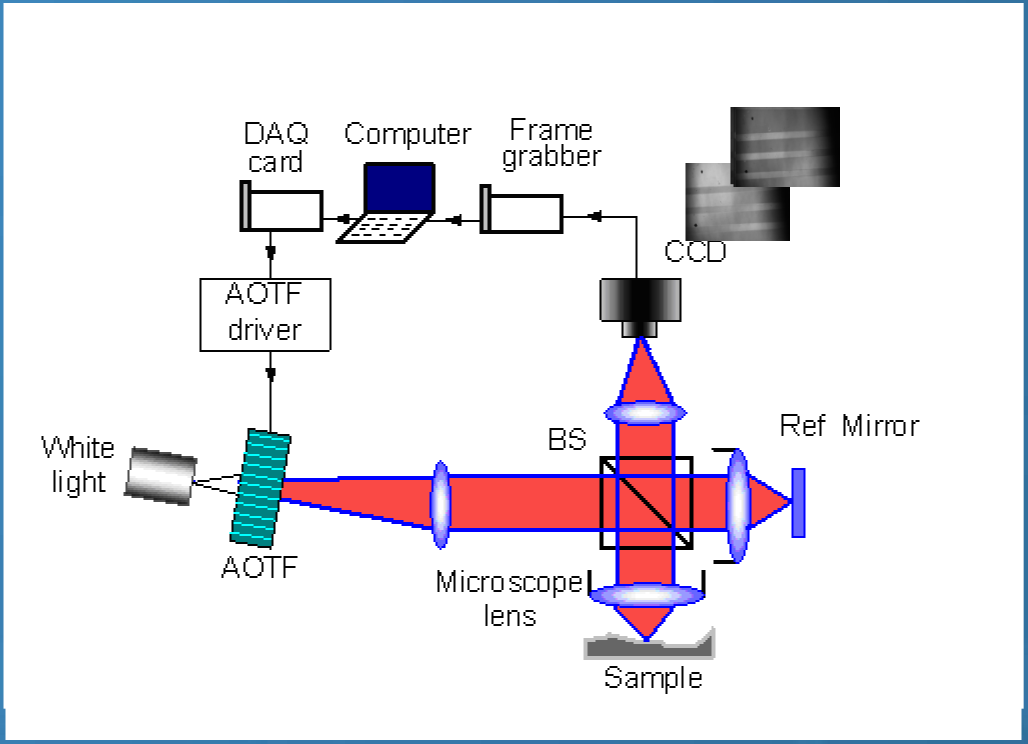


$$\lambda = \Delta n \alpha \frac{v_a}{f_a}$$

Optical setup

1. Linnik interferometer was used for the measurement.

2. AOTF has been employed to shift the wavelength from 680.8nm to 529.8nm. A series of interferograms were obtained.



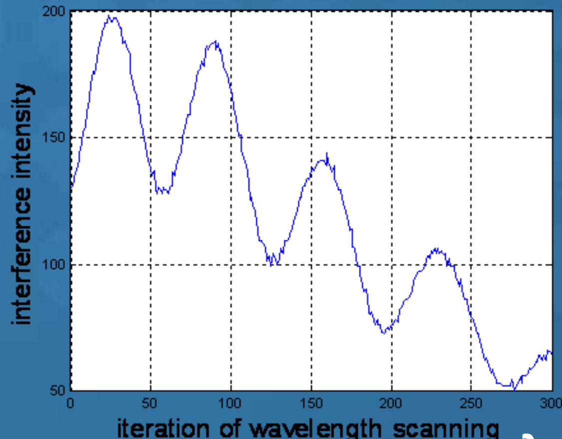
Intensity Pattern at each pixel in the CCD

- DC component
- Cosine term
- High frequency Noise

$$I(i) = I_1 + I_2 + 2\sqrt{I_1 + I_2}\cos(\varphi(i))$$

where

$$\varphi(i) = \frac{2\pi}{\lambda(i)} * 2 * t$$



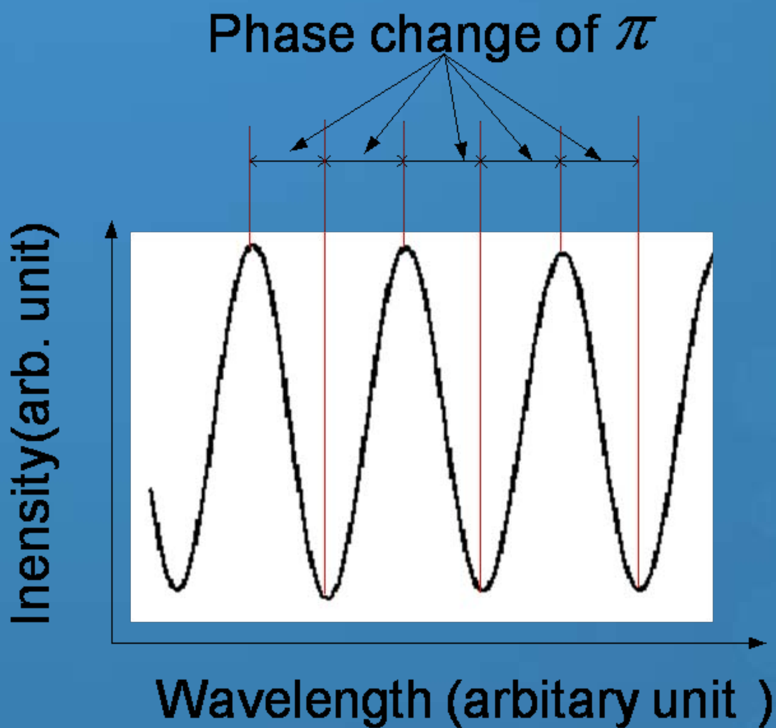
λ_1 λ_{300}

Analyze the intensity interferograms

- **Convolution**
- **FFT**

Calculation of the OPD

$$I(x,y,k) = A(x,y,k) + B(x,y,k)\cos(\varphi(x,y,k))$$



$$\varphi(x,y,k) = kh(x,y) = \frac{4\pi}{\lambda}h(x,y)$$

Phase

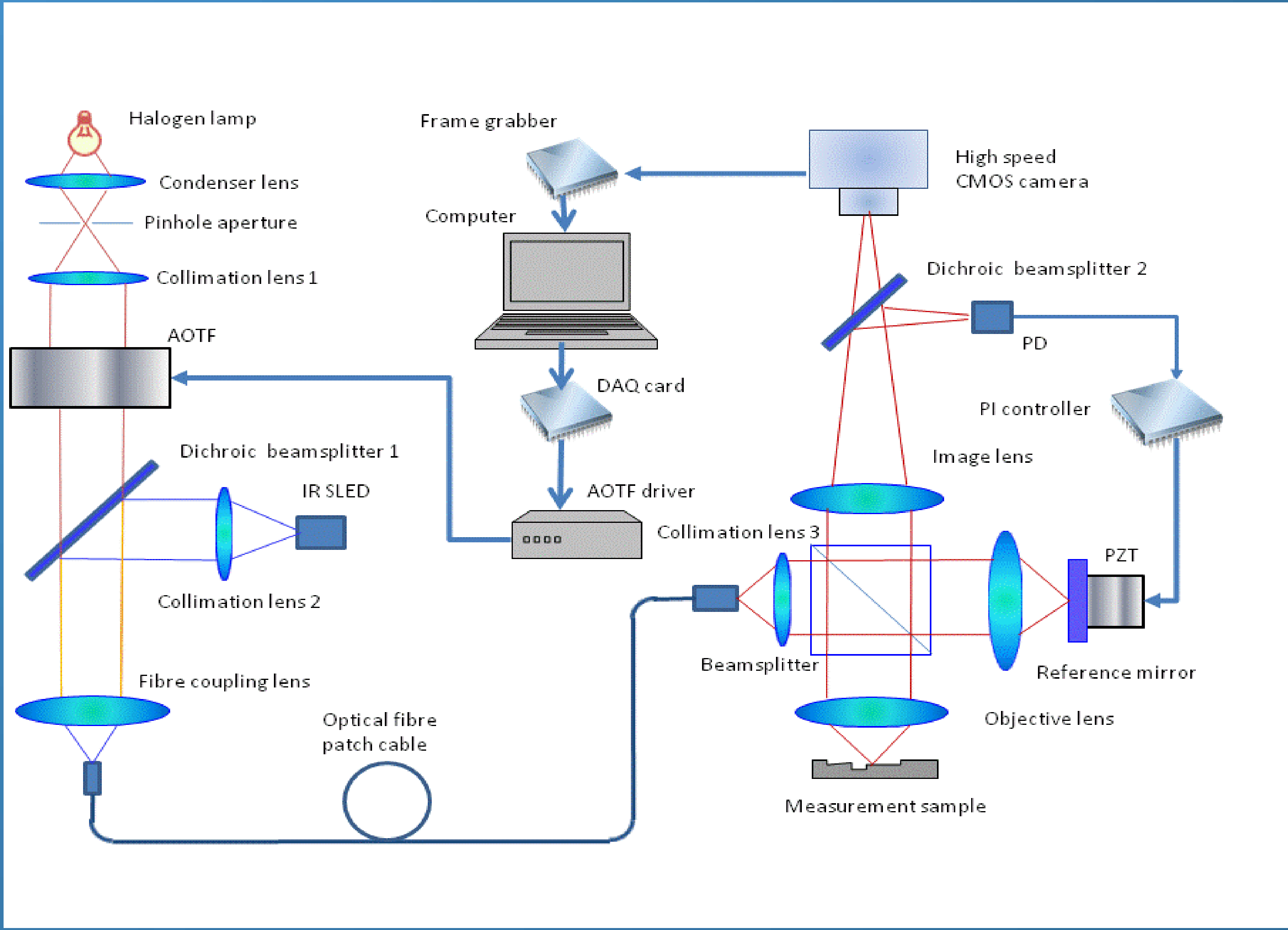
Wave number

Height

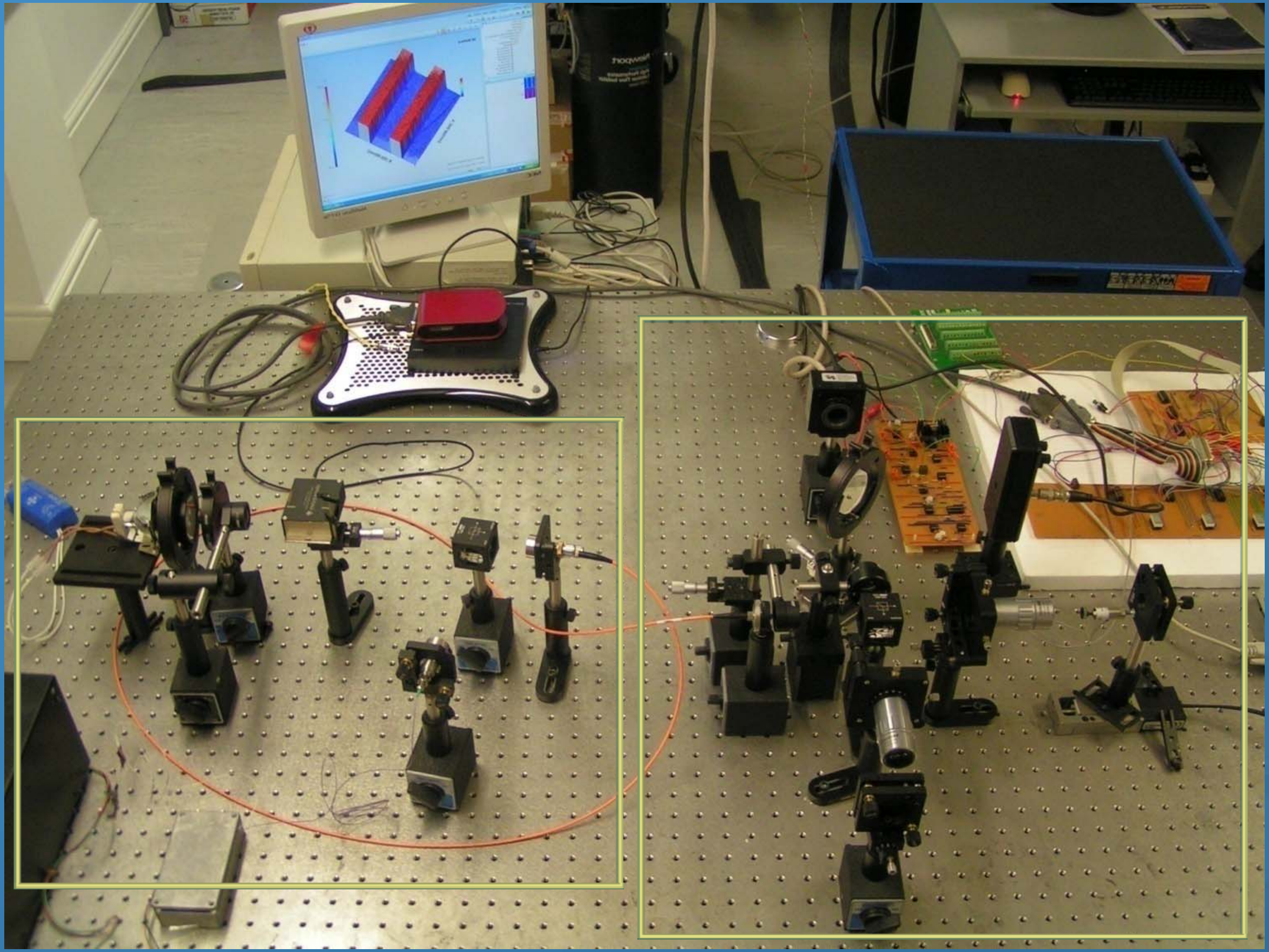
$$\Delta\varphi(x,y,\Delta k) = \Delta k h(x,y)$$

$$h(x,y) = \frac{\Delta\varphi(x,y,\Delta k)}{\Delta k}$$

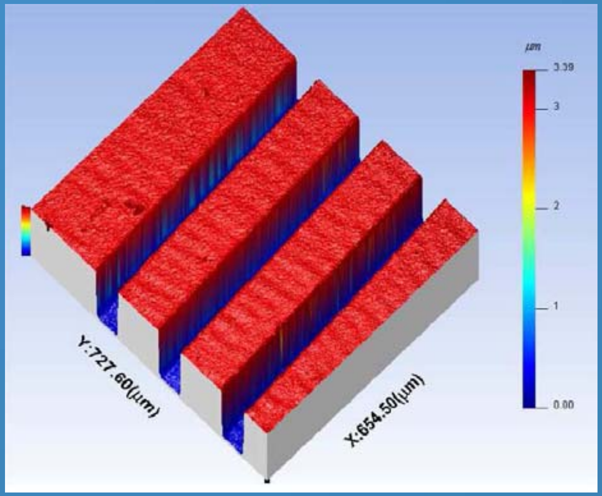
System configuration

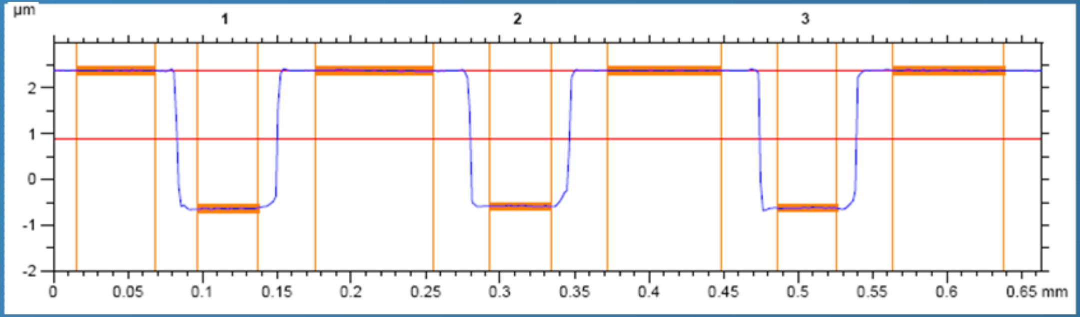


Experimental set up

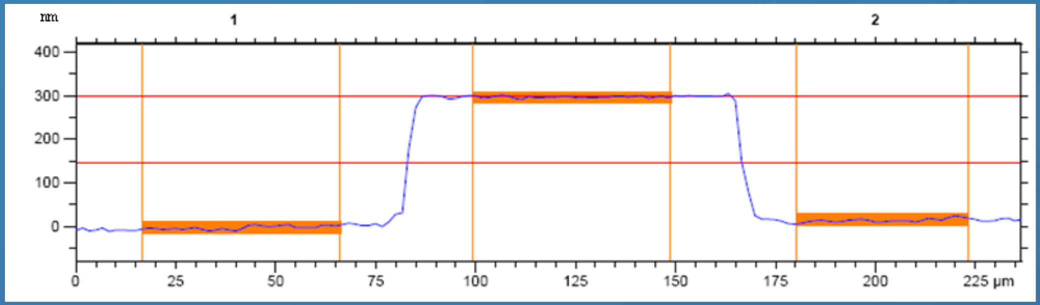


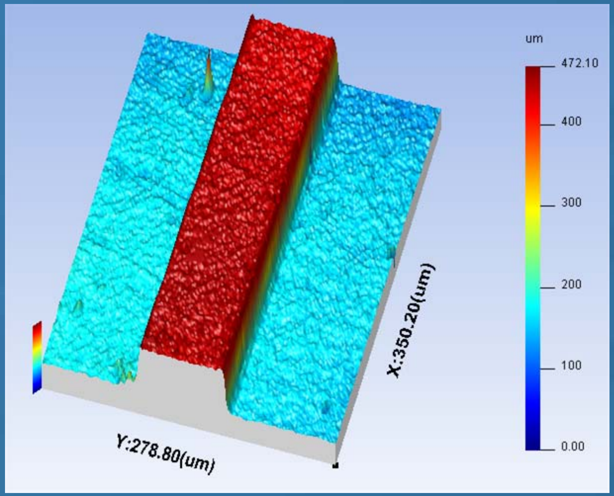
Measurements on step height standards





A 2.970 µm step height standard with uncertainty 1nm National Physical Laboratory (NPL)

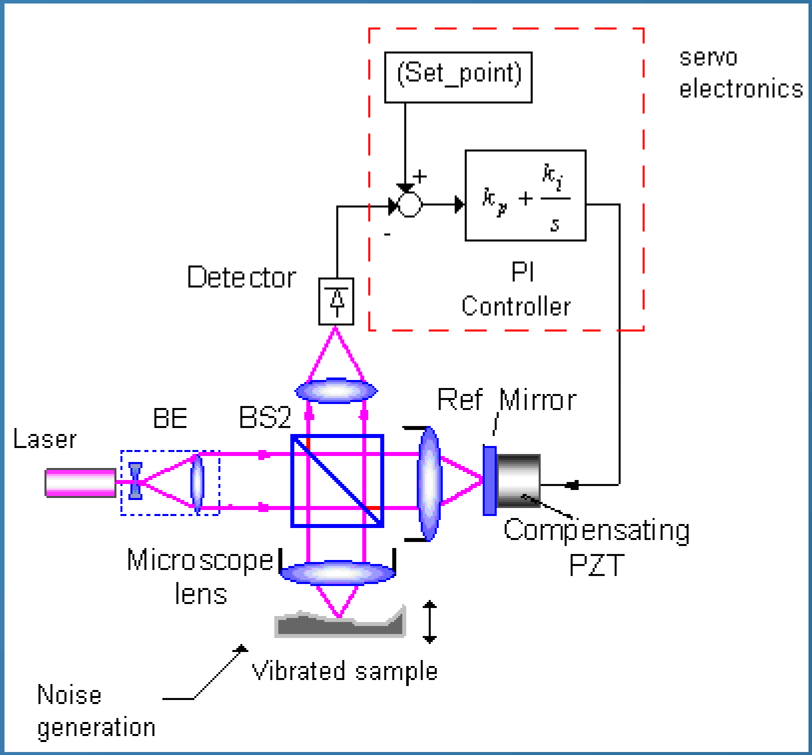




A 292 nm step height standard with uncertainty 0.9nm

Physikalisch-Technische Bundesanstalt (PTB)

Stabilisation



Stabilize Linnik Interferometer

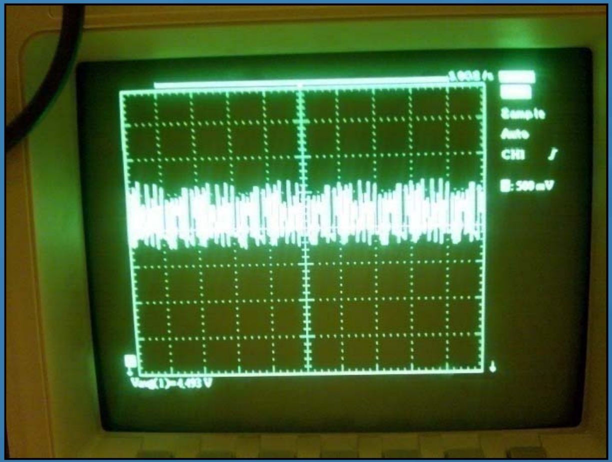
The PZT has been attached to the reference mirror to compensate for the environmental disturbances.

The environmental vibration is fed back to servo electronics that contains PI controller to control PZT movement

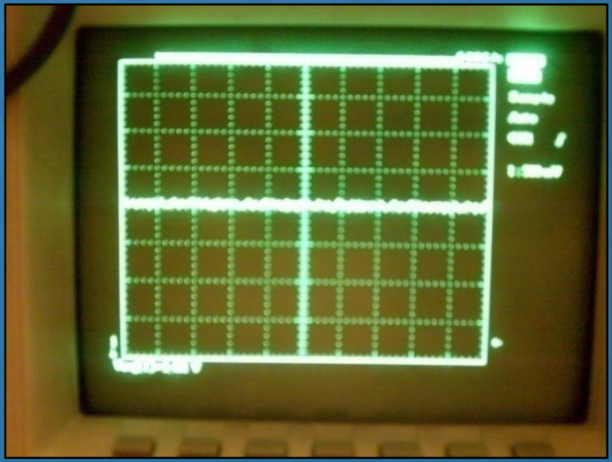
2V peak to peak and random frequency < 1KHz

The noise effect on the interferometer has been reduced 13.4dB

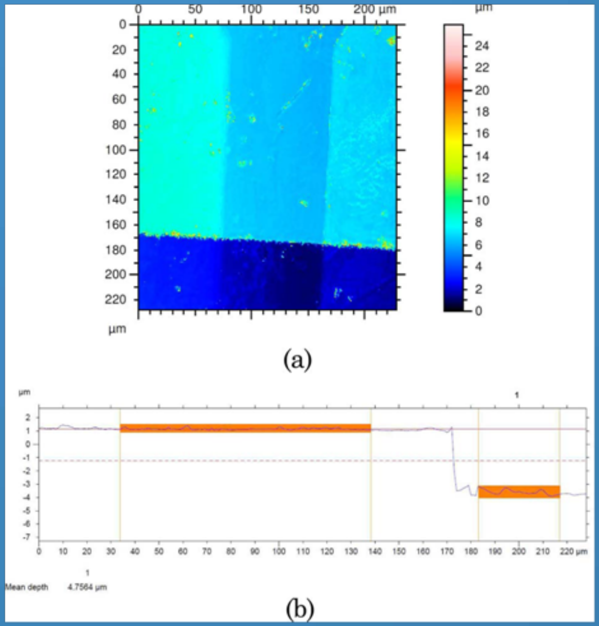
Before stabilization

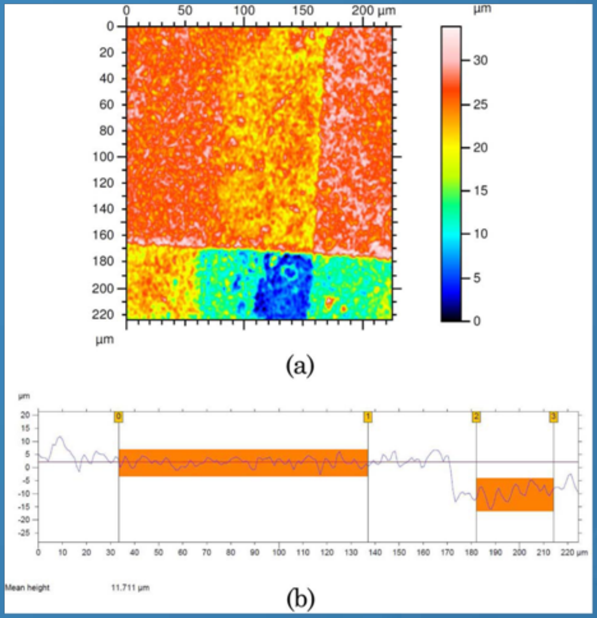


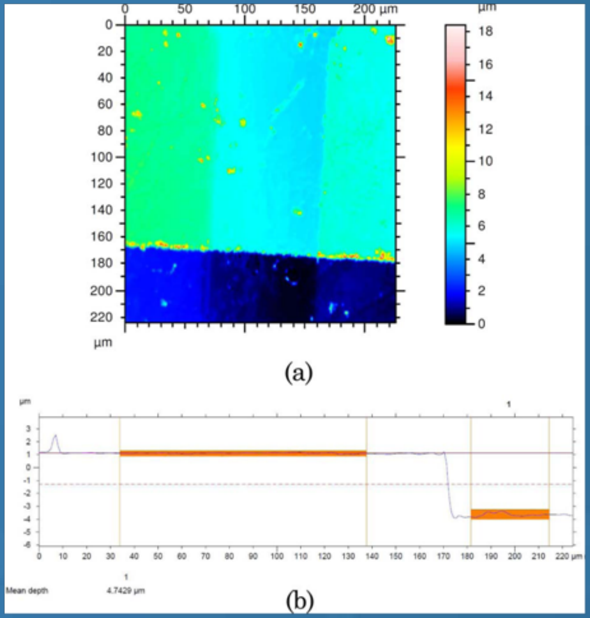
After stabilization



Anti vibration tests







A semiconductor chip sample was measured without inducing mechanical disturbance. The measured surface step height is **4.7564 µm**

A 40 Hz and 400 nm peak-to-peak sinusoidal mechanical disturbance using a PZT was applied to the reference mirror. During the disturbance, the measured surface step height is **11.711 µm**.

The measured step height is **4.7429 µm** when the vibration compensation system is on and 40 Hz 400 nm disturbance is applied.

Imaging processing using GPU

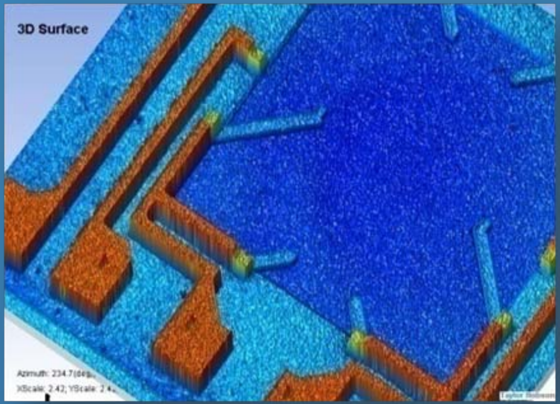
- A distinct advantage of the GPU technology compared to the CPU is that the GPU can process the images frame by frame while the CPU processes the images pixel by pixel.

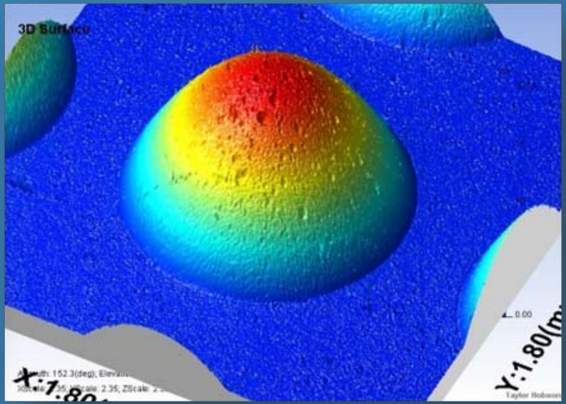
- The GeForce GTX 280 with 240 cores has been used.

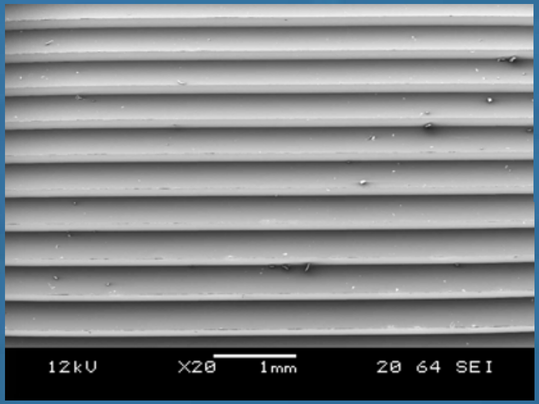
- The computing time has been reduced from 31.4 seconds to below a second.

The SWI was designed for Structured surfaces Measurement

Typical structured elements	Pitch lengths (µm)	Depths (µm)	Angles (°)
V-grooves/Pyramid	14-141 (most 35-106)	10-100 (most 25-75)	45
Micro lens	30-100	3-20	
Diffractive lens	25-180	1-60	A=70-89 B =0 –10



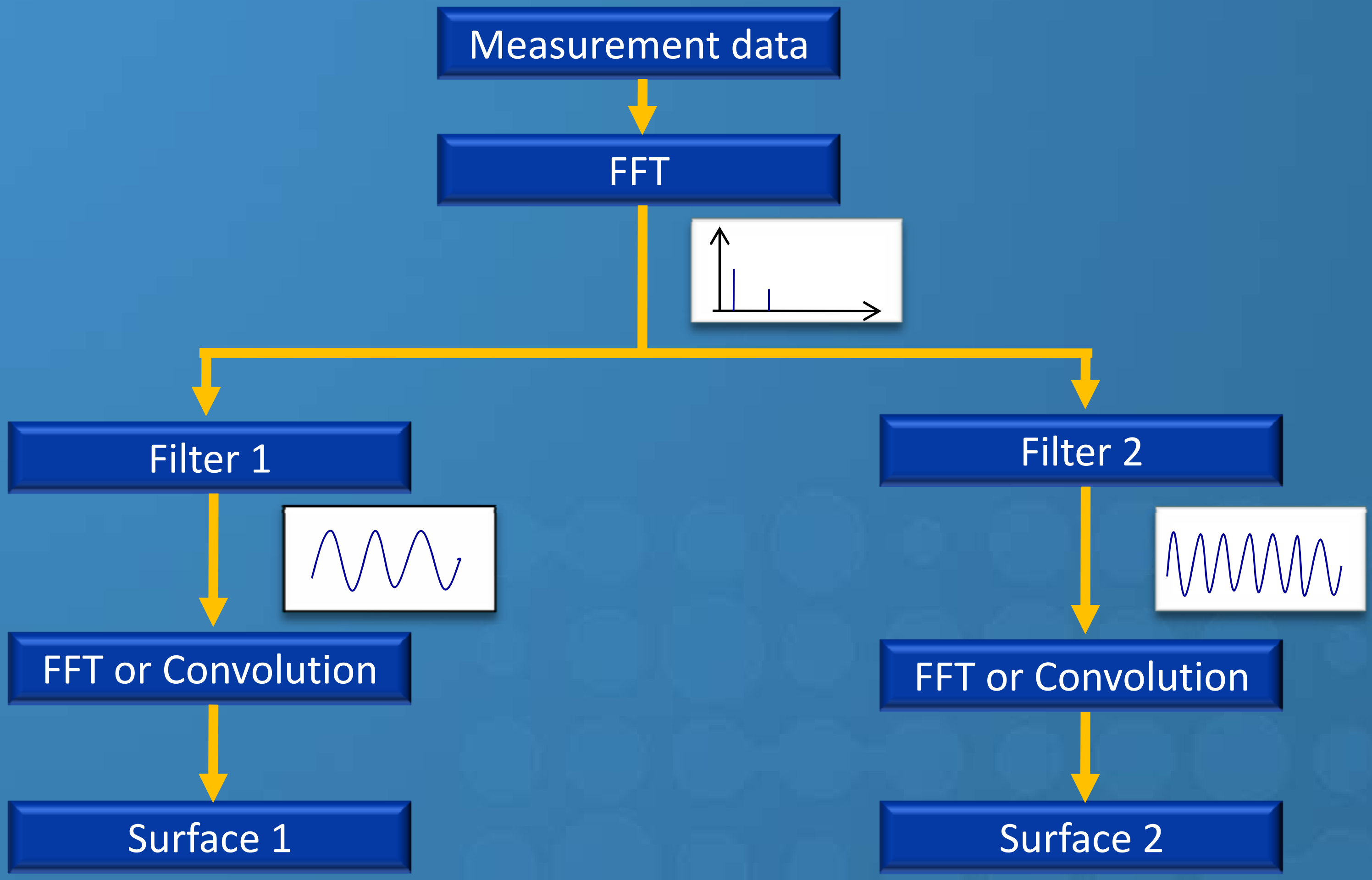




SWI for thin film measurement

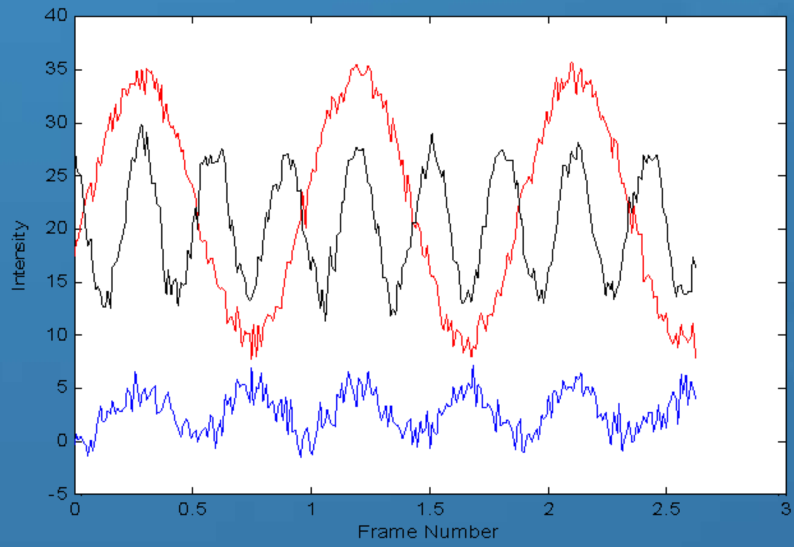
- SWI can be used for thin film measurement.
- The two surfaces of the film can be used as the two mirrors of an interferometer to measure the thickness of the film.
- Using the configuration of our SWI system the surface information of both top surface of the film and the surface of substrate maybe extracted from the interference signals.

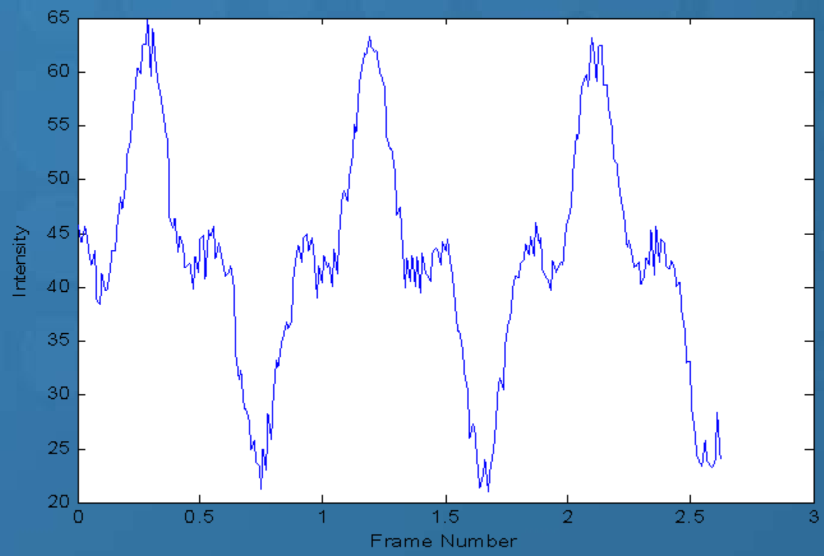
The flow chart of the analysis



Simulation study of the measurement on a 10um film surfaces

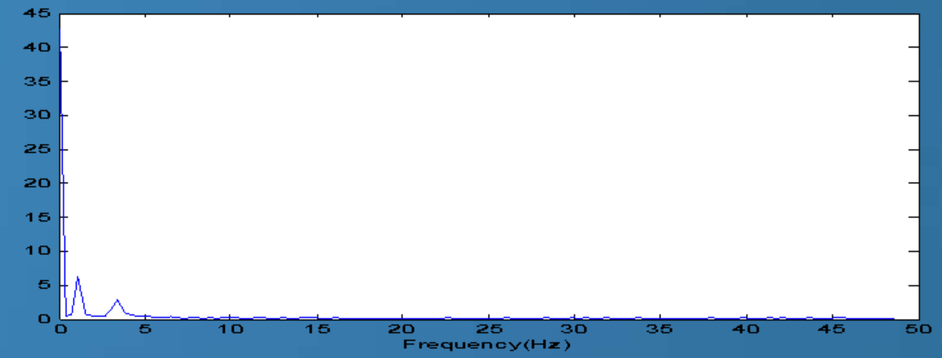
- Bottom left - Three simulated interference signals generated between the reference mirror and the top surface, the reference mirror and bottom surface and between the two film surfaces
- Bottom right - Simulated combined signal on CCD camera

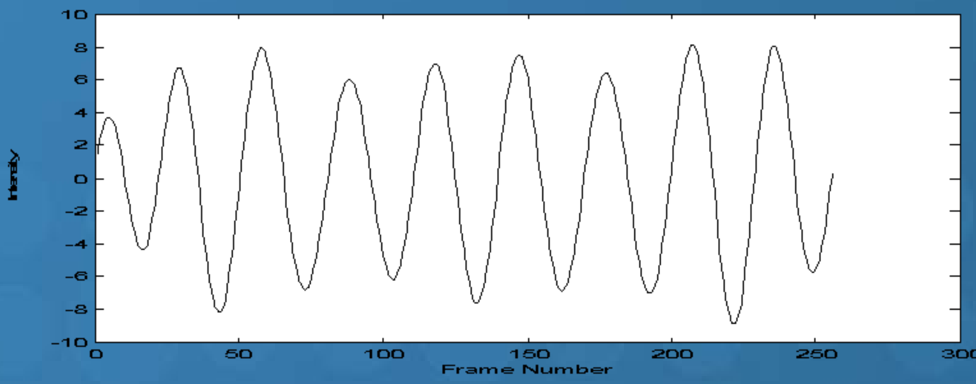


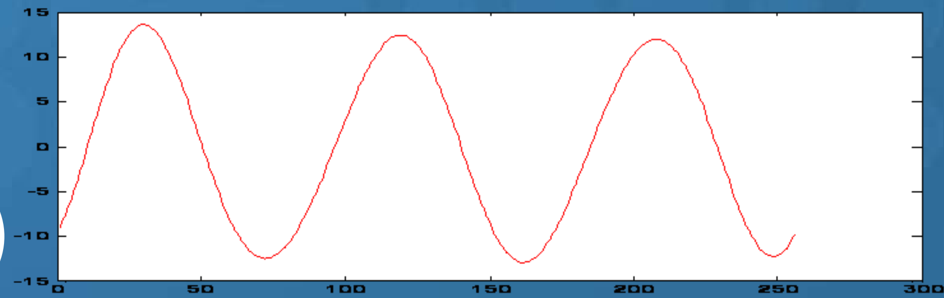


FFT analysis on the simulated signals

- Apply FFT analysis to find out the frequency components of the measured signal (top right)
- Construct filters according to the FFT analyse result
- Re-construct the two film surfaces (middle right and bottom right)

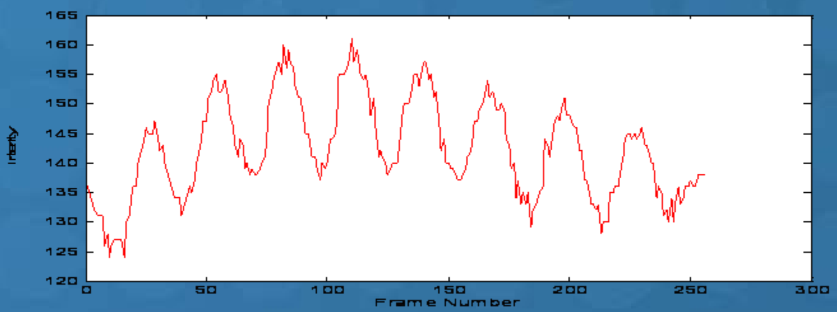


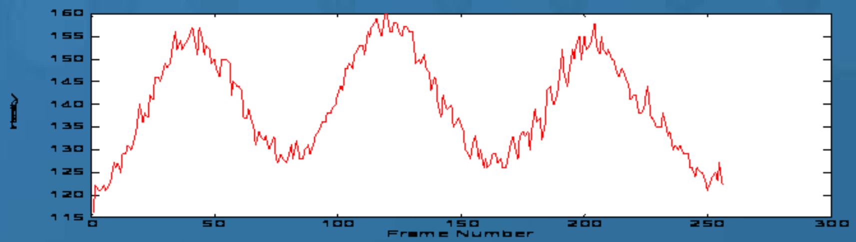




Real measurement signals on 10um film

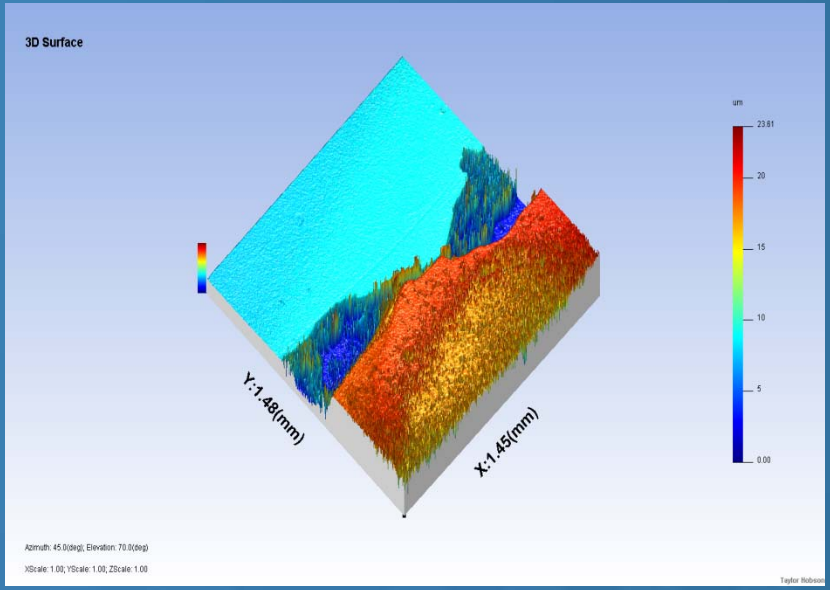
- Top right - Measured interference fringe
- Middle right - measured interferogram signal on film coated area
- Bottom right – Measured interferogram of glass substrate

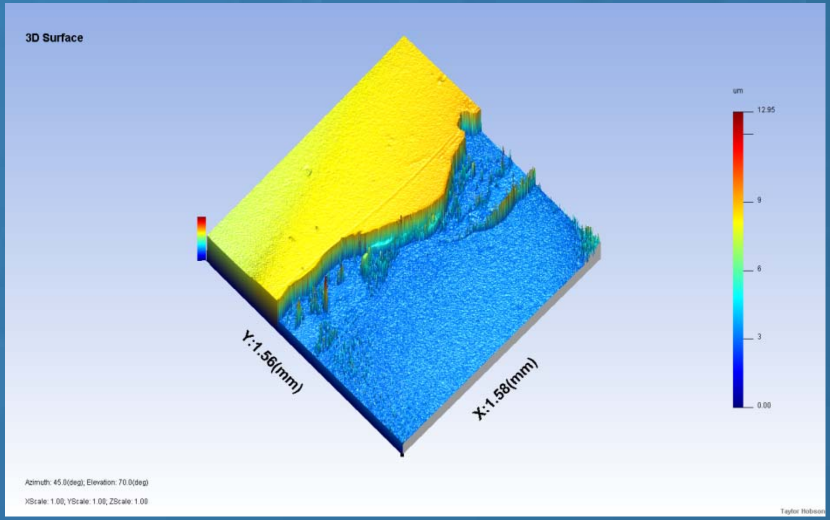




Two surfaces of the films

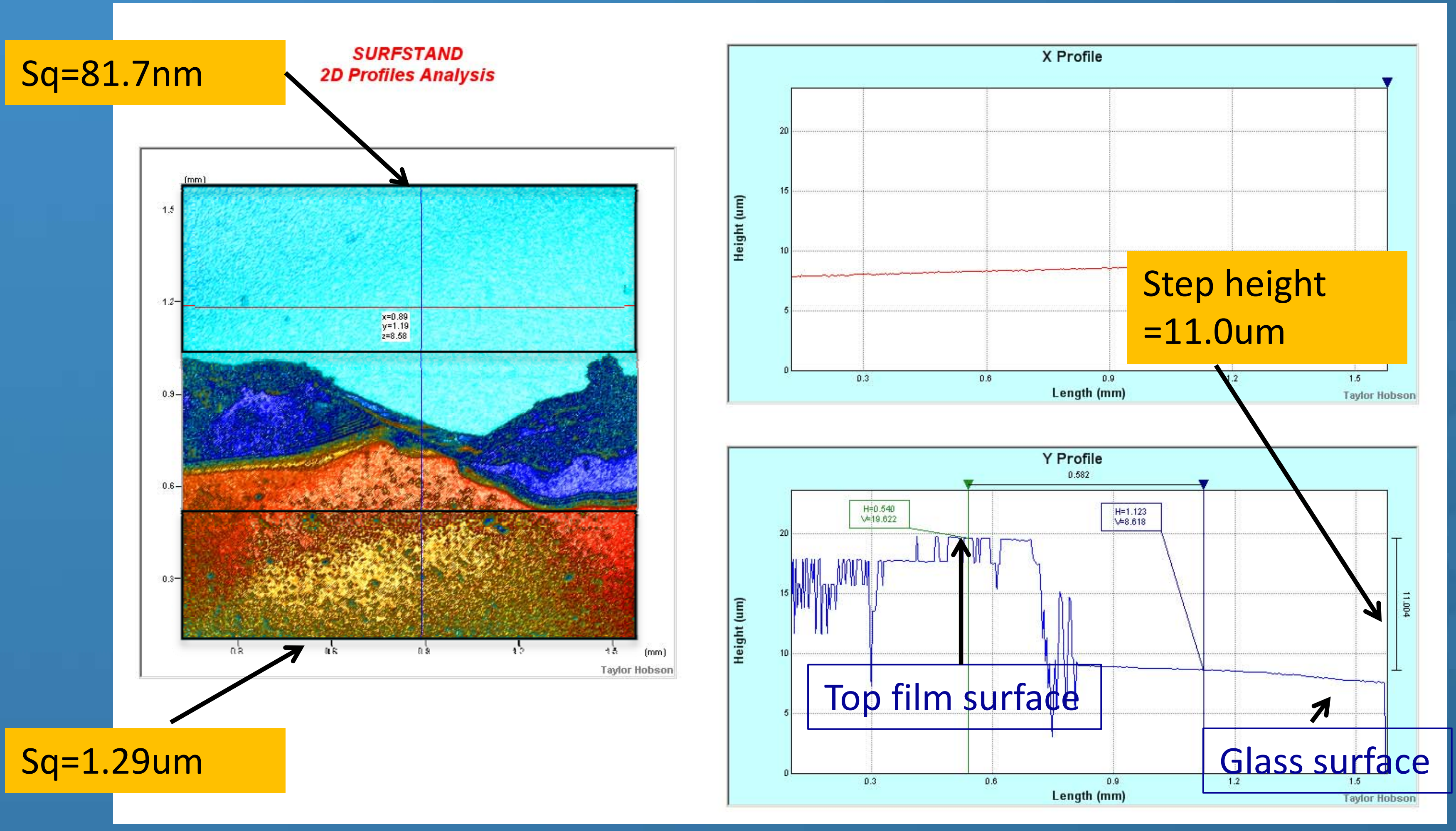
- Top Right - Reconstructed top surface and the glass substrate of the measured sample
- Bottom right - Reconstructed bottom surface of the film and the glass substrate





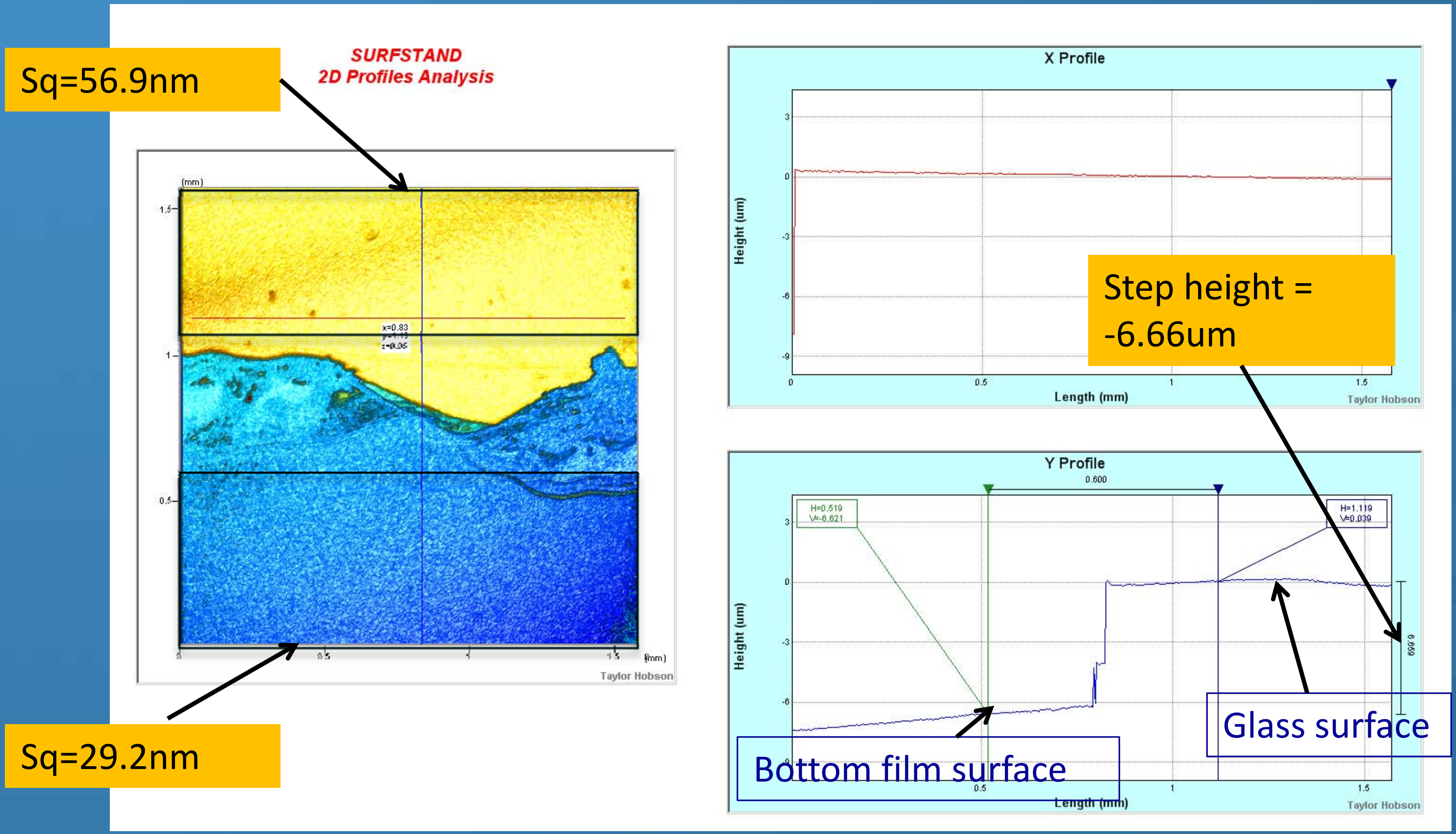
The top surface of the film

- A cross section of the measurement shows the measured step height at the section is 11.0um



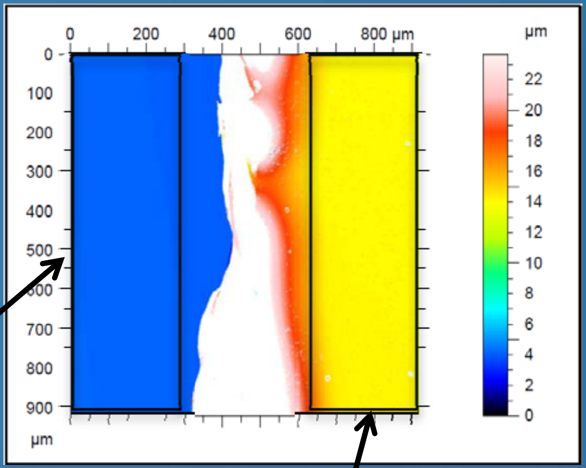
The bottom surface of the film

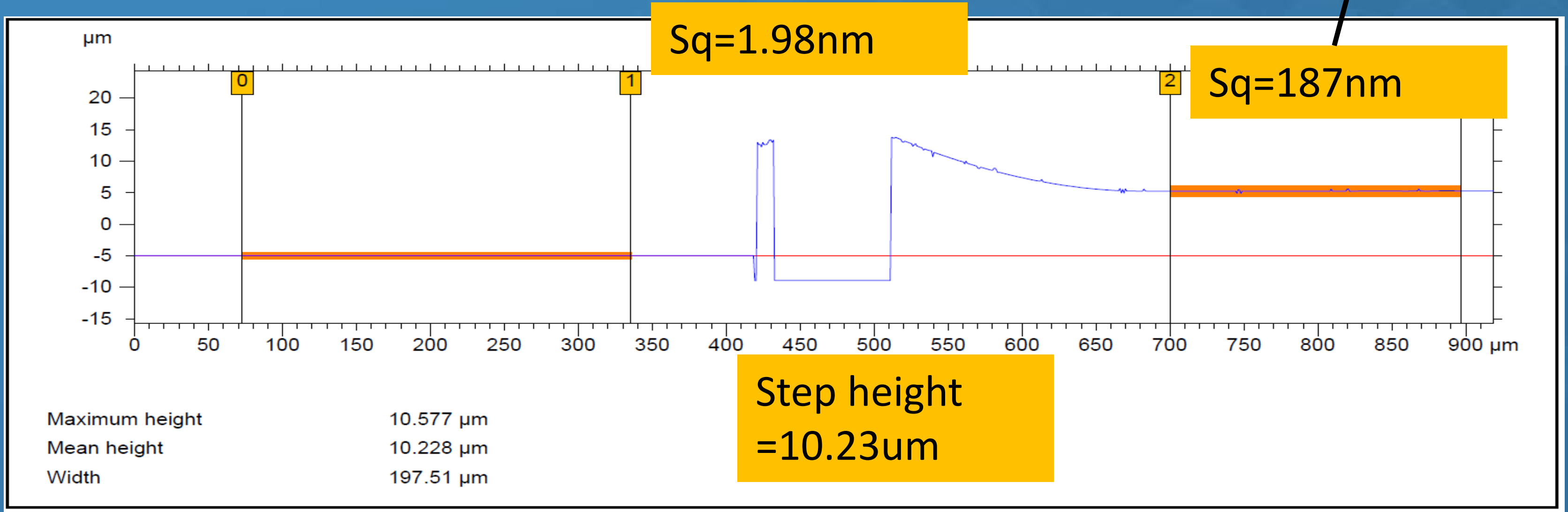
- A cross section of the measurement shows the measured step height at the section is -6.66um



Measurement on the same samples using CCI

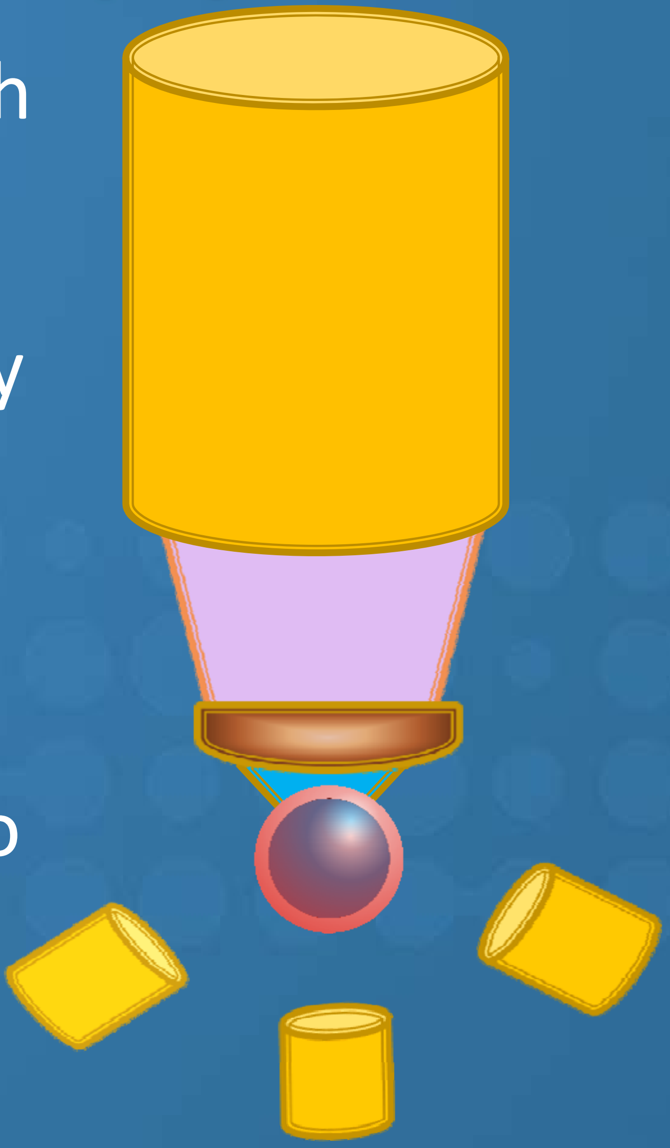
- Right - Measured image on the edge of the 10 um film on microscopic glass substrate
- Bottom - Profile of a cross section of measurement





Proposed full field scanning wavelength interferometry system

- A full field scanning wavelength interferometry system has the potential for imaging most of the pellet by arranging an array comprising several wavelength scanning interferometers to image a larger area. Advanced 3D data-stitching and fitting techniques would then need to be applied to provide a more complete surface model.



Conclusion

- The study shows the scanning wavelength interferometry is able to measure both the top and the bottom surfaces as well as the thickness of Parylene N film.
- It is possible to measure multi-layer films.
- Improvements are needed to achieve a reliable measurement
  - A better light source for longer coherence length and intensity
  - A none 50:50 ration beam splitter to improve interference signals
  - Improvement on characterisation algorithms

Thanks!