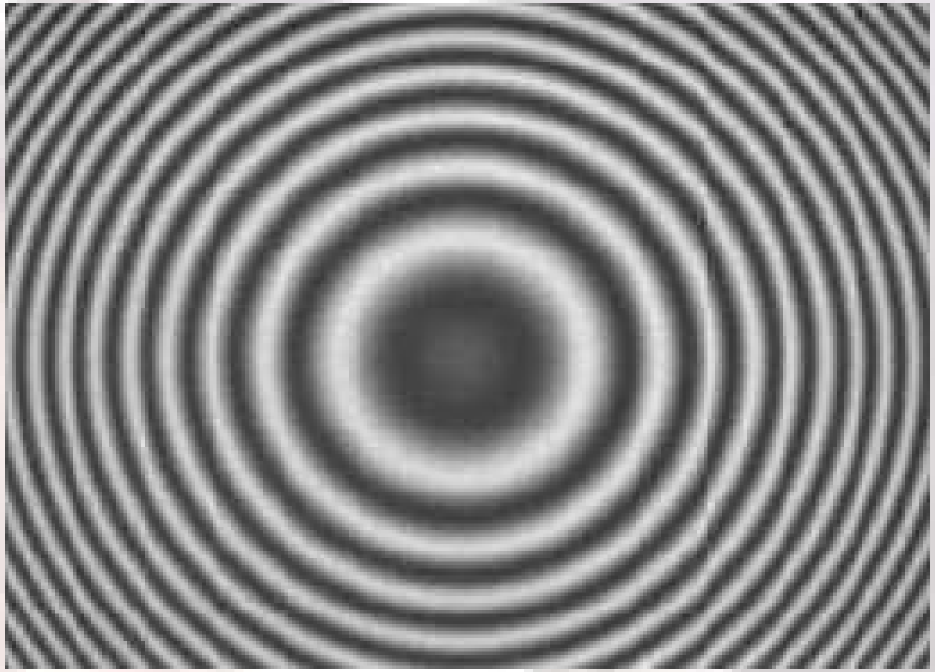
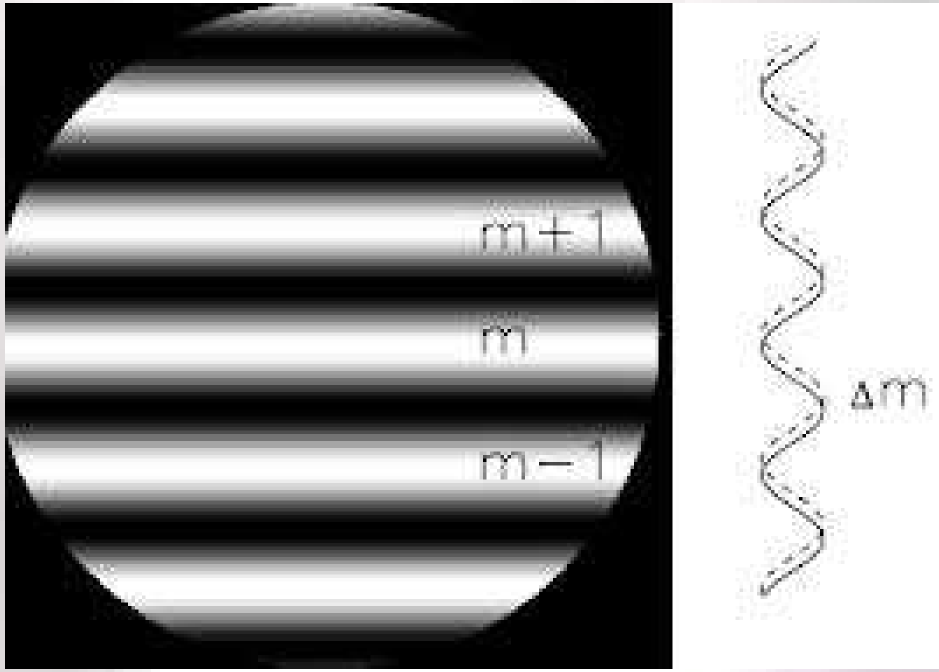
Theory-White Light Scanning Interferometer (WLSI)

Traditional Interferometer

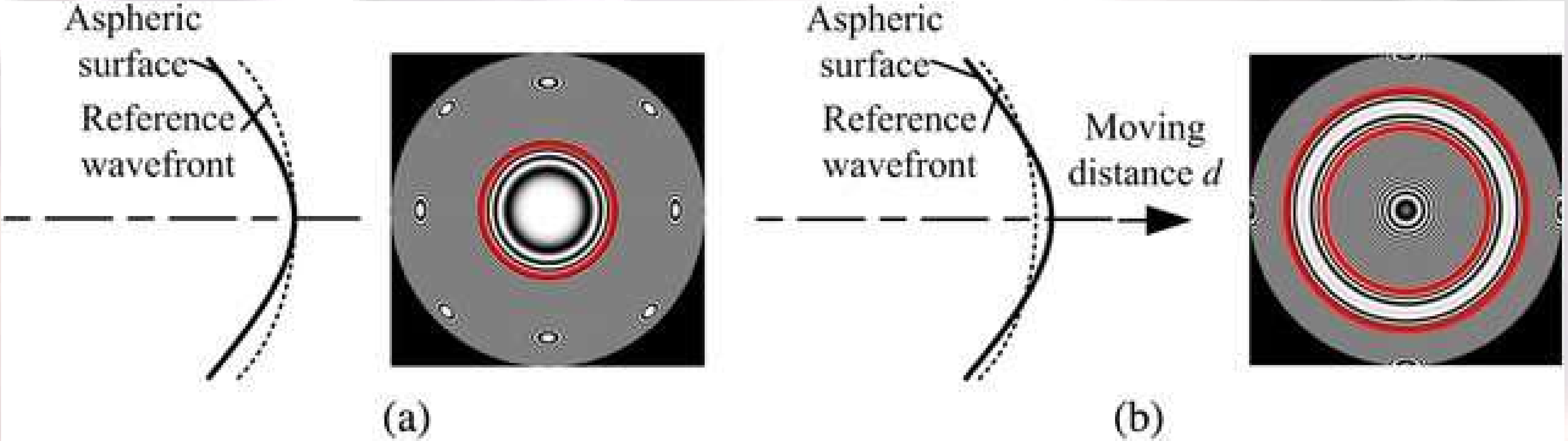
➢For typical optical interferometry, monochromatic light sources are frequently adopted and the phase ambiguity is the main restriction for height measurement.





➢Therefore, monochromatic interferometry is usually applied to measure samples with smoother profile.

https://www.google.com/search?biw=1440&bih=716&site=webhp&tbm=isch&sa=1&q=monochromatic+interferometry&oq=monochromatic+interferometry&gs_l=img.12...314650.314650.0.315769.1.1.0.0.0.0.221.221.2-1.1.0....0...1c..29.img..1.0.0.5eJRJyrBPKg



Schematic of annular subaperture test and corresponding fringe pattern. (a) Test in vertex curvature and (b) test after axial movement.

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White Light vs. Monochromatic Light

$$I(z) = I_B\{1 + \gamma g(z) cos(\phi_z)\}$$

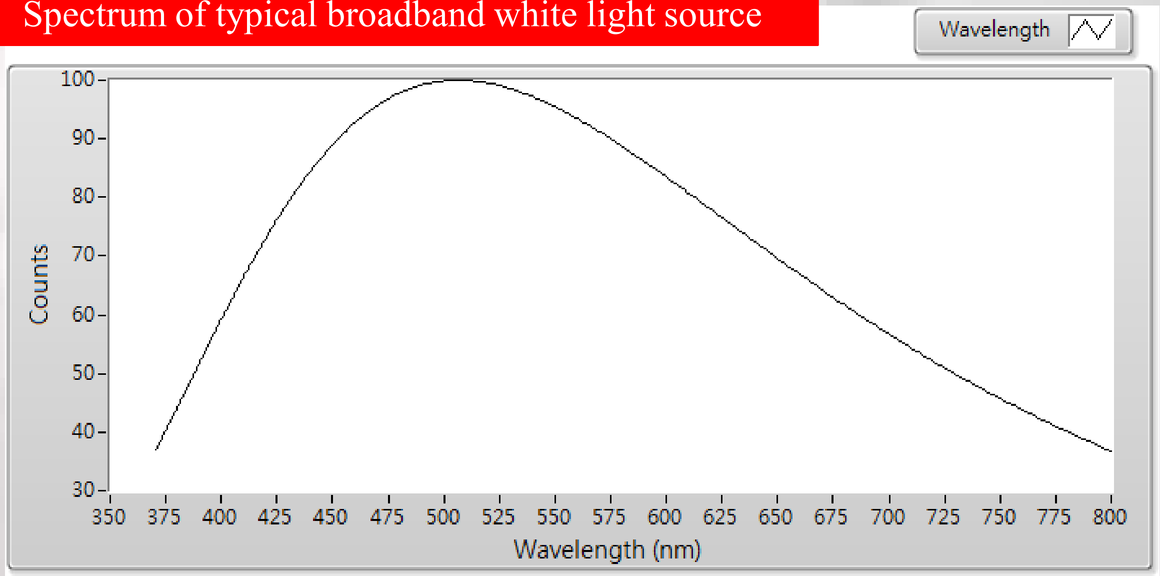
I_B: background intensity

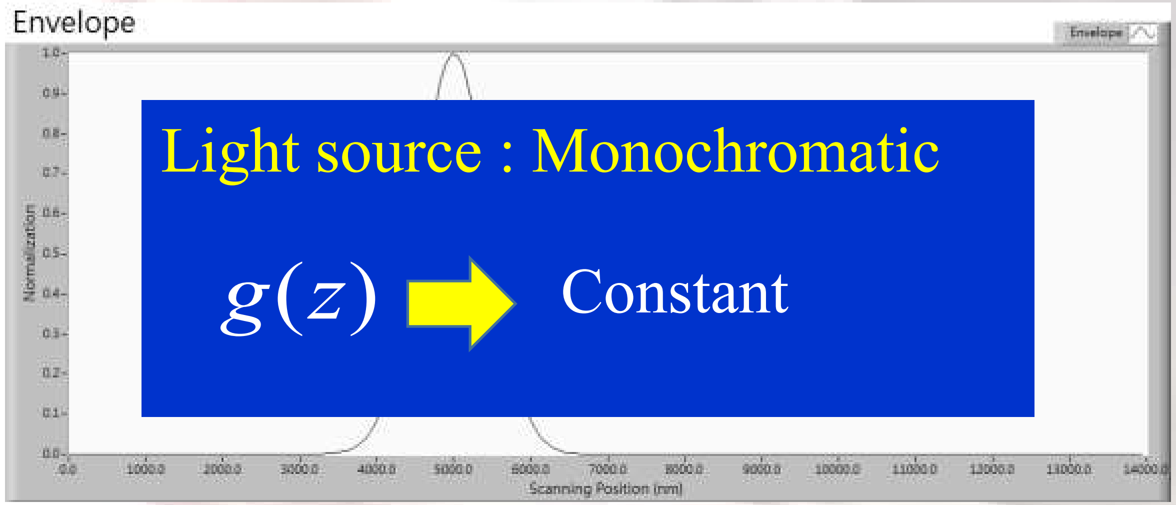
γ: fringe contrast

$g(z)$: envelope function

$\phi(z)$: phase

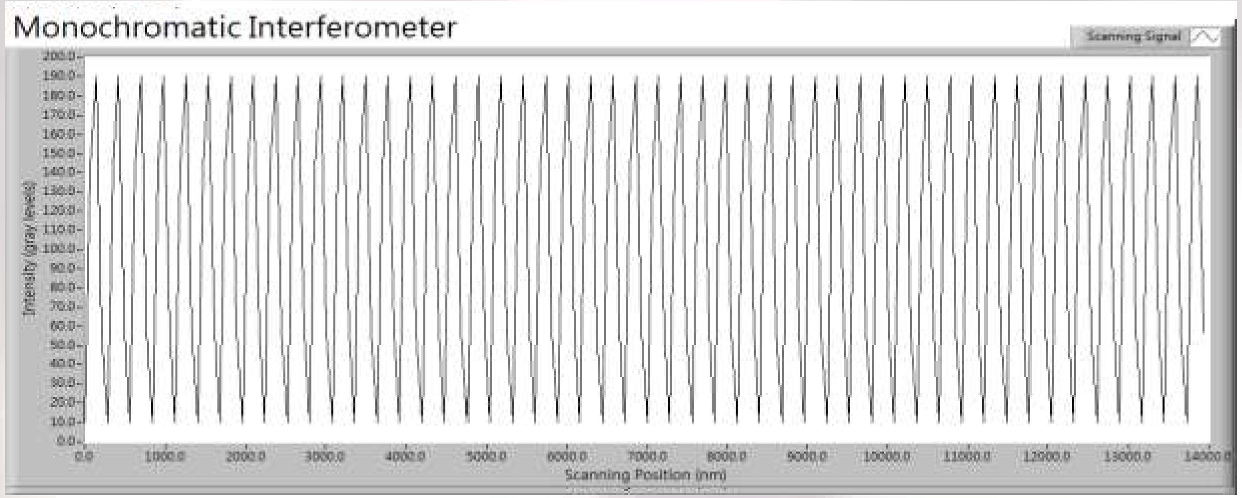
Spectrum of typical broadband white light source





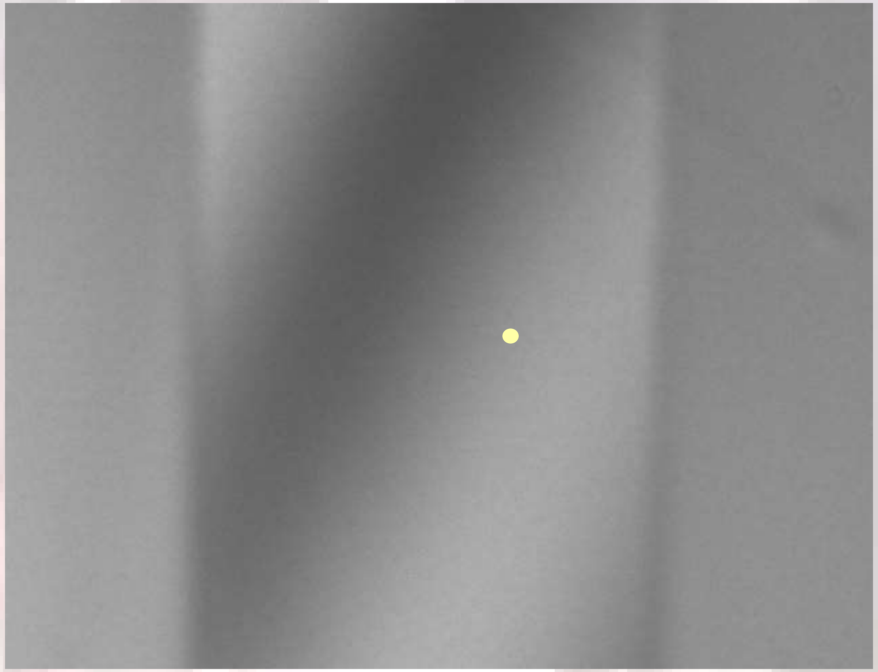
Light source : Monochromatic

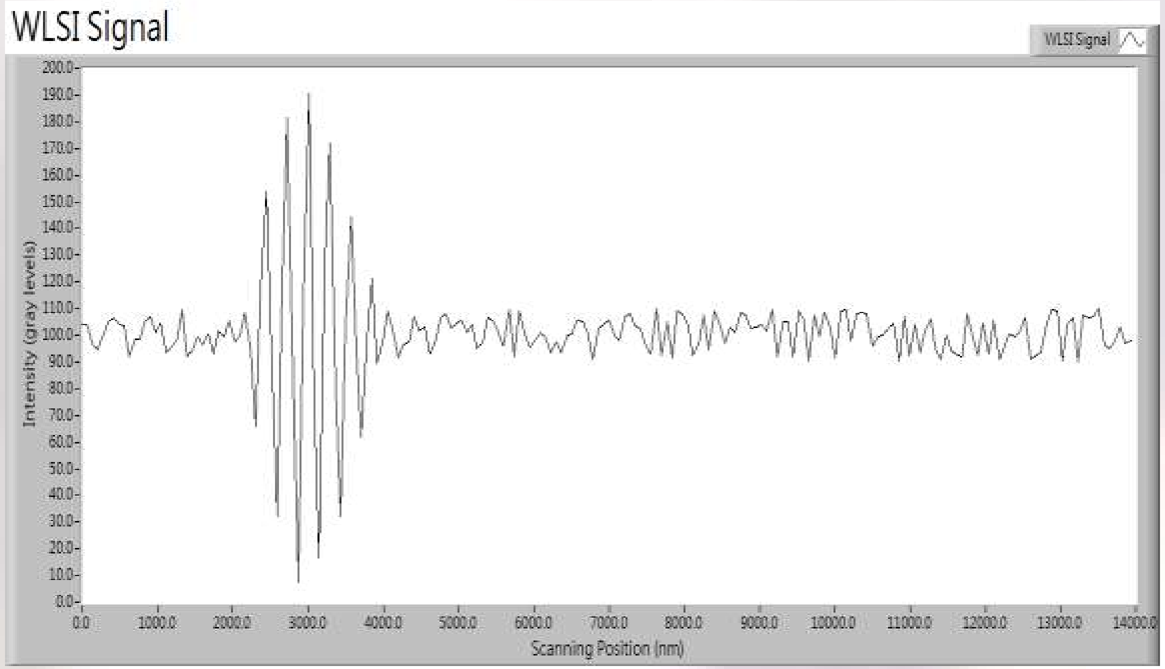
$g(z)$ ➡ Constant



White Light vs. Monochromatic Light

➢Different from monochromatic interferometry, the WLSI uses broadband light source, and can measure micro-specimens with discontinuous profile.

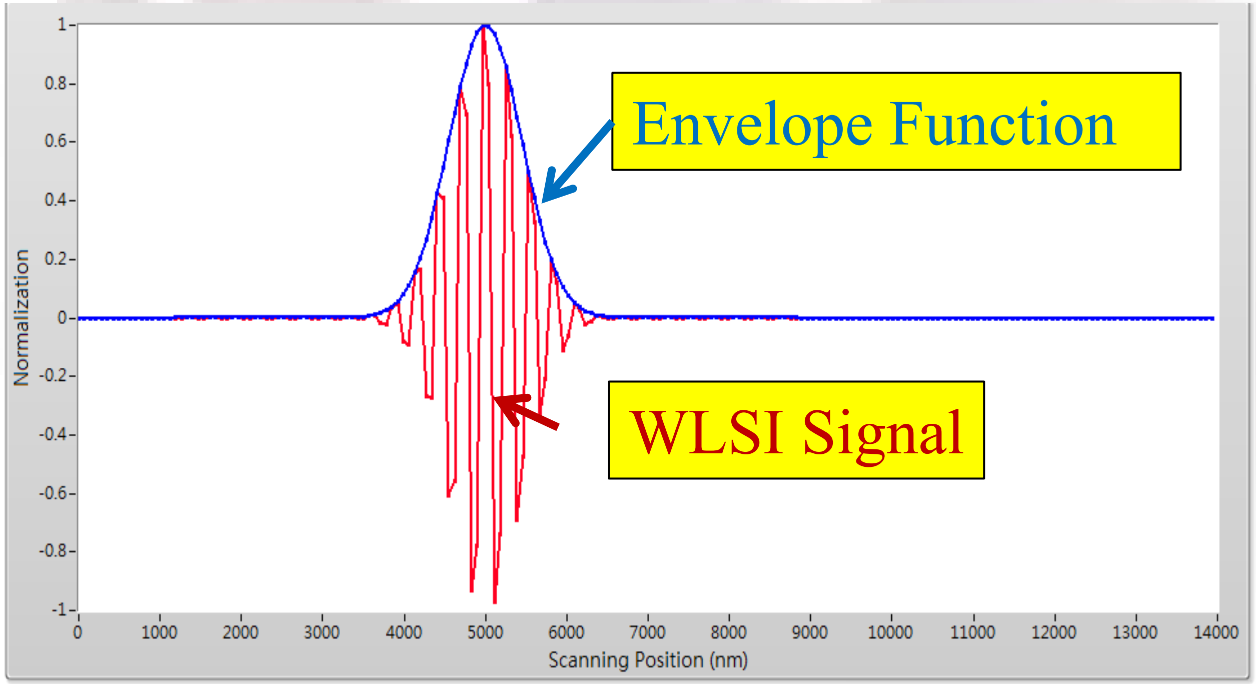




➢The surface profile can be determined by the locations of ZOPD. In real applications, the ZOPDs locate at peak position of WLSI signal envelops.

White Light vs. Monochromatic Light

➢In WLSI, along vertical scanning direction, the intensity of a point on the specimen recorded by a CCD camera can be plotted as



✓ *Coherence Peak Evaluation:*

Position of Envelope Maximum

→ height value : Z_{env}

✓ *Phase Evaluation:*

$$\varphi_0 = n_0 2\pi + \Delta\varphi$$

$\Delta\varphi$:phase value related to reference signal

height value : $$z_{\text{phase}} = \frac{\varphi_0}{4\pi}\lambda$$

Theory-WLSI

➢To retrieve ZOPD position precisely, PSAs are generally used to extract the phase value and peak position of the recorded WLSI signal.

$$I(z) = I_B\{1 + \gamma g(z) cos(\phi_z)\}$$

Local linear condition

$$g(z) = \frac{\delta z_2}{\delta z_2 - \delta z_1} g(z+\delta z_1) - \frac{\delta z_1}{\delta z_2 - \delta z_1} g(z+\delta z_2)$$

5-Step → **1 Item**

7-Step → **2 Items**

9-Step → **6 Item**

11-Step → **36 Items**

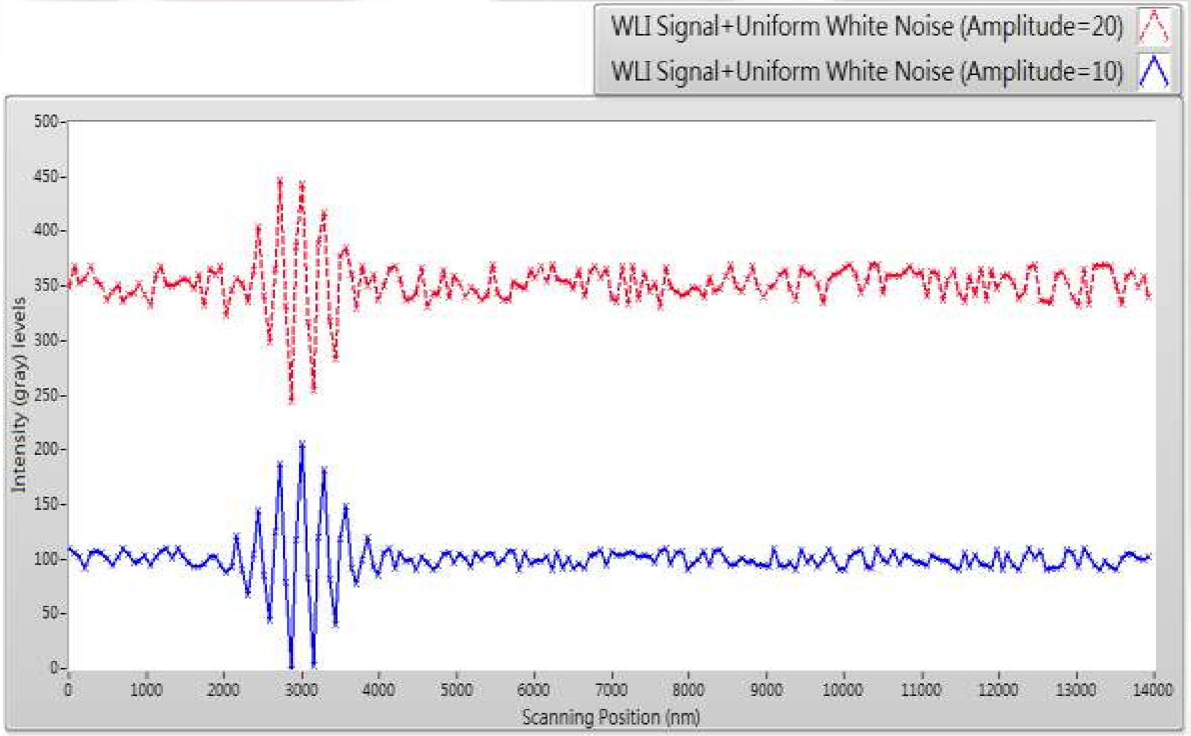
M. H. Shen, C.H. Hwang, W. C. Wang, "Using Higher Steps Phase-Shifting Algorithms and Linear Least-Squares Fitting in White-Light Scanning Interferometry," Optics and Lasers in Engineering, vol. 66, pp. 165-173, 2015.

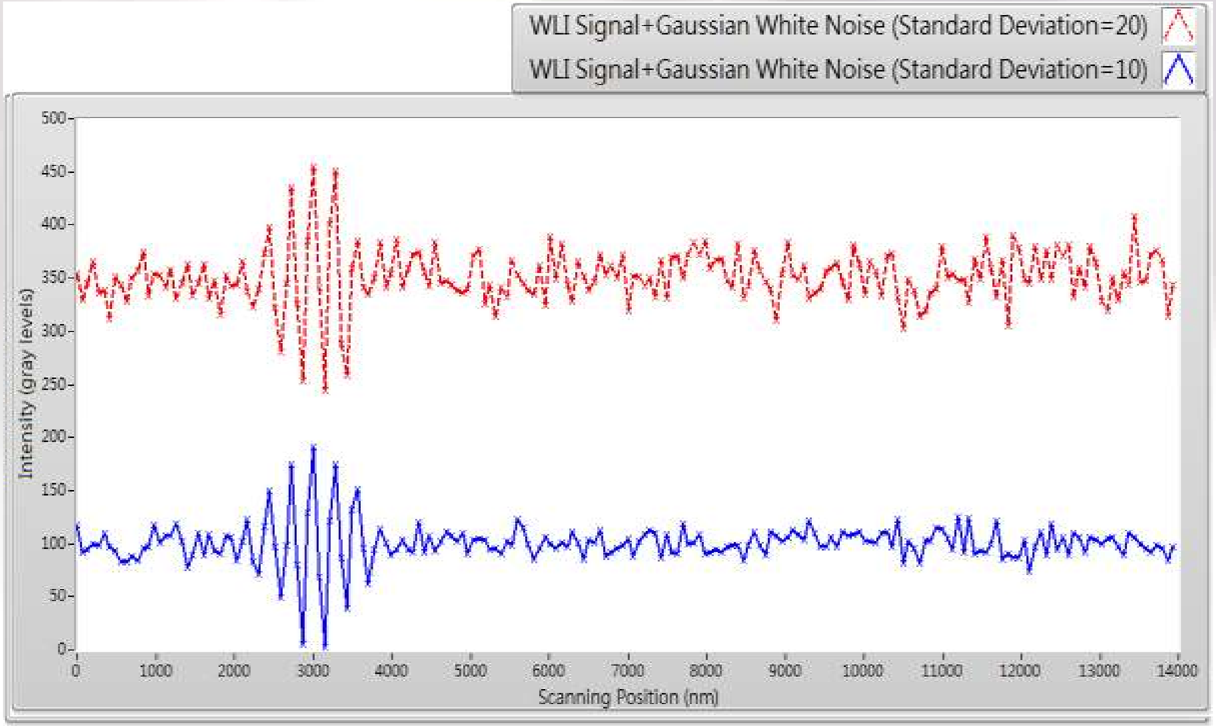
WLSI Single along vertical/ horizontal pixels

➢To study the noise effect, a uniform white noise and a Gaussian white noise mixed with WLSI signal were simulated.

➢ Gaussian White Noise:

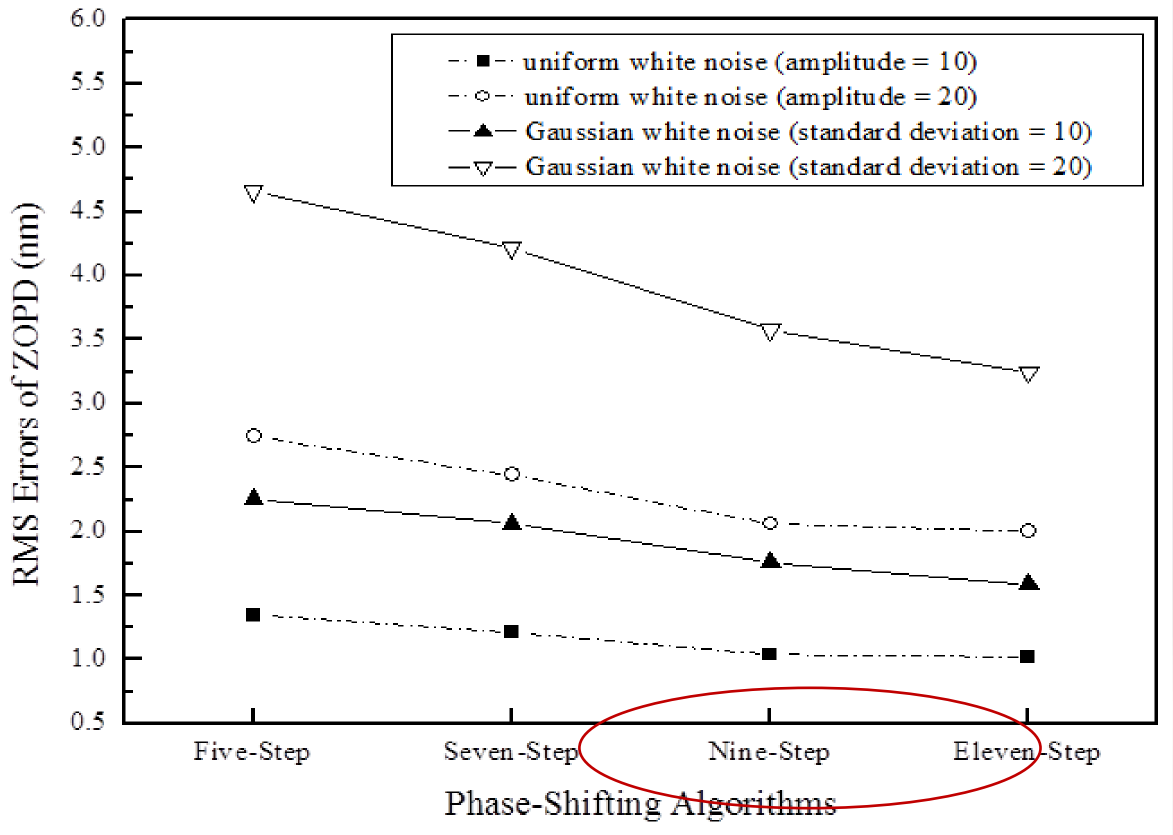
➢Uniform White Noise:

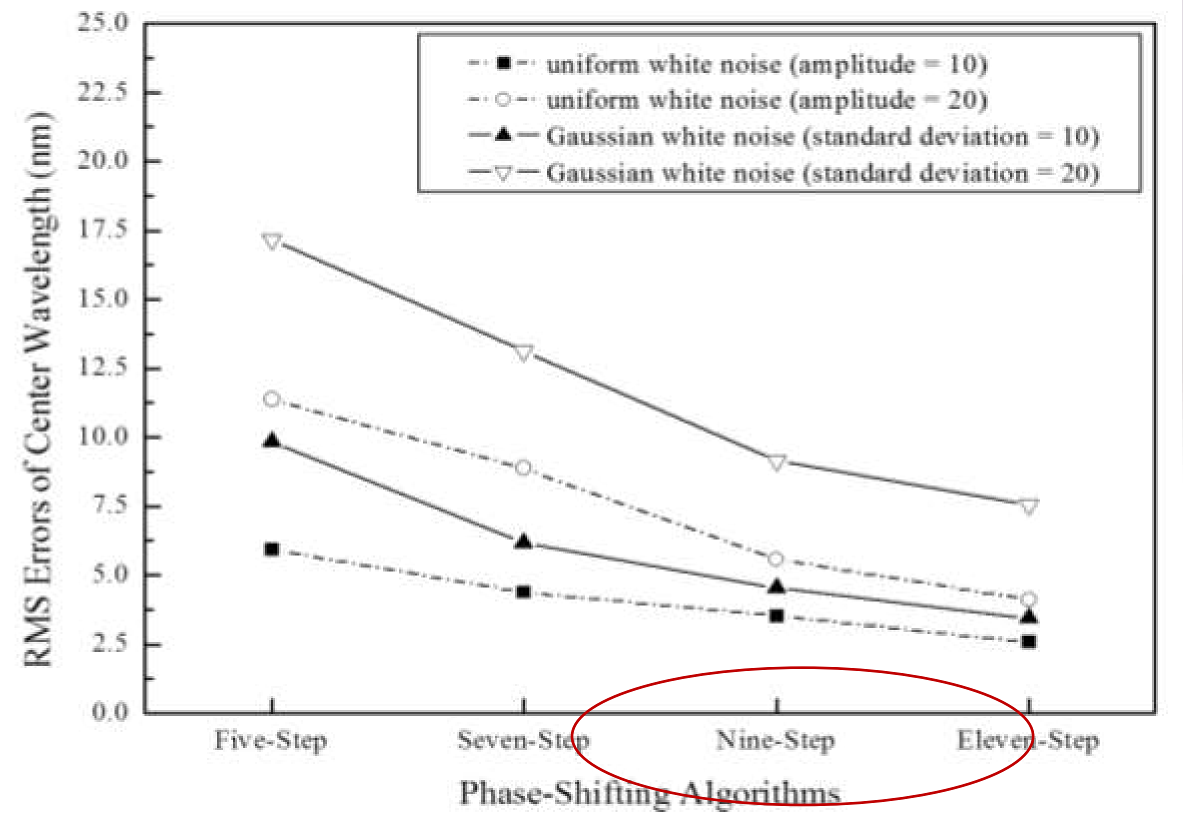




Measurement Capabilities for Different Phase Shifting

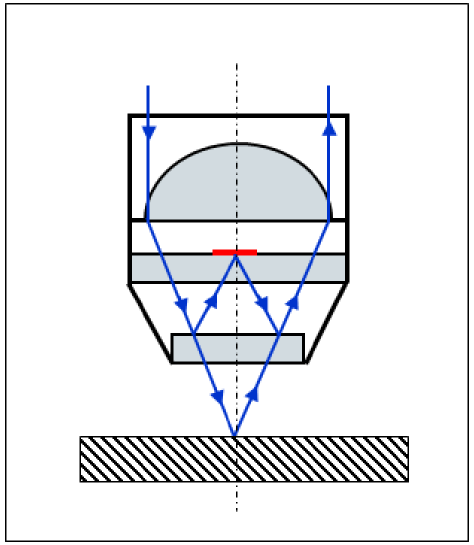
- The RMS errors of ZOPD and center wavelength were calculated with different PSAs from generated noise-contained WLSI.
- It is clear that the accuracy of nine- and eleven-step PSAs is better than that of the five- and seven-step PSAs.





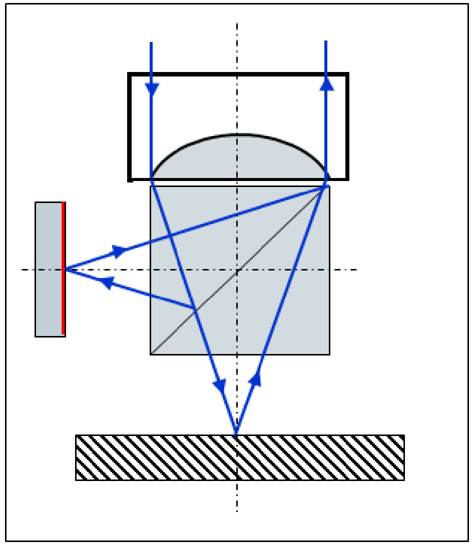
Optical Systems

Mirau – Interferometer



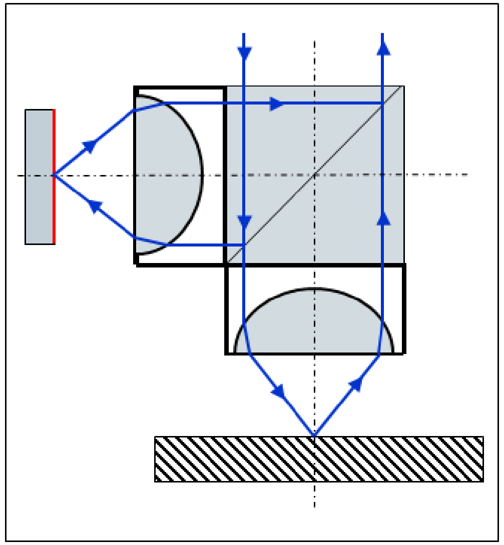
- short working distance
- NA 0,3 – 0,6
- magnification 10x – 50x

Michelson – Interferometer



- short working distance
- NA < 0,3
- magnification 1x – 10x

Linnik – Interferometer



- long working distance
- high NA possible
- two microscope objectives
- demanding adjustment

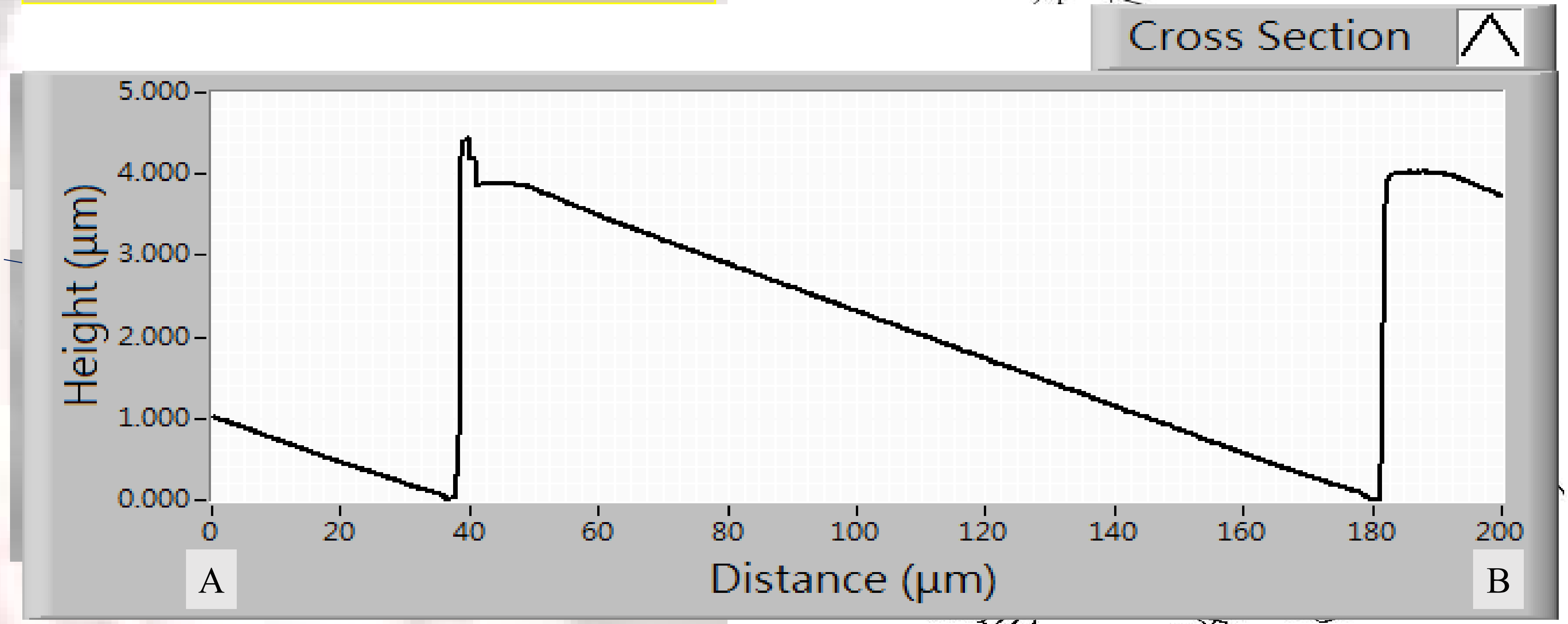
➢During the development of WLSI, optical systems such as Michelson, Mirau, and Linnik interferometers were proposed.

http://big5.china.com/gate/big5/pomeas.blog.china.com/201101/7569253.html

3D Shape

WLSI Mode

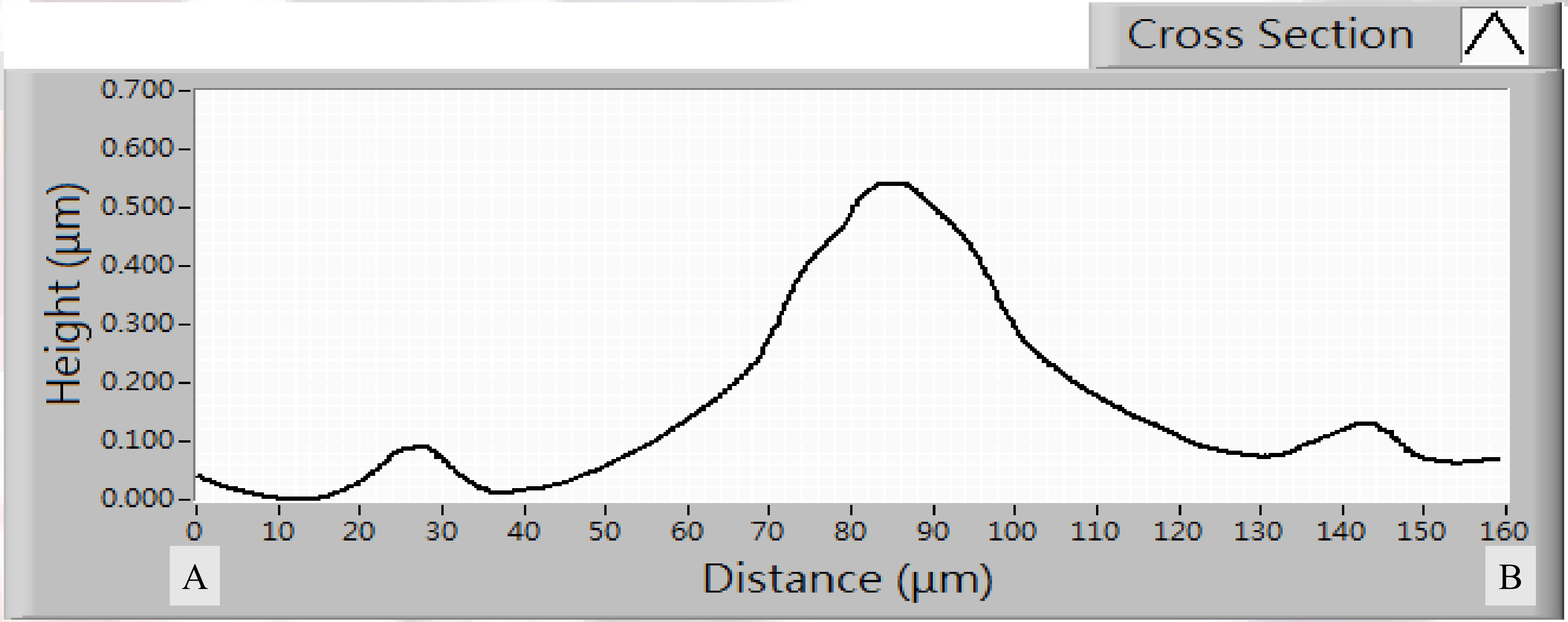
Light Guide (Cell Phone)



3D Shape

WLSI Mode

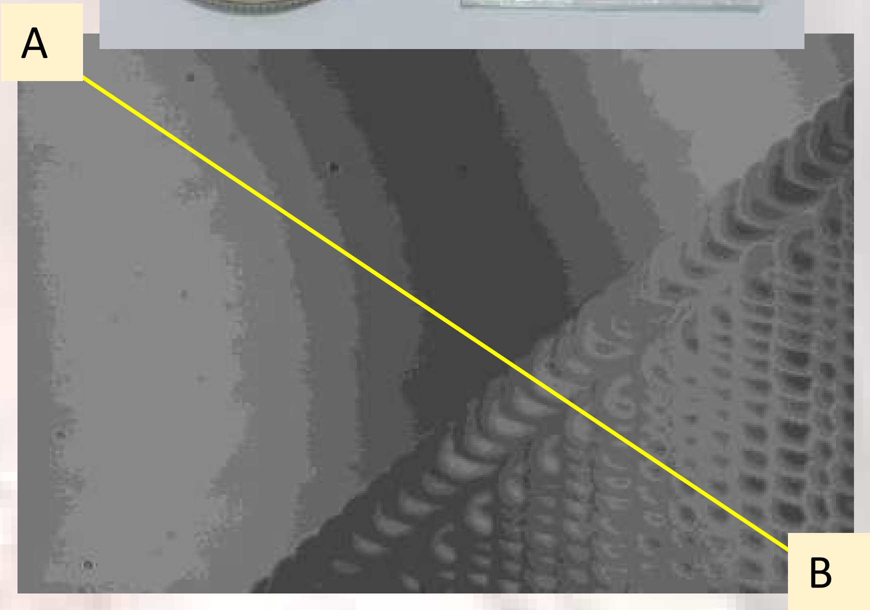
Color Filter (Cell Phone)

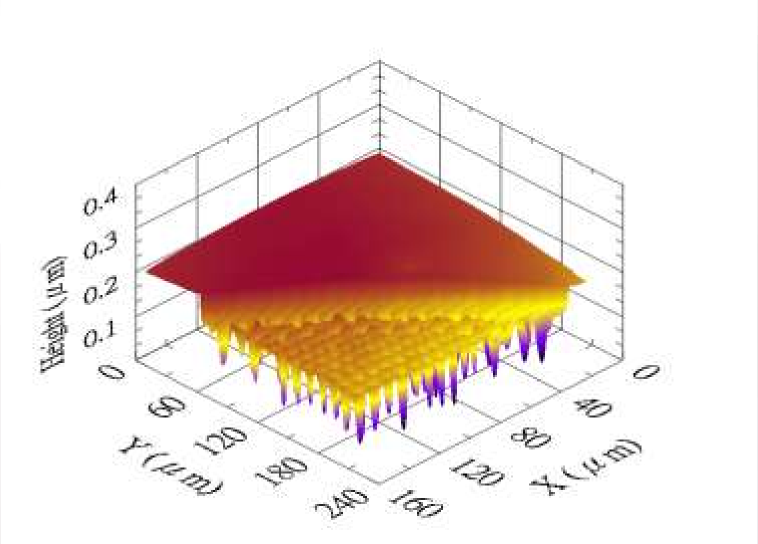


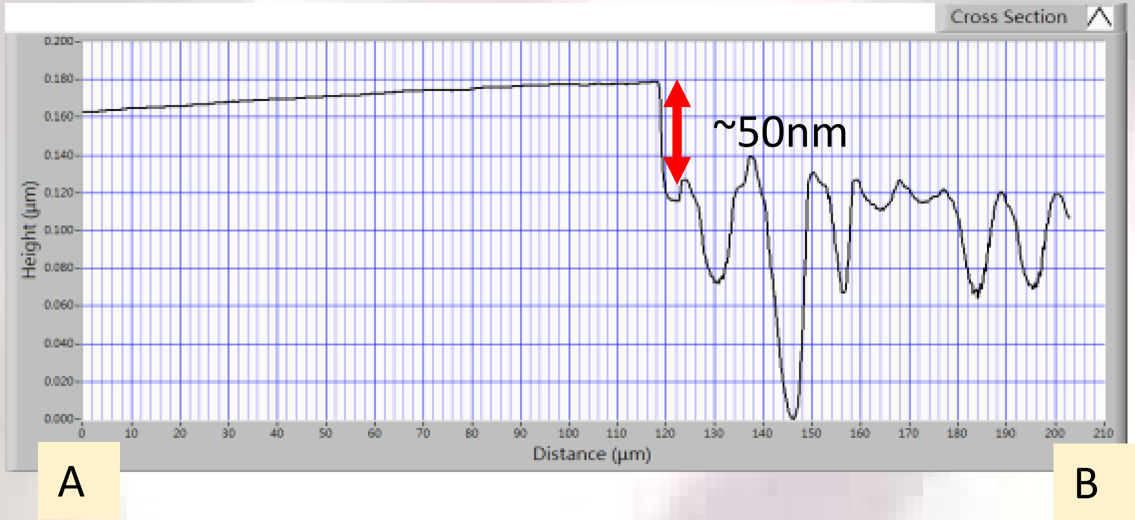
3D Shape

WLSI Mode

Thin Film (AZO)



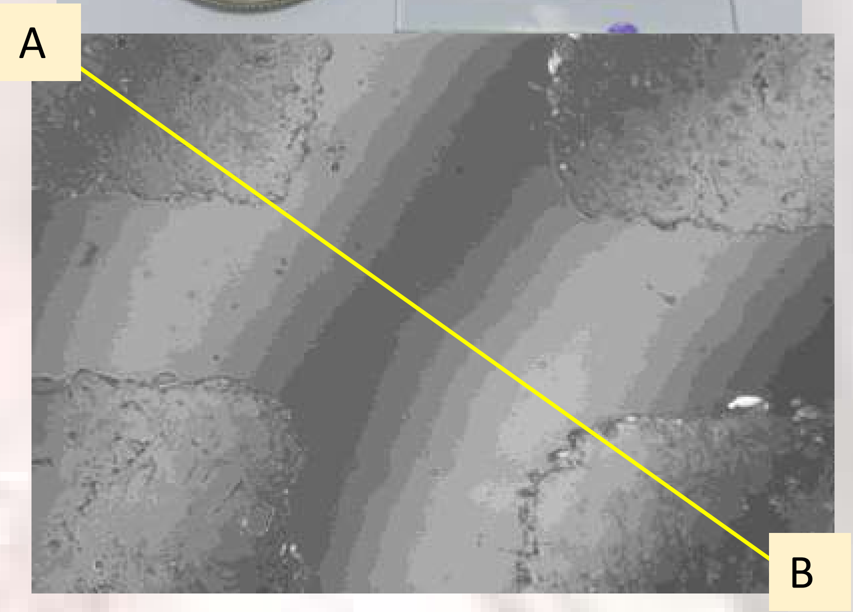


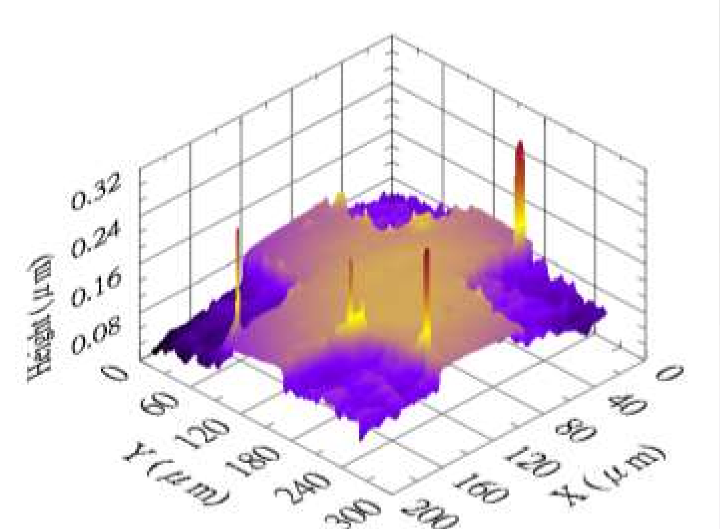


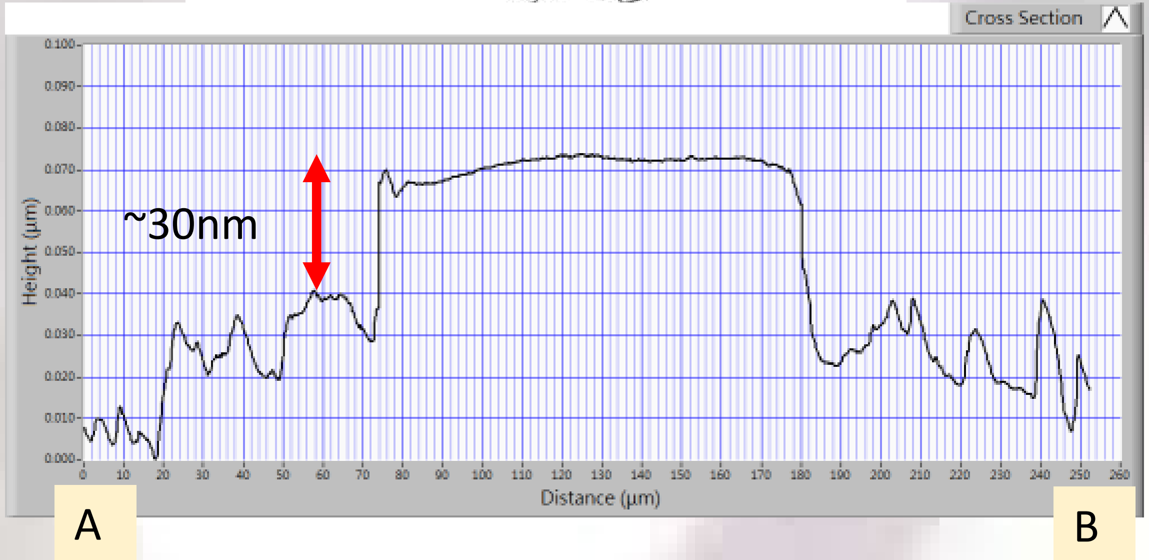
3D Shape

WLSI Mode

Thin Film (ITO)



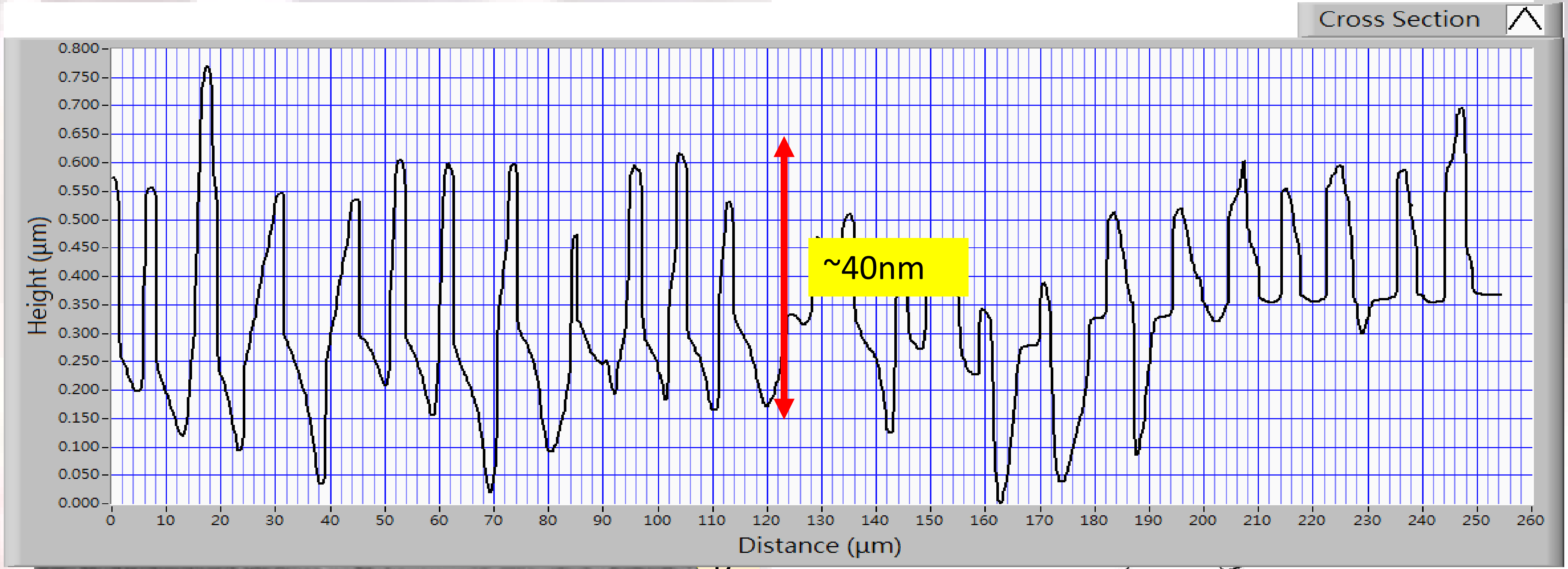




3D Shape

WLSI Mode

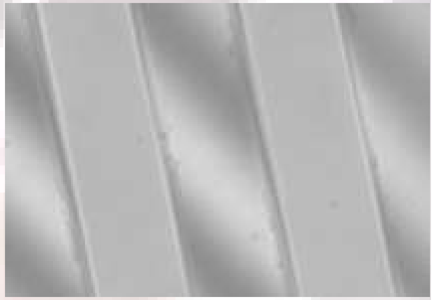
Roughness-AZO
(Laser Lithography)

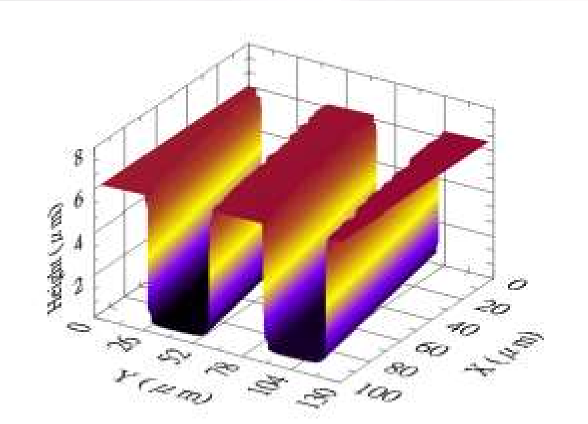


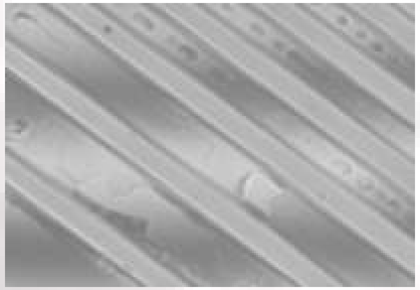
3D Shape

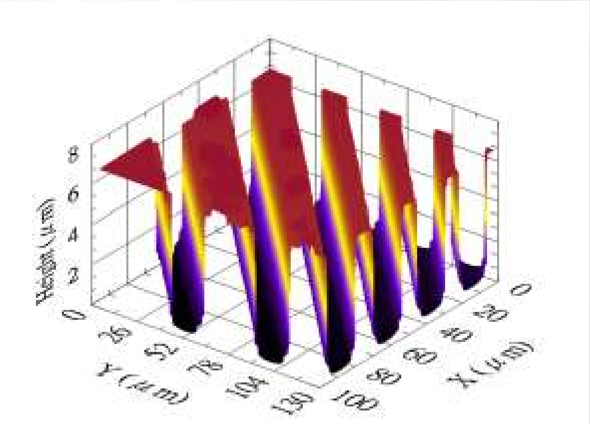
WLSI Mode

Microchannel









Grating