Surface Metrology

Application Brief

Optical Profiling of High Slope Surfaces

Improved capabilities on high slopes

Measuring the form of highly sloped surfaces has traditionally been a challenging application for optical profilers using Coherence Scanning Interferometry (CSI). Examples of these surfaces exist in virtually all industries and include optical micro-lenses, brightness enhancing structures, and machined cones. Advances in signal detection and processing available on ZYGO's CSI based profilers running Mx™ software vastly improve the ability to obtain valid topography data from surfaces with high slopes.

Theoretical limits

As a quick rule of thumb, the theoretical limit for a given microscope objective's slope capability is typically explained by a simple formula based on the Numerical Aperture (NA) of the lens:

arcsin(NA) = maximum angular acceptance

Usually, a high NA lens is also a high magnification lens. The dependence of the slope limitation on NA is key, as it points out that high magnification alone is not enough to achieve the highest possible slope resolution. For example, a 100x objective with a 0.7 NA would have a maximum slope acceptance of 44 degrees. A 0.85 NA objective with the same 100x magnification yields a maximum slope acceptance of 58 degrees — an improvement of more than 30%.

It is important to note that the formula provides a maximum theoretical acceptance angle for a specular test surface — a level that is quite challenging to meet in practice. As the surface slope is increased and approaches the theoretical limit, the strength of the light returning into the interferometer weakens. This will produce a low contrast interference signal, sometimes only barely distinguishable from the background illumination from the interferometer reference surface. The weak nature of this signal is one of the primary reasons that CSI profilers can have difficulty measuring highly sloped specular surfaces.

For non-specular surfaces, the theoretical limit can be exceeded in some cases by more than 50% due to the scattering structure of the surface. Using the 100x 0.85NA lens described above, has enabled angles as high as 87 degrees on a machined surface can be measured on the Nexview™ profiler.

In practice on a smooth surface

The test piece used for the example measurements here is a rectangular glass rod with extremely sharp 90 degree corners. Placing the rod in a V-block presents the edge of one of those corners to the system such that each of the faces is at 45 degrees to the reference surface in the interferometer. Using the 100x 0.85NA objective lens, the NewView 8000 profiler running Mx software is able to measure this surface with no difficulty at all in approximately 15 seconds (refer to Figure 1 & 2).

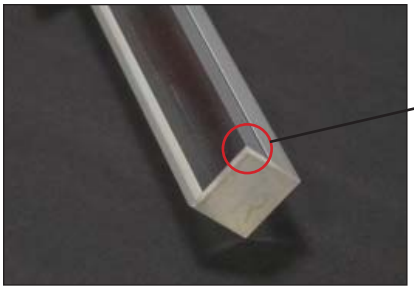

Figure 1: Quartz rod with near perfect 90° corners.

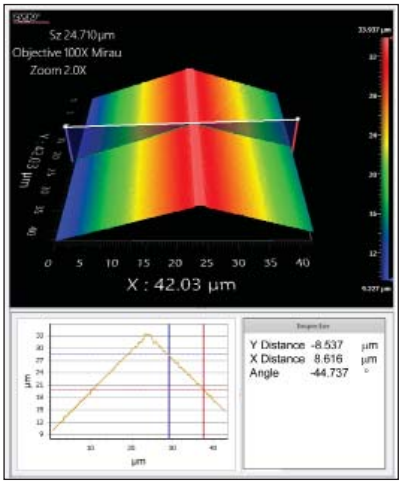

Figure 2: 45° slope measured on the Nexview™.

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Rotating the V-block by 10 degrees presents the corner such that one surface is tilted away at a slope of 55 degrees – approaching the theoretical limit of 58 degrees computed earlier. The signal strength of the interference pattern is weakened to the point that a measurement using typical settings is unable to detect the surface. Profilers running Mx™ software have the ability, though, to employ a technique called "Dynamic Noise Reduction" which reduces the measurement speed and enabling the system to decrease signal noise and make the very weak signal detectable.

For this measurement, a reduction factor of 6x was used and the surface was measured in 350 seconds (refer to Figure 3). Smaller noise reduction factors are also able to detect the surface, but can result in more missing data. Choosing the correct level of dynamic noise reduction is a tradeoff between data density and measurement throughput. Where more detailed structure information is desired, though, a higher noise reduction factor may be preferred in order to maximize the surface.

In practice on a rough surface

When measuring a rough surface that scatters light, significantly higher surface angles can be profiled than the theoretical specular limit would imply. Take the edge of a commercial razor blade for example. The blade itself has a surface slope of approximately 60 degrees, however it has a very distinct structure. Like the glass rod above, we can tilt the surface even further away by using a rotation fixture. This is demonstrated on a Nexview™ profiler with the blade rotated so the surface is presented as a slope of 86 degrees. Figure 4 shows the result of that measurement, which was obtained in 133 seconds using a 100x 0.85 NA lens and 3x Dynamic Noise Reduction.

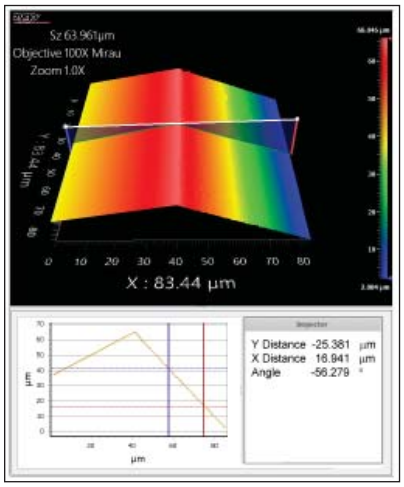

Figure 3: Quartz rod tilted 10° to present one surface at 56°.

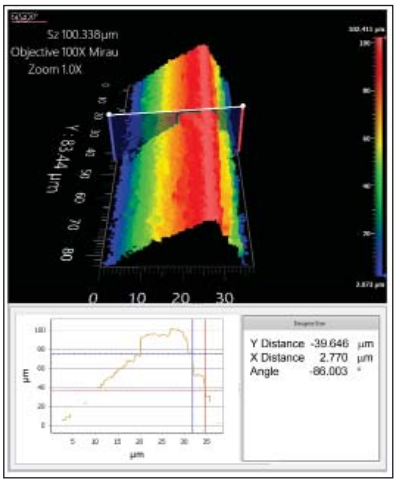

Figure 4: Commercial razor blade measured on edge shows a measurable surface slope of 86°.

Conclusion and next steps

The measurement techniques and algorithmic advances in ZYGO's CSI profilers running Mx software allow for significant improvements in the ability to measure steep slopes. In most cases the measurement capability approaches the theoretical limit, and on rough surfaces it is possible to exceed the limit. Due to variation in the many types of surfaces, ZYGO specifies our profilers with more conservative performance than seen in the examples above.

For applications requiring high slope metrology for angle and form measurements, these new tools can be exceptionally powerful. They can provide far more quantitative metrology data, quicker and with no risk of part damage, as compared to competitive non-interferometric techniques. To see if these improvements will solve your slope measurement challenges, we recommend a free application evaluation. For an evaluation or additional information, contact ZYGO profiler applications engineers.

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