A study of surface measuring limitation on a laser scanning microscope by the examination of response properties of surface texture and slope detection on a ruby sphere sample

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Abstract

A Laser Scanning Microscope (LSM) is an optical measuring instrument that is becoming widely adopted as an effective solution for surface metrology. However, measurements by optical methods may not always accurately represent minute, jagged surfaces or steep slopes. [1] This study aims to clarify the limitations imposed on LSMs by examining the response properties of surface texture as well as the largest detectable angle of slope surface. Specifically, we examined amplitude response properties for vertical measurements, which we define as the ratio: measurement result to nominal peak-valley as stated in the manufacturer’s documents. For the study of slope detection, we used a precise ruby sphere sample. The results presented indicate how best to maximise the accuracy and reliability of measurements made using LSM.

1 Measuring instruments and samples used in this study

We operated an LSM using four different lenses (Table 1). We also measured the same samples using a stylus instrument for comparison. For height measurements we used one-dimensional grating standards (Table 2). For assessing the performance of slope detection we used a precision ruby sphere with a diameter of 153 μm.

Table 1: Measuring instruments used in this study

Instrument	Lens Magnification and NA
Laser Scanning Miscroscope Olympus LEXT OLS4000 (Laser wavelength 405nm)	20x NA 0.6 (Ordinary lens) 20x NA 0.6 designed for 405 nm 50x NA 0.95 designed for 405 nm 100x NA 0.95 designed for 405 nm
Stylus Instrument	R 2μm

Table 2: Geometrical specifications of the samples

Sample	Nominal Surface Wavelength (μm)	Nominal Amplitude (μm)	Shape
Rubert No.531	100	1	Sinusoidal
Rubert No.528	50	1.5	
Rubert No.529	10	0.3	
Rubert No.542	8	0.2	
Rubert No.543	2.5	0.12	
Elionix Line & Space (resist pattern)	0.4, 0.36, 0.32, 0.28, 0.24	0.1	Rectangular

2 Measuring results of response properties

First, we examined the difference between an ordinary 20x lens and a 20x lens designed with ideal aberration correction for use at a wavelength of 405 nm, in order to assess the improvement. Figure 1 compares the cross-sectional profiles acquired using an LSM when measuring the Rubert 529. With the ordinary lens, the amplitude measured is larger than the nominal amplitude present at the off-axis area of the field of view. In contrast, when a 405nm optimised lens is used, this phenomenon does not occur and the amplitude is measured correctly. This demonstrates that the status of aberration correction strongly relates to measurement accuracy.

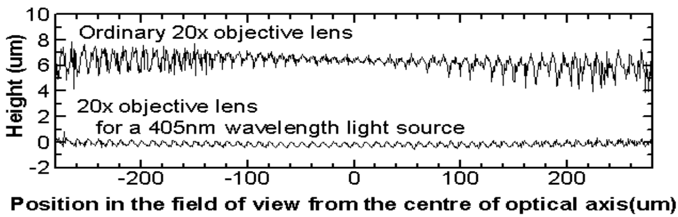


Figure 1: Effects of the optical lens on height measurement.

Next, we measured the Rubert 543 using both LSM and the stylus instrument (Figure 2). Rubert 543 is correctly measured using both the 100x NA 0.95 and the 50x NA 0.95 objective lenses, but the profile obtained using the 20x NA 0.6 lens exhibits a different amplitude response. Therefore, we infer that NA has the capacity to affect the amplitude response. The profile of the stylus instrument results in a smaller amplitude than the nominal value. In this case, the difference is caused by the λs profile filter embedded in the instrument (size, 2.5μm).

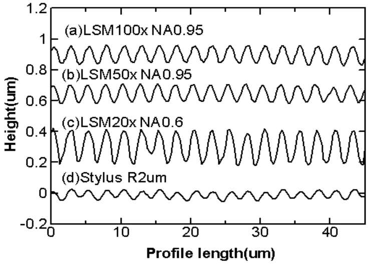


Figure 2: Profiles of Rubert 543

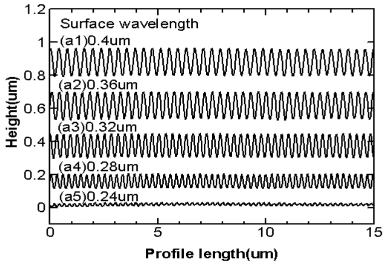


Figure 3: Profiles of the Elionix samples

Thirdly, we examined shorter wavelengths recorded using the 100x NA 0.95 lens. Figure 3 shows five profiles from the Elionix samples. The amplitude of the a1 profile is approximately 0.15µm. Then, as wavelength decreases, so does amplitude. In addition, we plotted the relationship between amplitude response and surface wavelength for each of the samples (Figure 4). Where the wavelength is longer than 10µm, each of the lenses and the stylus instrument, exhibited an amplitude response very close to 1, indicating that the result is equal to the nominal value. As the wavelength drops from 10µm down to 1µm, the results of the 100x and 50x lenses remain close to 1, but the result of the 20x lens exceeds 1. Below a wavelength of 1µm, all of the results using an LSM exceed 1 until 0.4µm, at which point the amplitude response rapidly drops below 1. We consider that the phenomenon observed when the amplitude response exceeds 1 is an 'overshooting spike' specific to optical instruments. A wavelength of 0.4µm is close to the size of the beam spot diameter of an LSM (calculated by the formula, λ/N.A. = 0.405µm /0.95), a wavelength conspicuously close to that at which the overshooting spike is observed. [2][3] The stylus instrument also shows a similar phenomenon – a decrease in amplitude as the wavelength becomes shorter as influenced by the size of stylus probe.

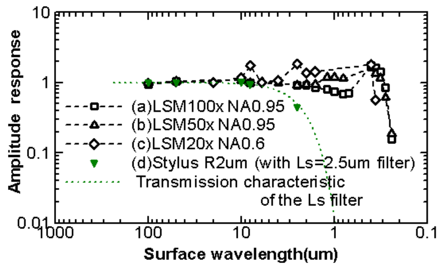
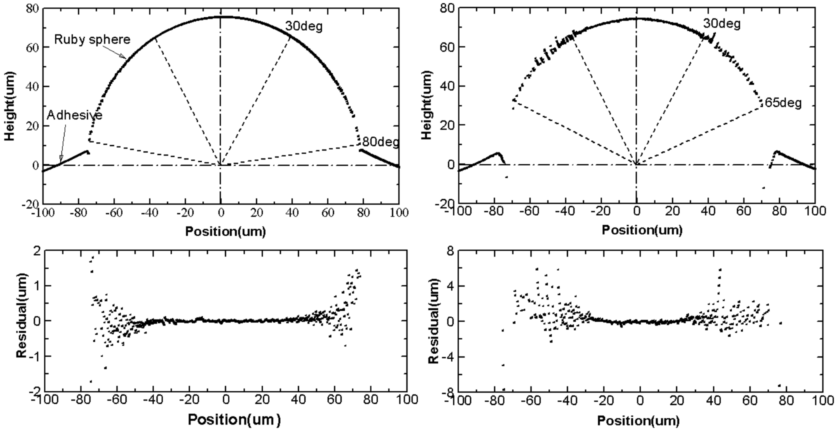


Figure 4: Response Properties

3 Limitation of slope detection

We measured a precision ruby sphere with a diameter of 153µm using two lenses, the 50x (NA 0.95) and the 20x (NA 0.6). The results are shown in Figure 5. A slope angle of up to 80° can be measured using the 50x lens, whereas an angle up to 60° can be measured using the 20x lens. We also compared the dimensional errors observed using our methods against the ideal R shape. At the edges of the detectable angle range, the error observed is only of the order of a few microns.



50x NA 0.95 20x NA 0.6

Figure 5: Slope detection limitation and errors when comparing with ideal R values

4 Conclusion

The accuracy of surface texture amplitude response properties measured using an LSM depends on the NA values of the objective lens. When a lens with an NA of 0.95 is used, measurements can be made accurately up to a wavelength of around 1μm, but below 1μm a phenomenon called ‘overshooting’ disrupts accuracy. LSM can measure the slope of a ruby sphere up to 80 degrees when using a lens with an NA of 0.95 and up to 60 degrees when using a lens with an NA of 0.6.

References:

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