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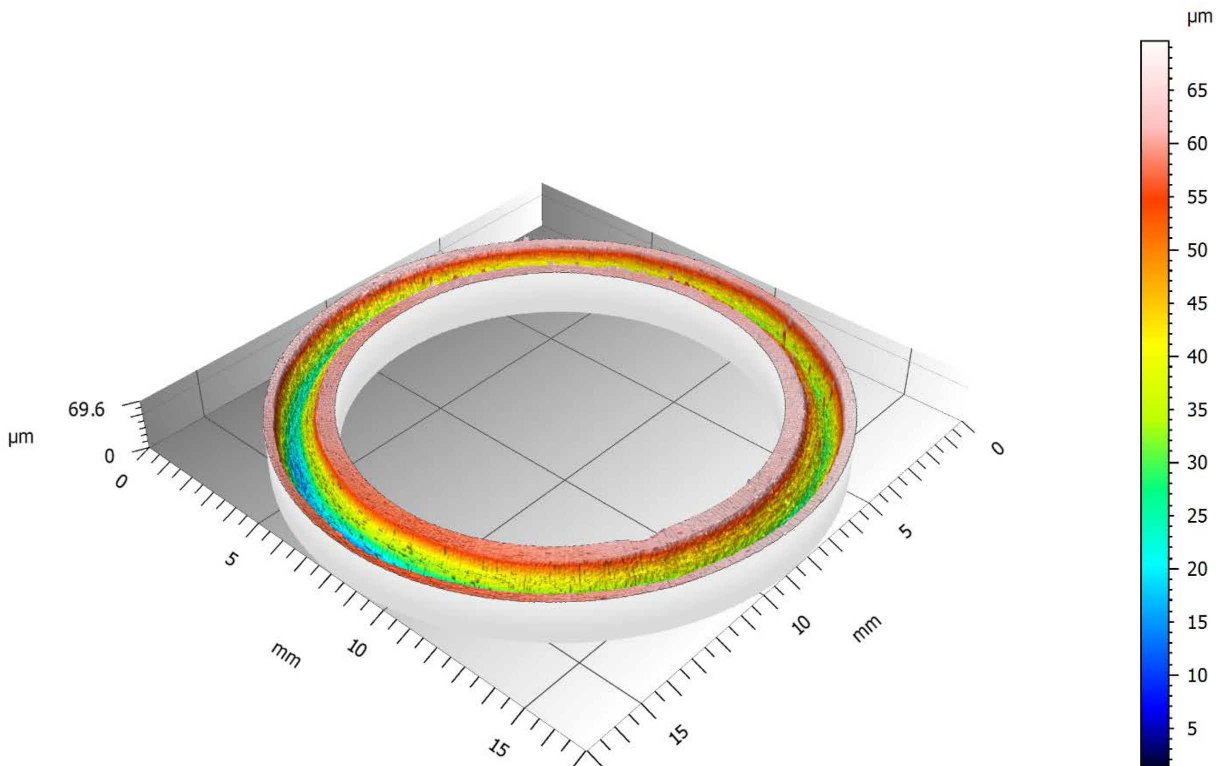
3D WEAR TRACK SCAN IN SITU ON TRIBOMETER



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INTRO

Wear occurs when two surfaces interact and cause material removal and deformation. Coefficient of friction (COF) and wear rate are two important parameters describing the state of contact in a tribo-system. The COF is the ratio of the friction force and the normal force between the two bodies sliding against each other. Wear rate is determined by the rate at which the material volume/mass is removed. Various techniques have been developed to obtain the best tribological properties, involving lubrication, protective coatings, multi-phase alloys and composite structure. Such a multifactorial tribo-system requires a dependable and repeatable tribometer to evaluate, in order to select the best candidate for the targeted application.

IMPORTANCE OF WEAR TESTING WITH THE IN SITU 3D WEAR TRACK SCAN

Conventional pin-on-disc or reciprocating tribometer records the COF during the wear test. The wear rate is measured after the wear test by moving the sample to a profilometer and scanning the cross section profiles of the wear track. Such a method may introduce errors when the sample possesses an inhomogeneous wear track. Moreover, samples like multilayer coatings possess different wear resistance at different layers of the coating. A more reliable and repeatable technique for wear evaluation is in need – Nanovea developed a tribometer equipped with a 3D non-contact profilometer that performs a 3D scan of the complete wear track on the sample stage of the tribometer. It monitors the evolution of the 3D wear track morphology, allowing users to accurately calculate the wear rate and determine the failure mode at different stages using one test sample.

MEASUREMENT OBJECTIVE

The wear behavior of a steel sample is measured in a controlled and monitored manner using the Nanovea Tribometer equipped with a 3D non-contact profilometer. We would like to showcase that the integrated 3D non-contact profilometer scans the full wear track with high resolution and accuracy.

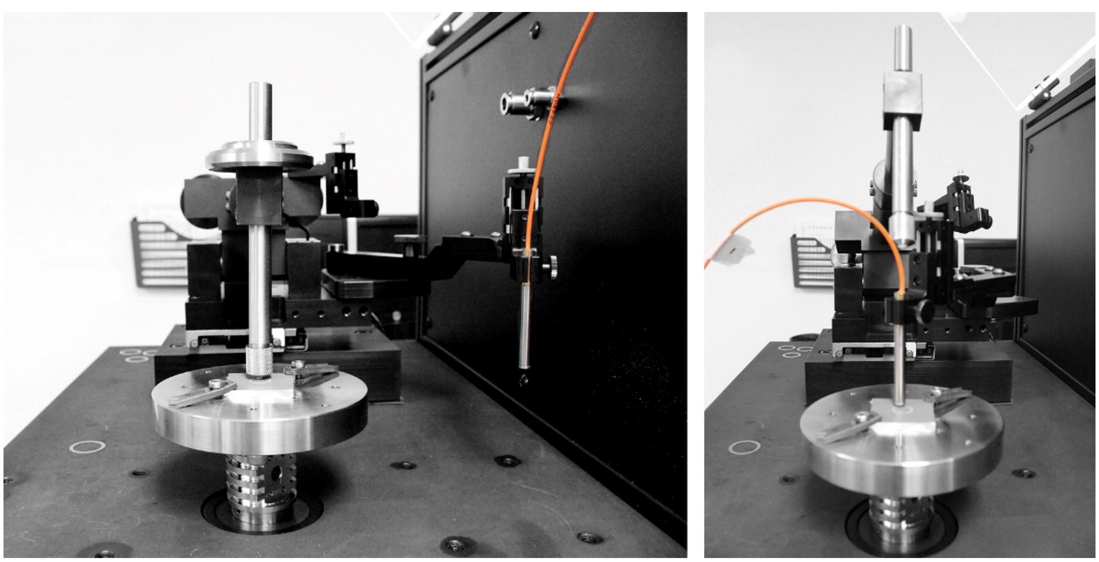


Fig. 1: Nanovea Tribometer equipped with a 3D non-contact profilometer.

TEST PROCEDURE

The tribological behavior, e.g. coefficient of friction, COF, and wear rate of a polished steel sample was evaluated with the Nanovea Tribometer equipped with a 3D non-contact profilometer. A normal load of 20 N was applied by an Al_2O_3 ball tip (6 mm dia.) against the steel sample. The COF was recorded *in situ*. The full 3D wear track profile was measured after the wear test. The test parameters are summarized in Table 1. The wear rate, *K*, was evaluated using the formula $K=V/(F\times s)$, where *V* is the worn volume, *F* is the normal load, and *s* is the sliding distance.

Test parameters	Value
Normal force	20 N
Rotational speed	400 RPM
Duration of test	90 min
Radius	7.5 mm
Revolutions	36000
Ball Diameter	6 mm
Ball Material	Al_2O_3
Atmosphere	Air
Temperature	24°C (room)

Table 1: Test parameters of the pin-on-disc measurement.

RESULTS AND DISCUSSION

The evolution of the coefficient of friction between the ball and the steel sample was recorded *in situ* during the wear test as shown in Fig. 2. The COF exhibits a starting value of ~0.30 at the beginning of the wear process. It progressively increases in the first 10000-cycle run-in period and then maintains a relatively constant value of ~0.4 throughout the rest of the test.

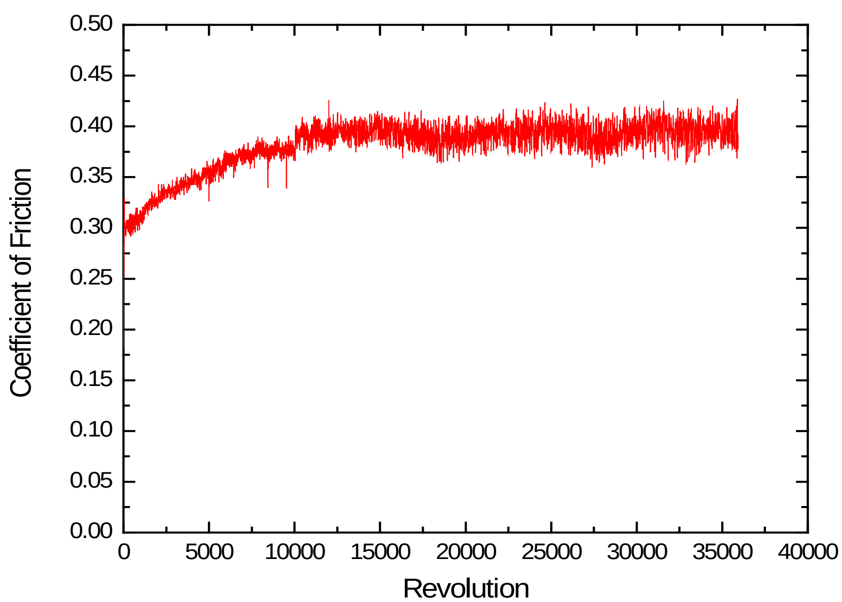
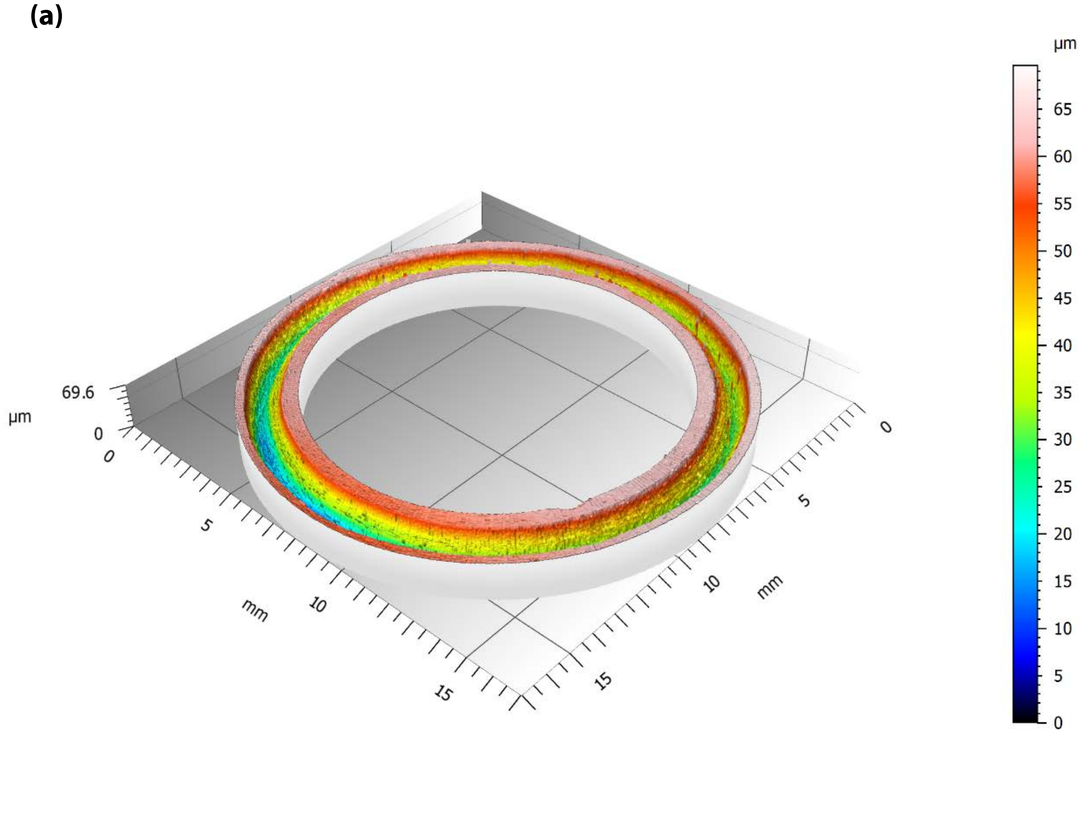


Fig. 2: Coefficient of friction during the wear test.

The 3D and false color views of the wear track are displaced in Fig. 3, providing users a straightforward tool to directly observe the wear track from different angles. The measured 3D wear track provides the accurate wear track volume of 1.28 mm^3 as calculated by Nanovea analysis software, which results in a wear rate of 3.8 $\times10^{-5}$ mm^3/N m. Fig. 4 presents the cross section profiles at three random locations of the wear track, and the wear track area and depth is summarized in Fig. 5. The seemingly homogeneous wear track has different wear rates at different sections. The size of the wear track area is 24539, 19389 and 37643 μm^2, respectively, for the three cross section wear track profiles. The average wear rates can be calculated using the formula $K=V/(F\times s)=A/(F\times n)$, where A is the cross-section area of the wear track as displayed in Fig. 4, and n is the number of revolutions. The calculated wear rate using the wear track areas are 3.4, 2.7 and 5.2 $\times10^{-5}$ mm^3/N m, respectively. Clearly, substantial error has been generated when the wear rate is calculated based on only a few 2D profiles across the wear track.

In addition, the calculated wear rate of a material strongly depends on the number of revolutions, which is directly related to the different stages of the wear process. In this study, the 3D scan of the wear track was measured with the sample sitting on the sample stage using the non-contact profilometer integrated on the tribometer. The user can continue the wear test after the 3D scan, so as to monitor the evolution of the wear process and determine the failure mode using one sample. It cuts the cost and time for the preparation of multiple samples, and eliminates the possibility of test result fluctuation due to the property variation from different samples. Moreover, compared to conventional pin-on-disc or Taber testers, it considerably facilitates the initial investigation on the test parameters, which in many cases is the most energy and time consuming process.

(a)



(b)

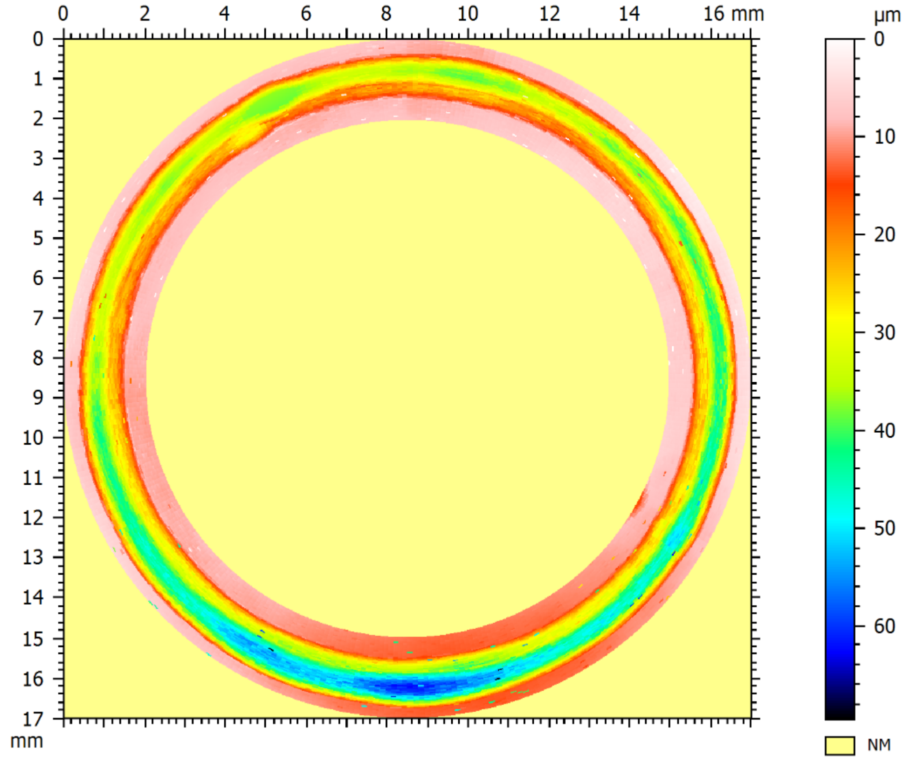


Fig. 3: (a) 3D view and (b) false color view of the wear track.

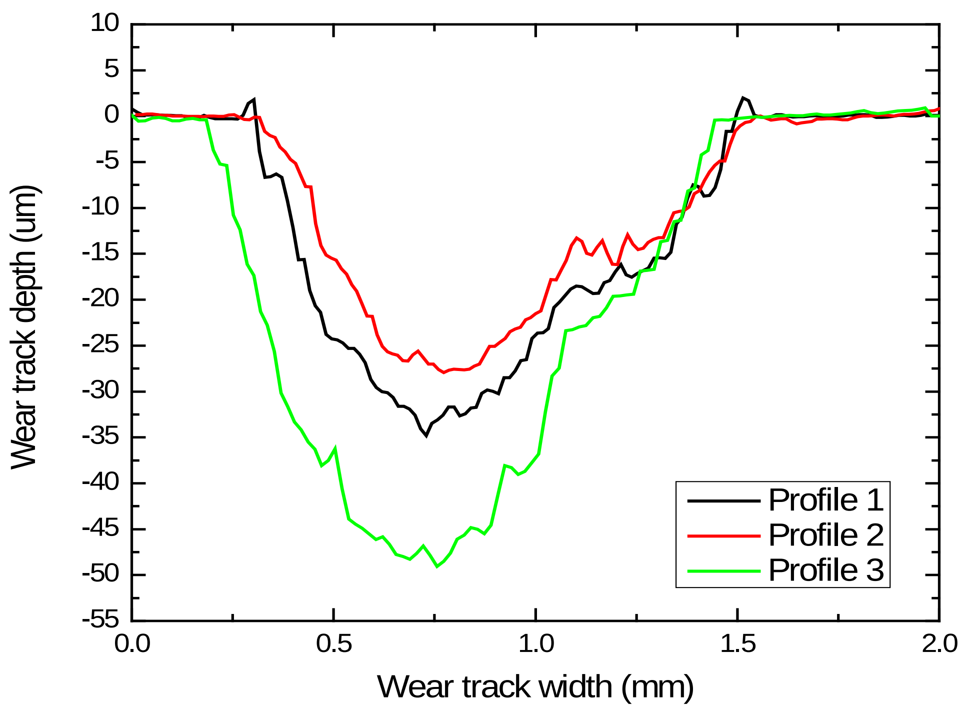


Fig. 4: Cross section profiles of wear tracks at three random locations.

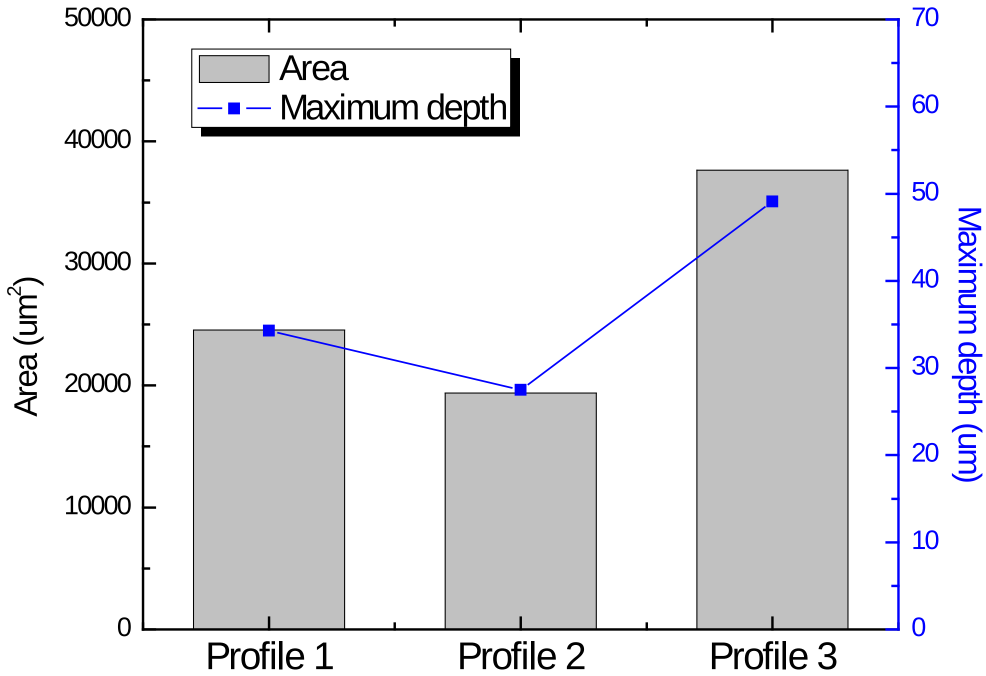


Fig. 5: The area and depth of the three cross section wear track profiles.

CONCLUSION

In this study, we showcased that Nanovea Tribometer equipped with a 3D non-contact profilometer is a superior tool for wear evaluation. The integrated 3D metrology scan provides accurate wear volume measurement and detailed information of the wear track, which enables users to improve fundamental understanding of the wear mechanism. The capacity of in-situ COF and wear rate measurements allow users to correlate different stages of wear process with the evolution of COF and wear rate.

Nanovea Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system.

Learn More about the Nanovea Tribometer and Lab Services

MEASUREMENT PRINCIPLE

TRIBOMETER PRINCIPLE

The sample is mounted on a rotating stage, while a known force is applied on a pin, or ball, in contact with the sample surface to create the wear. The pin-on-disk test is generally used as a comparative test to study the tribological properties of the materials. The, coefficient of friction, COF, is recorded in situ. The volume lost allows calculating the wear rate of the material. Since the action performed on all samples is identical, the wear rate can be used as a quantitative comparative value for wear resistance.

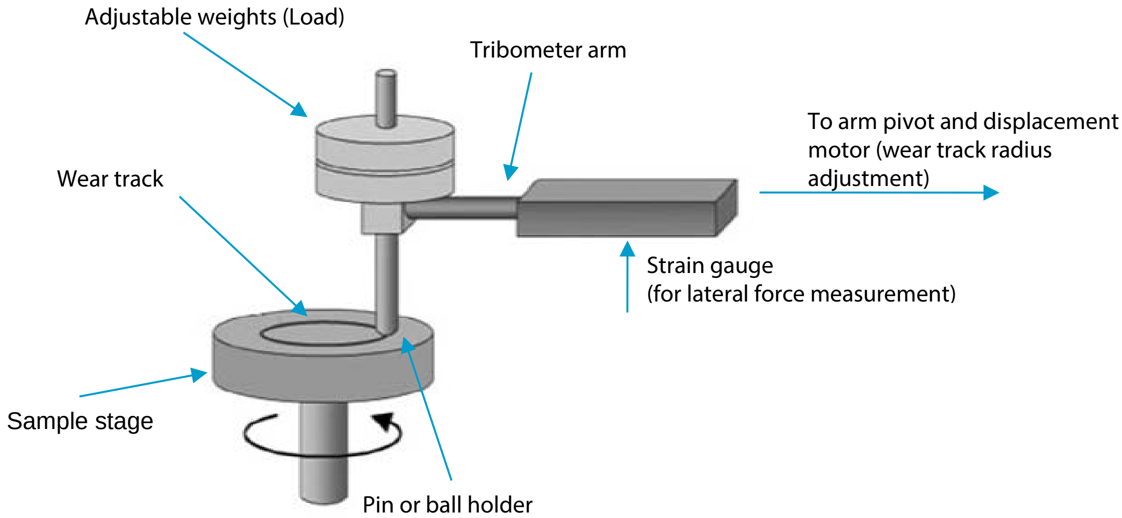


Fig. 6: Schematic of the pin-on-disk test.

PROFILOMETER PRINCIPLE

The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.

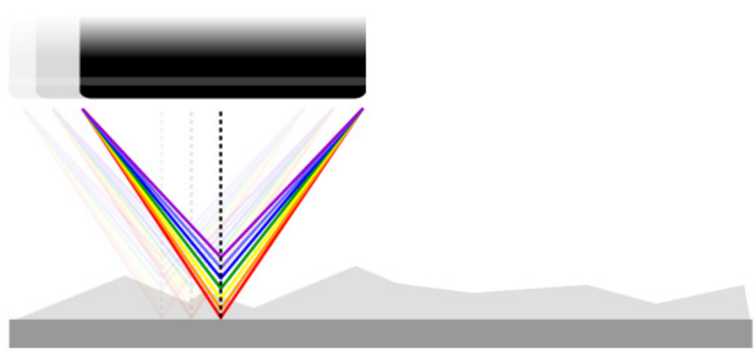


Fig. 7: Schematic of axial chromatism technique.

Nanovea optical pens have zero influence from sample reflectivity. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent or opaque, specular or diffusive, polished or rough.