Aperture Optical Sciences

WHAT IS SURFACE ROUGHNESS?

Surface roughness addresses the topography of a surface and quantifies the variations in its height on a micro-scale.

Roughness is defined by ISO standards. Depending on the type of surfaces being studied, different ISO standards may apply. Profile, or 2D, roughness is defined by ISO 21920. Ra and Rq are the profile values representing the arithmetic mean height and RMS surface height, respectively. For areal roughness, or 3D roughness, ISO 25178 is the standard. Sa is the arithmetic mean height over an area and Sq is the RMS surface height over an area.

Surface roughness is intrinsic to any surface; there are always slight surface height variations even on extremely flat surfaces. For flat optics, these variations are usually on the nanometer or Angstrom scale. Roughness is different than other cosmetic defects like scratches, digs, and pits, however they can be related. For example, a pit formed from the polishing process will show up in roughness measurements and affect the value. In addition, scratches ranging in size from nanometers to millimeters (depending on the polishing grit and material) can affect roughness measurements as well, depending where on the optic the measurement is taken.

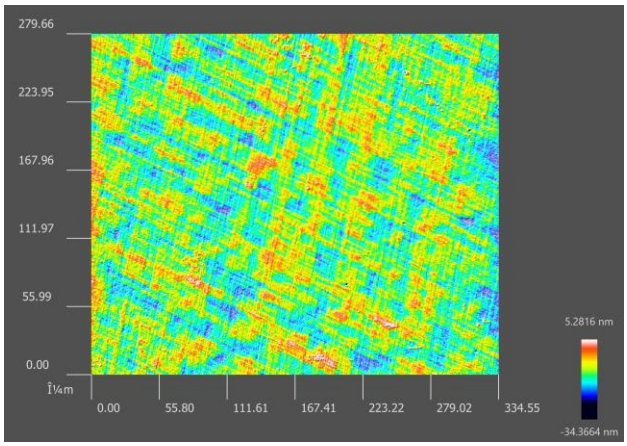


Figure 1.

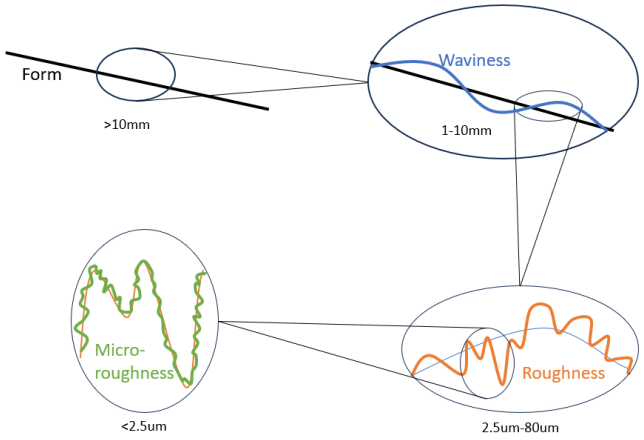


Figure 2.

Figure 1: A sample roughness measurement on plano SiC with x and y axes in microns. This particular measurement has an RMS surface height (Sq) value of 3.6 Angstroms. Standard low and high pass filters and form removal were applied.

Figure 2: Measurement types with scale for lateral feature sizes. Figure 2 is exaggerated for illustration.

Height Variation Types There are four different classes of optical surface height which are defined based on their spatial frequencies - form, waviness, roughness, and microroughness. Form is the general shape of the surface, like a plane, sphere, or cylinder. Generally, form addresses spatial scale lengths ≥ 10mm, but this can vary from large to small optics. The next finest is waviness, which is the general deviation from the form. Waviness can also address what we call mid-spatial frequency errors. The range can vary

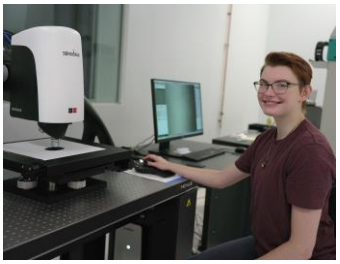
© 2023 Aperture Optical Sciences Inc.

by company and size of the optic. At AOS, we refer to mid-spatial frequency errors on a scale between 1 and 10mm. Roughness, as described above, is the metric of interest. Roughness is the deviation from surface height, usually denoted as RMS surface height. These height variations measured over a spatial scale length range between 2.5um and 80um. Microroughness below spatial scale lengths of 2.5 microns can still affect scattering in some applications.

Why Measure Roughness?

There are many parameters that are measured to determine the quality of an optical component such as cosmetic defects, laser-induced damage threshold, power spectral density, surface figure and reflected wavefront errors, optical aberrations, and so on. Surface roughness is simply one additional parameter. As previously stated, roughness affects how light scatters as it is reflected off the surface. The lower the surface roughness, the higher performance you can achieve. Less light will be scattered, and the optic will be more efficient as a result. 2nm RMS is a typical surface roughness for on off-axis parabolas and < 10 Angstrom RMS values for plano optics.

AUTHOR



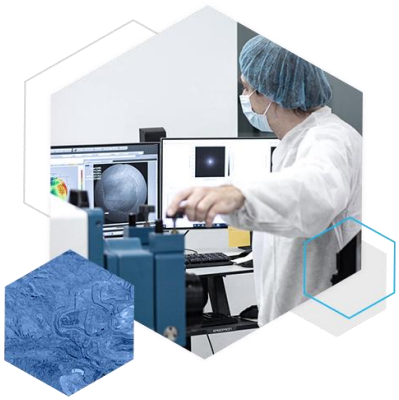
Torrie Sutherland, Applications Engineer, Aperture Optical Sciences Inc.

Torrie honed their skills the production floor, mastering metrology before entering the role of applications engineer. Torrie earned a master's degree in applied physics at Southern Connecticut State University in 2023, with a concentration in astronomical instrumentation and optics. Please address inquiries regarding this technical application note to info@apertureos.com.

APERTURE OPTICAL SCIENCES INC.

A passageway for light and innovation

Aperture Optical Sciences designs and manufactures precision optics components and systems for space–based imaging and optical communications, high energy lasers, airborne imaging, and industrial machines and instruments. We employ advanced technologies for making high resolution satellite telescopes, aspheric mirrors, and have championed the implementation of Silicon Carbide Optics in the commercial marketplace. We add value by providing rare expertise in robotic optical fabrication, design for manufacturability and assembly, and verifying product performance using advanced optical metrology.



Aperture Optical Sciences Inc.
170 Pond View Drive
Meriden, Connecticut 06450 USA
+1 (860) 316-2589
info@apertureos.com
www.apertureos.com

© 2023 Aperture Optical Sciences Inc.