Mid-Range Optical Profilometry: An Overview

Covalent Metrology's mission is to help customers solve measurement, materials and process problems quickly and efficiently.

Profilometry for surface characterization and dimensioning is a key area of expertise for Covalent Metrology and is proving invaluable to customers across a wide range of applications. At Covalent Metrology, profilometry covers a complete range of surface features using everything from atomic force microscopy (AFM) to optical systems to mechanical stylus systems. The purpose of this paper is to discuss the technology behind each of the three optical profilometry techniques Covalent Metrology offers and to discuss the relative advantages of each of them.

Optical profilometry encompasses a class of non-contact techniques used to examine a part or surface via light. Optical profilometry techniques can give information about the height of a surface as well as critical dimension measurements. One can measure differences in height between different areas and calculate the surface roughness and other parameters of interest. Lateral dimensions can also be acquired simultaneously. This makes optical profilometry a great option for the verification of critical dimensions such as thickness, planarity, roughness, and hole dimension and placement, among others. Like all optical techniques, the details of how the system interacts with the part being measured determines whether one has a successful, i.e. accurate and repeatable measurement, or not.

Covalent Metrology has three main tools for optical profilometry, each with strengths in different areas and different feature sets that make them suited to different applications. Appendix A contains a summary of the performance specifications of each tool and some of the typical applications where each is used. Detailed applications of each tool as well as their best known methods (BKMs) of measurement will be discussed in separate white papers.

Laser Confocal Microscope

A laser confocal microscope uses a laser as the light source. Modern instruments like the Keyence VK-X1100 use a solid state laser, usually with a wavelength either in the red or violet region of the visible spectrum. These sources have the advantage of being compact and of running at low power with a long operational lifetime. As shown in Figure 1, the laser light first passes through a pinhole before hitting the surface of a sample mounted on an x-y stage. Light reflected from the sample is passed back through a second pinhole to the detector.

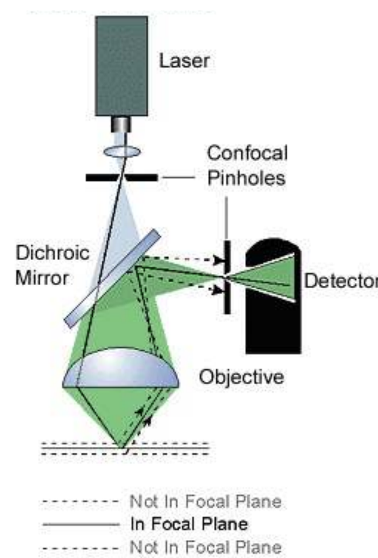

Figure 1: *Basic diagram of a laser confocal microscope*

The use of two pinholes results in a very small depth of field – the window in which the sample is in focus is very narrow. Light from regions that are not in focus will not reach the detector. By scanning the beam across the field of view while maintaining a fixed distance to the sample, one slice of a 3D image is generated. By using a motor in the z direction to change the distance to the sample while measuring, a full 3D image can be generated. Sophisticated image analysis software assembles, displays, and analyzes the image. Because the laser source is fixed at a single wavelength, this type of microscope has good lateral (x,y) resolution, as well as enhanced vertical (z) resolution from the confocal optics.

Wide Area Patterned Light Instrument

Patterned light instruments work by projecting patterns of light onto samples and using the distortion in the patterns to derive height. This is typically done from two sides, as shown in Figure 2a below. Two projection sources, one on the right and one on the left, create the patterns viewed by the center imaging column. As shown in Figure 2b, if the sample top surface is in focus, the two bands of light, one projected from each side, will converge (see the single line towards the back of the sample). As the sample height changes, the two bands diverge and, given the incoming angle of the light, the distance between the bands can be used to calculate the height difference from the surface that is in focus. The result is a high-speed height measurement over the entire field of view. With the addition of image stitching algorithms, large areas can be measured with good accuracy.

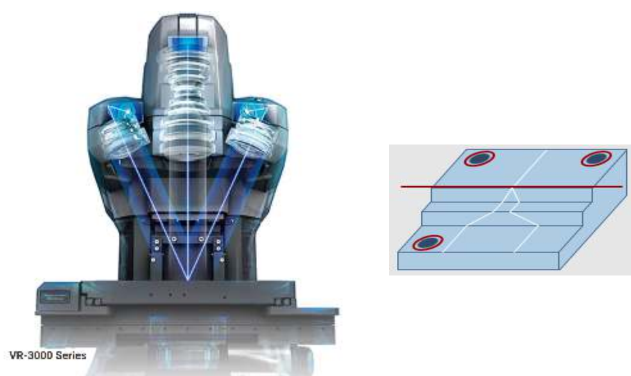

Figure 2: *a. Optical Schematic of a Keyence VR-3000*
b. Illustration of the effect of height on the projected pattern.

Systems of this type work well for critical dimension (CD) determination of parts that are opaque. Transparent parts can cause errors because a given band of light might be seen at multiple interfaces. Highly reflective parts can also cause errors as very little light from the sources will reach the imaging optics.

White Light Interferometer

White light interferometers take advantage of the basic physical properties of light. When two light beams of similar wavelength combine, the amplitude of the resultant wave depends on the amplitudes of the initial waves and the phase difference between them. If they are 180 degrees out of phase and of similar amplitudes, the resultant is null, i.e. the waves cancel due to destructive interference. If the two waves are in phase, the resultant wave should have twice the amplitude due to constructive interference.

As shown in figure 3a, white light interferometry mixes light reflected from a known reference mirror with light reflected from a sample. The phase of the light reflected from the sample depends on the path length, i.e. the height of the sample, meaning that constructive and destructive interference occur based on the height of the sample at a given location. The resultant patterns of light and dark areas, known as interference fringes, can be collected while varying the distance between the lens and the sample, and those images can be interpreted by software to give absolute height differences.

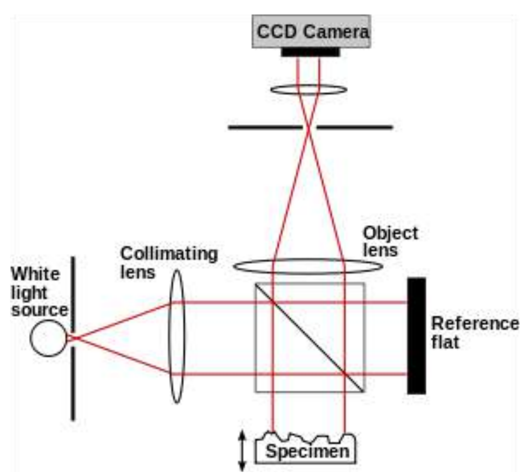

Figure 3: Schematic Diagram of a white light interferometer

In many cases, the laser confocal microscope image is both easier to understand and interpret. However, a white light interferometer has a higher vertical resolution and can make more sense on certain types of samples that require the most stringent precision. Interferometers also tend to take data more quickly as they capture the whole field of view at once, as opposed to raster scanning a laser.

Your Trusted Partner

This white paper is an overview of Covalent Metrology's range of available optical instruments. When combined with our extensive technical experience in solving problems, we enable you to both move quickly and efficiently in solving your problems. With our wide range of instruments, we make sure you have the right tool for the job.

Partner with Covalent Metrology Services Today

Covalent Metrology partners with clients to improve their overall metrology capabilities and ecosystem. In-house analytical services now include AFM, SEM and SEDM-EDS, ellipsometry, profilometry, UV-VIS-NIR spectrophotometry and nanomechanical characterization. Our Metrology Partners unit offers a suite of services based on client-specific development objectives aimed at improving in-house and external metrology quality, speed and cost. Headquarters are located in the heart of Silicon Valley.

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Appendix A

A comparison of the three optical profiling system available at Covalent Metrology.

Tool Name	Keyence: VK-X1100	Keyence: VR-3200	Zygo: ZeGage Plus
Technique	Laser Confocal Microscopy	Patterned Light	White Light Interferometry
Tool Image			
Resolution	3 nm height 120 nm width	1-5 µm height 1-5 µm width	1 nm height 250 nm width
Best uses	High vertical accuracy High lateral resolution	Measuring large areas quickly	High vertical resolution
Materials that can be measured	Opaque Transparent Mat to highly reflective	Opaque Translucent Mat to moderatly reflective	Opaque Transparent Moderatly to highly reflective
Measurement Area	µm to mm	mm to cm	µm to mm
Industries and Parts	Automotive Biotech and nano-devices Optical devices Metal Materials processing Semiconductor/Electronics Small Parts Ceramics	Automotive Biotech and nano-devices Optical devices Metal Electrical/Electronics Tooling PCB Connectors BGA Small Parts Surfaces Plastics	Automotive Biotech and nano-devices Metal Electrical/Electronics Tooling PCB Connectors BGA Small Parts