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A Solution for NDT Inspection

A growing number of application specialists are turning to a highly adaptable and flexible technology of high-speed low coherence interferometry to obtain real-time high-resolution 3-D measurements as well as surface mapping and characterization. Choosing an optimal NDT method for a lab or industrial application involves considerations such as:

- sample size, shape and material
- the speed and degree of precision required in the measurements
- the ease of use and flexibility of the inspection technology in the target environment

The surface roughness data acquired from a rotational pull-back probe inside the barrel can be reformatted by the host PC as an unfolded image of the internal surface with height encoded in the brightness of the pixels. *Source: Novacam*

Suitable for lab and high-volume production setup, a high-speed low coherence interferometric profilometer answers the needs of many applications: it can scan objects of various shapes and sizes, including multilayer sheet webs on production lines, it can characterize an object's surface, measure its coating thickness, calculate volume loss, and handle high aspect ratio surfaces. It can achieve these tasks in real-time, with micron precision, and at a standoff distance of up to 150 millimeters. Significantly, it can also operate in hard-to-reach spaces, including narrow tubes or crevices, and in inhospitable environments, such as high-vacuum evaporation chambers, radioactive environments or extremely hot or cryogenic temperatures.

A low coherence profilometer can characterize an object's surface as well as scan the thickness of objects from 10 microns to several millimeters thick with a precision better than 1 micron.
Source: Novacam

Applications of low-coherence interferometry range from automobile and aerospace parts inspection, to measuring multi-layer coating thicknesses on electronics wafers, to high-aspect surface measurements of fuel cells, to examining the roughness of the inside of a gun barrel or even a patient's larynx. New applications are constantly being discovered.

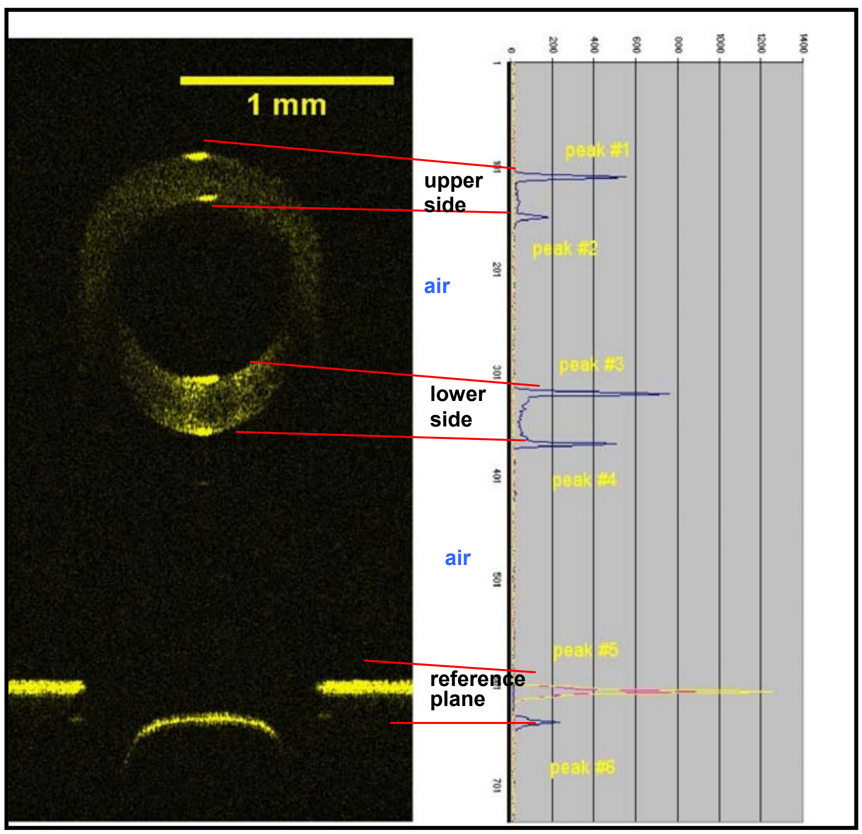
How does it work?

Vuk Bartulovic, president of Novacam Technologies (www.novacam.com, Pointe-Claire, Quebec, Canada), explains the principle: "A low coherence interferometer directs a beam of laser light in infrared range (1300 nanometers wavelength) at the sample surface. The returned light causes interference with the light in a reference arm of the interferometer, where the sample arm and the scanning reference arm are the same length. The interference pattern resulting from the scan is represented by a light intensity plot with peaks corresponding to differences in how far light travels from the object surface compared with the reference. By stitching together thousands of point measurements, the instrument can create a map of microscopic peaks and valleys on the part's surface."

Low coherence profilometers can be fiber-based or microscope-like with freestanding optics. A fiber-based profilometer collects sample data by a minute probe that can be located far from the interferometer. The small and rugged probe can operate at a standoff distance of a few millimeters to 150 millimeters and measures in the depth range of 3 millimeters. It can be mounted to a multi-axis scanning mechanism customized for each application. Alternatively, it can be mounted inside a machining centre to measure grooves in a part as soon as they are made. The probe can also be mounted above a continuously moving web or adjacent to a rotating part, such as a commutator. With optical switching, multiple probes can measure several features of a part at once.

Measuring Coating Thickness and Surface Roughness

The production of precision components for medical devices, electronics and aerospace frequently requires high-precision thickness measurements and detailed surface characterization of material coating. A low coherence profilometer can characterize an object's surface as well as scan the thickness of objects from 10 microns to several millimeters thick with a precision better than 1 micron. If the object's layers are even slightly transparent to light, the optical profilometer can scan through several of its layers to simultaneously measure the thickness of each layer as well as to characterize the surface of each such layer.

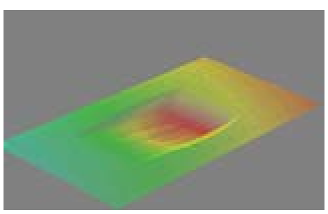


How does multi-layer scanning work? The interference pattern resulting from a multi-layer coating scan is represented by a light intensity plot with multiple peaks. A peak occurs each time the index of refraction of material changes, resulting in back scattering of light proportional to the magnitude of change of index of refraction. For each scanned material layer, two adjacent peaks on the plot identify the location of its top and bottom surfaces and the distance between these two peaks expresses the optical thickness of the layer. A multi-layer coating shows multiple peaks, which are optically separated and analyzed. The profilometer software uses each material's index of refraction to calculate the layer thickness.

A thin object such as medical catheter can be viewed and scanned as a multi-layer object, so that the interferometer's light beam traverses one wall, then the interior air column, then the other wall, another layer of air and then an optional reference plane. Scanning the tube from two directions simultaneously, with two probes at 90 degrees to each other, gives sufficient optical information to construct a cross-section image, and to calculate the inside and outside radius and the wall thicknesses with micron precision. This scanning, imaging and calculation can take place in real time, at the point of extrusion of any high-grade plastic tubing.

In industries that handle liquids, a low coherence profilometer can measure nanometre-sized variations in the liquid surface - whether the liquid is evaporating, solidifying or undergoing a casting process as on a metal casting production line.

Measuring Volume Loss



Data is acquired from the worn region of the sample and from the intact region around it, as seen in this 3-D rendering of the scanned surface of a sample (25 by 50 millimeters) after abrasion.
Source: Novacam

Loss of material due to abrasion, erosion or other types of wear is an important phenomenon in industries such as aerospace and automotive. Wear is quantified by measuring the volume loss after a wear test or after use of a component in the field. At present, volume loss calculation is commonly performed in two steps. First, the component is weighed in a lab when it is new. Later, the component is weighed again after use. Weight loss is converted to volume loss by dividing it by the material density.

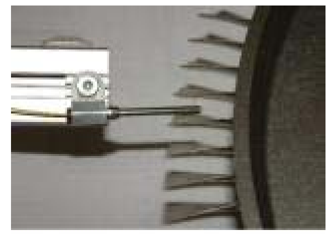
A low coherence interferometer can measure volume loss directly, with micron precision, on samples and components of various shapes and sizes. Data is acquired from the worn region of the sample and from the intact region around it. A reference plane is constructed for the intact surface. Volume loss is calculated from the differences between the interpolated reference plane and the actual worn surface.

The scanned object width can vary from a few microns to a cylindrical surface with a diameter of several meters such as an electric commutator.

Scanning Hard-To-Reach Surfaces

Traditionally, hard-to-reach surfaces have been measured by taking a mold by replication and bringing the replica under a profilometer. With a fiber-based profilometer, it is possible to measure hard-to-reach surfaces directly. No replication is necessary. Fiber-based probes can access hard-to-reach surfaces such as diesel injectors, gun barrels and bladed disks.

Fiber-based profilometry is especially suitable for inspecting long narrow apertures. Small diameter probes originally developed for biomedical applications have been specialized for industrial inspection. The probes include a reference that makes absolute accuracy measurements easier. Depending on the application, probes can be used with a Cartesian surface scanning system or a cylindrical scanning system.



Fiber-based profilometers with miniature probes 3 millimeters in diameter are used to inspect "blisks," bladed disks used in aeronautics. *Source: Novacam*

Inspecting the inside of a rifled gun barrel for forensic purposes is an example of such an application. The surface roughness data acquired from a rotational pull-back probe inside the barrel can be reformatted by the host PC as an unfolded image of the internal surface with height encoded in the brightness of the pixels.

Diesel injectors and nozzles in the automotive industry can be imaged with a similar setup. With the optical profilometer, metal aerospace or medical parts that have undergone the finishing process of shot peening can be inspected on site, without needing to be moved or taken apart for lab analysis.

In the metal casting industry, fiber-based profilometry can be used to inspect hard-to-reach surfaces of high-integrity castings for defects that could promote corrosion or thermal failure.

Operating in Hostile Environments

Since the profilometer probes are small, hardy and fiber-based, they can operate in hostile environments where humans or other technology cannot access. For example, to gather high-precision measurements of a surface inside a radioactive chamber, the replaceable fiber-based probes can operate on the inside, while the interferometer remains on the outside. A similar configuration can be set up for an evaporation vacuum chamber, or a cryogenic or extremely hot environment.

Alternately, since the probe can operate at the standoff distance of up to 150 millimeters, it can be placed on the outside of a window to a radioactive chamber for example, and still gather high-precision measurements on a surface inside the chamber.

High-Aspect Ratio Imaging and Measurements

In addition to regular surface mapping, a low coherence interferometer can also obtain images of high-aspect ratio surfaces. In aerospace parts production, blisks are pre-drilled with minute cooling holes that present a sudden and sharp edge in the scanned surface and may be problematic for many imaging technologies. A low coherence interferometer can produce precision images of these cooling holes, so that the size and incident angle of the holes can be determined. Similarly, the profilometer can measure high aspect ratio surfaces such as rivet holes and heads and fiber layers in composite structures in the aerospace field.

In the electronics industry, the surface of Chemical Mechanical Polishing (CMP) pads (used for smoothing interlevel dielectric layers) is patterned with channels for guiding abrasive chemical slurry around the polished wafer surface. The optical profilometer scans this high aspect ratio surface to diagnose the depth of the channels and thus helps evaluate the efficacy of the CMP pad. The depth of etching on IC wafers with high aspect ratios may be handled in the same manner.

Applications for high-speed low coherence interferometry are numerous and varied. Thanks to the flexibility and adaptability of this fiber-based technology, the optical profilometer fills numerous measuring needs both on web based factory production lines and labs in many specialized and emerging industry niches.

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