

Inspecting Hard-to-Reach Surfaces with a Fiber-based Profilometer

Keywords: low coherence interferometry, white light interferometry, fiber-based profilometry, hard-to-reach surfaces, high-aspect ratio imaging, 3D industrial inspection, mapping internal surface, small probes

Introduction

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. Fibre-based probes can access hard-to-reach surfaces such as diesel injectors, gun barrels, and bladed disks (blisks—see Figure 1). Using light sources in the near infrared range, a fiber-based profilometer can measure with micron precision. Fiber-based profilometers are used for 3D surface characterization and dimensional measurements.

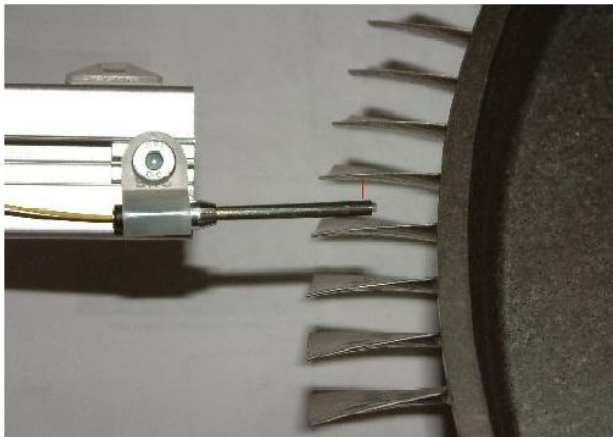


Figure 1. Fiber-based profilometers with miniature probes (3mm in diameter) are used to inspect “blisks” (bladed disks used in aeronautics).

Fiber-based Profilometers vs. Microscope-type Profilometers

Non-contact profilometers are typically based on a technique known as “low coherence interferometry” or “white light interferometry”. These profilometers can be fiber-based or microscope-like with free-standing optics. In a fiber-based profilometer, light is emitted and collected by a minute probe that can be located far from the interferometer enclosure. They are specialized for imaging hard-to-reach surfaces. Microscope-type interferometers cannot reach hard-to-reach surfaces because of their size. A fiber-based profilometer acquires one point at a time. Its lightspot must be moved in order to acquire an entire profile or surface. A microscope-type profilometer acquires one small area at a time. For bigger areas, the images must be stitched together.

Advantages of a Common-path Interferometer

The fiber-based profilometer is a low coherence interferometer with a common path configuration.

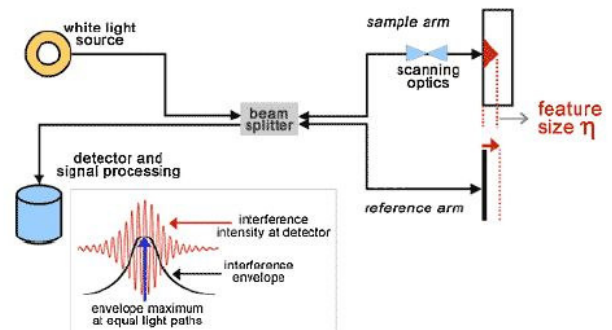


Figure 2. Basic configuration of an interferometric detector

Probes

Small diameter probes originally developed for biomedical applications have been specialized for industrial inspection. See Figure 3 and Figure 4. 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.

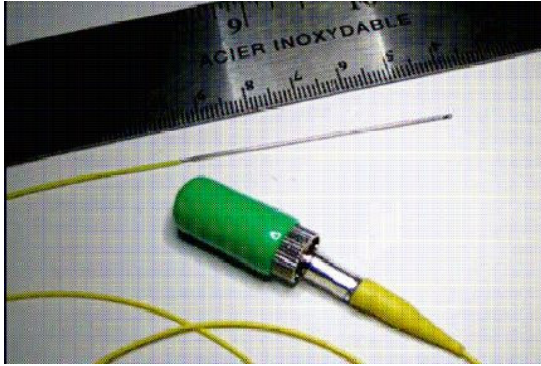


Figure 3. A 0.9 mm diameter rotational probe lying on a table above a green FC optical connector.

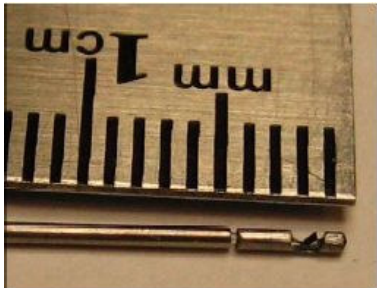


Figure 4. Enlarged view of the tip of the 0.9 mm rotational probe in Figure 3. Light is emitted at 90 degrees to the probe.

Looking Down the Barrel of a Gun

Fiber-based profilometry is especially suitable for inspecting long narrow apertures. Inspecting the inside of a rifled gun barrel (Figure 5) for forensic purposes is an example of such an application. To acquire the necessary high aspect ratio images, the probe is installed in a cylindrical scanning system (Figure 6). Diesel injectors and nozzles could be imaged with a similar setup.

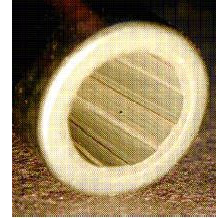


Figure 5. Interior surface of a rifled gun barrel.

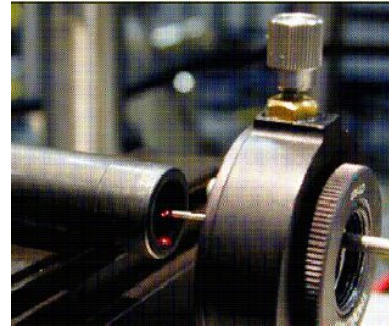


Figure 6. A probe is set up in a cylindrical scanning system to inspect the inside of a gun barrel.

Figure 7 is an unfolded image of the internal surface of the gun barrel in Figure 5. Height is encoded in the brightness of the pixels. Dark to bright gray levels represent a depth span of 750 μm . Surface features in the order of a few microns would contribute to the signature transferred to bullets.

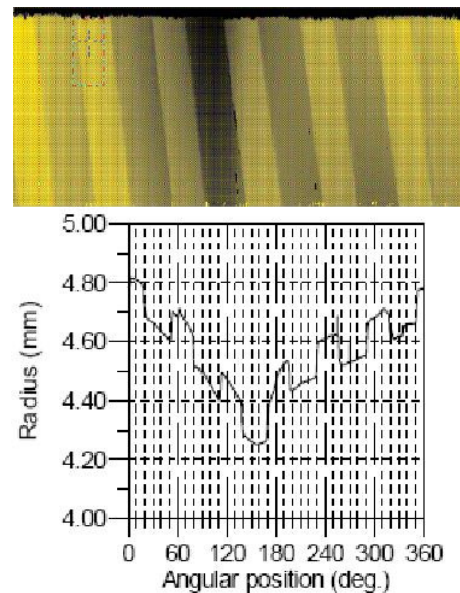


Figure 7. (Top) A 3D image of the interior of the gun barrel in Figure 5. (Bottom) A profile through the top image.

Inspecting Parts with Multiple Surfaces

Blisks (bladed disks) are key components used in aeronautics. Blisks have multiple surfaces that are coated during manufacture. The thickness of the coating can be obtained from profilometric measurements taken before and after the coating process to see if it complies with specifications. During the maintenance phase, the blades can be inspected for wear and defects, and to ensure that the shape and surface characteristics are up to required standards.

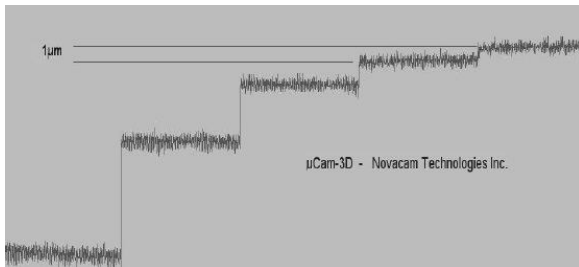


Figure 8. Acquired profile of the step gauge showing better than 1 µm resolution

Since a fiber-based probe acquires only one point, a scanning mechanism is required to

move the probe around between blades of a blisk. An inspection station can be configured with multiple axes (linear and rotational) in order to customize it for a particular application. Linear motion is accomplished with high precision X-Y table and rotational motion is carried out by means of a fiber-optic rotary joint. A workstation controls the motion system and acquires the data from the profilometer.

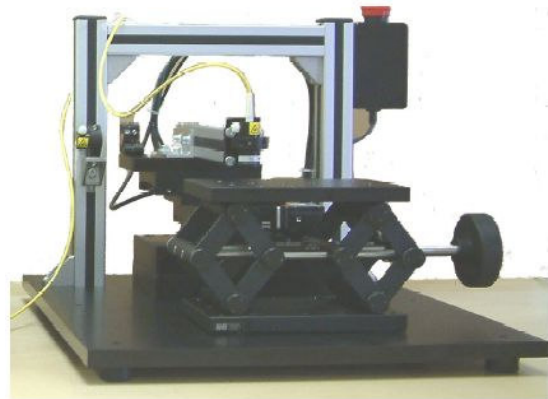


Figure 9. Inspection Station with a high precision X-Y table with manual elevator

Superior Microm measurements

The fiber-based profilometer suitable for imaging hard-to-reach surfaces has the following characteristics and capabilities:

Light source: SLD (super-luminescent diode)

Wavelength: 1310 nm

Acquisition rate: 1000 points / sec

Axial resolution: < 1 µm

Lateral resolution: 8-75 µm (depending on the probe used)

Depth range scanned: < 8 mm

Standoff distance: From a few millimeters to 1 meter

Distance of the probe from the detector enclosure: Up to 1 km