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Inspection of hard-to-reach industrial parts using small-diameter probes

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Optical tools originally developed for in-vivo coronary artery inspection prove adept at profiling the internal surface of a worn plasma torch electrode.

Inspection of industrial surfaces sometimes requires threading an optical probe inside the part through small apertures only a few millimeters or even smaller in diameter. The surfaces can be imaged with specially bundled fibers. But accurate 3D mapping in the micron range is a more challenging problem.

Measuring the insertion depth of a connector pin in an electronic panel is an easy task for instruments that are based on low-coherence interferometry (LCI). From the rear of the panel, the light can reach the pin extremity even if it is deep (5mm) in a narrow access hole (1mm), as illustrated in Figure 1. However, mapping the narrow, cylindrical shape of the internal wall surface of the hole itself requires getting the probe inside.

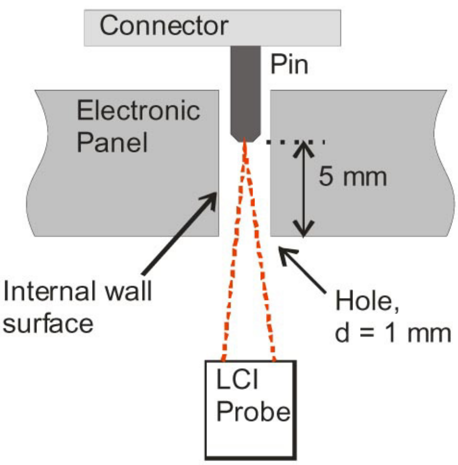

Figure 1. This scheme shows measurement of the insertion depth of a pin in an electronic panel. LCI: low-coherence interferometry.

LCI-based optical inspection instrumentation has been developing rapidly over the last 10 years, especially for cardiovascular arterial wall mapping in vivo using small catheter probes.[1] Advances in fiber-optic technology and micro-optical components make it possible to produce probes less than 1mm in diameter. But optical fibers are sensitive to temperature and mechanical perturbations, which compromise absolute accuracy measurements.

Our solution to the problem has long been to use LCI in a common-path configuration. This approach provides a means to define a reference at the probe location and thus to compensate for perturbations. The probe can be installed hundreds of meters away from the control unit, yet still guarantee accuracy in the micron range.

The principles of common-path interferometry for industrial inspection (for a film thickness gauge) were first disclosed in a patent in 1967.[2] Progress made since in optical telecommunications technologies now enables assembly of miniaturized and rugged interferometers based on the initial concept. The idea consists in comparing reflections of light from the sensing probe onto two surfaces: the sample surface and a reference surface. In Figure 2, the reference is the fiber end, which reflects a small fraction of the incoming light. The reflections are sent to an analyzing interferometer through a unique single-mode fiber. Owing to the short coherence length of the source (less than 20μm), the interferometer is able to compare the distance traveled by the reflections and to render a precise measurement.

Our configuration integrates an efficient scanning delay line (patent pending) developed in collaboration with Novacam Technologies Inc..[3,4] Thousands of measurements per second are made over a depth range as long as 8mm at stand-off distances from 0 to 100cm. The probes are designed to scan a surface a single point at a time. Mapping the entire surface necessitates

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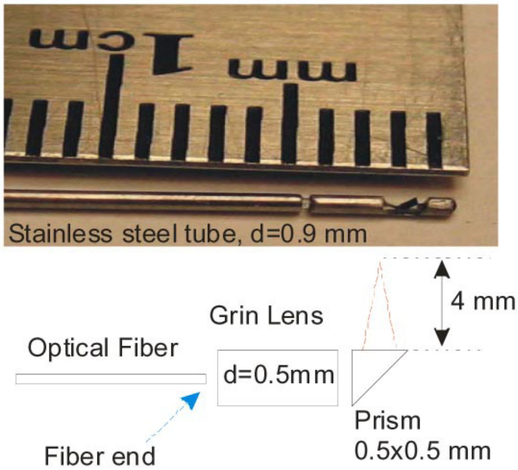

Figure 2. *The optical probe is attached at the end of an optical fiber.*

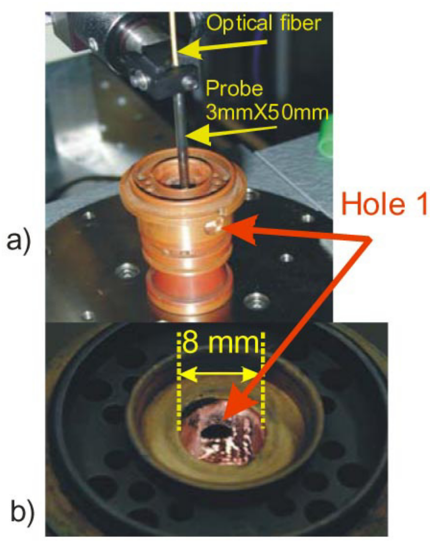

Figure 3. *(a) The internal surface of the plasma torch electrode has a cylindrical shape, 8mm in diameter and 4cm long. A portion of the internal surface is visible in (b).*

a separate mechanical system. A cylindrical map requires one translation drive and one rotation.

The internal surface of a plasma torch electrode, illustrated in Figure 3, was damaged by high-current electrical arcs. A raised point, for example, 'Defect1' in Figure 4, is an arc initiator and induces instabilities. To better understand the physics of this phenomenon, we mapped the internal surface using a 50mm-long, 3mm-diameter probe. The map is shown in Figure 4.

In summary, LCI using a common-path configuration enables highly-accurate, micron-scale measurements in industrial plants. The availability of micro-optical components facilitates the assembly of submillimeter-sized probes. Integrating these technologies makes it easier to geometrically characterize small industrial parts and surfaces that would otherwise be inaccessible.

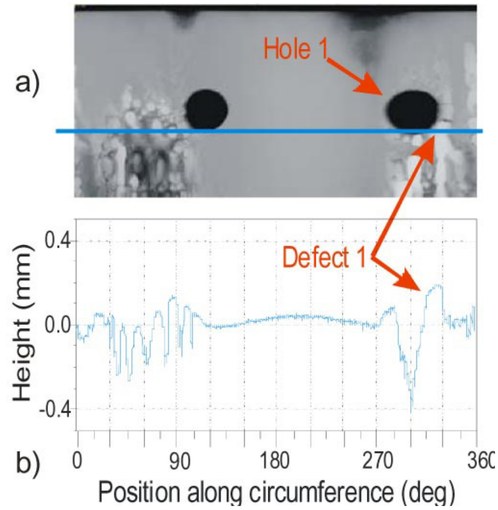

Figure 4. *(a) Shown is an unfolded 3D image of the internal surface of the electrode. Depth is encoded as black (deeper) to bright values. The two holes visible in the image are aligned 180 from each other. (b) Height variations of the surface along one full circle are indicated.*

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3. M. L. Dufour *et al.*, *Surface inspection of hard to reach industrial parts using low-coherence interferometry*, **Proc. SPIE 6343**, p. 63431Z, 2006.
4. http://www.novacam.com