3D Profilometry of Micrometer-Sized Cylinders

Sensor Heads D12/F2.8 and D1.2 in Combination with ANSxyz100 and ANPxyz101

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Introduction

In many research and industrial applications, ultra-precise and contactless surface analyses are of major interest in order to guarantee the quality of the material under investigation, as well as to detect even the tiniest contour deviations.

The large acceptance angle is one of the strongest benefits of attocube's Industrial Displacement Sensor (IDS) – an optical fiber-based, three-channel Fabry-Pérot interferometer. Due to its proprietary patented techniques, the system allows for measurements on surfaces with more than 10° inclination with respect to the measurement direction. This Application Note demonstrates such techniques, showing nanometer-precise 3D profilometry data of micrometer-sized metal cylinders.

Setup

The measured object itself was mounted on an attocube 3D positioner set (ANPxyz101) with a 3D scanner (ANSxyz100) on top. This allowed for easy and fast positioning within a 5 x 5 x 5 mm³ travel range as well as precise, fine positioning within 50 x 50 x 24 µm³.

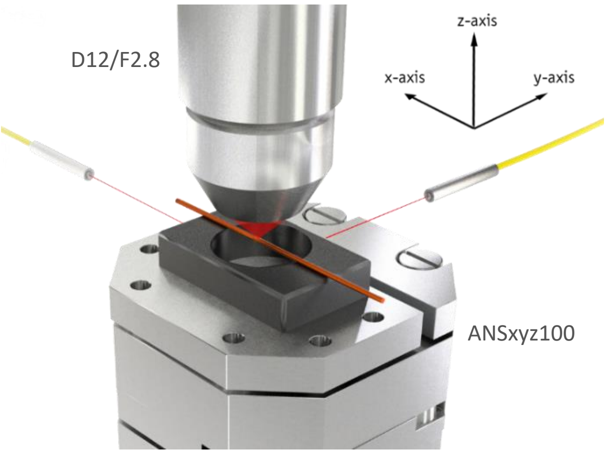

Figure 1: Metal cylinders were mounted on a 3D stack consisting of positioners (not shown) and precision scanners. A cylinder's surface was measured from above (z-axis), all while its position (x- and y-axis) was simultaneously tracked.

Figure 1 shows the experimental setup employing three sensor heads connected to attocube's IDS. A 12 mm diameter focusing sensor head with a 2.8 mm working distance (D12/ F2.8) and a spot size smaller than 2 µm measured the surface of the cylinders. Perpendicular to this, two focusing sensor heads with a diameter of 1.2 mm were used to measure the relative displacements along (x-axis) and perpendicular (y-axis) to the cylinder's axial orientation. Hence, all three coordinates of each measured surface point were recorded, allowing for a full 3D reconstruction.

Measurement Results

Once the setup was prepared, the alignment of the cylinder into the focus point of the D12/F2.8 sensor head took less than one minute, and as soon as the cylinder was close to the focus point, the alignment signal immediately showed high contrast. The maximum allowable z-displacement was found to be 120 µm in total for the D12/F2.8 sensor head.

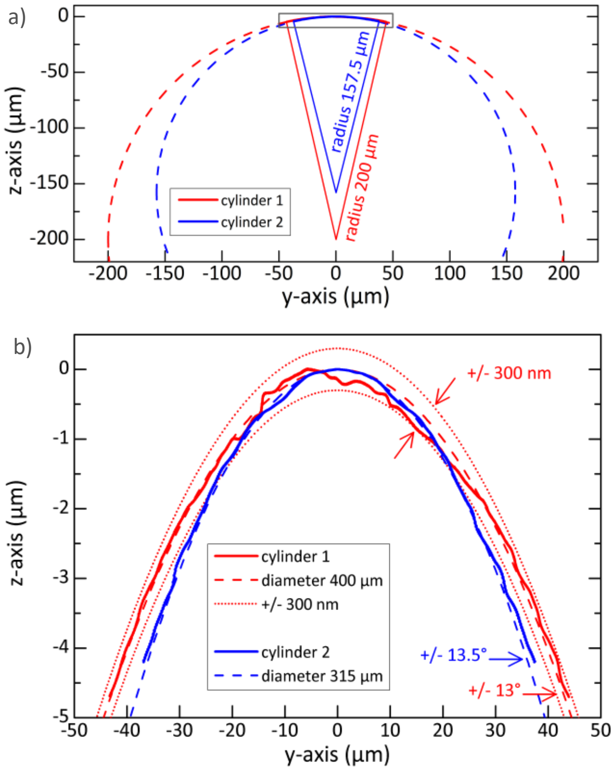

Figure 2: Profilometry measurements on two metal cylinders with diameters of 400 µm and 315 µm. The measured profiles (solid red and blue lines) are shown over a range of ± 230 µm (a), and over ± 50 µm (b). The nominal diameters of the cylinders are depicted with dashed lines. Red dotted lines (b) represent a diameter tolerance of ± 300 nm for cylinder 1.

Figure 2a) depicts the measured z-displacements (solid red and blue lines) and the specified z-positions (dashed lines) along the y-position of two metal cylinders with diameters of 400 µm and 315 µm. The corresponding zoom-in plot is shown in Figure 2b). From this graph, we can directly deduce the angular alignment tolerance of the D12/F2.8 sensor head to be greater than ±10°. This wide angular tolerance explains why setting up the measurement could be done so quickly.

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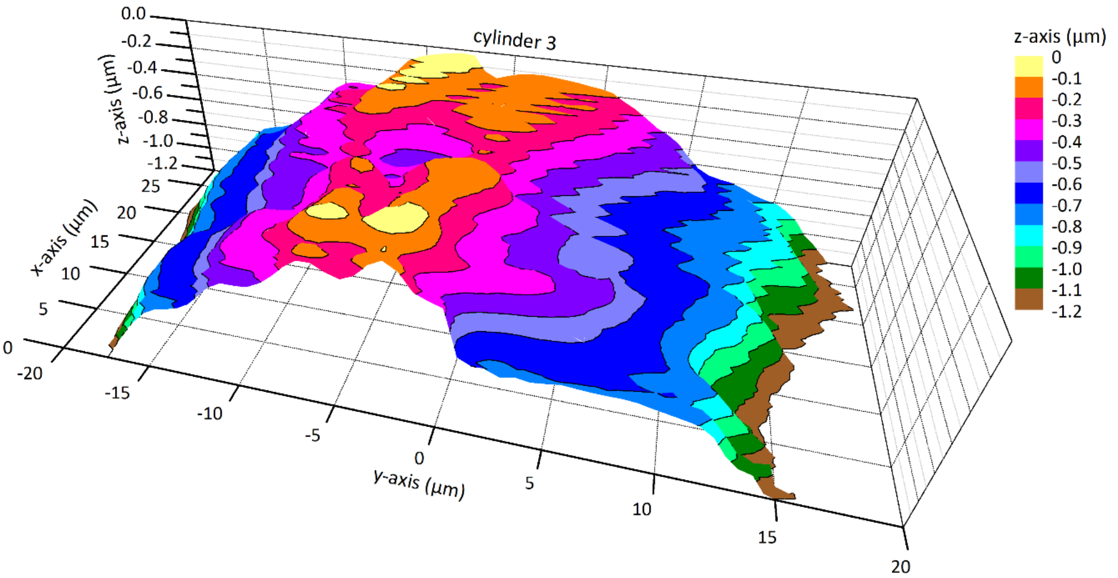

Figure 3: 3D color plot showing the surface morphology of a 200 µm diameter cylinder. Each color represents a 100 nm height step in z-direction.

Note that this alignment tolerance will be even larger when measuring on materials with lower reflectivity, such as glass or sapphire. Moreover, curved objects with larger dimensions (for example rotating shafts, or spherical touch probes of coordinate measuring machines) can also be easily analyzed in detail.

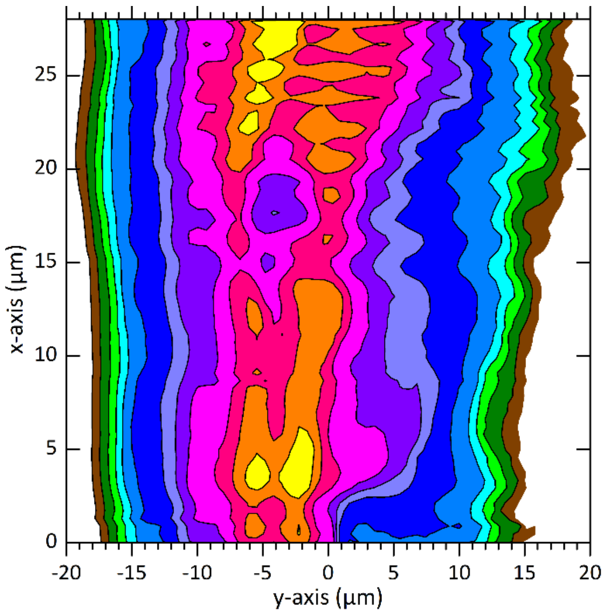

Figure 4: The surface of the metal cylinder shown as a 2D figure. Each color represents a 100 nm height step in z-direction.

The measured surface contours of two metal cylinders shown in Figure 2b) (red and blue solid lines) can now be compared with their respective ideal circular forms (red and blue dashed lines): At the top of cylinder 1 (red line) a deviation of approximately 300 nm (red dotted lines) can be seen. For cylinder 2 (blue line), the maximum deviation is less than 200 nm. Other than these maximums, the measured surface profiles fit well to the specified diameters of 400 and 315 µm.

Using all interferometric axes simultaneously, a 3D surface of a separately measured 200 µm metal cylinder was constructed. Figure 3 shows the measured profile covering a 40 x 28 µm² area. The corresponding two-dimensional top view is plotted in Figure 4. Several deformations can be seen: In the center position, the object profile clearly shows a dent on its surface with a depth of around 400 nm. In addition the diameter contour in the front part near X = 0 has a plateau over a length of approximately 10 µm.

Conclusion

In summary, this Application Note shows the IDS' capability to precisely measure surface profiles of micron-sized objects. Additionally, this technique is not limited to static analyses – measurements of moving or vibrating microscale-objects (even under the influence of external force) have already been well implemented.