Tips and settings for measuring features on challenging surfaces, using 4D InSpec

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Measuring Transparent, Flat or Shiny Surfaces with the 4D InSpec

The 4D InSpec® surface defect gauge measures a large variety of materials; however, transparent materials (such as glass or plastic) are difficult for a couple of reasons. Due to their smooth surfaces and high reflectivity, they are unique in their measurement techniques and results. This study will discuss ways to measure the surface directly, with limitations, and present alternatives when the limitations are not acceptable for a given application.

The signal used for measurement by the 4D InSpec generally comes from what is known as a diffuse surface reflection. When light is incident on a smooth surfaced sample, it reflects away from the surface at the same angle to the surface normal in which it originated. This is known as specular reflection. For rougher surfaces, light scatters in all directions, and this is known as diffuse reflection (see Figure 1). Generally, the 4D InSpec is designed such that light comes at the sample at a 25-degree angle and the imaging is straight-on to the sample. This means most of the 4D InSpec's signal must be from diffuse reflection (see Figure 2).

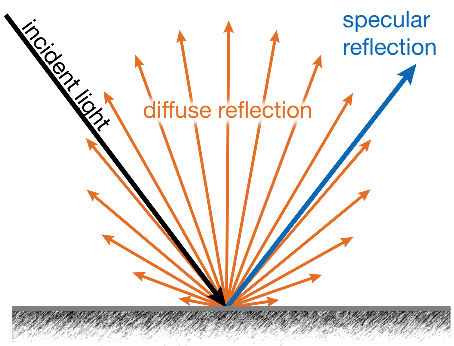

Figure 1. Incident light reflects at the same outgoing angle, as specular reflections. But surface features scatter diffuse reflections in a less predictable manner.[1]

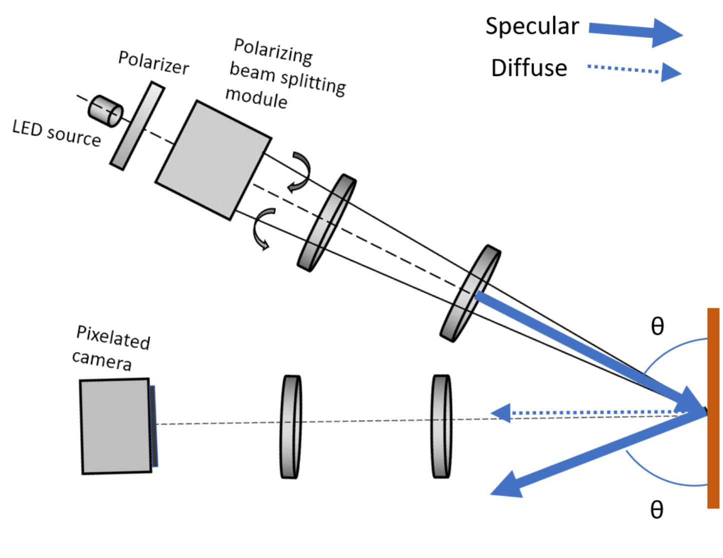

Figure 2. Simplified, default 4D InSpec schematic. Notice that in the default orientation, only diffuse reflection reaches the camera

By changing the angle of incidence (AOI), you can alter the proportion of specular or diffuse light entering the camera. For transparent surfaces, the diffuse reflection is nearly non-existent and the direct, specular reflection is too bright. Thus, the goal for these materials is to angle the sample so that only the very edge of the specular reflection is captured. A test setup is shown in Figure 3. In the setup, there is a glass substrate at the focal distance of the 4D InSpec. Since this material requires a precise non-perpendicular angle, it is mounted on a goniometer for ease of use.

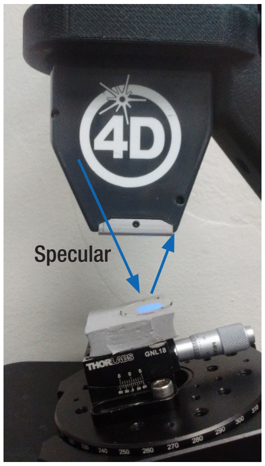

Figure 3. Test setup with diagram showing specular reflection. Notice that the reflected beam is just barely clipping the incoming side of the 4D InSpec. The 4D InSpec is mounted in a stand for ease of use.

Example: glass substrates

This example uses the test setup shown in Figure 3. Figure 4 shows the camera image of two slightly different orientation angles. By tilting slightly less (about 5 degrees) from the specular reflection angle, good signal and light levels are achieved. Glass thicker than 2.5 mm can typically be measured; thinner transparent material may allow signal from the underlying surface, or second surface of the glass, to combine in the measurement.

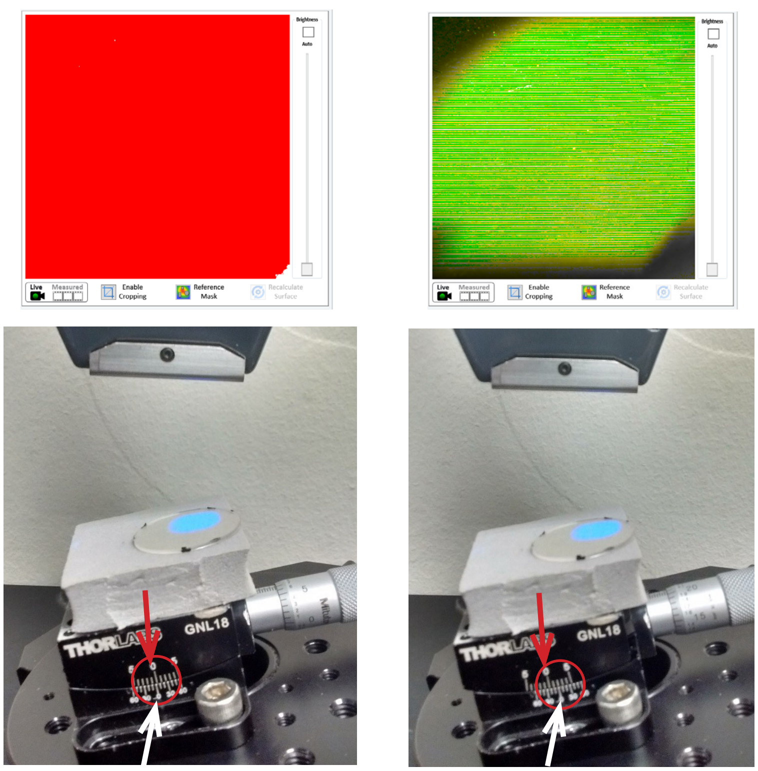

Figure 4. Left: Saturated pixels from direct specular reflection. **Right:** Good focus and light levels achieved with proper angling of the glass, of about 5 degrees less tilt than the specular reflection.

To achieve useable data, as in Figure 4, it was necessary to adjust a few software/camera parameters.

- On the main screen, adjust the brightness, also known as the gain of the camera. It is possible to adjust the exposure time too, which is an internal setting in each User Config. For convenience, 4D Technology has included a “brightsample” user setting, which can be loaded from the User Config folder (located C:\4D\InSpec\Config). This setting has a lower exposure, which further reduces the light level. This user setting can dramatically increase your ability to measure high reflectors.
- Signal Strength Threshold sets the minimum pixel value the software uses for unwrapping the data. If it is too low, you will get false data (*i.e.*, stray reflections), over-saturated, or empty space. Setting the threshold too high will remove all data. Experiment with various values, but we recommend switching between 5% or 0.5%, depending on your needs, since these will work for the vast majority of surface types. For the test setup measurement, we used 5%.
- Cropping is another way to avoid saturated areas, by narrowing your field of view to only the measurable area. This can be used in conjunction with adjusting the signal strength, or separately. For example, if you have a super-bright surface next to a really low reflector (the defect area), you may want to crop out the bright area and then use a higher signal strength threshold to capture the darker area of interest.

In addition to optimizing the camera/software parameters, there is one more setup parameter to watch out for. When measuring thin transparent substrates, it is easy to measure both sides simultaneously, due to the 2.5 mm depth-of-field of the 4D InSpec (~9 mm for the 4D InSpec XL). To avoid this double measurement, adjust the focus precisely such that only the high end is in focus. As a reminder, green is ideal focus on the live camera and yellow is partly focused. For this situation, adjust the focus from a high-point and stop closing in on the part when yellow appears on the screen. For an example see Figure 5 below. For these surfaces, the fringe pattern along with the color is a good sign you are at an appropriate focus. Note, this will limit the field of view even more and cropping should be used.

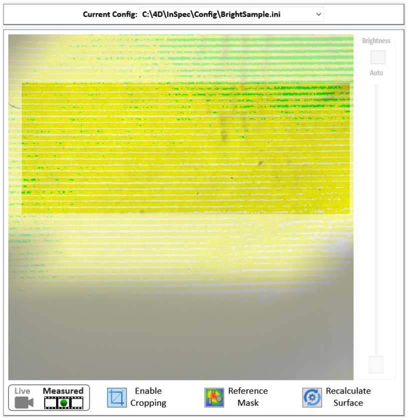

Figure 5. Measuring only the top surface of a thin substrate

Measuring defects on transparent surfaces and limitations

There are some limitations to measuring defects on transparent surfaces. Namely, that the depth of the defect is often not readable, at least not in conjunction with the nominal surface in focus. Generally, smooth surface imperfections can be measured, but if the surface is roughened by the defect, and becomes cloudy, it can disrupt the signal the 4D InSpec uses for measurement, leading to lost data. For an example, see Figures 6a and 6b below, where only some of the defect is properly measured, and much of the defect area has missing data, indicated by the gray-colored pixels.

Figure 6a. The sample: a plastic lid with scratches in the middle

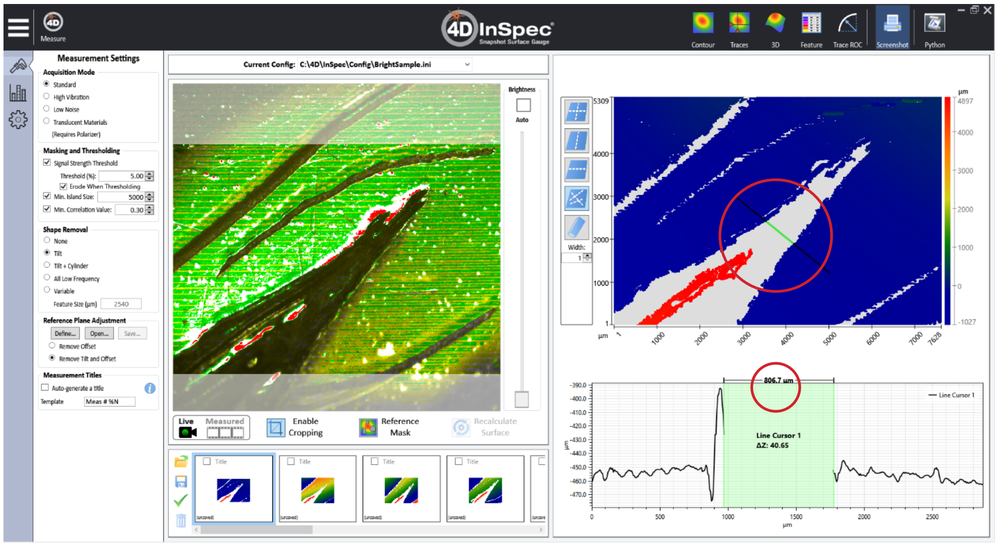

Figure 6b. Measurement of deep scratches on a clear, plastic surface.

As seen in Figure 6b, the defect area is not measurable and shows up as empty space. This is normal for transparent surfaces. Note, it is possible to focus in on part of the defect area but then the nominal surface will be out of focus. Even with this limitation, it is possible to derive the length and width with 2D-trace mode. See the red circles in Figure 6b. A profile segment is drawn across the empty space of the defect area, and shows as a gap of measurable distance in the line profile.

Alternatives when the defect is not measurable

As discussed earlier, sometimes the defective area is not measurable for parameters other than lateral dimensions. If the depth is needed, an easy solution would be to make a replica of the surface and then measure it with the 4D InSpec. The replica material is easy to measure and the data is displayed instantaneously using the 4D InSpec.

Conclusions

Transparent materials are measurable by the 4D InSpec, albeit with some limitations. The primary limitation is losing the ability to measure depth. With some specific setup and software parameters, the lateral dimensions of the defect remain measurable.

When these limitations are not acceptable for an application, alternatives are possible using the 4D InSpec in conjunction with a replica material. As discussed in another study, the replica material can be measured as precisely as any other non-transparent material and is a reliable and precise method for obtaining data with difficult materials or in hard to reach locations.

1. Recreated from source: en.wikipedia.org/wiki/Diffuse_reflection#/media/File:Lambert2.gif, 2018.11.15