

# SICK AG

# WHITE PAPER

## NON-CONTACT MEASUREMENT WITH DISPLACEMENT MEASURING SENSORS FOR QUALITY INSPECTION

### AUTHORS

#### **Ramona Heitz**

Product Manager Displacement Measurement Sensors  
at SICK AG in Waldkirch, Germany

#### **Stephan Mächerlein**

Head of Application  
at SICK AG in Waldkirch, Germany

### SUMMARY

To ensure consistent quality is achieved when manufacturing many different devices or components, the results of the production process need to be checked regularly by taking measurements. These checks are performed in various ways: either outside of the ongoing process, by regularly removing individual devices and checking them using appropriate mechanical or optical measuring instruments; or via measuring stations integrated into the process, which are equipped with mechanical sampling systems or other non-destructive measuring instruments. Optical measurement sensors are ideal here.

Their ability to measure precisely, quickly and without contact, plus the option to integrate the results of these measurements into the production process directly, leads to increased productivity. This results in faster production processes at a consistently high quality, without the need to make mechanical contact with the object or damage it in any way. Optical sensors provide extremely accurate results even when measuring very small objects.

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## Technologies

Various technologies are used to create precise optical measurement sensors.

### Laser triangulation principle

Laser triangulation is a single- or multi-dimensional distance measurement resulting from an angular calculation. The sensor projects a laser light onto the measuring object. The beam reflected there is then mapped, via optics, to a particular place on a position-sensitive receiver element, depending on the distances involved. The distance to the measuring object is determined by triangulating the light source, the measuring point on the object, and the image of the light on the receiver element. Sensors are available with light spots of different sizes. It is better to use small light spot geometries for very small objects, whereas a sensor with a larger light spot is recommended for rough surfaces.

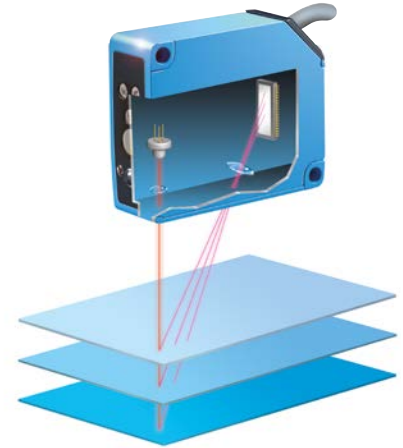


Figure 1: Laser triangulation principle

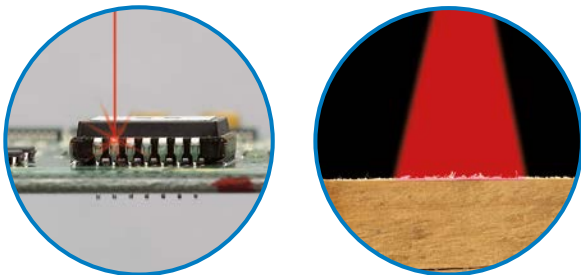


Figure 2: Light spot geometries (large on the right, small on the left)

The same principle of operation also applies to sensors which use not a light spot, but a laser line, combined with a CMOS matrix receiver. In this case, a profile can be detected and evaluated directly, without having to move the object.

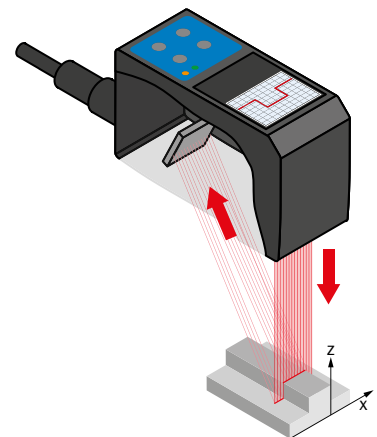


Figure 3: Laser profile sensor

**Chromatic-confocal and interferometric measurement principle**

Chromatic-confocal measurement sensors use white light sources, whose light spectrum is directed to the measurement head via optical fibers. The OC Sharp displacement measurement sensor from SICK allows the user to choose from two different measuring methods as described below.

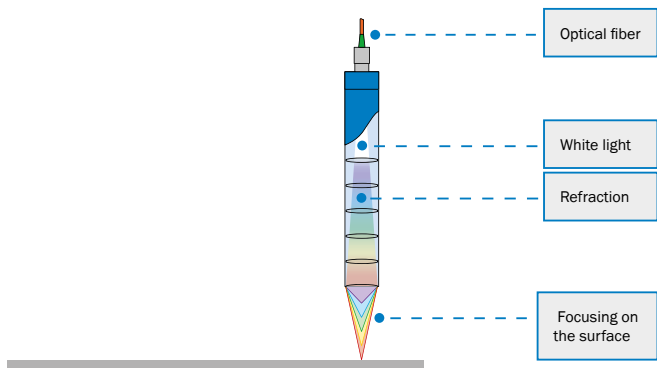


Figure 4: Chromatic-confocal and interferometric measurement principle

**Chromatic measuring method:**

The lens system integrated in the measurement head has been designed such that the individual wavelengths are all assigned to a different distance. We are making use here of chromatic aberration, which is usually an unwanted effect.

Each wavelength is focused at a different distance, reflected by the surface, and the reflected wavelength is then evaluated in a spectrometer. The wavelength determined is assigned to a distance value in turn.

As with many sensors which operate according to the laser triangulation principle, several reflected wavelengths can be evaluated in this case too, thus enabling a relative material thickness to be determined for single- or even multi-layered transparent objects.

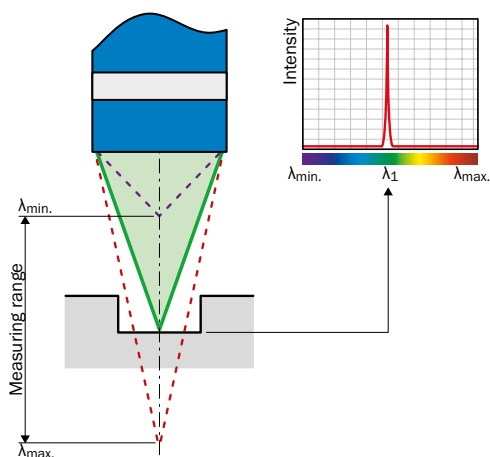
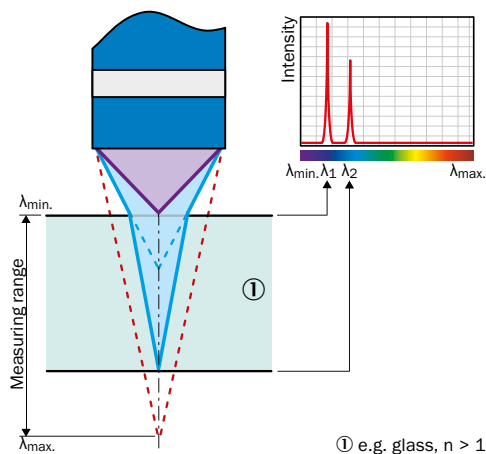


Figure 5: Distance measurement



① e.g. glass,  $n > 1$

Figure 6: Thickness measurement of transparent objects

Interferometric measuring method:

The interferometric measuring method uses the physical effect of interference on thin layers. We are familiar with this effect from puddles that shimmer with color, caused by a thin film of oil, or from soap bubbles, for example. Different wavelengths of the light are either weakened or strengthened by specific material thicknesses. A quick Fourier transformation is then used to evaluate the spectrum of the detected layers. Unlike with the chromatic-confocal measuring method, here it is not possible to evaluate an absolute distance, but just the thicknesses present in a system of layers.

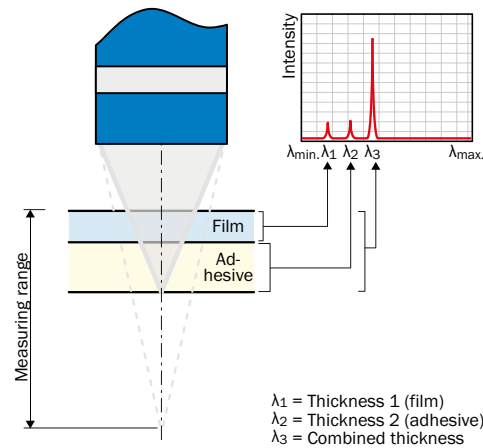


Figure 7: Interferometric measuring method for measuring the thickness of layers and transparent objects

Significant advantages over the laser triangulation principle:

- Larger tilt angles are usually permitted
- If the light path is partially shaded, a measurement result will still be obtained
- Light spot diameters of 4  $\mu\text{m}$  enable very small areas to be measured or even allow measurements to be taken inside holes (e.g., through-contacts for printed circuit boards/ICs)
- Even smaller layer thicknesses of transparent materials can be determined (over approximately 3  $\mu\text{m}$ )
- The measurement principle for taking measurements of surface roughness has been described in a standard (DIN EN ISO 25178, Part 602)
- The measurement head is a purely passive device and contains no electrical components

## Interfaces

Many sensors can be operated with an evaluation unit, in which various filter functions can already be set or calculations performed, without placing any strain on the customer's control system. The measurement results can be transferred over the various data interfaces which are available (RS-232, RS-422, RS-485, 4 mA ... 20 mA, -10 V ... 10 V, 0 V ... 10 V); alternatively, just the "good/bad" information can be polled via switching outputs.

## Challenges

There are many reasons to use optical measuring instruments:

- As a replacement for mechanical measuring instruments, which are subject to wear and therefore have to be replaced on a regular basis
- If damage to the final product, e.g., films or soft surfaces, caused by mechanical measuring instruments is to be avoided
- If the properties of the material to be measured do not generally allow for a mechanical measurement to be taken, e.g., media which are liquid, not yet hardened or basically soft, whose dimensions would change either reversibly or irreversibly if subjected to pressure
- If the surface to be measured cannot be accessed by mechanical measuring instruments, or can only be accessed with difficulty

When changing over to optical measuring instruments, a challenge which sometimes has to be met is how to achieve results that are comparable with those previously obtained by mechanical means. Due to the different ways in which optical and mechanical measuring instruments work, the following must be taken into consideration:

- Is it even possible to measure the object or will the results be significantly influenced by physical factors, e.g., by semitransparent surfaces or multiple thin layers?
- How are deposits (e.g., oil, dust, chips, and so on) on the surface dealt with? Are filter mechanisms required, which do not apply any defined pressure to the surface, unlike with mechanical measuring instruments?
- Since the measuring point for mechanical measuring instruments is usually much larger than that for optical measuring instruments, the measurement results obtained from the latter must be determined over a larger surface

The process of changing over from a mechanical to an optical measuring instrument can be quite costly and laborious; however, this must be balanced against the long-term benefits such as cost savings, increased throughput, no mechanical impact on the measuring object, and improved quality in every process step.

## A comparison of the significant advantages of various measuring methods

Mechanical	Optical
Established, consistently described in standards	Non-destructive
Contamination has a lesser impact on the measurement result	Fast
-	Inline
-	Measurements on very small objects that are tricky to access
-	2D profiles without having to move the object

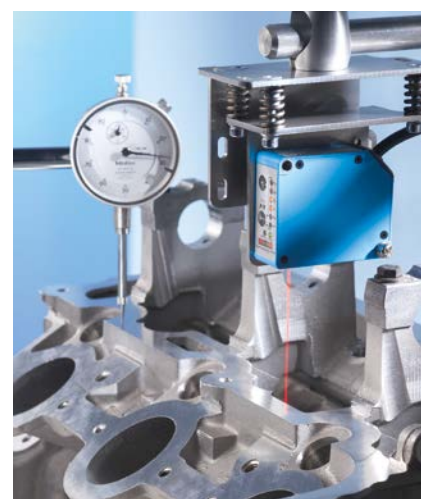


Figure 8: A comparison of mechanical and optical measuring methods

## Typical applications from various industries

### Wood industry: Measuring thickness and length on various materials

Optical measuring instruments are used in wood processing to monitor the thickness, length, and width of kitchen countertops, for example. The major challenge here is the huge variety of possible plastic surfaces applied to the chipboard. Optical measurement sensors offer a significant advantage here as they will not damage these sensitive surfaces.

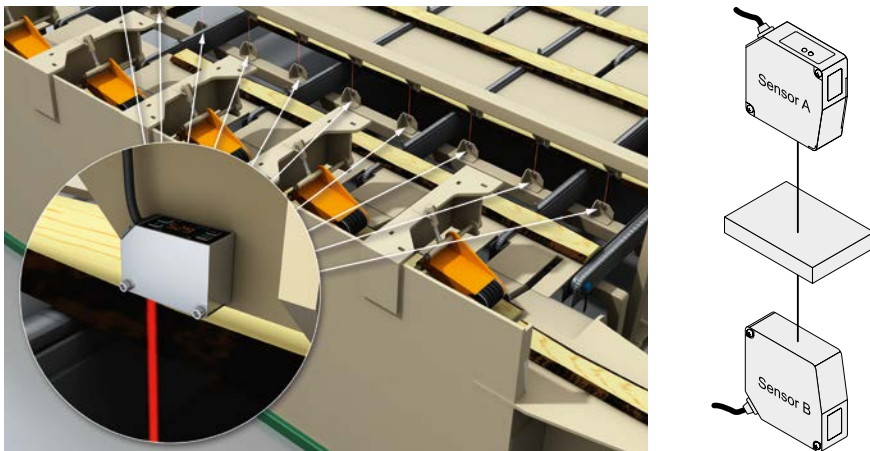


Figure 9: Measuring wane with the SICK OD Mini displacement sensor

### Metal processing: Detecting double layers of sheets as they pass

When processing sheet metal in various different sectors, not only does the thickness of an individual sheet need to be checked, but double layers of sheets need to be detected too. The methods used to do this typically rely on eddy currents, ultrasonic technology or mechanical measurements. However, such techniques soon reach their limits if they are required to deal with fast transport speeds and short sheet lengths.

What's more, if the surface properties of the sheets (scratches, drops of oil, burrs, and so on) mean that additional filters need to be activated in the sensor, then the fast response times and small light spots of optical measurement sensors make them the more appropriate solution.



Figure 10: Detecting double layers of sheets, without contact, with the OD Precision displacement sensor

**Metal processing: Checking distance at the cutter head and welding head**

In order to produce clean cuts or weld seams, it is important for the cutter head or welding head to be positioned at the correct distance from the material to be processed. The environment in which this measurement is taken can sometimes be subject to heavy smoke and electromagnetic interference, so it may be necessary to provide additional protection for the sensors. Once again, the advantages of optical measurement sensors win out here too, since they measure very close to the machining head and do not damage the material surface when taking the measurement.

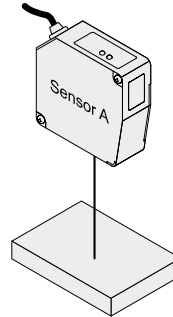


Figure 11: Checking distance at the cutter head with the OD Max displacement sensor

**Automotive industry: Measuring brake disks and wobble**

When manufacturing brake disks, the dimensional stability and maximum permissible axial runout have to be checked. Since even tiny deformations can have a significant impact on function, precise, non-contact measurement processes are used here.

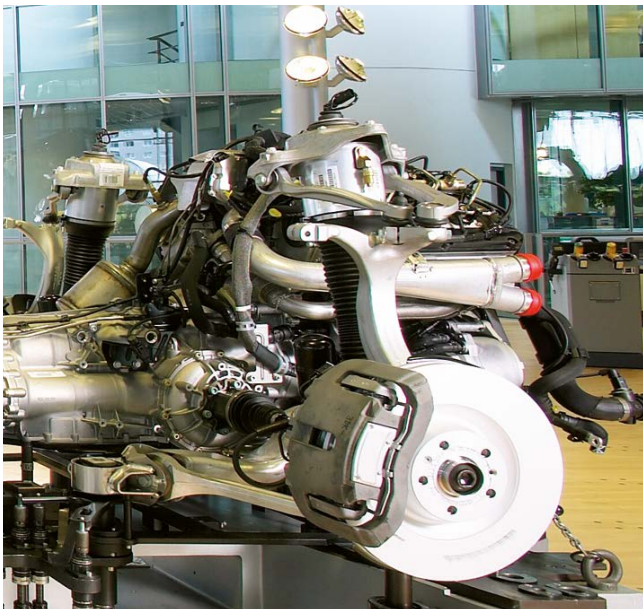


Figure 12: Measuring wobble on brake disks



**Electronics: Checking the height and length of devices**

When assembling PCBs, the components must be checked at an early stage of the process to ensure they have been positioned and connected correctly, e.g., they are not raised up on one side. A solution with optical measuring instruments is the best choice for this application too, due to the precise positioning of the light spot on very small elements in particular and the direct measuring of profiles using a sensor with a laser line.

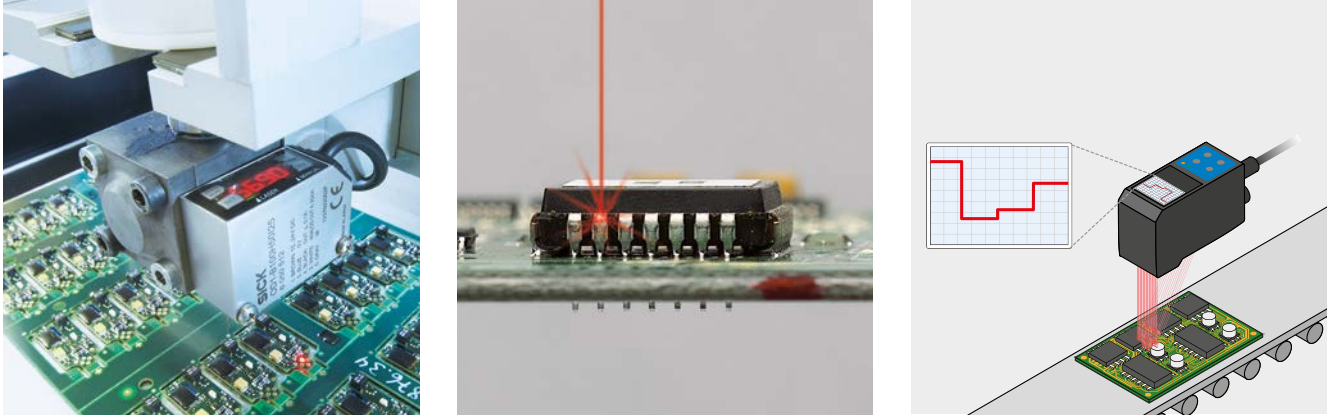


Figure 13: Checking the height and length of devices with displacement measurement sensors

Three sensor heads are able to measure whether the positioned devices are tilted in different axes. This measurement is incredibly important when fitting smartphone displays, for example.

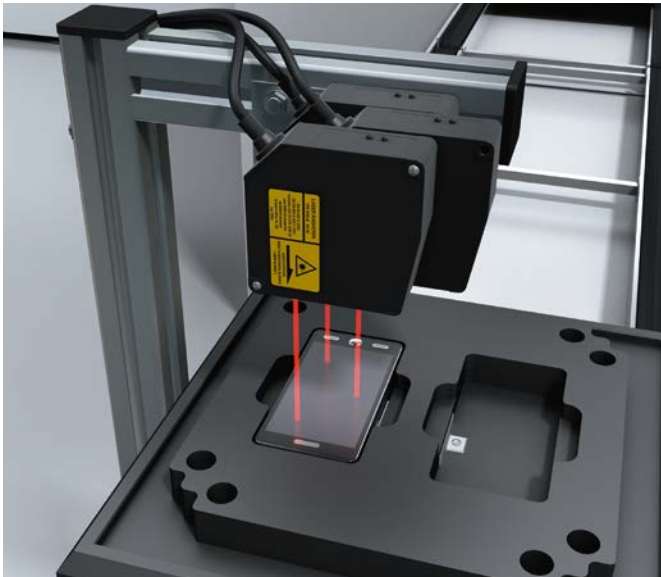
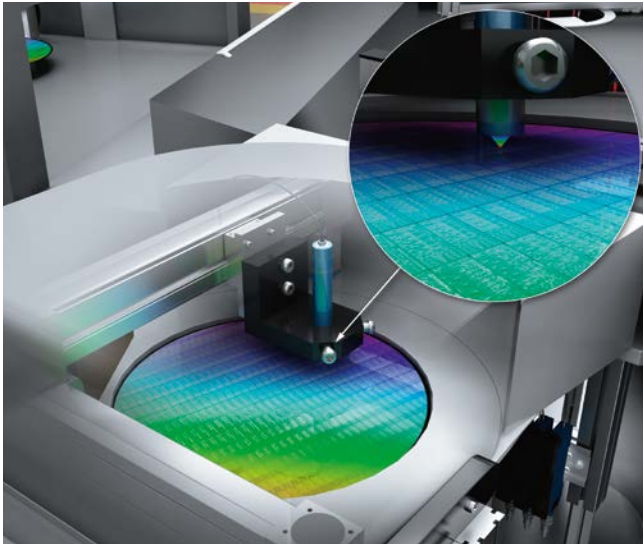


Figure 14: Measuring the correct position of device assemblies with the OD Precision displacement sensor

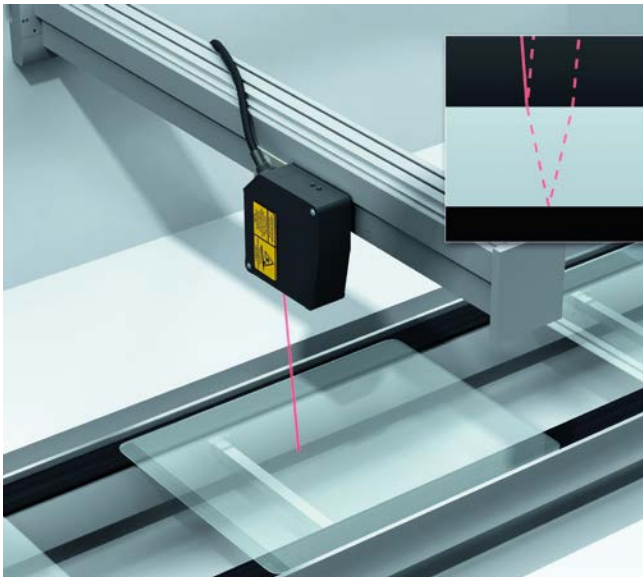
**Electronics and solar industries: Checking coatings**



Using the interferometric measuring method, an optical measurement sensor is able to detect layer thicknesses greater than 3  $\mu\text{m}$  accurately and without destroying the specimen. This improves the quality of the process directly, without taking the wafer out of that process.

Figure 15: Measuring the layer thicknesses of semiconductor wafers with the OC Sharp displacement sensor

**Glass industry: Measuring the distance and thickness of glass**

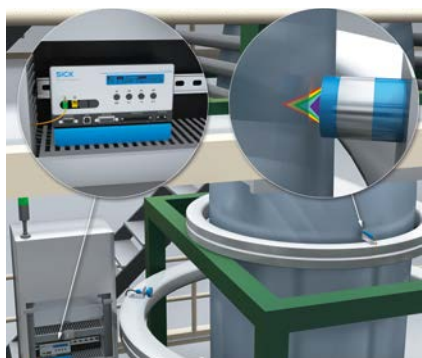


A distance measurement is critical for ensuring that a glass surface is positioned the right distance away from a gripper. Some laser-based sensors, as well as chromatic-confocal sensors or even ultrasonic sensors are suitable for this task.

However, optical measurement sensors are needed to measure the thickness from just one side. This makes sure that the right glass is positioned in the right place. Generally speaking, transparent objects with a thickness of approximately 3  $\mu\text{m}$  to 20 mm can be measured using the optical method.

Figure 16: Measuring glass thickness with just one OD Precision displacement sensor head

**Plastics industry: Measuring film thickness**



An even film thickness is a key feature of high-quality films. Optical measuring instruments are able to detect the thickness of blown films accurately and without destroying the specimen; any adjustments can then be made within the production process directly in order to achieve the highest possible quality.

Figure 17: Measuring the thickness of a transparent film with the OC Sharp displacement sensor

**Dispensing: Inspecting glue beads**

Only non-contact measuring instruments are able to detect the profile of a dispensed material (e.g., a glue bead) which has not yet hardened, since any type of mechanical contact would change the profile of the applied material immediately. Quality control is ideally performed using a line-based sensor, which travels along with the dispenser and checks the profile of the applied material as close to the material discharge point as possible.

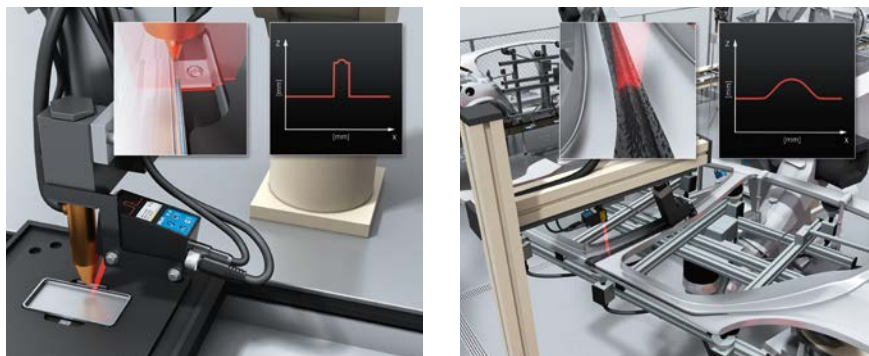


Figure 18: Inspecting glue beads in an ongoing process, without contact, with the Profiler 2 displacement sensor

**Precision engineering: Measuring small parts and watch components**



It is often the case that the very small parts that need to be measured are positioned in a way that makes them difficult to access. In such cases, very small surfaces, which therefore call for a very small and precise light spot, are the order of the day. Chromatic-confocal sensors provide exactly that. Thanks to their white light, they will not create peripheral-light or speckle effects either, unlike with a laser. The challenge of this application is much more about positioning the sensor accurately, which requires precise mechanical components.

Figure 19: Measuring tiny watch components precisely with displacement measurement sensors

**LINK TO MORE INFORMATION**

More information on displacement measurement sensors: → [www.sick.com/measurement-sensors](http://www.sick.com/measurement-sensors)