TechNote

MICRO-EPSILON

Precise Non-contact displacement sensors

Content:

Preamble

The use of non-contact displacement technologies in the field of precision measurement is rapidly growing. This is due to many factors, however 2 of the main factors are the drive to measure much more accurately to sub micron or even nanometer resolutions, and need to measure against fragile surfaces or surfaces that cannot be touched during the measurement process or surfaces that cannot be touched during the measurement process. For example silicon, glass, plastics, miniature electronic components, medical components and even food based surfaces.

This rapid growth has pushed the development of new technologies, and also the adaptation of already existing technologies to meet the new measurement requirements and to improve measurement accuracies and resolutions. It i therefore more important than ever to have a greater level c understanding of the strengths and limitations of each no contact measurement principle when selecting the correc sensor technology for the measurement task.

In practice, besides, eddy current and laser triangulatio sensors, capacitive and confocal sensors are becoming more prevalent in this field of measurement. But non-contact displacement sensors come in a wide variety of shapes, sizes and measurement principles. The key is selecting the most appropriate sensing technology for the measurement task.

Capacitive sensors

Confocal sensors

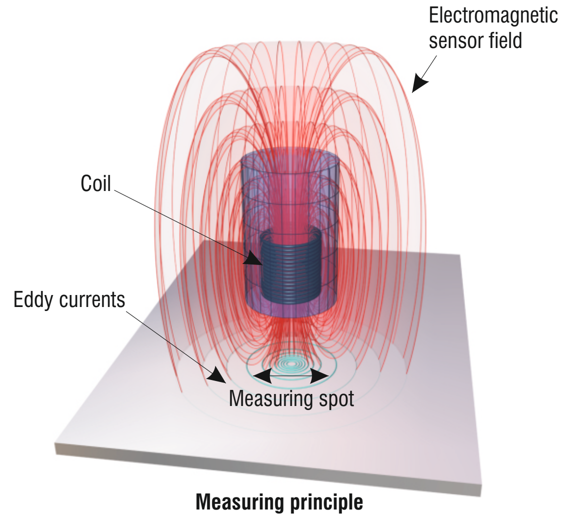
Eddy current sensors

Laser triangulation sensors

As a specialist in non-contact measurement, Micro-Epsilon has a variety of precision sensor technologies available for selection. The range includes eddy current, capacitive, confocal and laser triangulation sensors. The company prides itself on helping customers choose the correct technology for the application, including even hybrid technologies if this is appropriate.

The eddy current principle

The eddy current measurement principle is an inductive measuring method based on the extraction of energy from an oscillating circuit. This energy is required for the induction of eddy currents in electrically conductive materials.
A coil is supplied with an alternating current, which causes a magnetic field to form around the coil. If an electrically conducting object is placed in this magnetic field, eddy currents are induced, which form an electromagnetic field according to Faraday's Induction Law. This field acts against the field of the coil, which also causes a change in the impedance of the coil. The controller calculates the impedance by considering the change in amplitude and phase position of the sensor coil.



Measuring principle

Advantages of measuring by eddy current:

- Useable on all electric conductive objects with ferromagnetic and non-ferromagnetic features.
- Small sensor size
- Wide temperature range
- Impassibly for dirt, dust, humidity, oil, high pressures and dielectric materials between the measuring gap
- High accuracy

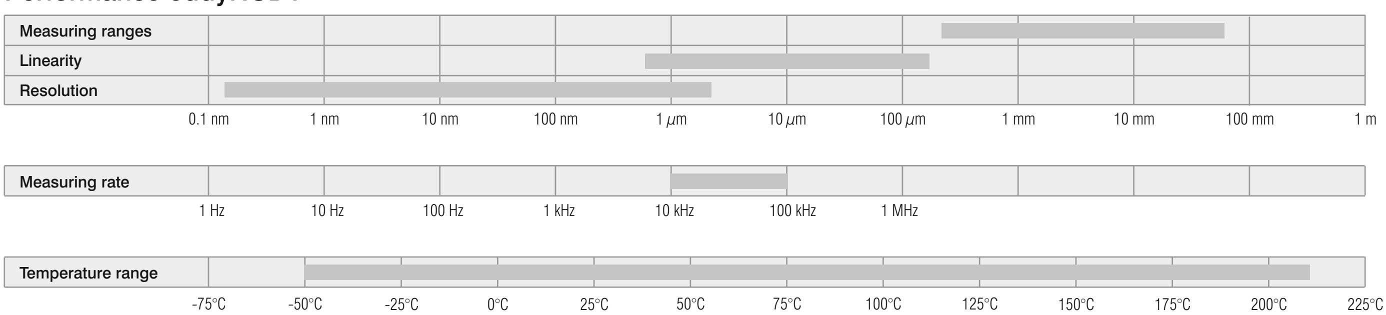
eddyNCDT 3100

Restrictions in the application:

- Output and linearity depend on the electric and magnetic features of the target material
- Individual linearization and calibration is necessary
- Cable length max. 15 m
- Diameter of the sensor and therewith the effective measuring diameter rises with bigger measuring ranges

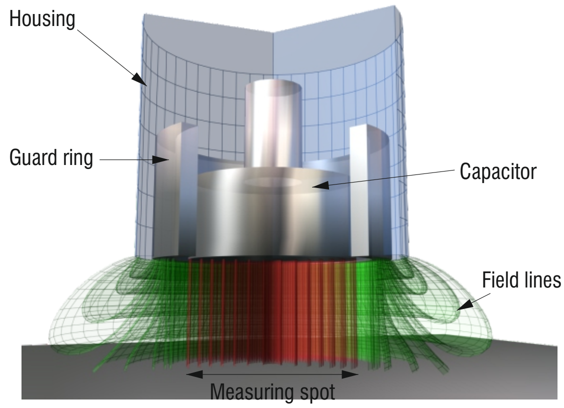
eddyNCDT 3300

Performance eddyNCDT



The capacitive principle

With the capacitive principle, sensor and target operates like an ideal parallel plate capacitor. The two plate electrodes are formed by the sensor and the opposing target. If an AC current with constant frequency flows through the sensor capacitor, the amplitude of the AC voltage on the sensor is proportional to the distance between the capacitor electrodes. An adjustable compensating voltage is simultaneously generated in the amplifier electronics. After demodulation of both AC voltages, the difference is amplified and output as an analogue signal.
Because the sensor is constructed like a guard ring capacitor, almost ideal linearity and sensitivity to metals is achieved.



Measuring principle

Advantages of capacitive sensors:

- Constant sensibility and linearity against all conductive objects
- High temperature stability
- Also possible for isolators
- Special sensor designs
- Nanometre resolution

capaNCDT 6019

capaNCDT 6100

Restrictions in the application:

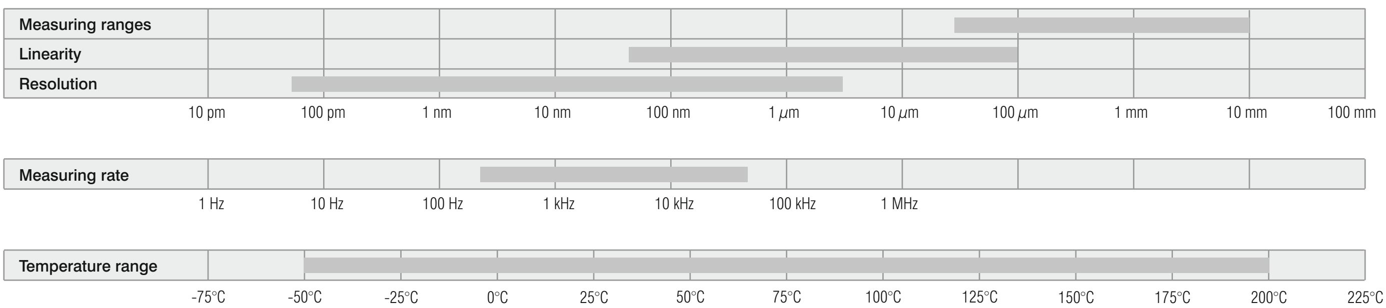
- Sensible for changing the dielectricum in the sensor gap. Hence, only applicable in clean and dry ambition
- Diameter of the sensor and therewith the effective measuring diameter rises with bigger measuring ranges

capaNCDT 6200

capaNCDT 6300

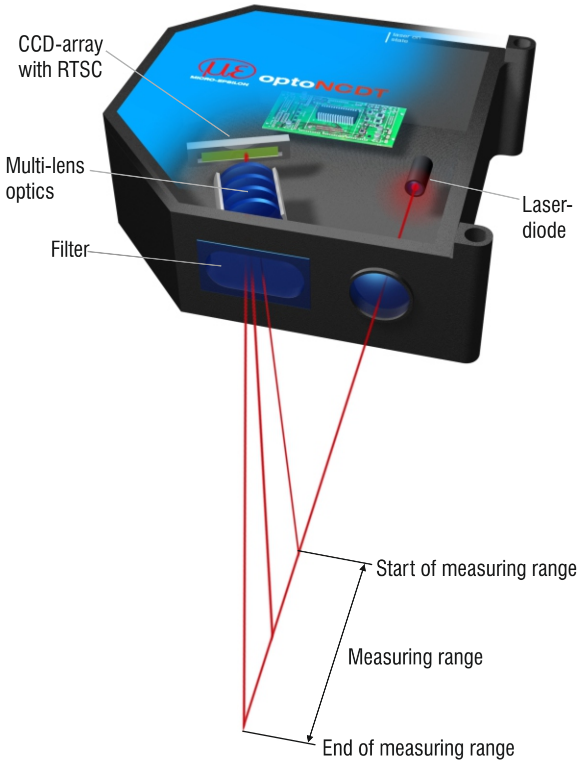
capaNCDT 6500

Performance capaNCDT



The laser triangulation principle

In the laser triangulation principle, laser diode projects a visible point of light onto the surface of the object being measured. The back scattered light reflected from this point is then projected onto a CCD- / CMOS array by a high quality optical lens system. If the target changes position with respect to the sensor, the movement of the reflected light is projected on the CCD array and analysed to output the exact position of the target. The measurements are processed digitally in the integral controller and then converted into a scaled output via analogue (I/U) and digital interface RS232, RS422 or USB.



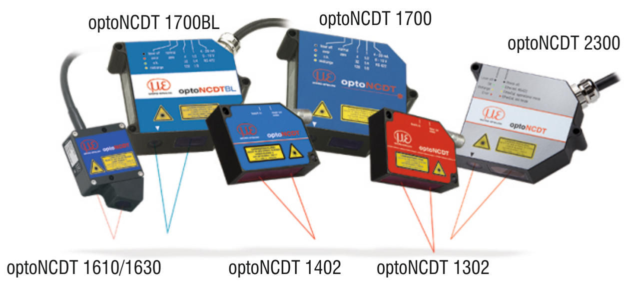
Measuring principle

Advantages of triangulation sensors:

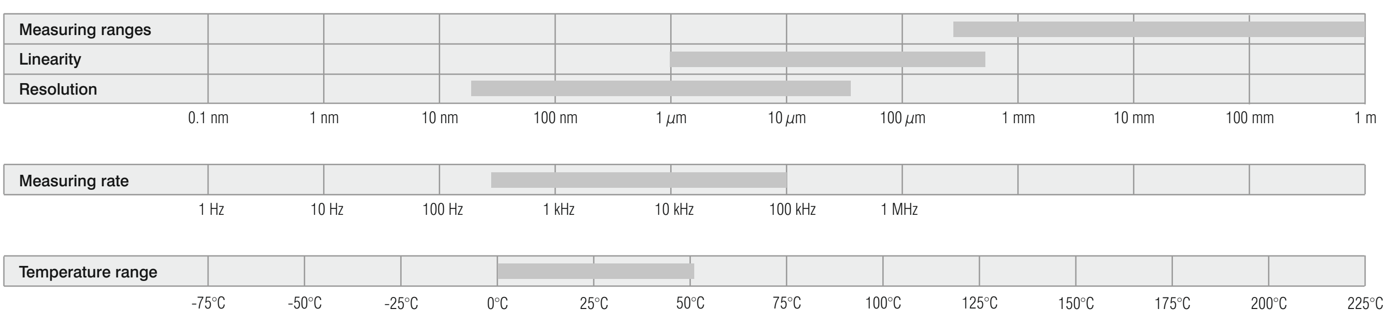
- Small beam-spot
- High reference distance between sensor and target
- Huge measuring ranges are possible
- Nearly material independent

Restrictions in the application:

- Kind of surface dependence
- Clean ambient in the optical path is necessary
- Big sensor construction related to confocal, capacitive and triangulating sensors
- For direct reflecting targets only with specific sensor alignment

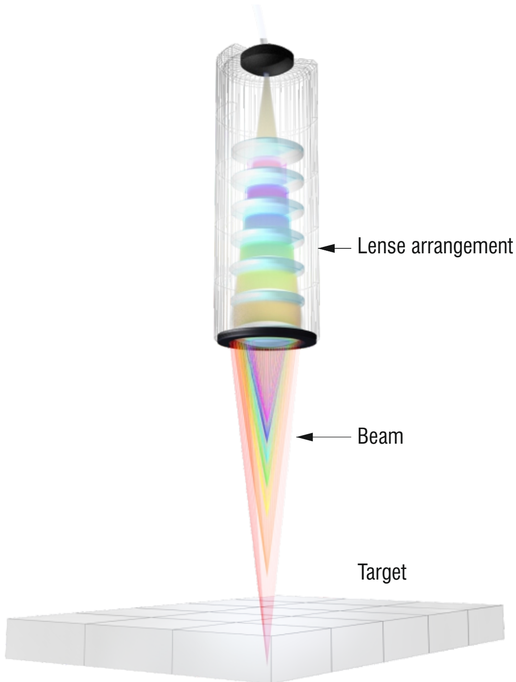


Performance optoNCDT



The confocal principle

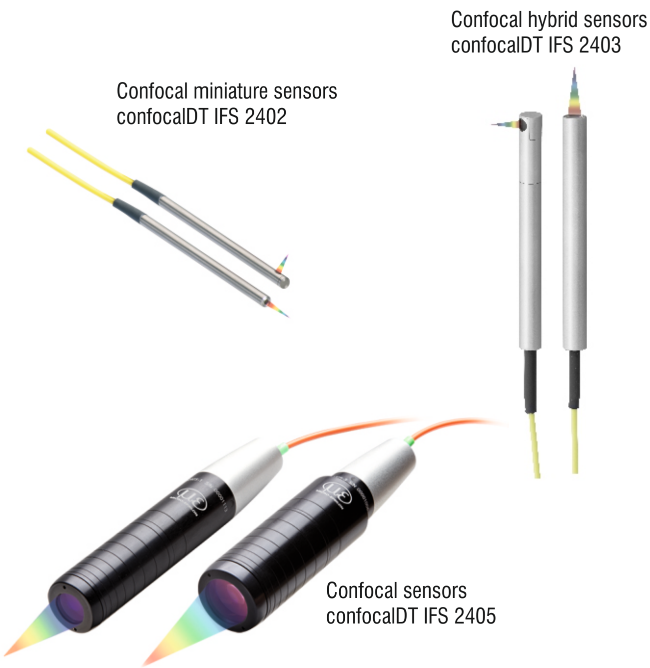
The technology works by focussing polychromatic white light onto the target surface using a multi-lens optical system. The lenses are arranged in such a way that the white light is dispersed into a monochromatic light by controlled chromatic deviation. A certain deviation is assigned to each wavelength by a factory calibration. Only the wavelength that is exactly focussed on the target surface or material is used for the measurement.
This light reflected from the target surface is then passed via a confocal aperture to the receiver, which detects and processes the spectral changes. This unique measuring principle enables displacements and distances to be measured very precisely.
Both diffuse and spectral surfaces can be measured and with transparent materials such as glass, a one-sided thickness measurement can be accomplished along with the distance measurement. And, because the emitter and receiver are arranged in one axis, shadowing is avoided.



Measuring principle

Advantages of confocal sensors:

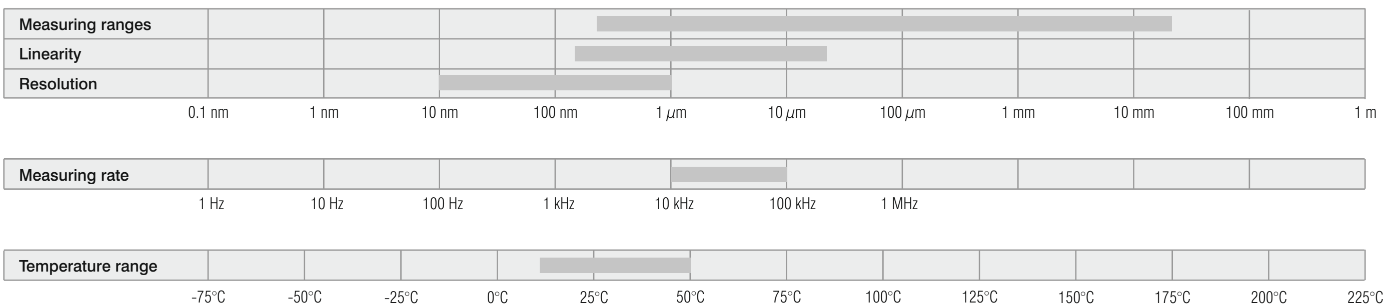
- Resolution in the nanometre range
- Nearly material independent
- Tiny constant spot
- Compact course of beam
- One-sided thickness measurement on transparent materials
- Radial version for measure a drill hole wall with miniaturized sensors
- White light instead of a laser



Restrictions in the application:

- Limited distance between sensor and target
- The beam require a clean environment

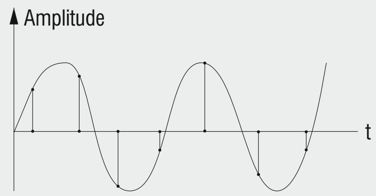
Performance confocalDT



Glossary, Definitions

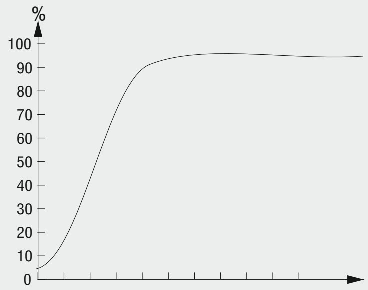
Sampling rate

The sampling rate is the frequency with which analog signals are sampled in time during an A/D conversion.



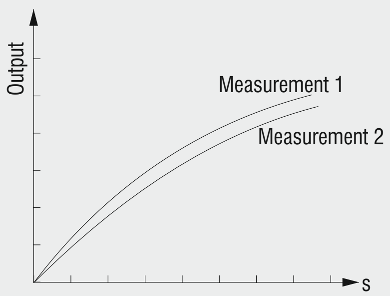
Response time

The response time is the time taken required by the signal output to increase the signal level from 10% to 90%. With digital measurement devices this is the time taken to output a stable measurement.



Repeatability

Quantitative specification of the deviation of mutually independent measurements which are determined under the same conditions.



Signal-to-noise ratio

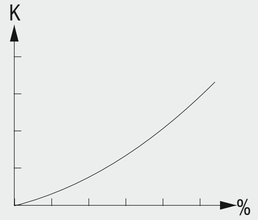
The quality of a transmitted useful signal can be stated with the signal-to-noise ratio.

Noise arises with any data transmission. The higher the separation between noise and useful signal, the more stable can the transmitted information be reconstructed from the signal. If, during the digital sampling, the noise power and the useful signal power come too close, an incorrect value may be detected and the information corrupted.

Glossary, Definitions

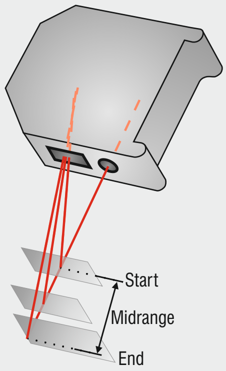
Temperature stability

The temperature stability indicates the percentage possible error in the measurement per unit (K or °C). This error is attributable to the physical expansion of built-in components or to the effect of temperature on electronic components. This effect results in a slight deviation of the results at different temperatures. The temperature stability is decisive for ensuring the measurement accuracy, particularly in industrial applications with large temperature variations.



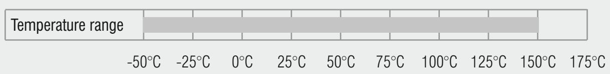
Measurement range

The measurement range describes the space of a sensor in which the object to be measured must be situated so that the specified technical data are satisfied. The extreme regions of this space are termed the start and end of the measurement range. Some sensors exhibit a space (cf. start of measurement range) between the measurement range and the sensor.



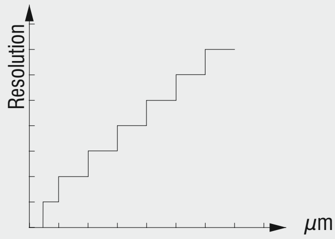
Temperature range

The range of ambient temperature in which the sensor or the controller electronics can be operated without permanent change to its performance data.



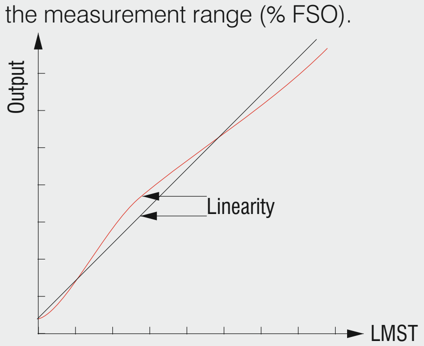
Resolution

The resolution describes the smallest possible change of a quantity which can be reliably measured by a sensor. In practice the resolution is determined by the signal-to-noise ratio, taking into account the acquired frequency spectrum.



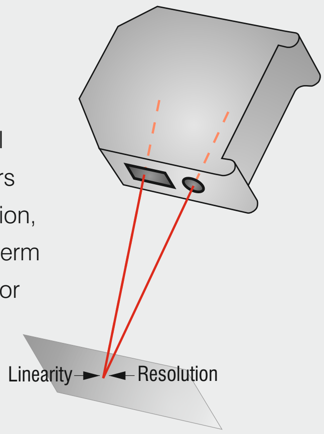
Non-Linearity >> Linearity

The maximum deviation between an ideal straight-line characteristic and the real characteristic is termed the non-linearity or linearity. The figure is given as a percentage of the measurement range (% FSO).



Accuracy

The accuracy states the maximum measuring error taking into account all the factors which affect the real measurement. These factors include the linearity, resolution, temperature stability, long-term stability and a statistical error (which can be removed by calculation).



Comparison of usage criteria to performance characteristics

All measurement technologies have different advantages and limitations. To aid the decision making process in selecting a suitable technology, the most common performance criteria can be compared. The table below shows each of the four measurement technologies described in this article compared side by side and is intended as a selection guide. The user must also note, however, that many and sensor modifications can be used to improve a sensor technology beyond the above guidelines. Please consult Micro Epsilon for further information on sensor modifications.

Measuring system		Eddy current	Capacitive	Triangulation	Confocal
Accuracy		+	+	+	+
Resolution		+	+	+	+
Hightemperature		+	+	o	o
Temperature range	up to 40 °C	+	+	+	+
	up to 90 °C	+	+	o	+
	up to 150 °C	+	+	o	o
Sensor size		+	o	-	o
Measuring spot		o	o	+	+
Environmental compatibility		+	-	-	o
Longrange		o	-	+	-
Critical frequency		+	o	o	o
Target	Transparent objects	-	+	o	+
	Metals	+	+	+	+
	Isolators	-	o	+	+
	Surface texture	+	+	o	+
	Electrical run out (Inhomogeneous electromagnetic materials)	-	+	+	+

+ good   o neutral   - problematic

Principle		Eddy current	Capacitive	Triangulation	Confocal
Measuring range	mm	0.4 - 80	0.05 - 10	0.5 - 1000	0.3 - 30
Linearity	µm	8	0.01	0.4	0.15
Reachable resolution	µm	0.02	0.0000375	0.03	0.01
Bandwidth	kHz	up to 100	up to 8.5	37.5	
Sampling rate	kHz		up to 50	up to 50	up to 70
Temperature range	°C	-50 ... 350	- 50 ... 200	0 ... 55	10 ... 50
Temperature stability	FSO / °C	< ± 0.015	< 0.0005	< 0.01	< 0.01

FSO = Full Scale Output

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