INTERNATIONAL STANDARD

ISO 25178-602

First edition
2010-07-01

Geometrical product specifications (GPS) — Surface texture: Areal —

Part 602:
Nominal characteristics of non-contact (confocal chromatic probe) instruments

Spécification géométrique des produits (GPS) — État de surface: Surfacique —

Partie 602: Caractéristiques nominales des instruments sans contact (à capteur confocal chromatique)

Reference number
ISO 25178-602:2010(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 25178-602 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 25178 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Surface texture: Areal*:

— *Part 2: Terms, definitions and surface texture parameters*

— *Part 3: Specification operators*

— *Part 6: Classification of methods for measuring surface texture*

— *Part 7: Software measurement standards*

— *Part 601: Nominal characteristics of contact (stylus) instruments*

— *Part 602: Nominal characteristics of non-contact (confocal chromatic probe) instruments*

— *Part 603: Nominal characteristics of non-contact (phase-shifting interferometric microscopy) instruments*

— *Part 701: Calibration and measurement standards for contact (stylus) instruments*

The following parts are under preparation:

— *Part 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments*

— *Part 605: Nominal characteristics of non-contact (point autofocusing) instruments*

Introduction

This part of ISO 25178 is a geometrical product specification standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 5 of the chain of standards on roughness profile, waviness profile and primary profile and areal surface texture.

For more detailed information on the relationship of this standard to the GPS matrix model, see Annex D.

The confocal chromatic optical principle can be implemented in various set-ups. The configuration described in this document comprises three basic elements: an optoelectronic controller, a linking fibre optic cable and a chromatic objective (sometimes called “optical pen”).

Several techniques are possible to create the axial chromatic dispersion or to extract the height information from the reflected light. In addition to implementations as point sensors, chromatic dispersion may be integrated into line sensors and field sensors. Annex B describes in detail confocal chromatic imaging and its implementation into distance measurement probes.

This type of instrument is mainly designed for areal measurements, but it is also able to perform profile measurements.

This part of ISO 25178 describes the metrological characteristics of an optical profiler using a confocal chromatic probe based on axial chromatic dispersion of white light, designed for the measurement of areal surface texture.

For more detailed information on the chromatic probe instrument technique, see Annex B. Reading this annex before the main body may lead to a better understanding of this part of ISO 25178.

Geometrical product specifications (GPS) — Surface texture: Areal —

Part 602: **Nominal characteristics of non-contact (confocal chromatic probe) instruments**

1 Scope

This part of ISO 25178 defines the design and metrological characteristics of a particular non-contact instrument for measuring surface texture using a confocal chromatic probe based on axial chromatic dispersion of white light.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3274:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 10360-1, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3274, ISO 4287, ISO 10360-1, ISO/IEC Guide 99 and the following apply.

NOTE Several of the terms given below are common to other types of instruments that use single point sensors and lateral scanning.

3.1 General terms and definitions

3.1.1
coordinate system of the instrument
orthonormal system of axes (X,Y,Z) defined as:

— (X,Y) is the plane established by the areal reference guide of the instrument;

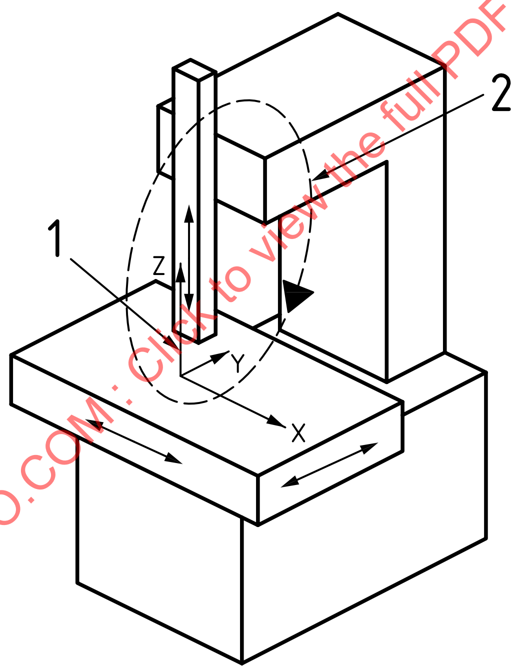
— the Z axis is mounted parallel to the optical axis and is perpendicular to the (X,Y) plane

NOTE Normally, the X-axis is the tracing axis and the Y-axis is the stepping axis.

3.1.2
measurement loop
closed chain which comprises all components connecting the workpiece and the **chromatic probe** (3.3.2), e.g. the means of positioning, the workholding fixture, the measuring stand, the **drive unit** (3.2.3 and 3.2.4) and the **probing system** (3.3.1)

See Figure 1.

NOTE The measuring loop will be subjected to external and internal disturbances which influence the measurement uncertainty.



Key
1 coordinate system of the instrument
2 measurement loop

Figure 1 — Coordinate system and measurement loop of the instrument

3.1.3
real surface of a workpiece
set of features which physically exist and separate the entire workpiece from the surrounding medium

[ISO 14660-1:1999, definition 2.4]

3.1.4
real electro-magnetic surface
surface obtained by the electro-magnetic interaction with the real surface of a work piece

[ISO 14406:—[1]), definition 3.2.2]

NOTE The real electro-magnetic surface considered for the instrument described in this part of ISO 25178 may be different from the real electro-magnetic surface for other types of optical instruments.

3.1.5
primary extracted surface
finite set of data points sampled from the primary surface

[ISO 14406:—[1]), definition 3.7]

3.1.6
measurement error
error of measurement
error
measured quantity value minus a reference quantity value

NOTE 1 The concept of "measurement error" can be used both

a) when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of a measurement standard with a measured quantity value having a negligible measurement uncertainty or if a conventional quantity value is given, in which case the measurement error is known, and

b) if a measurand is supposed to be represented by a unique true quantity value or a set of true quantity values of negligible range, in which case the measurement error is not known.

NOTE 2 Measurement error should not be confused with production error or mistake.

[ISO/IEC Guide 99:2007, definition 2.16]

3.1.7
systematic measurement error
systematic error of measurement
systematic error
component of **measurement error** (3.1.6) that in replicate measurements remains constant or varies in a predictable manner

NOTE 1 A reference quantity value for a systematic measurement error is a true quantity value, or a measured quantity value of a measurement standard of negligible measurement uncertainty, or a conventional quantity value.

NOTE 2 Systematic measurement error, and its causes, can be known or unknown. A **correction** (3.1.11) can be applied to compensate for a known systematic measurement error.

NOTE 3 Systematic measurement error equals measurement error minus **random measurement error** (3.1.8).

[ISO/IEC Guide 99:2007, definition 2.17]

3.1.8
random measurement error
random error of measurement
random error
component of **measurement error** (3.1.6) that in replicate measurements varies in an unpredictable manner

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1) To be published.

NOTE 1 A reference quantity value for a random measurement error is the average that would ensue from an infinite number of replicate measurements of the same measurand.

NOTE 2 Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

NOTE 3 Random measurement error equals measurement error minus **systematic measurement error** (3.1.7).

[ISO/IEC Guide 99:2007, definition 2.19]

3.1.9
adjustment of a measuring instrument
adjustment
set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

NOTE 1 Types of adjustment of a measuring system include zero adjustment of a measuring system, offset adjustment, and span adjustment (sometimes called gain adjustment).

NOTE 2 Adjustment of a measuring system should not be confused with calibration, which is a prerequisite for adjustment.

NOTE 3 After an adjustment of a measuring system, the measuring system must usually be recalibrated.

[ISO/IEC Guide 99:2007, definition 3.11]

NOTE 4 This is an operation normally carried out by the instrument manufacturer because it requires specialized equipment and knowledge that users normally do not have.

3.1.10
user adjustment
⟨measuring instrument⟩ **adjustment of a measuring instrument** (3.1.9) employing only the means at the disposal of the user

NOTE This is an operation normally carried out by the user. It involves the use of a measurement standard, usually supplied with the instrument. The result of this operation automatically or manually adjusts certain parameters in order for the instrument to operate correctly.

3.1.11
correction
compensation for an estimated systematic effect

NOTE 1 See ISO/IEC Guide 98-3:2008, definition 3.2.3, for an explanation of “systematic effect”.

NOTE 2 The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.

[ISO/IEC Guide 99:2007, definition 2.53]

3.1.12
residual correction error
difference between the value of a quantity obtained after correcting the **systematic measurement error** (3.1.7) and the real value of this quantity

NOTE The residual error is composed of **random errors** (3.1.8) and uncorrected systematic errors.

3.2 Terms and definitions relative to the lateral scanning system

3.2.1
lateral scanning system
system that performs the scanning of the surface to be measured in the (X,Y) plane

NOTE Typically, the lateral scanning system is composed of the **drive unit X** (3.2.3) and the **drive unit Y** (3.2.4).

3.2.2
areal reference guide
component of the instrument that generates the reference surface in which the **probing system** (3.3.1) moves relative to the surface being measured according to a theoretically exact trajectory

NOTE In the case of areal surface texture measurement instruments, the reference guide establishes a reference surface (see ISO 25178-2). It can be achieved through the use of two perpendicular reference guides (see ISO 3274:1996, 3.3.2) or one reference surface guide.

3.2.3
drive unit X
component of the instrument that moves the **probing system** (3.3.1) or the surface being measured along the reference guide on the X-axis and returns the horizontal position of the measured point in terms of lateral X coordinate of the profile

3.2.4
drive unit Y
component of the instrument that moves the probing system or the surface being measured along the reference guide on the Y-axis and returns the horizontal position of the measured point in terms of lateral Y coordinate of the profile

3.2.5
lateral position sensor
component of the drive unit that provides the lateral position of the measured point

NOTE The lateral position can be measured or inferred by using, for example, a linear encoder, a laser interferometer, or a counting device coupled with a micrometer screw.

3.3 Terms and definitions relative to the probing system

3.3.1
probing system
⟨surface texture, confocal chromatic probe⟩ components of the instrument called *confocal chromatic probe*, consisting of an optoelectronic controller, a fibre optic cable and a confocal chromatic objective

3.3.2
chromatic probe
device that converts the height of a point on the surface into a signal during measurement, using the confocal chromatic dispersion of a white light source

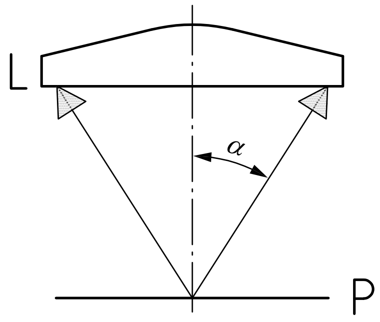
NOTE Chromatic dispersion can be realized by using various optic configurations (see Annex B).

3.3.3
angular aperture
angle of the cone of light entering an optical system from a point on the surface being measured

3.3.4
half aperture angle
α
one half of the **angular aperture** (3.3.3)

See Figure 2.

NOTE This angle is sometimes also called the *half cone angle*.



Key

L lens or optical system

P focal point

α half aperture angle

Figure 2 — Half aperture angle

3.3.5
numerical aperture
A_N
sine of the **half aperture angle** (3.3.4) multiplied by the refractive index n of the surrounding medium

$$A_N = n \sin \alpha$$

NOTE 1 In air, n approximately equals 1 and can be omitted from the equation.

NOTE 2 For a **chromatic probe** (3.3.2), the numerical aperture is dependent on the wavelength of light. Typically the numerical aperture is specified for the wavelength focused at the middle of the **vertical range** (3.3.14).

3.3.6
confocal chromatic microscopy
surface topography measurement method consisting of a confocal microscope with chromatic objective integrated with a detection device (e.g. spectrometer) whereby the surface height at a single point is sensed by the wavelength of light reflected from the surface

[ISO 25178-6:2010, 3.3.7]

3.3.7
achromatic objective
objective that produces a single focus for all wavelengths of the transmitted light

3.3.8
objective with axial chromatic dispersion
objective that produces a different focus along its optical axis for each wavelength of the transmitted light

3.3.9
light source
⟨chromatic probe⟩ source of light containing a continuum of wavelengths in a predefined spectral region

NOTE 1 The spectral region emitted by the source should be compatible with the spectral bandwidth of the detector.

NOTE 2 Typically, this spectral region extends from wavelength values of 0,4 µm to 0,8 µm.

3.3.10
light source pinhole
small hole placed following the **light source** (3.3.9), transforming the light source into a point light source

NOTE See notes in 3.3.11.

3.3.11
discrimination pinhole
small hole placed in front of the detector, providing depth discrimination on a beam reflected from the sample surface by blocking defocused light

NOTE 1 The system contains two pinholes: the first one is the **light source pinhole** (3.3.10). It defines a small spot of light that acts as the point light source for the instrument. The second one is the discrimination pinhole. It limits the transmitted beam to the part that is in focus on the sample surface and is reflected by it along the optical axis (see Figure B.1).

NOTE 2 In practice, the pinholes are obtained by using a fibre optic which provides spatial discrimination and allows the optical head to be used away from the optoelectronic controller.

3.3.12
chromatic depth of field
distance between the focal point of the shortest wavelength and the focal point of the longest wavelength of the spectral continuum emitted by the source

NOTE This definition differs from the typical definition for *depth of field* used in other optical systems, such as a conventional microscope.

3.3.13
working distance
⟨chromatic probe⟩ distance measured along the optical axis between the element closest to the surface and the point on the surface located in the middle of the **vertical range** (3.3.14)

3.3.14
vertical range
⟨chromatic probe⟩ distance measured between the focal point of the shortest wavelength and the focal point of the longest wavelength detected on the spectrometer

NOTE The vertical range depends on the **chromatic depth of field** (3.3.12) and on the spectral range of the spectrometer.

3.3.15
optical pen
part of a **chromatic probe** (3.3.2) containing the chromatic lens and located close to the surface during the measurement

3.3.16
stray light signal
signal composed of the stray light entering the **discrimination pinhole** (3.3.11), sensed by the detector when no sample is present, and the internal signal produced by the detector itself

NOTE The stray light signal is generally captured during a calibration procedure in order to correct the measurements.

3.4 Metrological characteristics of the instrument

3.4.1
metrological characteristic
MC
⟨measuring equipment⟩ characteristic of measuring equipment, which may influence the result of measurement

[ISO 14978:2006, definition 3.12]

NOTE 1 Calibration of metrological characteristics may be necessary.

NOTE 2 The metrological characteristics have an immediate contribution to measurement uncertainty.

3.4.2
measuring volume
range of the instrument stated as simultaneous limits on all spatial coordinates measured by the instrument

NOTE For areal surface texture measuring instruments, the measuring volume is defined by

— the measuring range of the **drive unit X** (3.2.3) and the **drive unit Y** (3.2.4),

— the measuring range of the **probing system** (3.3.1).

3.4.3
hysteresis
property of measuring equipment, or a characteristic whereby the indication of the equipment or value of the characteristic depends on the orientation of the preceding stimuli

NOTE 1 Hysteresis can also depend, for example, on the distance travelled after the orientation of stimuli has changed.

[ISO 14978:2006, definition 3.24]

NOTE 2 For lateral scanning systems, the hysteresis is mainly a repositioning error.

3.4.4
response curve
F_x, F_y, F_z
graphical representation of the function that describes the relation between the actual quantity and the measured quantity

See Figure 3.

NOTE 1 An actual quantity in X (respectively Y or Z) corresponds to a measured quantity x_m (respectively y_m or z_m).

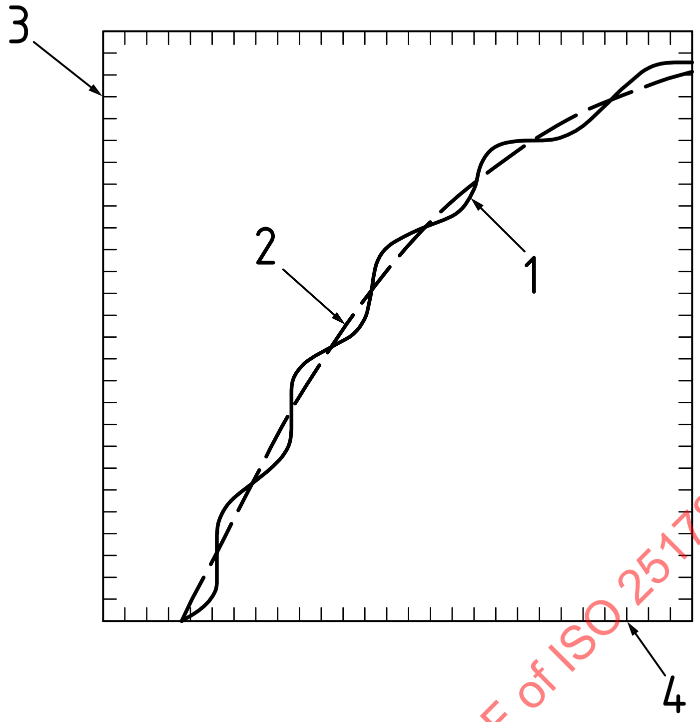
NOTE 2 The response curve can be used for adjustments and error corrections.

3.4.5
amplification coefficient
α_x, α_y, α_z
slope of the linear regression curve obtained from the response curve

See Figure 4.

NOTE 1 There will be amplification coefficients applicable to the X, Y and Z quantities.

NOTE 2 The ideal response is a straight line with a slope equal to 1 which means that the values of the measurand are equal to the values of the input quantities.



Key

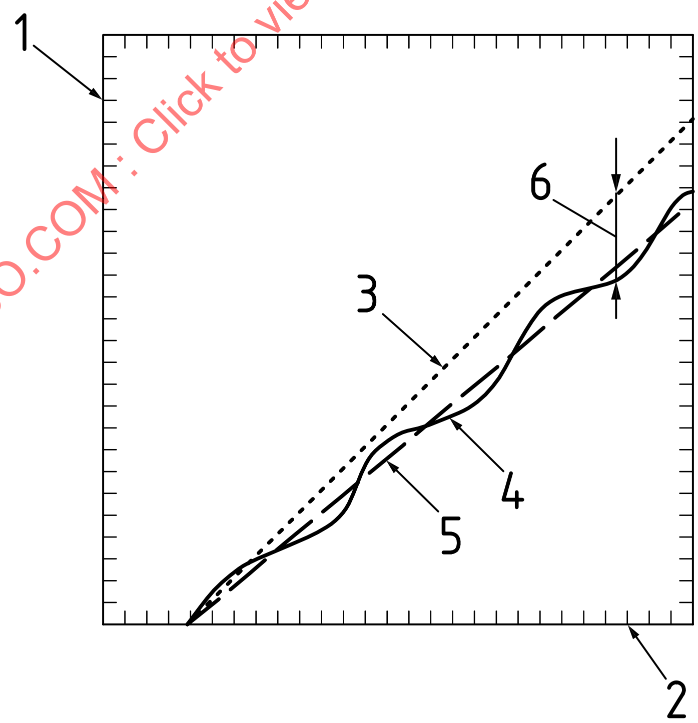
1 response curve

2 assessment of the response curve by polynomial approximation

3 measured quantities

4 input quantities

Figure 3 — Example of a non-linear response curve



Key

1 measured quantities

2 input quantities

3 ideal response curve

4 linearized response curve

5 straight line whose slope is the amplification coefficient α

6 local residual correction error before adjustment

Figure 4 — Example of the linearization of a response curve

3.4.6
instrument noise
internal noise added to the output signal caused by the instrument if ideally placed in a noise-free environment

NOTE 1 Internal noise can be caused by the electronic noise such as amplifiers.

NOTE 2 This noise typically has high frequencies which limit the ability of the instrument to detect small scale surface texture.

NOTE 3 The S-filter specified in ISO 25178-3 can reduce this noise.

3.4.7
static noise
N_{s}
combination of the instrument and environmental noise on the output signal when the instrument is not scanning laterally

NOTE 1 Environmental noise is caused by, e.g., seismic, sonic and external electro-magnetic disturbances.

NOTE 2 Notes 2 and 3 of 3.4.6 also apply to this definition.

3.4.8
dynamic noise
N_{d}
noise occurring during the motion of the drive units on the output signal

NOTE 1 Notes 2 and 3 of 3.4.6 also apply to this definition.

NOTE 2 Dynamic noise includes the **static noise** (3.4.7).

3.4.9
sampling interval in X
D_x
distance between two adjacent measured points along the X-axis

3.4.10
sampling interval in Y
D_y
distance between two adjacent measured points along the Y-axis

3.4.11
digitization step in Z
D_z
smallest height variation along the Z-axis between two ordinates of the extracted surface

NOTE 1 The height of a point is evaluated by searching for the position of the maximum peak on the spectrometer curve. Although the lateral resolution of the spectrometer is relatively small (small number of pixels), the digitization step in Z of the **chromatic probe** (3.3.2) is improved with the use of sub-pixel algorithms.

NOTE 2 Several algorithms may be used to detect the position of the maximum peak. The most likely ones are given in Table 1.

Table 1 — Efficiency of detection algorithms

Algorithm	Accuracy	Speed
Simple detection of the pixel position of maximum intensity	Poor	High
Fitting of a known curve (Gaussian, Pearson, etc.)	Good	Low
Barycentre of the peak	Good	High

3.4.12
lateral resolution
R_l
smallest distance between two features which can be detected separately

3.4.13
width limit for full height transmission
W_l
width of the narrowest rectangular groove whose measured height remains unchanged by the measurement

EXAMPLE 1 Measuring a grid for which the width of the grooves, t, is greater than the width limit for full height transmission, W_l, leads to a correct measurement of the groove depth (see Figures 5 and 6).

EXAMPLE 2 Measuring a grid for which the width of the grooves, t, is smaller than the width limit for full height transmission, W_l, leads to an incorrect groove depth (see Figures 7 and 8). In this situation, the signal is generally disturbed and may contain non-measured points.

NOTE Metrological characteristics including

— the sampling interval in X and Y,

— the digitization step in Z, and

— the filter used

should be adapted in such a way that they do not influence the lateral resolution and the width limit of full height transmission.

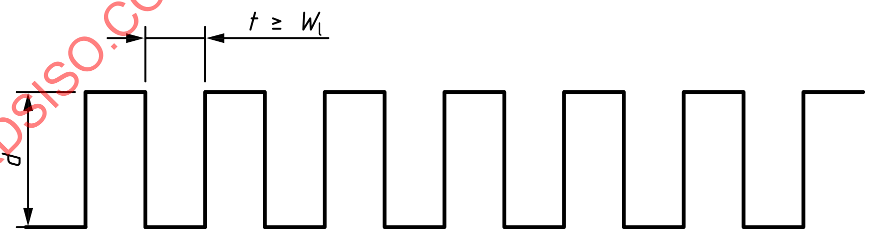
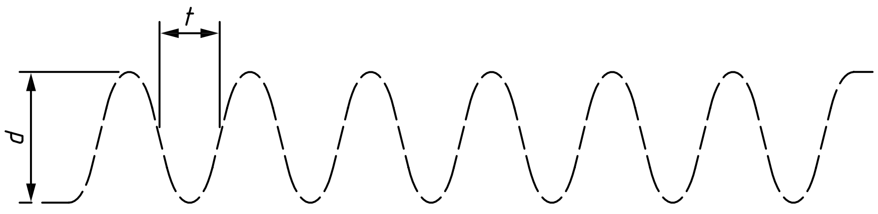


Figure 5 — Grid with horizontal spacing



NOTE The spacing and depth of the grid are measured correctly.

Figure 6 — Measurement of the grid

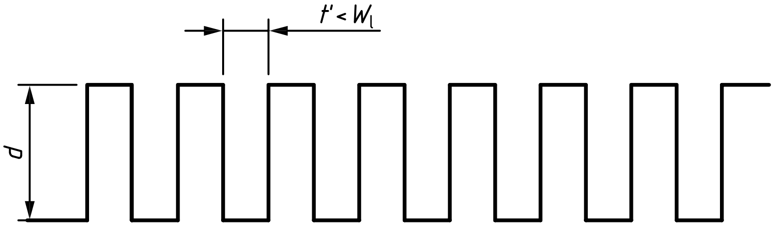
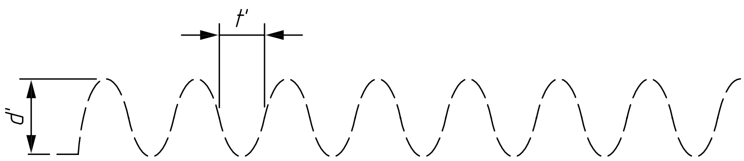


Figure 7 — Grid with horizontal spacing



NOTE The spacing is measured correctly but the depth is smaller ($d' < d$).

Figure 8 — Measurement of the grid

3.4.14
maximum acceptable local slope
greatest local slope of a surface feature that can be assessed by the probing system

EXAMPLE 1 On a tilted mirror (specular reflection), the maximum slope is about equal to the half aperture angle of the lens (see Figures 9 and 10). If the tilt angle exceeds this angle, the light reflected by the surface will not be collected by the lens.

In Figure 9, R_1 is a ray of light reflected towards the detector. R_2 is a ray of light reflected outside the lens. Only part of the illumination rays will be reflected towards the detector, leading to a lower signal level compared to the reflection on a non-tilted mirror. When the tilt angle approaches the half aperture angle, the signal approaches to zero (Figure 9).

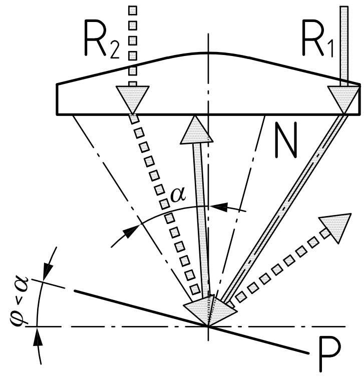
When the plane mirror is tilted at an angle greater than the half aperture angle α, all illumination rays will be reflected outside the lens (see Figure 10).

EXAMPLE 2 On a rough surface (diffuse reflection), the maximum slope is larger than the half aperture angle α. The angular distribution of the scattered light depends on the roughness and local slopes of the facets inside the spot size. The larger the roughness, the more light will be scattered at larger angles from the specular direction.

In Figure 11, the diffuse reflection caused by the rough surface allows a certain percentage of the illumination rays to be reflected towards the detector while the main part misses the collection lens. This shows why larger slopes can be measured on rougher surfaces than on smoother surfaces.

NOTE 1 The term *local slope* is defined in ISO 4287.

NOTE 2 The maximum acceptable slope is highly dependent on the workpiece roughness, the workpiece reflectivity and the integration time used during the measurement.



Key

P plane mirror

N axis normal to the plane mirror

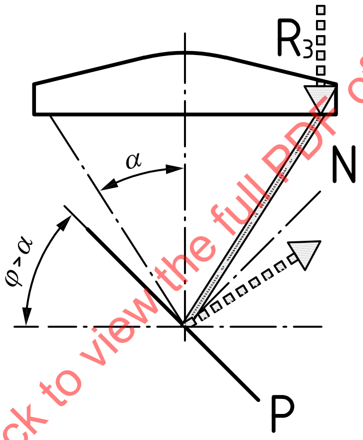
R_1 ray of light reflected towards the detector

R_2 ray of light reflected outside the lens

α half aperture angle

φ inclination angle

Figure 9 — Reflection from a mirror tilted at an angle smaller than the half aperture angle



Key

P plane mirror

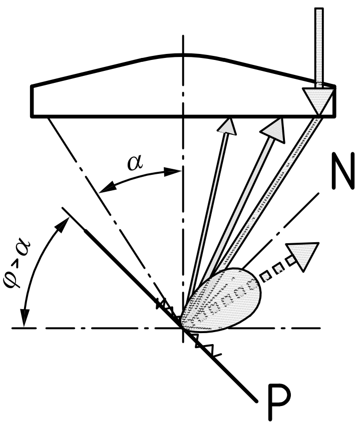
N axis normal to the plane mirror

R_3 ray of light reflected outside the lens

α half aperture angle

φ inclination angle

Figure 10 — Reflection from a mirror tilted at an angle greater than the half aperture angle



Key

P rough plane surface

N axis normal to the surface

α half aperture angle

φ inclination angle

Figure 11 — Reflection from a rough plane surface tilted at an angle larger than the half aperture angle

3.4.15
spot size
W_{spot}
maximum lateral size of the projected image of the source pinhole

NOTE 1 The spot size depends on the design characteristics of the system: **numerical aperture** (3.3.5), magnification, **light source pinhole diameter** (3.3.10), diffraction and residual geometrical aberrations.

NOTE 2 The spot size depends on the wavelength of light. Therefore it is not constant over the vertical height measurement range.

NOTE 3 The larger the spot size, the coarser will be the lateral resolution and there will be more smoothing of the surface irregularities.

NOTE 4 The visible spot size appears to be much larger than the in-focus spot size of a monochromatic light beam because the human eye sees the envelope of the beam composed of in-focus and out-of-focus images formed by all the visible wavelengths (see Figure 12). Since the wavelengths in white light are focused at different points along the optical axis by a chromatic lens, most of them are out-of-focus in the plane of the sample surface and hence create a spot size appearing visually larger than the in-focus spot diameter formed by a monochromatic light beam.

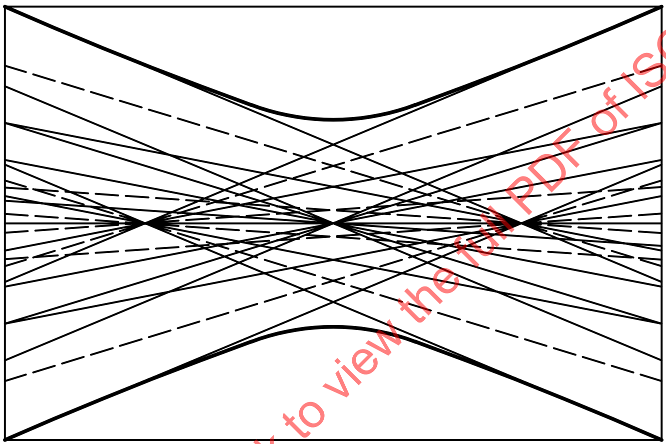


Figure 12 — Caustic generated by all wavelengths

3.4.16
integration time
T_i
time during which the incoming light is accumulated (integrated) on the detector in the spectrometer

NOTE 1 The longer the integration time, the more light will be collected. A long integration time used on a bright sample may saturate the detector [the saturation depends on the reflectivity of the sample and the intensity of the **light source** (3.3.9)].

NOTE 2 The shortest integration time is usually limited by the speed of the detector (delay needed to transfer the spectrum signal from the detector to the memory), the computation capability of the processor (the signal needs to be processed before the next cycle), the intensity of the light source and the detector pinhole size (enough light needs to be collected during the interval).

NOTE 3 During the scan of a profile line, each data point is integrated over a segment along X whose size depends on the speed of the traverse unit and the integration time. The effective lateral resolution in X may be larger than the static lateral resolution due to the movement.

3.4.17
measurement frequency
f_m
number of data points provided per second by the **probing system** (3.3.1)

NOTE 1 The measurement frequency determines the **sampling interval in X** (3.4.9) as follows:

$$D_x = v_x / f_m$$

where

D_x is the lateral sampling interval in X, in micrometres;

v_x is the measurement speed in X, in micrometres per second;

f_m is the measurement frequency, in hertz.

NOTE 2 The measurement frequency cannot be larger than the integration frequency (i.e. the time between two data points should be larger than the integration time plus the calculation time). However, a measurement frequency of 300 Hz may be chosen with an integration frequency of 1 kHz (integration time of 1 ms), for example.

NOTE 3 *Integration time* is used instead of integration frequency because it is related to an exposure time on the detector. On the contrary, the term *measurement frequency* is used instead of measurement time because the user selects a data rate in points/second, and because the term *measurement time* could be confused with the duration of the whole measurement.

4 Summary of metrological characteristics

Metrological characteristics for areal surface texture instruments shall be in accordance with Table 2 which indicates the axes that are affected by deviations of metrological characteristics.

Table 2 — Metrological characteristics

Component	Element	Metrological characteristics		May introduce error along
Probing system	Optical pen	W_{spot}	spot size	X, Y and Z
		A_N	numerical aperture	X, Y and Z
		R_l	lateral resolution	X, Y and Y
	Opto-electronic device	C_z	height adjustment coefficient	Z
		α_z	height amplification coefficient	Z
		z_{HYS}	vertical hysteresis	Z
		F_z	response curve	Z
		D_z	height digitization step	Z
		T_i	integration time	X and Z
		f_m	measurement frequency	X
Lateral scanning system	Position sensor (linear encoder, micrometer screw, …)	F_x or F_y	response curves	X or Y
		α_x or α_y	lateral amplification coefficients	X or Y
		D_x or D_y	lateral sampling interval	X or Y
		x_{HYS}	hysteresis of repositioning in X, between two adjacent profiles	X
		y_{HYS}	hysteresis of repositioning in Y	Y
		v_x	measurement speed in X	X and Z
	Areal reference guide (height component)	$z_{FLT(X,Y)}$	height component of the flatness of the movement in the XY plane $z_{FLT(X,Y)}$ contains in particular :	Z
		$z_{STR(X)}$	height component of the straightness along the X-axis	
		$z_{STR(Y)}$	height component of the straightness along the Y-axis	
	Areal reference guide (lateral component)	Δ_{PER}	perpendicularity between X and Y axes	X and Y
		$y_{STR(X)}$	lateral component Y of the straightness along the X axis	X and Y
		$x_{STR(Y)}$	lateral component X of the straightness along the Y axis	X and Y
Instrument		N_s	static noise	Z
		N_d	dynamic noise	Z

Annex A
(normative)

Classification of the different configurations for areal surface texture scanning instrument

There are essentially four aspects to a surface texture scanning instrument system: the X-axis drive, the Y-axis drive, the Z-measurement probe and the surface to be measured. There are different ways in which these may be configured and thus there will be a difference between different configurations as explained in Table A.1.

Table A.1 — Possible configurations for the lateral scanning system

Drive unit				
Two reference guides (X and Y)			**One areal reference guide**	
PX o CY[a] probing system moving along the X-axis and component moving along the Y-axis	PX o PY probing system moving along the X and Y-axes	CX o CY component moving along the X and Y-axes	PXY probing systems moving in the XY plane	CXY Component moving in the XY plane
NOTE For two given functions f and g, $f \circ g$ is the composite function of f and g.				
[a] PX = probing systems moving along the X-axis PY = probing systems moving along the Y-axis CX = component moving along the X-axis CY = component moving along the Y-axis.				

Annex B
(informative)

General principles

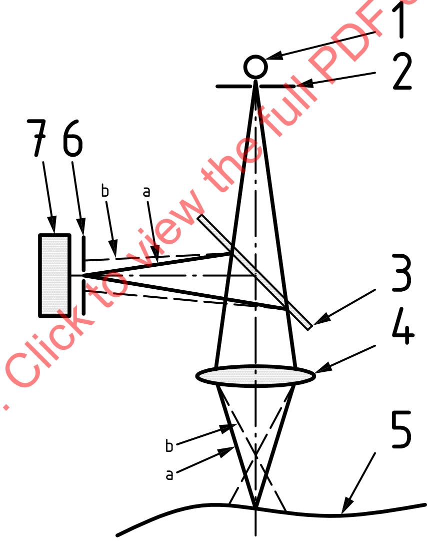
B.1 Basic principles

B.1.1 Principle of confocal microscopy

Confocal microscopy (or confocal imaging) consists of:

- imaging the light source pinhole in a focused spot on the surface;
- imaging this spot onto the discrimination pinhole.

Figure B.1 illustrates the optical principle of confocal microscopy.



Key

1 light source
2 light source pinhole
3 semi-transparent mirror
4 achromatic objective lens
5 workpiece
6 discrimination pinhole
7 photo-detector

a Beam focused on workpiece.
b Defocused beam.

Figure B.1 — Principle of a confocal sensor

Such an optical system is characterised by the following features:

- the two pinholes are conjugate pinholes (confocal principle);
- the light passes through the objective twice (in opposite directions);
- the setup is coaxial.

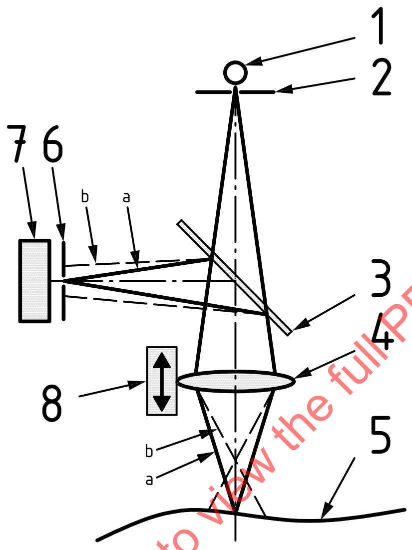
A light beam emitted by the source passes through the light source pinhole and then is focused on the surface with an achromatic objective lens. The beam reflected from the surface is sent back to a detector (generally a photo-detector) through a discrimination pinhole which only transmits the light focused on the pinhole and not the out-of-focus light surrounding the pinhole.

The detector will receive the maximum light intensity when the light beam is in focus on the surface.

The height discrimination provided by this device may be used as the surface height sensor of a surface texture measuring instrument.

B.1.2 Focus-sensing confocal sensor

Figure B.2 illustrates the principle of measurement of height using focus-sensing.



Key

1 light source
2 light source pinhole
3 semi-transparent mirror
4 achromatic objective lens
5 workpiece
6 discrimination pinhole
7 photo-detector
8 vertical displacement device

a Beam focused on workpiece.
b Defocused beam.

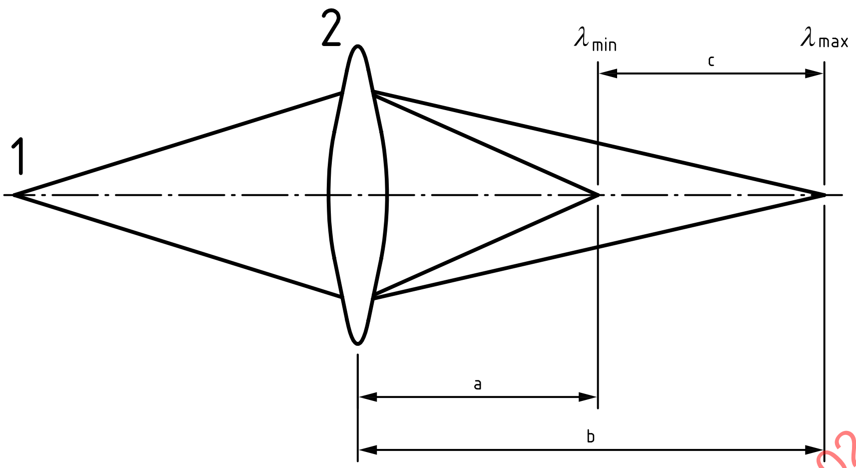
Figure B.2 — Principle of a focus-sensing confocal sensor

By moving the objective lens along the vertical axis, the signal will be a maximum when the beam is focused on the surface. Therefore, it is possible to detect the surface height by analysing the detector signal.

B.1.3 Principle of axial chromatic dispersion

In a chromatic optical system, the position of the image of any given point source depends on the wavelength of the light beam. When the light beam is polychromatic, the chromatic optical system exhibits a continuum of images corresponding to the spectral content of that beam.

Axial chromatic dispersion is a physical property inherent in all refractive, diffractive and gradient index optical systems. Figure B.3 illustrates this property.



Key

1 point light source

2 chromatic objective lens

a Focal distance of the shortest optical wavelength.

b Focal distance of the longest optical wavelength.

c Axial chromatic dispersion.

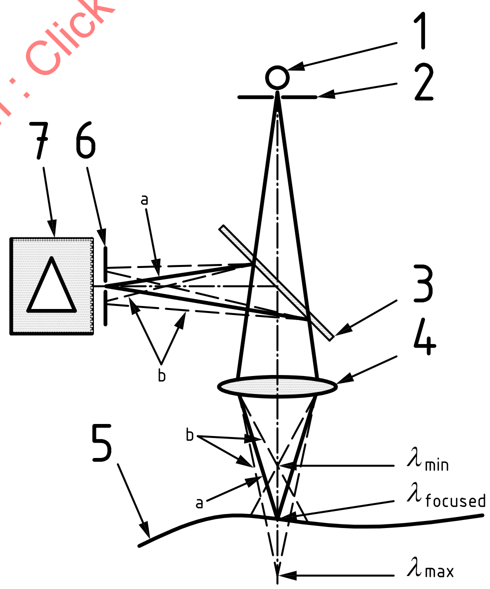
Figure B.3 — Principle of axial chromatic dispersion

B.2 Confocal chromatic dimensional metrology

The measurement principle consists of two operations.

1) Performing a *spectral encoding* of the measurement space. This encoding is performed by stretching the axial chromatic dispersion of the illuminating beam in a controlled manner.

2) Performing a *spectral decoding* of the reflected beam. This decoding can be performed, for example, by using a spectrometer.



Key

1 light source

2 light source pinhole

3 semi-transparent mirror

4 objective lens with axial chromatic dispersion

5 workpiece

6 discrimination pinhole

7 spectrometer

a Beam focused on workpiece.

b Defocused beams.

Figure B.4 — Principle of a confocal chromatic sensor

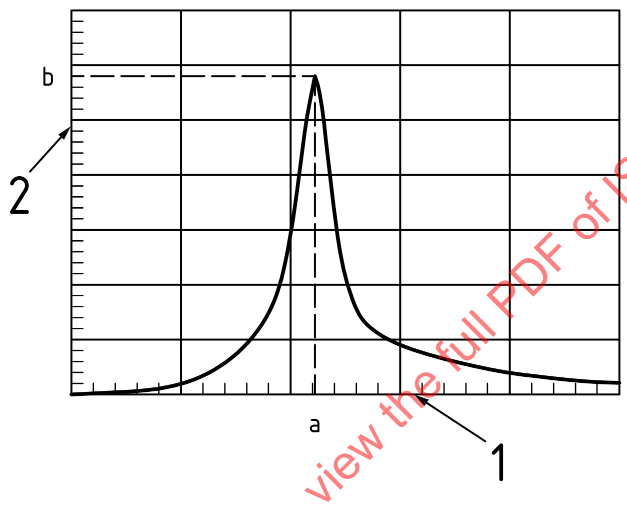
There are different ways to analyse the spectral content of the light beam that is filtered by the discriminating pinhole. One of them is the traditional spectrometer comprising a dispersive element (a grating or a prism) and a linear detector array.

The relative height of the surface at any given point (x, y) is obtained from the spectrometer data as follows:

— the light reflected by the surface is sent to the spectrometer through the discrimination pinhole which eliminates most wavelengths except those close to the focused wavelength;

— in the spectrometer, the focused wavelength will have a higher intensity than the defocused ones and will produce a peak in the spectrometer curve (see Figure B.5);

— if the sensor has been calibrated, the wavelength at the peak of the spectrometer curve can be converted into a distance from a pre-defined reference plane.



Key

1 wavelength axis (pixels of the CCD in the spectrometer)

2 intensity axis (arbitrary units)

a Position of the focused wavelength.

b Intensity of the peak.

Figure B.5 — Intensity peak on the spectrometer curve

The vertical range of the sensor (in the Z direction) is equal to the axial chromatic dispersion observed between the shortest and longest wavelengths by the detector. This type of sensor is able to achieve vertical ranges of relative surface texture heights from several tens of micrometers to several millimetres, depending on the objective lens.

Since the sensor measures the height at a single point on the workpiece, it is possible to use it to measure a profile or a surface. It will be necessary to scan in X to get a profile and in X and Y to get an areal topographic image.

Since this sensor does not include any vertical scanning device, the motion noise generated by the sensor is smaller and the measurement faster than in single point focus-sensing confocal systems.

The width of the spectral peak is determined by the size of the pinholes, the numerical aperture of the chromatic objective and the amount of chromatic dispersion.

B.3 Features of an areal surface texture measuring instrument

B.3.1 General

Surface texture measuring instruments enable the assessment of quantities in X, Y and Z from which areal surface texture parameters are calculated (see Figure B.6).

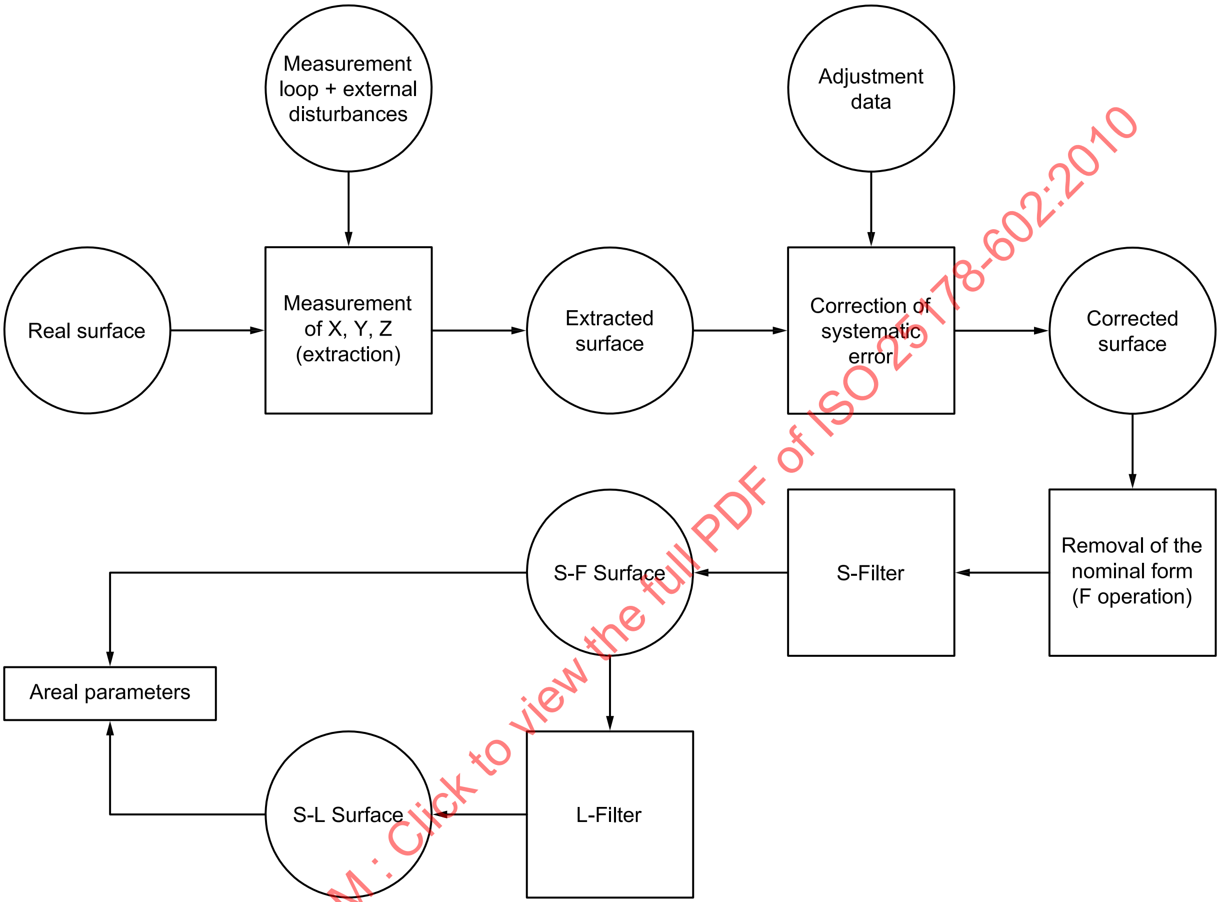


Figure B.6 — Typical measurement method applied to an areal surface texture measuring instrument

Quantities in X and Y characterize the lateral position of the measured point. The quantity Z characterizes the height of the measured point.

The knowledge of these three quantities allows the calculation of various areal surface texture parameters.

B.3.2 Confocal chromatic probe areal surface texture measuring instrument

An areal surface texture measuring instrument is composed of a lateral scanning system and a probing system.

A chromatic probe areal surface measuring instrument uses a non-contact probing system which is based on the confocal chromatic dispersion optical principle for determining surface heights.

This type of instrument is also able to perform profile measurements. The range of height measurements usually only allows measurements of surface texture on flat or slightly curved workpieces; typically, the height measuring range is less than a few millimetres.

B.3.3 Measurement process

A typical areal surface texture measuring instrument uses the following measurement process:

— the probing system performs profile acquisition through continuous measurement along the X-axis over a length l_x;

— after the profile has been measured, the probing system returns to its starting position (see below);

— the perpendicular drive unit along the Y-axis steps by one sampling interval distance along the Y-axis;

— these operations are repeated until the measurement is completed;

— the raw surface is then obtained. It contains n profiles separated from each other by the Y sampling interval, each profile containing m points separated by the X sampling interval.

It is also possible to perform the measurement without reversing the probe after each profile. The next profile may be scanned in the opposite direction compared to the previous scan. In this case, it is recommended to check that the repositioning hysteresis is compatible with the admissible measurement uncertainty. However, typical probing systems are generally designed for measuring in only one direction.

Recommendations for choosing evaluation areas and sampling distances are found in ISO 25178-3.

B.4 Comparison of instrument characteristics for the stylus and the chromatic probe

The chromatic probe has many similarities with a contact probe such as the stylus. Measurement protocols are kept the same, the instrument needs to move the workpiece or the sensor to generate a profile or a topographic image. Concepts such as stylus tip, cone angle, mechanical filtering, etc. can be compared with similar concepts for a chromatic probe.

The accuracy of measurement and the vertical resolution are of the same order of magnitude for the stylus and the chromatic probe. Therefore, a number of International Standards originally created for contact stylus instruments are suitable for instruments equipped with chromatic probes.

Table B.1 compares the characteristics of a traditional pivoting contact stylus probe and a chromatic probe.

Table B.1 — Comparison of metrological characteristics for the stylus and the chromatic probe

Stylus	Chromatic probe
r_{tip}: Tip radius	W_{spot}: Analysis spot diameter
α: Conical angle	A_N: Numerical aperture
L: Length	D: Working distance
H: Height	
Vertical range	Chromatic depth of field
	λ ($\Delta\lambda$): Light source wavelength (spectral bandwidth)
F_z: Response curve	F_z: Response curve
α_z: Amplification coefficient	α_z: Amplification coefficient
z_{HYS}: Hysteresis	
J_y: Lateral component of the pivot tracking error	
D_z: Vertical digitization step	D_z: Vertical digitization step

B.5 Non-measured points (missing data)

Each time the sensor is not able to assess the Z position of a point on the surface, the point is marked as "non-measured" (i.e. no information is provided for this point).

A non-measured point is usually generated when the processing unit cannot identify any peak in the spectrum, i.e. in one of the conditions given in Table B.2.

Table B.2 — Possible explanations for why there can be non-measured points

Condition	Comment	Solution
The workpiece is too dark	The intensity of the reflected light is too low	Increase the integration time or increase light source power
The workpiece is too shiny	The intensity of the reflected light is too high and saturates the detector	Decrease the integration time or decrease light source power
The local slope is too high	Most reflected light is sent outside the pinhole in front of the detector	None
Out of range	The peak is on the edge of the spectrum or outside the pinhole in front of the detector	None

NOTE Non-measured points may also be reconstructed by an interpolation technique (this subject is to be covered by a document in the ISO/TS 16610 series).

B.6 Outliers

Outliers are bad points generated when the sensor misinterprets the spectrometer data.

This may happen, for example, in the following cases:

— steep slopes;

— sudden height transition (step);

— semi-transparent particles;

— low intensity of the reflected signal (poor signal to noise ratio);

— spurious focus caused by surface curvature;

— heterogeneous surface conditions within the spot size.

These outliers usually appear as positive or negative peaks around step-type transitions, or around non-measured areas.

These points should be eliminated or corrected before proceeding to a calculation (roughness parameter). They sometimes explain deviations observed in surface parameters when comparing with a stylus measurement.

B.7 Measurement of transparent materials

The chromatic probe generates one intensity peak on the spectrometer for the focused wavelength. If more than one wavelength is focused in the range of the detector, such as in the case of a transparent layer, it is possible to identify the position of the two (or more) peaks.

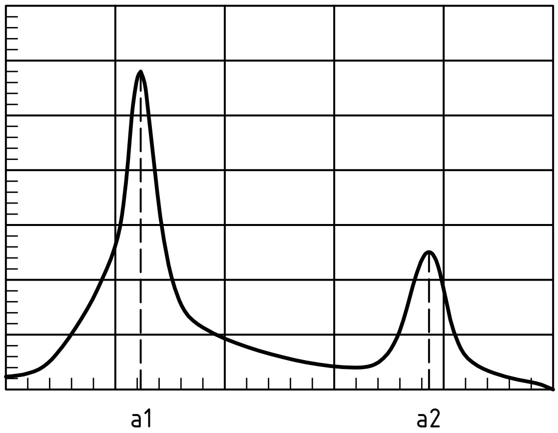


Figure B.7 — The two interfaces of a transparent layer are detected (the horizontal axis represents the distance to the surface, the vertical axis represents the intensity of the reflected light)

The condition for detecting two interfaces of a transparent material is that the optical thickness is smaller than the range of the sensor (see Figure B.7). For example: with a 1 mm range sensor, it is possible to measure an optical thickness smaller than 1 mm.

Instead of detecting the two interfaces, it is possible to retain only one of the two (for example the second interface). This ability allows the sensor to measure topography below a transparent layer (a film of oil, varnish, etc.).