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

Part 605:
Nominal characteristics of non-contact (point autofocus probe) instruments

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

Partie 605: Caractéristiques nominales des instruments sans contact (capteur autofocus à point)

Reference number
ISO 25178-605:2014(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is 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 1: Indication of surface texture*

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

— *Part 3: Specification operators*

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

— *Part 70: Material measures*

— *Part 71: 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 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments*

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

— *Part 606: Nominal characteristics of non-contact (focus variation) instruments*

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

The following parts are under preparation:

— *Part 72: XML file format x3p*

Calibration and measurement standards for non-contact (confocal chromatic probe) instruments and calibration and measurement standards for non-contact (phase-shifting interferometric microscopy) instruments are to form the subject of future parts 702 and 703.

A part 600 is planned which is intended to contain provisions common with the other 600-level parts of ISO 25178. Once it has been submitted as a Final Draft International Standard, those provisions in the other 600-level parts that are then redundant will be removed from them.

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 the chain link 5 of the chains of standards on roughness profile, waviness profile, primary profile, and areal surface texture.

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

The ISO/GPS Masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this standard is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this standard and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this standard, unless otherwise indicated.

The point autofocus optical principle can be implemented in various set-ups. The configuration described in this document comprises three basic elements: an autofocus optical system, an autofocus mechanism, and an electronic controller.

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 point autofocus probe for the measurement of areal surface texture.

For more detailed information on the point autofocus method, see Annex A. Reading this annex before the main body may lead to a better understanding of this standard.

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

Part 605: Nominal characteristics of non-contact (point autofocus probe) instruments

1 Scope

This part of ISO 25178 describes the metrological characteristics of a non-contact instrument for measuring surface texture using point autofocus probing.

2 Normative references

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

ISO 4287:1997, *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 14406:2010, *Geometrical product specifications (GPS) — Extraction*

ISO 14978:2006, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

ISO 25178-2:2012, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 2: Terms, definitions and surface texture parameters*

ISO 25178-3:2012, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 3: Specification operators*

ISO 25178-6:2010, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 6: Classification of methods for measuring surface texture*

ISO 25178-601:2010, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 601: Nominal characteristics of contact (stylus) instruments*

ISO 25178-602:2010, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 602: Nominal characteristics of non-contact (confocal chromatic probe) instruments*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4287, ISO 10360-1, ISO 14406, ISO 14978, ISO 25178-2, ISO 25178-3, ISO 25178-6, ISO 25178-601, ISO 25178-602 and the following apply.

3.1 Terms and definitions related to all areal surface texture measurement methods

3.1.1
areal reference
component of the instrument that generates a reference surface with respect to which the surface topography is measured

3.1.2
coordinate system of the instrument
right hand orthonormal system of axes (*x,y,z*)

Note 1 to entry: In this system (*x,y*) is the plane established by the areal reference of the instrument (Note that there are optical instruments that do not posses a physical areal guide).

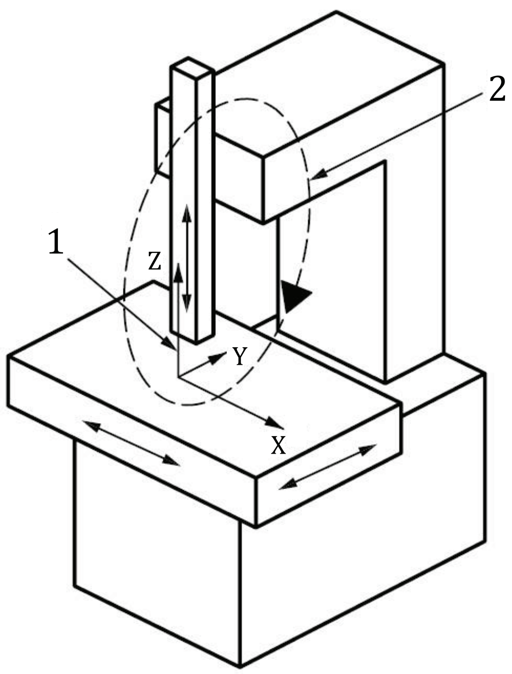
Note 2 to entry: In this system, *z*-axis is mounted parallel to the optical axis and is perpendicular to the (*x,y*) plane for an optical instrument. The *z*-axis is in the plane of the stylus trajectory and is perpendicular to the (*x,y*) plane for a stylus instrument (see Figure 1)

Note 3 to entry: Normally, the *x*-axis is the tracing axis and the *y*-axis is the stepping axis. (This note is valid for instruments that scan in the horizontal plane.)

Note 4 to entry: See also *specification coordinate system* and *measurement coordinate system*, as defined in ISO 25178-2:2012, 3.1.2 and ISO 25178-6:2010, 3.1.1, respectively.

3.1.3
measurement loop
closed chain which comprises all components connecting the workpiece and the probe, e.g. the means of positioning, the work holding fixture, the measuring stand, the drive unit, the probing system

Note 1 to entry: See Figure 1. The measurement loop will be subjected to external and internal disturbances that influence the measurement uncertainty.



Key

1 coordinate system of the instrument

2 measurement loop

Figure 1 — Coordinate system and measurement loop of instrument

3.1.4
real surface of a workpiece
set of features which physically exist and separate the entire workpiece from the surrounding medium

[SOURCE: ISO 14660-1:1999, 2.4]

Note 1 to entry: The real surface is a mathematical representation of the surface that is independent of the measurement process.

Note 2 to entry: See also *mechanical surface*, as defined in ISO 25178-2:2012, 3.1.1.1 or ISO 14406:2010, 3.1.1, and *electromagnetic surface*, as defined in ISO 25178-2:2012, 3.1.1.2 or ISO 14406:2010, 3.1.2.

Note 3 to entry: The electromagnetic surface considered for one type of optical instrument may be different from the electromagnetic surface for other types of optical instruments.

3.1.5
surface probe
device that converts the surface height into a signal during measurement

Note 1 to entry: In earlier standards this was termed transducer.

3.1.6
measuring volume
range of the instrument stated in terms of the limits on all three coordinates measured by the instrument

Note 1 to entry: For areal surface texture measuring instruments, the measuring volume is defined by:

— the measuring range of the x- and y- drive units,

— the measuring range of the z-probing system.

[SOURCE: ISO 25178-601:2010, 3.4.1]

3.1.7
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

Note 1 to entry: See Figure 2.

Note 2 to entry: An actual quantity in x (respectively y or z) corresponds to a measured quantity x_M (respectively y_M or z_M).

Note 3 to entry: The response curve can be used for adjustments and error corrections.

[SOURCE: ISO 25178-601:2010, 3.4.2]

3.1.8
amplification coefficient
α_x, α_y, α_z
slope of the linear regression curve obtained from the response curve

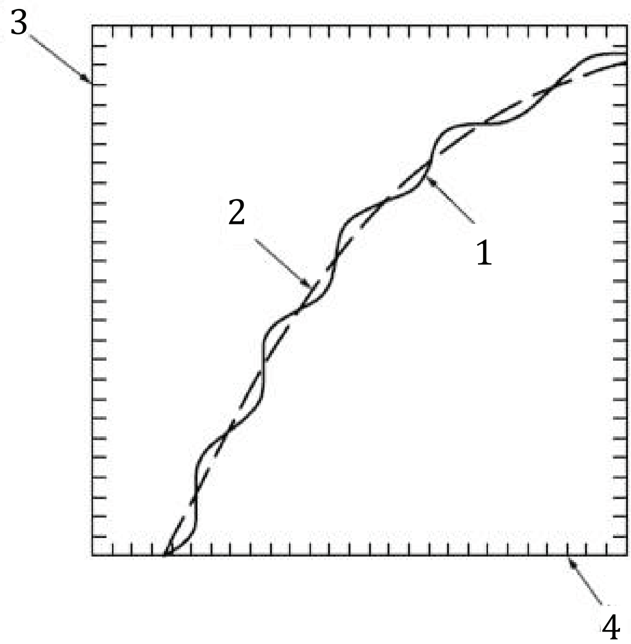
Note 1 to entry: See Figure 3.

Note 2 to entry: There will be amplification coefficients applicable to the x, y and z quantities.

Note 3 to entry: 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.

Note 4 to entry: See also *sensitivity of a measuring system* (VIM, 4.12)[1]

[ISO 25178-601:2010, 3.4.3, modified — Note 4 has been added.]



Key

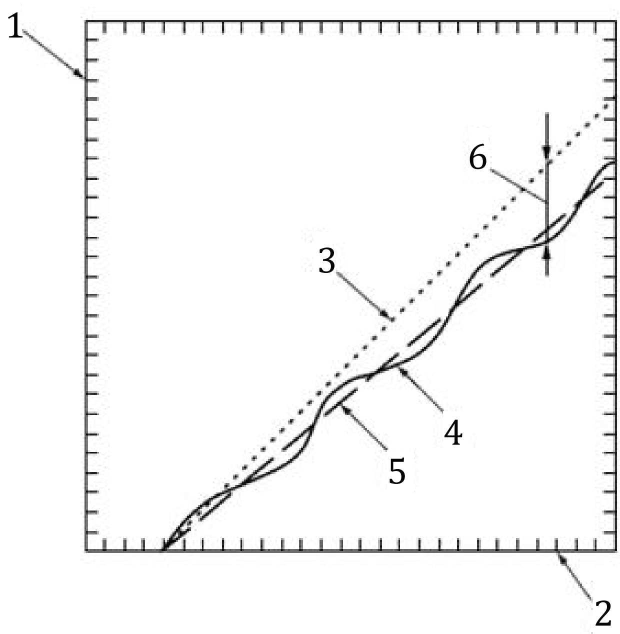
1 response curve

2 assessment of the linearity deviation by polynomial approximation

3 measured quantities

4 input quantities

Figure 2 — Example of nonlinear response curve



Key

1 measured quantities
2 input quantities
3 ideal response curve
4 linearization of the response curve of Figure 2
5 line from which the amplification coefficient α (slope) is derived
6 local residual correction error

Figure 3 — Example of linearization of response curve

3.1.9
instrument noise
N_I
internal noise added to the output signal caused by the instrument if ideally placed in a noise-free environment

Note 1 to entry: Internal noise can be due to electronic noise, as e.g. amplifiers, or to optical noise, as e.g. stray light.

Note 2 to entry: This noise typically has high frequencies and it limits the ability of the instrument to detect small scale spatial wavelengths of the surface texture.

Note 3 to entry: The S-filter according ISO 25178-3 may reduce this noise.

Note 4 to entry: For some instruments, instrument noise cannot be estimated because the instrument only takes data while moving.

3.1.10
measurement noise
N_M
noise added to the output signal occurring during the normal use of the instrument

Note 1 to entry: Notes 2 and 3 of 3.1.9 apply as well to this definition.

Note 2 to entry: Measurement noise includes the instrument noise.

3.1.11
surface topography repeatability
repeatability of topography map in successive measurements of the same surface under the same conditions of measurement

Note 1 to entry: Surface topography repeatability provides a measure of the likely agreement between repeated measurements normally expressed as a standard deviation

Note 2 to entry: See VIM,[1] 2.15 and 2.21, for a general discussion of repeatability and related concepts.

Note 3 to entry: Evaluation of surface topography repeatability is a common method for determining the measurement noise.

3.1.12
sampling interval in x [y]
D_x **[**D_y**]**
distance between two adjacent measured points along the x- [y-] axis

Note 1 to entry: In many microscopy systems the sampling interval is determined by the distance between sensor elements in a camera, called *pixels*. For such systems, the terms *pixel pitch* and *pixel spacing* are often used interchangeably with the term *sampling interval*. Another term, *pixel width*, indicates a length associated with one side (x or y) of the sensitive area of a single pixel and is always smaller than the pixel spacing. Yet another term, sampling zone, may be used to indicate the length or region over which a height sample is determined. This quantity could either be larger or smaller than the sampling interval.

3.1.13
digitisation step in z
D_Z
smallest height variation along the z-axis between two ordinates of the extracted surface

3.1.14
lateral resolution
R_l
smallest distance between two features which can be detected

[SOURCE: ISO 25178-601:2010, 3.4.10]

3.1.15
width limit for full height transmission
W_l
width of the narrowest rectangular groove whose measured height remains unchanged by the measurement

Note 1 to entry: Instrument properties such as

— the sampling interval in x and y,

— the digitisation step in z, and

— the short wavelength cut-off filter

should be chosen so that they do not influence the lateral resolution and the width limit for full height transmission.

Note 2 to entry: When determining this parameter by measurement, the depth of the rectangular groove should be close to that of the surface to be measured.

Note 3 to entry: An example is the measuring of a grid for which the grooves are wider than the width limit for full height transmission. This leads to a correct measurement of the groove depth (see Figures 4 and 5).

Note 4 to entry: Another example is the measuring of a grid for which the grooves are narrower than the *width limit for full height transmission*. This leads to an incorrect groove depth (see Figures 6 and 7). In this situation, the signal is generally disturbed and may contain non-measured points.

[ISO 25178-601:2010, 3.4.11, modified — The original notes have been replaced.]

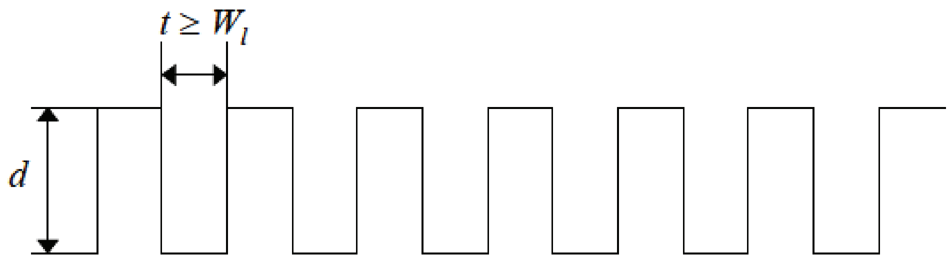


Figure 4 — Grid with horizontal spacing and t greater than or equal to W_l

Figure 5 — Measurement of grid in Figure 4 — Spacing and depth of grid measured correctly

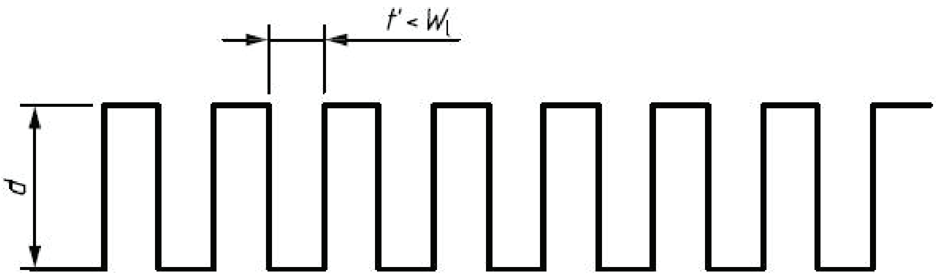


Figure 6 — Grid with horizontal spacing and t' smaller than W_l

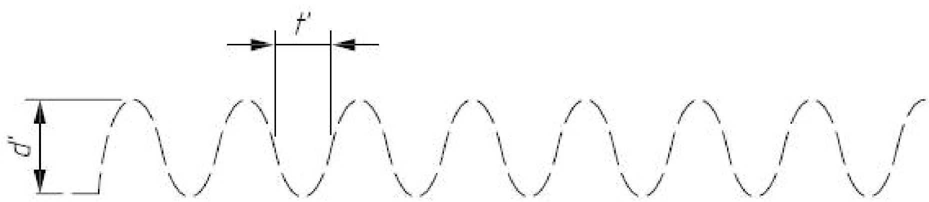


Figure 7 — Measurement of grid in Figure 6 — Spacing measured correctly but depth smaller ($d' < d$)

3.1.16
lateral period limit

D_{LIM}

spatial period of a sinusoidal profile at which the height response of an instrument falls to 50 %

Note 1 to entry: The lateral period limit is one metric for describing spatial or lateral resolution of a surface topography measuring instrument and its ability to distinguish and measure closely spaced surface features. Its value depends on the heights of surface features and on the method used to probe the surface. Maximum values for this parameter are listed in ISO 25178-3:2012, Table 3, in comparison with recommended values for short wavelength (s-)filters and sampling intervals.

Note 2 to entry: Spatial period is the same concept as spatial wavelength and is the inverse of spatial frequency.

Note 3 to entry: One factor related to the value of D_{LIM} for optical tools is the *Rayleigh criterion* (3.3.7). Another is the degree of focus of the objective on the surface.

Note 4 to entry: One factor related to the value of D_{LIM} for contact tools is the stylus tip radius, r_{TIP} (see ISO 25178-601).

Note 5 to entry: Other terms related to lateral period limit are structural resolution and topographic spatial resolution

3.1.17
maximum local slope

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

Note 1 to entry: The term *local slope* is defined in ISO 4287:1997, 3.2.9.

3.1.18
instrument transfer function

ITF

f_{ITF}

function of spatial frequency describing how a surface topography measuring instrument responds to an object surface topography having a specific spatial frequency

Note 1 to entry: Ideally, the ITF tells us what the measured amplitude of a sinusoidal grating of a specified spatial frequency, v, would be relative to the true amplitude of the grating.

Note 2 to entry: For several types of optical instruments, the ITF may be a nonlinear function of height except for heights much smaller than the optical wavelength.

3.1.19
hysteresis

x_{HYS}, y_{HYS}, z_{HYS}

property of measuring equipment or characteristic whereby the indication of the equipment or value of the characteristic depends on the orientation of the preceding stimuli

Note 1 to entry: Hysteresis can also depend, for example, on the distance travelled after the orientation of stimuli has changed.

Note 2 to entry: For lateral scanning systems, the hysteresis is mainly a repositioning error.

[SOURCE: ISO 14978:2006, 3.24]

3.1.20
metrological characteristic

<measuring equipment> characteristic of measuring equipment, which may influence the results of measurement

Note 1 to entry: Calibration of metrological characteristics may be necessary.

Note 2 to entry: The metrological characteristics have an immediate contribution to measurement uncertainty.

Note 3 to entry: Metrological characteristics for areal surface texture measuring instruments are given in Table 1.

[ISO 14978:2006, 3.12, modified — The original notes have been replaced.]

Table 1 — List of metrological characteristics for surface texture measurement methods

Metrological characteristic	Symbol	Definition	Main potential error along
Amplification coefficient	α_x, α_y, α_z	3.1.8 (see Figure 3)	x, y, z
Linearity deviation	l_x, l_y, l_z	Maximum local difference between the line from which the amplification coefficient is derived (see Figure 3, key item 5) and the response curve (see Figure 3, key item 4)	x, y, z
Residual flatness	z_{FLT}	Flatness of the areal reference	z
Measurement noise	N_{M}	3.1.10	z
Lateral period limit	D_{LIM}	3.1.16	z
Perpendicularity	Δ_{PERxy}	Deviation from 90° of the angle between the x- and y-axes	x, y

3.2 Terms and definitions related to x- and y-scanning systems

3.2.1
areal reference guide
component(s) of the instrument that generate(s) the reference surface, in which the probing system moves relative to the surface being measured according to a theoretically exact trajectory

Note 1 to entry: Note to entry: In the case of *x*- and *y*-scanning areal surface texture measuring instruments, the areal reference guide establishes a reference surface [ISO 25178-2:2012, 3.1.8]. It can be achieved through the use of two linear and perpendicular reference guides [ISO 3274:1996, 3.3.2] or one reference surface guide.

3.2.2
lateral scanning system
system that performs the scanning of the surface to be measured in the (x,y) plane

Note 1 to entry: 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 2.

Note 2 to entry: When a measurement consists of a single field of view of a microscope, *x*- and *y*-scanning is not used. However, when several fields of view are linked together by *stitching* methods [2], the system is considered to be a scanning system.

Table 2 — Possible different configurations for reference guides (*x* and *y*)

		Drive unit				
		Two reference guides (*x* and *y*)			**One areal reference guide**	
		P*x* o C*y*	P*x* o P*y*	C*x* o C*y*	P*xy*	C*xy*
Probing system	A: without arcuate error correction	P*x* o C*y*-A	P*x* o P*y*-A	C*x* o C*y*-A	P*xy*-A	C*xy*-A
	S: without arcuate error or with arcuate error corrected	P*x* o C*y*-S	P*x* o P*y*-S	C*x* o C*y*-S	P*xy*-S	C*xy*-S
For two given functions, f and g, f o g is the combination of these functions. P*x* = probing systems moving along the *x*-axis P*y* = probing systems moving along the *y*-axis C*x* = component moving along the *x*-axis C*y* = component moving along the *y*-axis						

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

3.2.4
lateral position sensor
component of the drive unit that provides the lateral position of the measured point

Note 1 to entry: 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 micrometre screw.

3.2.5
speed of measurement
V_x
speed of the probing system relative to the surface to be measured during the measurement along the *x*-axis

[SOURCE: ISO 25178-601:2010, 3.4.13]

3.2.6
static noise
N_S
combination of the instrument and environmental noise on the output signal when the instrument is not scanning laterally

Note 1 to entry: Environmental noise is caused by e.g. seismic, sonic and external electromagnetic disturbances.

Note 2 to entry: Notes 2 and 3 in 3.1.9 apply to this definition.

Note 3 to entry: Static noise is included in *measurement noise* (3.1.10)

3.2.7
dynamic noise
N_D
noise occurring during the motion of the drive units on the output signal

Note 1 to entry: Notes 2 and 3 in 3.1.9 apply to this definition.

Note 2 to entry: Dynamic noise includes the static noise.

Note 3 to entry: Dynamic noise is included in *measurement noise* (3.1.10).

3.3 Terms and definitions related to optical systems

3.3.1
light source
optical device emitting an appropriate range of wavelengths in a specified spectral region

3.3.2
measurement optical bandwidth
$B_{\lambda 0}$
range of wavelengths of light used to measure a surface

Note 1 to entry: Instruments may be constructed with light sources with a limited optical bandwidth and/or with additional filter elements to further limit the optical bandwidth.

3.3.3
measurement optical wavelength
λ_0
effective value of the wavelength of the light used to measure a surface

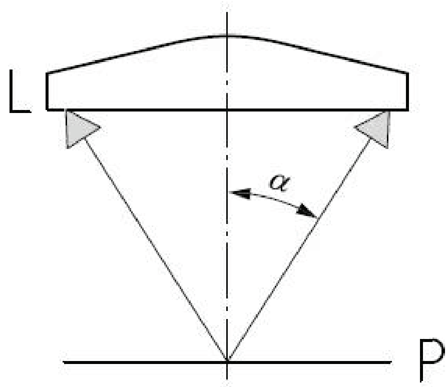
Note 1 to entry: The measurement optical wavelength is affected by conditions such as the light source spectrum, spectral transmission of the optical components, and spectral response of the image sensor array.

3.3.4
angular aperture
angle of the cone of light entering an optical system from a point on the surface being measured

[SOURCE: ISO 25178-602:2010, 3.3.3]

3.3.5
half aperture angle
α
one half of the angular aperture

Note 1 to entry: This angle (see Figure 8) is sometimes also called *half cone angle.*



Key

L lens or optical system

P focal point

α half aperture angle

Figure 8 — Half aperture angle

3.3.6
numerical aperture
A_N
sine of the half aperture angle multiplied by the refractive index n of the surrounding medium ($A_N = n \sin\alpha$)

Note 1 to entry: In air for visible light, $n \cong 1$.

Note 2 to entry: The numerical aperture is dependent on the wavelength of light. Typically the numerical aperture is specified for the wavelength that is in the middle of the measurement optical bandwidth.

3.3.7
Rayleigh criterion
quantity characterizing the spatial resolution of an optical system given by the separation of two point sources at which the first diffraction minimum of the image of one point source coincides with the maximum of the other

Note 1 to entry: For a theoretically perfect, incoherent optical system with a filled objective pupil, the Rayleigh criterion of the optical system is equal to 0,61 λ_0/A_N.

Note 2 to entry: This parameter is useful for characterizing the instrument response to features with heights much less than λ_0 for optical 3D metrology instruments.

3.3.8
Sparrow criterion
quantity characterizing the spatial resolution of an optical system given by the separation of two point sources at which the second derivative of the intensity distribution vanishes between the two imaged points

Note 1 to entry: For a theoretically perfect, incoherent optical system with a filled objective pupil, the Sparrow criterion of the optical system is equal to 0,47 λ_0/A_N, approximately 0,77 times the *Rayleigh criterion* (3.3.7).

Note 2 to entry: This parameter is useful for characterizing the instrument response to features with heights much less than λ_0 for optical 3D metrology instruments.

Note 3 to entry: Under the same measurement conditions as the notes above, the Sparrow criterion is nearly equal to the spatial period of 0,50 λ_0/A_N, for which the theoretical instrument response falls to zero.

3.4 Terms and definitions related to optical properties of workpiece

3.4.1
surface film
surface layer
material deposited onto another surface whose optical properties are different from that surface

3.4.2
thin film
film whose thickness is such that the top and bottom surfaces cannot be readily separated by the optical measuring system

Note 1 to entry: For some measurement systems with special properties and algorithms, the thicknesses of thin films may be derived.

3.4.3
thick film
film whose thickness is such that the top and bottom surfaces can be readily separated by the optical measuring system

3.4.4
optically smooth surface
surface from which the reflected light is primarily specular and scattered light is not significant

Note 1 to entry: An optically smooth surface behaves locally like a mirror.

Note 2 to entry: A surface that acts as optically smooth under certain conditions, such as wavelength range, numerical aperture, pixel resolution, etc., can act as optically rough when one or more of these conditions change.

3.4.5
optically rough surface
surface that does not behave as an optically smooth surface, i.e. where scattered light is significant

Note 1 to entry: A surface that acts as optically rough under certain conditions, such as wavelength range, numerical aperture, pixel resolution, etc., can act as optically smooth when one or more of these conditions change.

3.4.6
optically non-uniform material
sample with different optical properties in different regions

Note 1 to entry: An optically non-uniform material may result in measured phase differences across the field of view that can be erroneously interpreted as differences in surface height.

3.5 Terms and definitions specific to point autofocus profiling

3.5.1
probing system
<surface texture, point autofocus probe> components of the instrument called *point autofocus probe*, consisting of an autofocus optical system, an autofocus mechanism and an electronic controller

3.5.2
point autofocus probe
device that converts the height of a point on a surface into a signal during measurement using the autofocus function

3.5.3
point autofocus profiling
surface topography measurement method whereby the local surface height is measured by automatically centring a focused light beam reflected from the sample onto a position sensitive detector as a function of surface height

[SOURCE: ISO 25178-6:2010, 3.3.11]

3.5.4
objective
objective lens that focuses the light source image on to the workpiece surface

3.5.5
autofocus sensor
optical sensor that detects a focal position using the reflected light from the workpiece surface

3.5.6
autofocus mechanism
autofocus driving mechanism that positions optical elements or the whole optical system

3.5.7
***z* position sensor**
sensor that measures the vertical position of the measured point

3.5.8
working distance
<point autofocus probe> distance measured along the optical axis between the element closest to the surface and the focus point on the surface

3.5.9
spot size
W_{spot}
<point autofocus probe> size that forms the focus image of the light source on the workpiece surface

3.5.10
focus range
range of *z* height, within which the focusing point exists

Note 1 to entry: Range where the autofocus sensor can detect the extreme defocused points.

3.5.11
vertical range
R_{VERT}
<point autofocus probe> measuring range that can output digital data with demonstrated measuring accuracy along a vertical direction in the movable range of the autofocus mechanism

3.5.12
measurable minimum reflection ratio
M_{REF}
minimum ratio of the reflected light intensity to the incident light intensity for a measurable workpiece surface

3.5.13
autofocus repeatability
R_{AF}
measurement repeatability of the autofocus function that does not include environmental noise

3.5.14
speckle noise
uneven reflected optical intensity generated by irregular micro-scale geometry within the spot size

4 Descriptions of the influence quantities

4.1 General

Point autofocus probe instruments provide a measurement of lateral (*x* and *y*) and height (*z*) values from which surface texture parameters are calculated. Point autofocus probe instruments use the following measurement process.

The instrument measures surface texture by automatically focusing a laser beam on a point on the workpiece surface, moving the workpiece surface in a fixed measurement pitch using an *x*-*y* scanning stage, and measuring the workpiece surface height at each focused point (see Annex A).

4.2 Influence quantities

Influence quantities for point autofocus probe instruments are given in Table 3. The table indicates the metrological characteristics (see 3.1.20 and Table 1) that are affected by deviations of influence quantities.

Table 3 — Influence quantities

Component	Element	Influence quantities		Metrological characteristic affected ...
Probing system	Light source	λ_0	Measurement optical wavelength	D_{LIM}
	Autofocus probe	W_{spot}	Spot size	D_{LIM}
		A_N	Numerical aperture	D_{LIM}
		M_{REF}	Measurable minimum reflection ratio	N_M
		R_{AF}	Autofocus repeatability	N_M
		D_z	Height digitisation step	N_M
Drive unit	Position sensor (linear scale, encoder, ...)	δ_x	x position sensor resolution	D_{LIM}
		δ_y	y position sensor resolution	D_{LIM}
		δ_z	z position sensor resolution	N_M
	Areal reference guide (height component)	$z_{STR(x)}$	Height component (z-axis direction) of the straightness of the stage movement along the x-axis	z_{FLT}
		$z_{STR(y)}$	Height component (z-axis direction) of the straightness of the stage movement along the y-axis	z_{FLT}
	Areal reference guide (lateral component)	$x_{STR(y)}$	Lateral component x of the straightness of the stage movement along the y axis (twist)	Δ_{PERxy}, l_y
		$y_{STR(x)}$	Lateral component y of the straightness of the stage movement along the x axis (twist)	Δ_{PERxy}, l_x
Instrument		D_x or D_y	Lateral sampling interval, equal to the lateral scanning pitch of the x-y scanning stage	D_{LIM}
		N_S	Static noise	N_M
		N_D	Dynamic noise	N_M
		N_{VIB}	Environmental Vibration: unwanted motion between the surface being measured and the optical system.	N_M
Sample		θ_{TLT}[a]	Tilt: relative angle between the optical axis of the system and the sample normal	α_x, α_y, α_z
		Φ_{DIS}[a]	The relative phase shift upon reflection of dissimilar materials	α_z
		T_{FLM}[a]	Thickness of transparent or semi-transparent films. These films typically have thickness comparable to the illumination wavelength. Note that thinner contamination or native oxide films do not necessarily affect the phase measurement process.	α_z

[a] These influence quantities affect the calculation of areal parameters but should not influence the metrological characteristics described in Table 1.

Annex A
(informative)

General principles

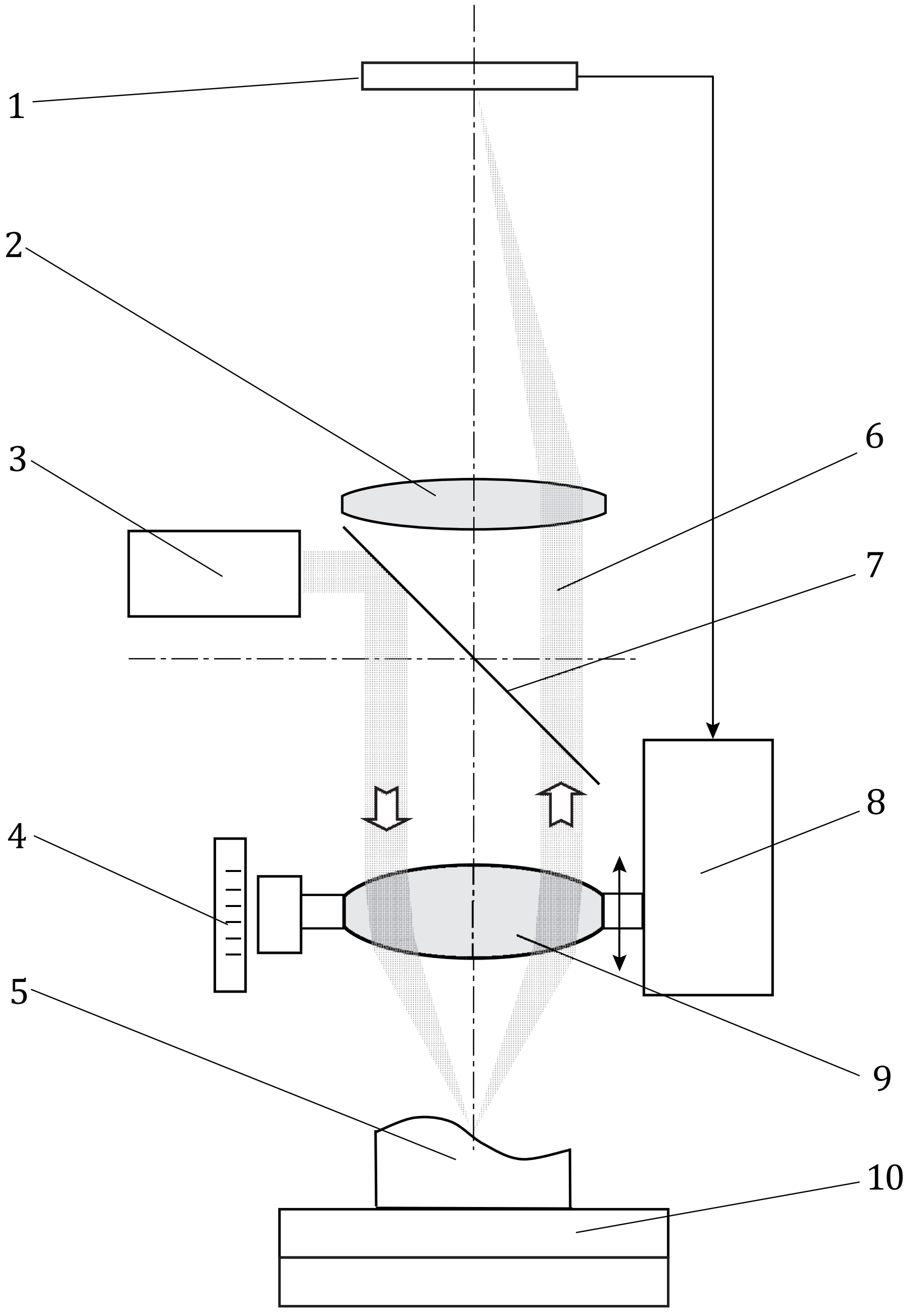
A.1 Introduction

A point autofocus profiling instrument measures surface texture by automatically focusing a laser beam on to a point on the specimen surface, moving the specimen surface with a fixed measurement pitch using an *x*-*y* scanning stage, and measuring the specimen surface height at each focused point.

A.2 Principle of a typical point autofocus probe

Figure A.1 illustrates a typical optical system for point autofocus probing. A laser beam that can be focused to a small spot is generally used for the light source. The laser beam passes through the left-hand side of the objective and focuses on to the workpiece surface at the centre of the optical axis. The reflected laser beam passes through the right-hand side of the objective and forms an image on the autofocus sensor after passing through the imaging lens. Figure A.1 shows the “in-focus” state.

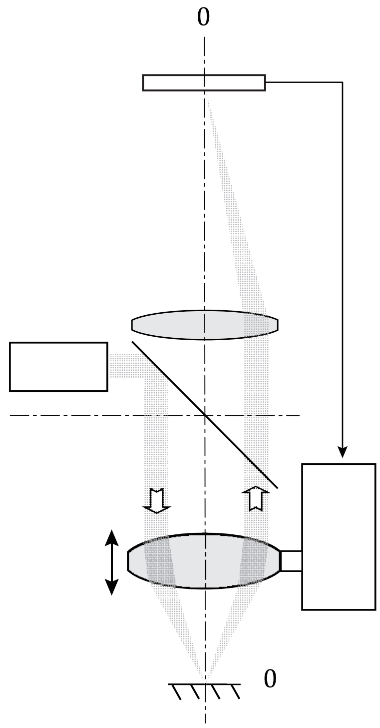
Figure A.2 shows the principle of the autofocus operation. 1) shows the in-focus state. 2) shows the defocus state. When the workpiece surface is displaced downward, the laser beam position on the autofocus sensor changes accordingly. The autofocus sensor detects the laser spot position; hence, the sensor detects the laser spot displacement and feeds this information back to the autofocus mechanism in order to adjust the objective to the in-focus position. The workpiece surface displacement ($z1$) is equal to the moving distance of the objective ($z2$), and the vertical position sensor (typically a linear position scale is used) obtains the height information of the workpiece (3). A distinctive feature of the point autofocus probe is that it is not influenced by the colour or reflection coefficients of workpiece surfaces since the autofocus sensor detects the position of the laser spot, not the intensity. Also, point autofocus probes have a wide measuring range and high resolution in the z coordinate, which is equivalent to the movable range and repeatability of the autofocus mechanism.



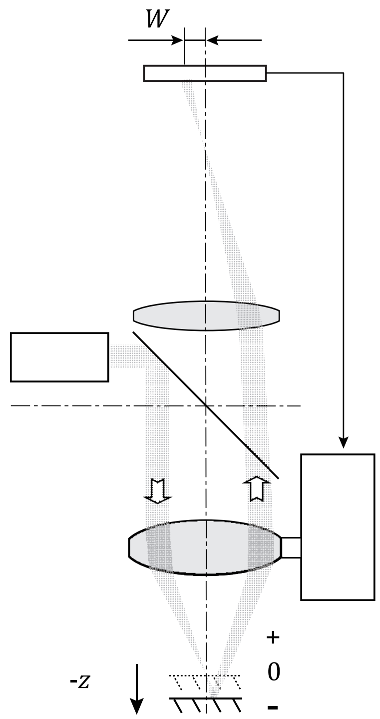
Key

1 autofocus sensor
2 image lens
3 light source
4 vertical positioning sensor
5 workpiece
6 laser beam
7 half mirror
8 autofocus mechanism
9 objective
10 *x-y* scanning stage

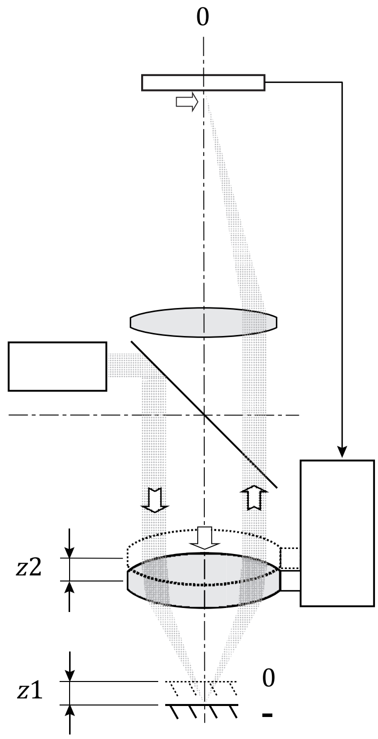
Figure A.1 — Schematic diagram of a typical point autofocus probe



a) In-focus



b) Defocus



c) Refocus

Figure A.2 — Principle of a typical point autofocus operation

Annex B
(informative)

Spot size and focal shift

The spot size not only determines the lateral resolution but also provides the focal shift parameter for surface measurement. When a parallel beam with a uniform intensity distribution enters from the back of the objective, the spot size (W_{spot}) at its focal plane is generally given by:

$$W_{spot} = \frac{1{,}22\lambda}{A_N}$$

where

λ is wavelength of the light source

A_N is the numerical aperture

However, in the case of a light source with a Gaussian intensity distribution, such as a laser, the spot size is expressed as a diameter, where the intensity is a specified fraction of the maximum intensity. A commonly used fraction is $1/e^2$ (≈13,5 %) of the maximum intensity (Figure B.1). The associated spot size is given by

$$W_{spot} = \frac{0{,}64\lambda}{A_N}$$

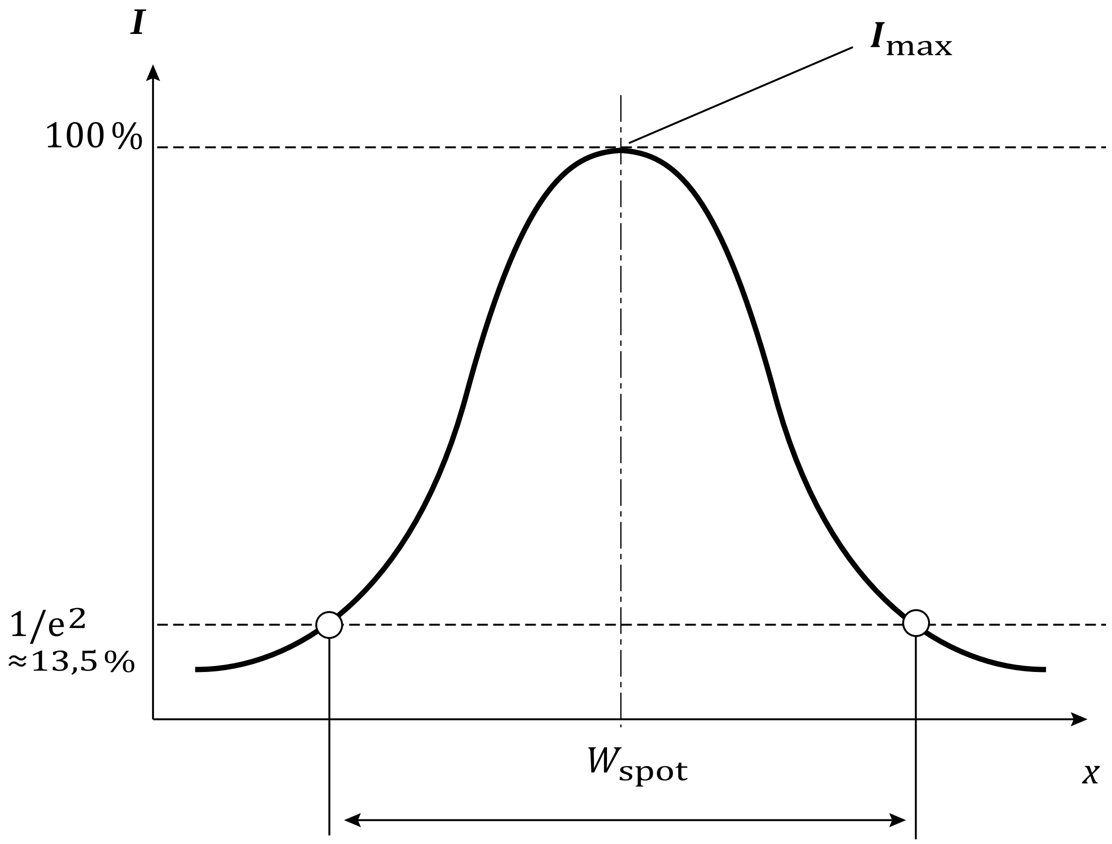
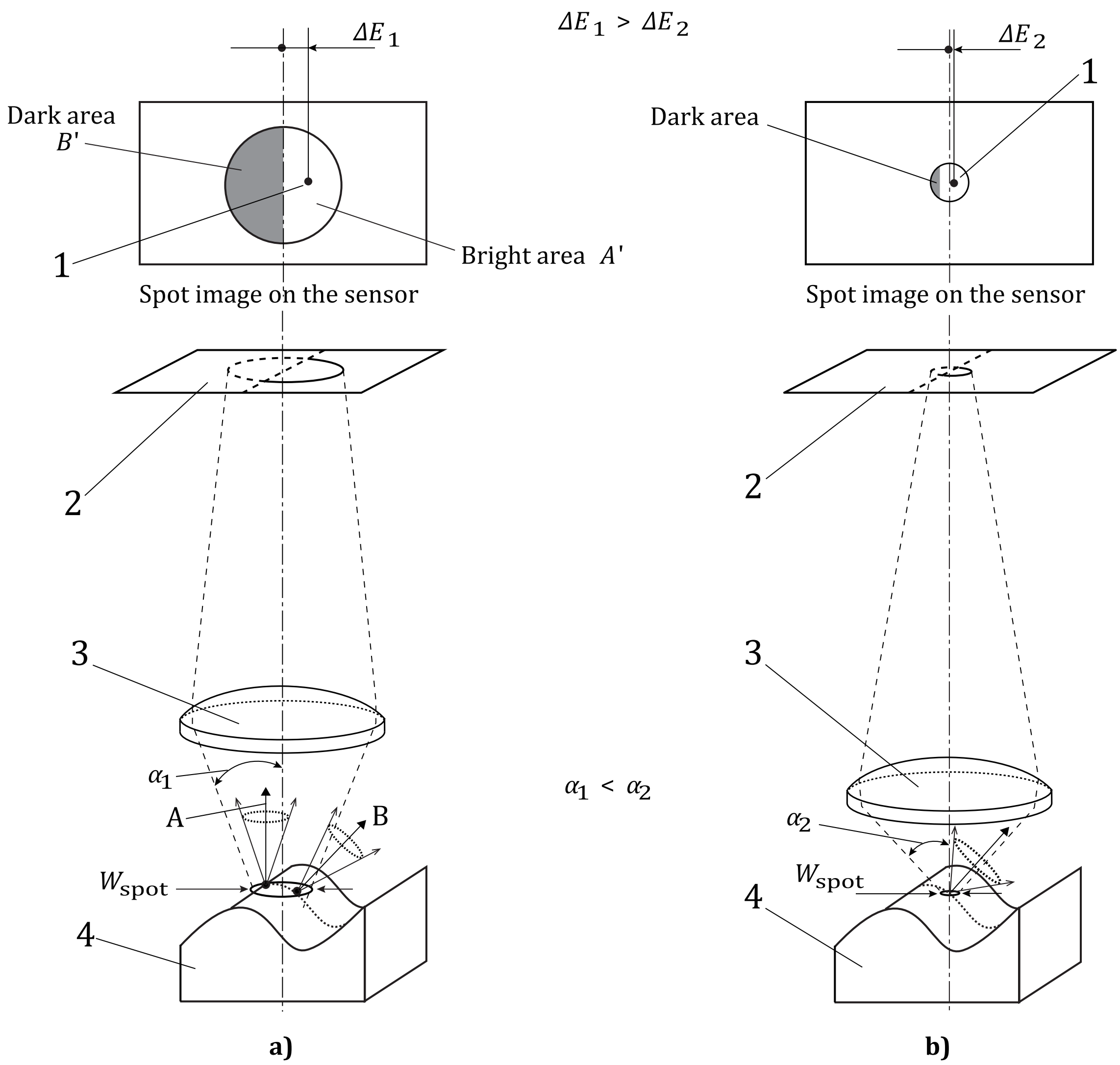


Figure B.1 — Spot size

Figure B.2 shows an example of focal shift factors caused by different spot sizes.

Figure B.2 a) shows a large spot image on the autofocus sensor resulting from reflection of the incident laser beam from an irregular workpiece surface. In this case the reflecting angle of ray (A) at the peak of the convex workpiece surface is less than the half aperture angle (α_1) and forms the image on the autofocus sensor that results in a bright area (A'). Conversely, the reflecting angle of ray (B) on the slope of the convex workpiece surface is greater than α_1, which causes ray (B) to miss the objective and thus form no image on the autofocus sensor resulting in the dark area (B'). This is how uneven optical intensity can occur within the spot area on the autofocus sensor. When the autofocus sensor detects the geometrical centre of the spot area, the focus position shifts to ΔE_1. This effect is a source of measurement error.

The half aperture angle (α_2) in the optical system in Figure B.2 b) is greater than α_1 in Figure B.2 a). Therefore, the autofocus sensor detects the ray on the slope of the convex workpiece surface, resulting in a smaller dark area and less variation of optical intensity in the spot area. In addition, a smaller spot size generates a smaller focus position shift, ΔE_2.



Key

1 geometrical centre of spot

2 autofocus sensor

3 objective

4 workpiece

α_1 half aperture angle

α_2 half aperture angle

W_{spot} spot size

A reflecting angle of ray

B reflecting angle of ray

Figure B.2 — Simplified diagram of the point autofocus optical system showing the spot size and focal shift

Annex C
(informative)

Beam offset direction and maximum acceptable local slope

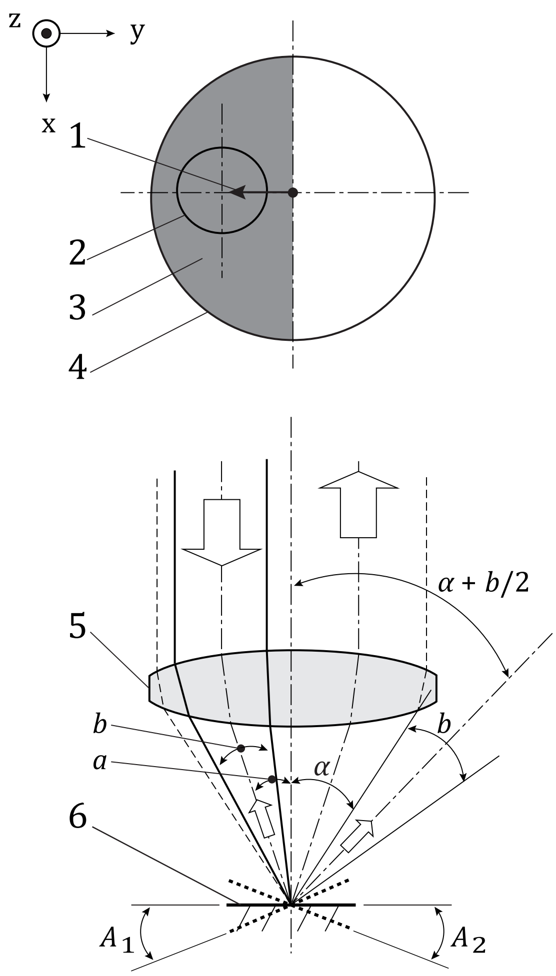
The maximum acceptable local surface slope that can be measured with a point autofocus sensor varies with the laser beam offset direction. Figure C.1 shows the laser beam path offset along the *y* coordinate direction. The maximum acceptable local slope angles parallel to the offset direction are A_1 and A_2 [Figure C.1. a)]. The maximum acceptable local slope angle perpendicular to the offset direction is A_3 [Figure C.1. b)]. The maximum acceptable local slope angles A_1, A_2 and A_3 are given by

$$A_1 < a$$

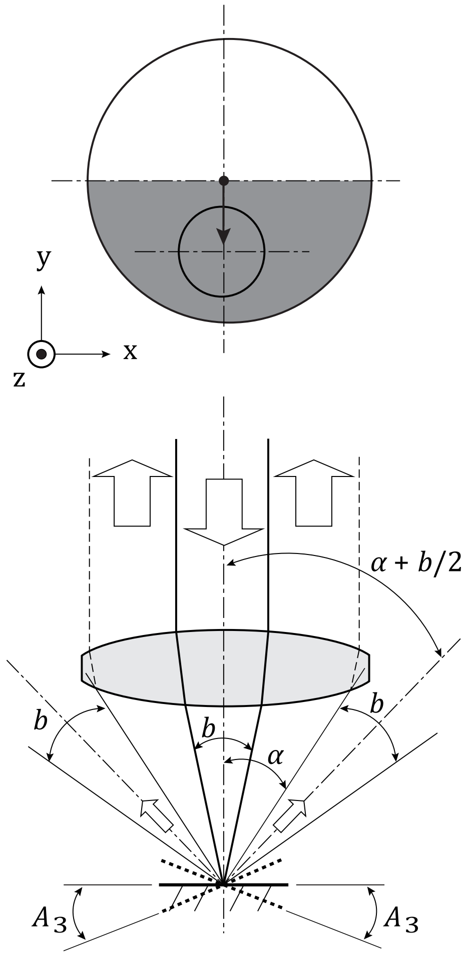
$$A_2 < \frac{\left(\alpha + \frac{b}{2} - a\right)}{2}$$

$$A_3 < \frac{\alpha}{2} + \frac{b}{4}$$

NOTE Greater slope angles are measurable if the surface roughness produces appreciable diffusely scattered light (see ISO 25178-602:2010, 3.4.14).



a) Parallel to offsite direction



b) Perpendicular to offsite direction

Key

1 offset direction
2 light beam
3 offset area
4 aperture
5 objective
6 plane mirror
a angle of incidence
b collection angle
α half aperture angle

Figure C.1 — Maximum acceptable local slope depends on offset direction

Annex D
(informative)

Features of an areal surface texture measuring instrument

D.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 D.1).

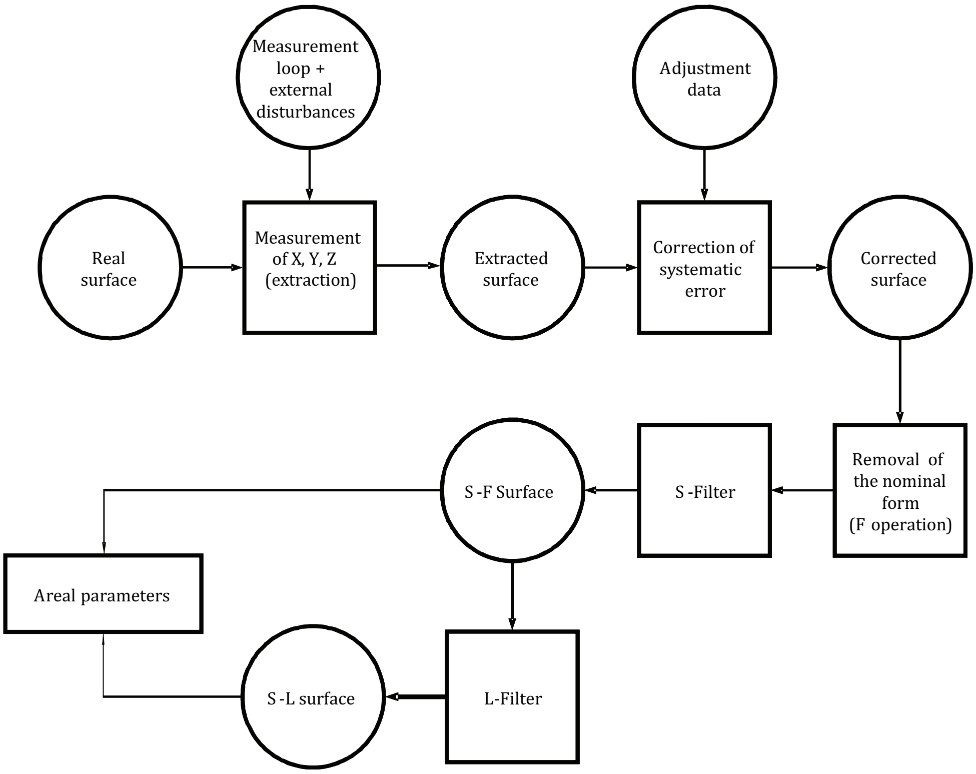


Figure D.1 — Typical measurement method applied to an areal surface texture measuring instrument

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.

D.2 Point autofocus areal surface texture measuring instrument

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

A point autofocus probe areal surface measuring instrument uses a non-contact probing system which is based on the point autofocus principle for determining surface heights.

This type of instrument is also able to perform profile measurements.

The range of height measurement is determined by the movable range of the autofocus positioning mechanism and the working distance of the objective. A typical measuring range is from several millimetres to several tens of millimetres.

D.3 Measurement process

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

a) the probing system performs profile acquisition through continuous measurement along the *x*-axis over a length l_x;

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

c) the perpendicular drive unit along the *y*-axis steps by one sampling interval distance along the *y*-axis;

d) these operations are repeated until the measurement is completed;

e) 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.

NOTE It is also possible to perform the measurement without returning to the starting position after each profile. The next profile may be scanned in the opposite direction from that of the previous scan. In this case, it is recommended to check that the repositioning hysteresis is compatible with the intended measurement uncertainty. Nevertheless, a typical probing system is generally designed for measuring in only one direction.

Recommended values for *m*, *n*, l_x and l_y are found in ISO 25178-3.

Annex E
(informative)

Others: Non-measured point (autofocus error)

Each time the sensor is not able to assess the *z* position of a point on the surface, the point is marked as an "autofocus error" (i.e. no information is provided for this point).

An autofocus error point is usually generated when the point autofocus system cannot identify any spots on the autofocus sensor, generally due to one of the conditions given in Table E.1.

Table E.1 — Possible explanations for why there can be non-measured points

Autofocus error	Condition	Cause	Solution
Dim	Insufficient reflected optical intensity	1. Low reflection coefficient for the workpiece surface 2. High slope angle 3. Sudden height transition 4. No workpiece	1. Increase light source power 2. None 3. Extend the autofocus range 4. None
Hunting	Autofocus mechanism oscillates near the focus position	1. Servo-gain of the autofocus mechanism is set too high 2. The phase of the secondary reflected ray detected is the reverse of the primary ray	1. Lower servo-gain 2. Avoid detection of the secondary reflected ray
Shadowing	The dark area where the laser beam does not fall	Dead angle	None

NOTE Non-measured points can be reconstructed by an interpolation technique.

Annex F
(informative)

Relation to the GPS matrix

For full details about the GPS matrix model, see ISO/TR 14638.

The ISO/GPS Masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this standard is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this standard and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this standard, unless otherwise indicated.

F.1 Information about this part of ISO 25178 and its use

This part of ISO 25178 gives the metrological characteristics of point autofocus profiling areal surface texture instruments.

F.2 Position in the GPS matrix model

This part of ISO 25178 is a general GPS standard, which influences chain link 5 of the chain of standards on roughness profile, waviness profile, primary profile and areal surface texture in the GPS matrix structure, as illustrated in Figure F.1.

Fundamental GPS standards

Global GPS standards

General GPS matrix						
Chain link number	1	2	3	4	5	6
Size						
Distance						
Radius						
Angle						
Form of line independent of datum						
Form of line dependent of datum						
Form of surface independent of datum						
Form of surface dependent of datum						
Orientation						
Location						
Circula run-out						
Total run-out						
Datums						
Roughness profile						
Waviness profile						
Primary profile						
Surface imperfections						
Edges						
Areal surface texture						

Figure F.1 — Position in the GPS-Matrix model

F.3 Related standards

The related international standards are those of the chains of standards indicated in Figure F.1.

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