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ISO 10110-8

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Optics and photonics — Preparation of drawings for optical elements and systems —

Part 8: **Surface texture**

Optique et photonique — Indications sur les dessins pour éléments et systèmes optiques —

Partie 8: État de surface

Reference number
ISO 10110-8:2019(E)

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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.

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 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and Photonics*, Subcommittee SC 1, *Fundamental Standards*.

This third edition cancels and replaces the second edition (ISO 10110-8:2010), which has been technically revised.

The main changes compared to the previous edition are as follows:

a) a drawing notation and interpretation is provided for the following additional areal terms: *Sa*, *Sq*, *SΔq*, and APSD;

b) the following terms are explicitly allowed: *Ra*, *Rsk*, *Rku*, and *ACV*, which also required the addition of more definitions, and additional examples.

c) this edition removes the reference to micro-defects as a method of determining polish grade, and replaces it with specific rms roughness values.

A list of all parts in the ISO 10110 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Optics and photonics — Preparation of drawings for optical elements and systems —

Part 8: **Surface texture**

1 Scope

This document specifies rules for the indication of the surface texture of optical elements, in the ISO 10110 series, which standardizes drawing indications for optical elements and systems. Surface texture is the characteristic of a surface that can be effectively described with statistical methods. Typically, surface texture is associated with high spatial frequency errors (roughness) and mid-spatial frequency errors (waviness).

This document is primarily intended for the specification of polished optics.

This document describes a method for characterizing the residual surface that is left after detrending by subtracting the surface form. The control of the surface form specified in ISO 10110-5, ISO 10110-12, and ISO 10110-19 is not specified in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1302:2002, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 10110-1, *Optics and photonics — Preparation of drawings for optical elements and systems, Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4287 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
surface texture
characteristic relating to the profile of an optical surface that can be effectively described with statistical methods

Note 1 to entry: Localized defects, known as surface imperfections, are specified in ISO 10110-7.

3.2
matt surface
optical surface for which the height variation of the surface texture is not considerably smaller than the wavelength of light

Note 1 to entry: Matt surfaces are usually produced by brittle grinding of glass or other dielectric material, or by etching.

3.3
optically smooth surface
optical surface for which the height variation of the surface texture is considerably smaller than the wavelength of light

Note 1 to entry: Due to the smaller height variation, the amount of light scattered is small.

Note 2 to entry: Optically smooth surfaces are usually produced by polishing or moulding.

3.4
reference profile
trace on which the probe of contact (stylus) instruments is moved within the intersection plane along the guide

[SOURCE: ISO 3274:1996, 3.1.2, modified — "of contact (stylus) instruments" has been inserted and the Note to entry has been omitted.]

3.5
total profile
digital form of the traced profile relative to the reference profile, with the vertical and horizontal coordinates assigned to each other

[SOURCE: ISO 3274:1996, 3.1.3, modified — The Note to entry has been omitted.]

3.6
profile filter
filter which separates profiles into longwave and shortwave components

Note 1 to entry: There are three filters used in instruments for measuring roughness, waviness and primary profiles (see Figure 1). They all have the same transmission characteristics, defined in ISO 11610-21, but different cut-off wavelengths.

[SOURCE: ISO 4287:1997, 3.1.1, modified — In the definition, ISO 11562 has been deleted. In Note 1 to entry, ISO 11562 has been replaced by ISO 11610-21.]

3.7
profile filter λ_s
filter which defines the intersection between the roughness and the even shorter wave components present in a surface (see Figure 1)

[SOURCE: ISO 4287:1997, 3.1.1.1, modified — "λ_s profile filter" has been replaced by "profile filter λ_s".]

3.8
profile filter λ_c
filter which defines the intersection between the roughness and waviness components (see Figure 1)

[SOURCE: ISO 4287:1997, 3.1.1.2, modified — "λ_c profile filter" has been replaced by "profile filter λ_c".]

3.9
profile filter λ_f
filter which defines the intersection between the waviness and the even longer wave components present in a surface (see Figure 1)

[SOURCE: ISO 4287:1997, 3.1.1.3, modified — "λ_f profile filter" has been replaced by "profile filter λ_f".]

3.10
primary profile
total profile after application of the short wavelength filter, λ_s

[SOURCE: ISO 3274:1996, 3.1.4, modified — The Note to entry has been removed.]

3.11
roughness profile
profile derived from the primary profile by suppressing the longwave component using the profile filter λ_c; this profile is intentionally modified (see Figure 1)

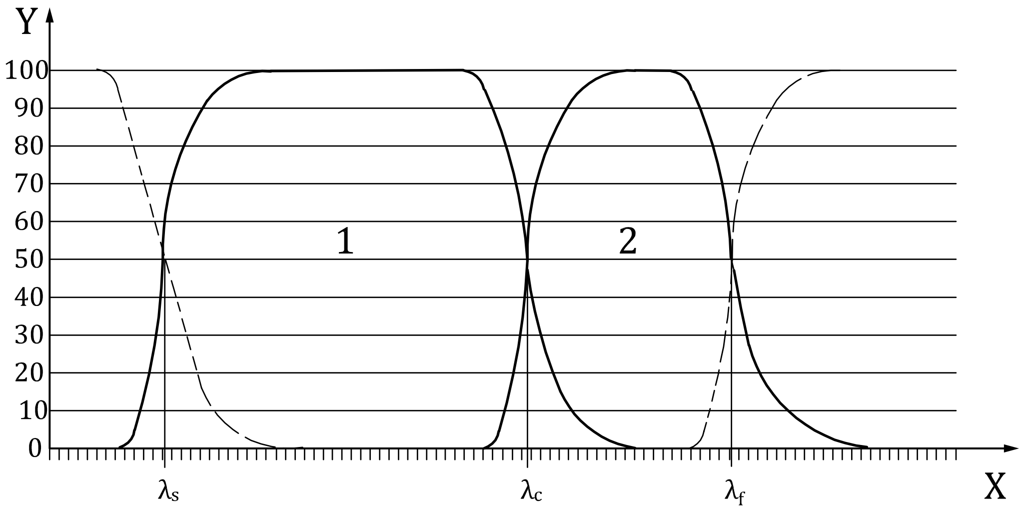
[SOURCE: ISO 4287:1997, 3.1.6, modified — The Notes to entry have been removed.]

3.12
waviness profile
profile derived by subsequent application of the profile filter λ_f and the profile filter λ_c to the primary profile, suppressing the longwave component using the profile filter λ_f, and suppressing the shortwave component using the profile filter λ_c

Note 1 to entry: This profile is intentionally modified (see Figure 1).

Note 2 to entry: Most optical components require at most two surface texture bands; typically defined as roughness and waviness. The designation of these two bands as “roughness” and “waviness” is arbitrary. In some applications it will be desirable to segment the surface texture into three or more bands; in this case additional bands can be added using the same profile segmentation logic provided here. The additional bands can be distinguished by an index value (e.g. *Wq*1, *Wq*2, *Sq*1, *Sq*2) if desired.

[SOURCE: ISO 4287:1997, 3.1.7, modified — The notes to entry have been omitted, "(see Figure 1)" and new Notes to entry have been added.]



Key

X wavelength
Y transmission %
1 roughness profile
2 waviness profile

NOTE The cut-offs are not drawn to scale.

Figure 1 — Transmission characteristics of roughness and waviness profile

3.13
spatial wavelength
peak to peak scale-length of a sinusoidal surface undulation, especially when viewed in a Fourier transform

Note 1 to entry: See ISO 3274 and ISO 16610-21 for more information.

3.14
spatial band
range of surface spatial wavelengths which are to be included in the specification, defined as the band of sinusoidal profile wavelengths which are transmitted at more than 50 % when two phase correct filters of different cut-off wavelength are applied to the profile

Note 1 to entry: This is equivalent to the term "transmission band" as used in ISO 1302. In order to prevent confusion with spectral transmission bands, the term "spatial band" is used instead of "transmission band" in this document.

Note 2 to entry: Profile filters act as longpass or shortpass filters. That is, the profile filter with the shorter cut-off wavelength retains the long wave profile component (longpass) and the profile filter with the longer cut-off wavelength retains the short wave profile component (shortpass).

3.15
sampling length
length in the direction of the X-axis used for identifying the irregularities characterizing the profile under evaluation

Note 1 to entry: The sampling length for the roughness and waviness profile is numerically equal to the characteristic wavelength of the profile filters λ_c and λ_f, respectively. The sampling length for the primary profile is equal to the evaluation length.

[SOURCE: ISO 4287:1997, 3.1.9, modified — The symbols l_p, l_r, l_w have been removed.]

3.16
evaluation length
length in the direction of the X-axis used for assessing the profile under evaluation

Note 1 to entry: The evaluation length may contain one or more sampling lengths.

Note 2 to entry: For default evaluation lengths, see ISO 4288: 1996, 4.4. ISO 4288 does not give a default evaluation length for *W*-parameters.

[SOURCE: ISO 4287:1997, 3.1.10, modified — The symbol l_n has been removed.]

3.17
profile ordinate value
$Z(x)$
height of assessed profile at any position x

Note 1 to entry: This is equivalent to the term "ordinate value" as used in ISO 4287. In order to differentiate the term from the equivalent areal definition, the term "profile ordinate value" is used in this document.

3.18
surface ordinate value
$Z(x,y)$
height of assessed surface at any position x, y

3.19
detrending
extracting long scale form error from a measurement to mitigate spectral leakage

Note 1 to entry: Detrending is usually applied to the input data to avoid masking low-amplitude high frequency errors with the large amplitude, low frequency surface form errors. The resultant set of data points represents the residual surface. See also 3.21, 3.22, and 3.23.

Note 2 to entry: For the purposes of this document, the surface form used for detrending is a polynomial fit to the measured surface with an order sufficient to remove all spatial wavelengths longer than the spatial band of the specification.

3.20
measured surface
Z_m
function of raw surface measurement data, prior to detrending

3.21
surface form
Z_f
fit to a measured surface

Note 1 to entry: In a typical 2D polynomial fit to a surface, the surface polynomial can be written as a Zernike polynomial or another polynomial equation. For example in Cartesian coordinates:

$$Z_f(x,y)=\sum_{i=1}^{p}\sum_{j=1}^{q}C_{ij}P_{ij}(x,y) \tag{1}$$

where P_{ij} is a polynomial function of order p,q that describes the underlying shape of the surface.

3.22
residual surface
Z
function that is calculated by subtracting the surface form Z_f from a measured surface Z_m

Note 1 to entry: For example in 2D, this is expressed mathematically as: $Z(x,y) = Z_m(x,y) - Z_f(x,y)$ or in polar coordinates $Z(r,\theta) = Z_m(r,\theta) - Z_f(r,\theta)$.

Note 2 to entry: Neglecting correction factors for instrument response, the residual surface is taken as the surface height data.

3.23
average roughness
Ra
arithmetic mean deviation of the roughness profile within the sampling length

3.24
rms roughness
Rq
root mean square value of the height of the roughness profile within the sampling length

3.25
area average roughness
Sa
arithmetic mean deviation of the surface within the sampling area

3.26
area rms roughness
Sq
root mean square value of the height of the surface within the sampling area

3.27
average waviness
Wa
arithmetic mean deviation of the waviness profile within the sampling length

3.28
rms waviness
Wq
root mean square value of the height of the waviness profile within the sampling length

3.29
power spectral density
PSD
squared magnitude of the Fourier transform of the residual surface height function along one dimension using an appropriate weighting function

Note 1 to entry: The PSD describes surface texture in a spatial frequency context allowing the waviness or ripples in the surface to be described and controlled.

Note 2 to entry: An alternative and analogous function for describing and controlling surface texture in a spatial frequency context is the Auto-Covariance or ACV, which is given by the overlap integral of shifted and unshifted 1D profiles over the evaluation length.

3.30
area power spectral density
APSD
squared magnitude of the two-dimensional Fourier transform of a two-dimensional residual surface height function using an appropriate weighting function

3.31
local slope
$\frac{dz}{dx}$
slope of the assessed profile at a position x_i

Note 1 to entry: The numerical value of the local slope, and thus the parameters, $R\Delta q$ and $W\Delta q$, depends critically on the ordinate spacing Δx.

Note 2 to entry: A formula for estimating the local slope is

$$\frac{dz_i}{dx} = \frac{1}{60\Delta x}\left(z_{i+3} - 9z_{i+2} + 45z_{i+1} - 45z_{i-1} + 9z_{i-2} - z_{i-3} \right) \quad (2)$$

The above formula should be used for the sample spacing stipulated in ISO 3274 for the filter used, where z_i is the height of the i^{th} profile point and Δx is the spacing between adjacent profile points.

Note 3 to entry: The local slope is unitless, however we express the slope as the arctangent of the surface slope in microradians.

Note 4 to entry: This differencing calculation always results in the loss of data points at each end of the slope profile.

[SOURCE: ISO 4287:1997, 3.2.9, modified — The symbol dZ/dX to the term was changed to $\frac{dz}{dx}$. In Note 1 $P\Delta q$ has been removed; the Notes 2 and 3 to entry have been added and the Figure has been removed.]

3.32
rms slope
$R\Delta q$
root mean square value of the local slope within the sampling length

Note 1 to entry: The rms slope is expressed in microradians.

3.33
area rms slope
*S*Δ*q*
root mean square value of the local slope within the sampling area

Note 1 to entry: The area rms slope is expressed in microradians.

3.34
surface lay symbol
symbol indicating the lay of the surface profile parameter

Note 1 to entry: According to ISO 1302:2002, Table 2, the following symbols are used for surface lay; R (radial), C (circular), X (crossed), = (parallel to projection), ⊥ (perpendicular to projection), etc.

4 Description of surface texture

4.1 General

Surface texture is a global statistical characteristic of the profile of the optical surface. It is assumed for this document that the character and magnitude of the texture in any one area of the surface is similar to all other areas within the effective aperture of the same surface. This assumption is made so that a measurement made in one part of an indicated test region or surface can be considered representative of the entire test region or surface.

Unless stated otherwise, the indication of surface texture applies to surfaces before coating. This is an exception to the general statement in ISO 10110-1:2019, Clause 4, paragraph 1.

Materials having a crystal structure and production processes such as diamond turning can give rise to non-random surface texture. Care should be used in applying statistical surface properties for surface texture with these types of surfaces.

Because the magnitude of the measured roughness is a function of the spatial wavelengths considered, this document provides for the indication of the spatial band.

This document makes use of the terminology of profilometry, as specified in ISO 4287. Although the main effect of surface roughness is optical scattering, no reference is made to scattering measurements because there are causes of scattering other than texture (details of the relationship between surface texture and optical scattering are given in References [7] to [17]). Although the terminology in this document is that of profilometry, areal measurements (that is, measurements over a specified area) can also be used to characterise surface texture.

Surface texture specifications are applicable to matt surfaces as well as to optically smooth surfaces made by polishing or moulding. In this document, texture also refers to statistical properties of micro-roughness. Surface texture also refers to other statistical properties of the surface of longer scale-lengths, such as mid-spatial frequency waviness, which can be specified using root mean square (rms) roughness, rms slope, PSD and other statistical methods.

Depending on the application of a surface and the magnitude of surface height variation, one or more methods outlined below can be appropriate for describing surface texture numerically.

In calculating any statistical surface property, care should be taken regarding the spatial wavelength ranges over which the calculation is to be made. Both limits of the spatial band, in a long-scale length sense and a short-scale length sense, should be carefully considered. Significant errors can be introduced in the process of bandpass filtering or detrending of surface height data. See also References [18] to [20].

NOTE Computing the slope between adjacent sampled height points results in a large rms slope number that is usually dominated by instrument noise. To suppress the high frequency slope bias, one needs to first filter the height data with a low-pass filter before differentiating the height profile.

4.2 Description of matt surfaces

Matt surfaces shall be specified by indication of the rms height variation, *Rq* (as defined ISO 4287:1997, 4.2.2). This quantity depends on the range of spatial wavelengths to be considered. For this reason it is often necessary to specify the lower and upper limits of the spatial band.

If no spatial band is specified, the spatial band is assumed to be 0,002 5 mm to 0,08 mm.

In some cases, functional requirements can dictate a roughness criterion other than *Rq* or the other mentioned ones. In such cases, that other criterion shall be indicated as described in Clause 6 of ISO 1302:2002.

4.3 Description of optically smooth surfaces

4.3.1 Description methods

There are eight statistical methods of describing optically smooth surfaces which are explicitly defined in this document:

a) by means of the rms roughness, *Rq*;

b) by rms waviness, *Wq*;

c) by area rms roughness, *Sq*;

d) by indicating a polish grade P1, P2, P3, or P4;

e) by using a power spectral density (PSD) function;

f) by using an area power spectral density (APSD) function;

g) by specifying the rms slope, $R\Delta q$;

h) by specifying the area rms slope, $S\Delta q$.

These methods can be used in combination, and can be used over various spatial bands in the same region.

Alternative means of describing surface texture parameters of interest such as skew (*Rsk*), kurtosis (*Rku*), average roughness (*Ra*), roughness amplitude (*Rz*), average waviness (*Wa*) or autocovariance (*ACV*), or their areal equivalents area skew (*Ssk*), area kurtosis (*Sku*), area average roughness (*Sa*), area roughness amplitude (*Sz*), or area autocovariance (*AACV*) are not supported explicitly in this document, but may be used in an analogous manner. In these cases, the terms shall be defined in a note or reference on the drawing.

4.3.2 Rms roughness and rms waviness

Optically smooth surfaces are commonly specified by indication of the rms roughness, *Rq*. For longer spatial wavelength ranges, the rms waviness, *Wq*, is used.

If the surface height variations obey certain statistical distribution properties, the rms value, *Rq*, can be related to the magnitude of the optical scattering (see Annex A). The rms description is incomplete without indicating the spatial band limits.

In the event that no spatial band is specified, the spatial band is assumed to be 0,002 5 mm to 0,08 mm for roughness (e.g. *Rq*) and 0,08 mm to 2,5 mm for waviness (e.g. *Wq*).

NOTE These default values can be significantly different depending on the requirements for *Rq* or *Wq*. Therefore, the correct requirements for *Rq* or *Wq* are necessary to ensure that they are consistent with the spatial band of the specification.

The rms computed over the band can vary depending on specific filtering implementation. The default is that the metrologist may use their choice of filters unless the designer communicates a required filtering scheme.

Optically smooth surfaces can also be specified by indication of the areal rms, *Sq*. In the event that no spatial band is specified, the spatial band is assumed to be 0,002 5 mm to 0,08 mm for *Sq*.

4.3.3 Polish grades

Optically smooth surfaces may be specified by polish grade. Polish grade shall be determined by estimating the rms roughness, *Rq*, over the spatial frequencies 0,002 mm to 1,0 mm and comparing to Table 1 below. Only polish grades P1, P2, P3, and P4 are allowed.

Table 1 — Indication of the degree of smoothness by polish grade.

Polish grade designation	Estimated *Rq* over a spatial band of 0,002 mm to 1,0 mm
P1	≤8 nm
P2	≤4 nm
P3	≤2 nm
P4	≤1 nm

NOTE In previous versions of this standard, the polish grades were defined by a number of micro-defects per 10 mm trace.

4.3.4 Power spectral density (PSD) function

The PSD function is directly related to the frequency spectrum of the surface roughness. It allows a complete description of the surface texture characteristics, and is particularly useful for specifying super-smooth surfaces used in high technology applications, or in controlling mid-spatial frequency waviness on a surface. The PSD function description places no restrictions on the nature of, or the statistical properties of, the measured surface.

In the one-dimensional case, i.e. when the surface texture can be determined by measurement along a line on the surface, the PSD, expressed in $nm^2 \times mm$, can be modelled by Formula (3):

$$PSD = \frac{A}{f^B} \text{ for } \frac{1}{D} < f < \frac{1}{C} \tag{3}$$

where

f is the spatial frequency of the roughness or waviness, in inverse millimetres (mm^{-1});

B is the power to which the spatial frequency is raised;

C and D are the limits of the spatial band, in millimetres;

A is a constant.

The value of B shall be greater than zero. (For many real surfaces, $1 < B < 3$, see Reference [21]).

In this way, the surface texture requirement can be given by specifying the four values A, B, C and D, for which Formula (3) shall hold.

This one dimensional PSD can be calculated for any line of data. Such a line of data can be generated from 1D surface profilometry along any direction on a surface or by integrating an area PSD (described in 4.3.5) along one dimension. The calculation of the PSD from the line data is described in Reference [17] and elsewhere. Note that windowing of the data is required prior to calculation of the PSD; such windowing can be described in a note, or is assumed to be a Hamming filter as described in

Reference [20]. In the event that the directionality of the PSD is considered significant, a surface lay symbol is added to the surface texture specification.

The Cartesian 1D PSD of a 2D residual surface can be calculated from the measured surface by taking any single linear slice of the data, e.g. the slice of data for all $Z(x)$ at $y = 0$, or any vertical slice of the data, e.g. the slice of data for all $Z(y)$ at $x = 10$ mm. If a specific linear slice or set of linear slices is desired, this shall be indicated in a note. These line traces can be used as 1D residual data for PSD calculations. The result of the PSD calculation often is strongly dependent on the way the data is sliced.

The polar coordinate 1D PSD of a 2D residual surface can be calculated by taking a radial slice of the data, e.g. the slice of data for all $Z(r)$ at an angle $\theta = 0°$, or circumferential slice of the data, e.g. the slice of data for all $Z(\theta)$ at $r = 10$ mm. If a specific radial or circumferential slice or set of slices is desired, this shall be indicated in a note. These line traces can be used as 1D residual data for PSD calculations.

In the case of a circumferential slice, no windowing shall be applied.

If an optic is produced with a high likelihood of a center singularity, an inner diameter specification is recommended to avoid inclusion of the singularity in the average.

In the event that no spatial band is specified, the PSD is expected to be evaluated with a spatial band of 0,08 mm to 2,5 mm.

It is recommended that both limits of the spatial band are indicated in drawings, since spatial bands depend on the applications, wavelengths of use, and measurement equipment available.

4.3.5 Area power spectral density (APSD) function

The APSD function is a two-dimensional equivalent function to the one dimensional PSD described above.

In the two-dimensional case, i.e. when the surface texture is described as an array of points such as $Z(x,y)$ or $Z(r,q)$, the APSD, expressed in $\text{nm}^2 \times \text{mm}^2$, can be modelled by Formula (4):

$$APSD = \frac{A'}{\left(f_x^2 + f_y^2\right)^{\frac{B'}{2}}} \quad \text{for} \quad \frac{1}{C'} \le \sqrt{f_x^2 + f_y^2} \le \frac{1}{D'} \tag{4}$$

where

f_x, f_y are the spatial frequencies of the roughness or waviness, in inverse millimetres (mm^{-1});

B' is the power to which the spatial frequencies are raised;

C' and D' are the limits of the spatial band, in millimetres;

A' is a constant.

The value of B' shall be greater than zero. (For many real surfaces, $1 < B < 3$, see Reference [21]).

In this way, the surface texture requirement can be given by specifying the four values A', B', C' and D', for which Formula (4) shall hold.

This two-dimensional PSD can be calculated for any array of data. The calculation of the APSD from the array of data is described in Reference [17] and elsewhere. Note that windowing of the data is required prior to calculation of the PSD; such windowing can be described in a note, or is assumed to be a Hamming filter as described in Reference [20].

In the event that no spatial band is specified, the APSD is expected to be evaluated with a spatial band of 0,08 mm to 2,5 mm.

It is recommended that both limits of the spatial band are indicated in drawings, since spatial bands depend on the applications, wavelengths of use, and measurement equipment available.

NOTE The Cartesian 1D PSD can be calculated from the 2D APSD.

4.3.6 Rms slope

Optically smooth surfaces can also be specified by indication of the rms slope, $R\Delta q$.

If the surface slope variations obey certain statistical distribution properties, the rms value, $R\Delta q$, can be related to the image quality. The rms slope description is incomplete without indicating the spatial band limits.

In the event that no spatial band is specified, the surface slope spatial band is assumed to be 0,08 mm to 2,5 mm.

4.3.7 Area rms slope

Optically smooth surfaces can also be specified by indication of the area rms slope, $S\Delta q$.

The rms slope description is incomplete without indicating the spatial band limits.

In the event that no spatial band is specified, the surface slope spatial band is assumed to be 0,08 mm to 2,5 mm.

NOTE The area rms slope is defined as the rms of the local slope for all points within the areal field. That is, the Area rms slope is described by the following formula:

$$S\Delta q = \sqrt{\frac{1}{A}\iint\left[\left(\frac{\delta z}{\delta x}\right)^2 + \left(\frac{\delta z}{\delta y}\right)^2\right]\mathrm{d}x\mathrm{d}y} \, .$$

5 Indication in drawings

5.1 General

The symbols for indicating surface texture in drawings shall be in accordance with ISO 1302, if necessary, they can be modified as described below.

5.2 Indication for matt surface texture

The matt surface texture is indicated according to ISO 1302:2002, Clause 5, with the addition of the letter G [for “Ground”[1)]] above the horizontal line, as shown in Figure 2. The maximum permissible rms roughness Rq in micrometres, is indicated under the horizontal line. When a single value of Rq is given, it represents the upper limit of the surface roughness parameter. When the roughness is not permitted to lie below a certain value the upper and lower limits of the rms roughness is indicated with a bilateral tolerance according to ISO 1302:2002, 6.6. The upper limit of the rms roughness is identified with “U”, and the lower limit is identified with “L”. See Figure 2 b).

The spatial band can be indicated under the horizontal line, as shown in Figure 2 a). The upper limit is separated from the lower limit by a hyphen, and the spatial band is separated from the Rq notation by an oblique stroke (/). Spatial band limits shall be expressed in millimetres.

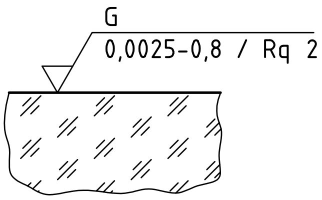
In the event that only the upper limit of the spatial band is to be specified, it is given as shown in Figure 2 b), after the hyphen.

EXAMPLE 1 0,002 5–0,8/*Rq* 2 (example where the spatial band is specified); see Annex B.

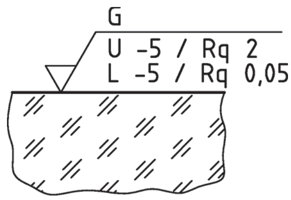
1) The letter “G” is used to denote all matt surfaces, including those not produced by brittle grinding, e.g. etching.

EXAMPLE 2 −0,8/*Rq* 2 (example where only the upper limit of the spatial band is specified); see Annex B.

NOTE The default evaluation length is five times the upper limit of the spatial band.



a) Indication for matt surface texture with *Rq* ≤ 2 mm over a spatial band of 0,002 5 mm to 0,8 mm



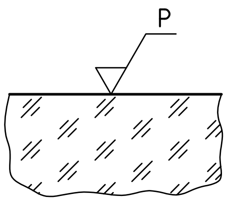
b) Indication for matt surface texture with 0,05 µm ≤ *Rq* ≤ 2 mm and an upper limit of spatial band of 5 mm

Figure 2 — Indication for matt surface texture

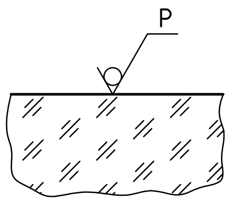
5.3 Indication for optically smooth surface texture

5.3.1 Optically smooth surface without quantitative modification

The indication for optically smooth surface texture shall include the letter P [for “Polished”[2)]] above the horizontal line, as shown in Figure 3. The use of the letter P alone means that no quantification of the surface texture is required but that the surface shall be smooth.



a) Polished surface



b) Moulded surface

Figure 3 — Indication for optically smooth surface texture without quantitative modifiers

5.3.2 Indication of smoothness by polish grade

The degree of surface smoothness can be indicated by placing a grade number between 1 and 4 to the right of the letter P, as shown in Figure 4. The range of the corresponding permissible roughness is given by grade in Table 1.

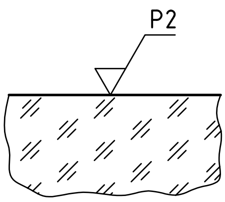


Figure 4 — Indication for optically smooth surface with quantitative modifiers; polish grade with *Rq* ≤ 0,004 µm over a spatial band of 0,002 mm to 1,0 mm

2) The letter “P” is used to indicate all optically smooth surfaces, including those not produced by polishing, e.g. moulded or float glass surfaces.

5.3.3 Indication of rms roughness and rms waviness

The rms roughness *Rq* or the rms waviness *Wq* is indicated by placing the maximum permissible value of the rms, expressed in micrometres, under the horizontal line, as shown in Figure 5. In this example, the rms roughness specification below the horizontal line is equivalent to a polish grade P3.

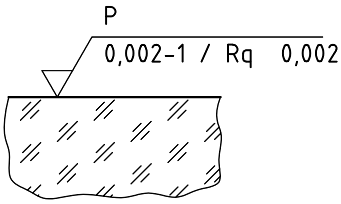


Figure 5 — Indication for optically smooth surface with quantitative modifiers; polish grade of *Rq* ≤ 0,002 µm over a spatial band of 0,002 mm to 1 mm

A lower limit of the spatial band or alternatively a spatial band can be indicated under the horizontal line, separated from the indication for rms roughness or rms waviness by an oblique stroke (/). Limits of spatial bands shall be given in mm.

EXAMPLE 1 –1,0/*Rq* 0,002 (surface roughness with only the upper limit of spatial band); see Annex B.

EXAMPLE 2 0,002–1,0/*Rq* 0,002 (surface roughness with spatial band); see Annex B.

EXAMPLE 3 0,5–2,5/*Wq* 0,002 (surface waviness with spatial band); see Annex B.

NOTE The evaluation length is five times the minimum sampling length.

This indication may be complemented by an indication of the polish grade according to 5.3.2.

5.3.4 Indication of PSD function specification

The maximum permissible value of the PSD function is indicated by placing the letters PSD and the values for *A* and *B*, as defined in 4.3.4 and separated by an oblique stroke (/), under the horizontal line, as shown in Figure 6. The upper and lower limits of the spatial band, *C* and *D*, expressed in millimetres, are placed under the horizontal line before the PSD note separated by an oblique stroke (/), as shown in Figure 6.

This indication can be complemented by an indication of the smoothness by polishing in accordance with 5.3.2.

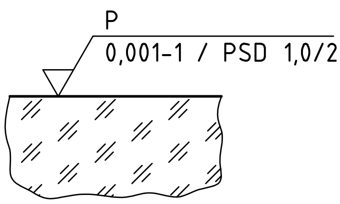


Figure 6 — Indication for an optically smooth surface; $PSD \leq \frac{1,0}{f^2}$ (nm² × mm) over a spatial band of 0,001 mm to 1 mm

5.3.5 Indication of APSD function specification

The maximum permissible value of the APSD function is indicated by placing the letters APSD and the values for *A*′ and *B*′, as defined in 4.3.5 and separated by an oblique stroke (/), under the horizontal line, as shown in Figure 7. The upper and lower limits of the spatial band, *C*′ and *D*′, expressed in millimetres, are placed under the horizontal line before the APSD note separated by an oblique stroke (/), as shown in Figure 7.

This indication can be complemented by an indication of the smoothness by polishing in accordance with 5.3.2.

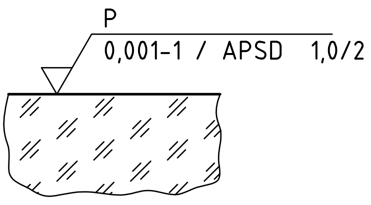
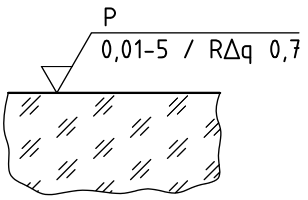


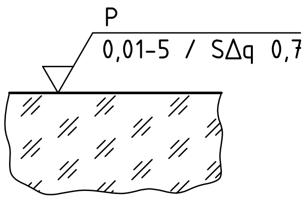
Figure 7 — Indication for an optically smooth surface; $APSD \leq \frac{1,0}{\left(f_x^2 + f_y^2\right)}$ **(nm² × mm²) over a spatial band of 0,001 mm to 1 mm**

5.3.6 Indication of rms or area rms slope specification

The rms slope $R\Delta q$ or its' areal equivalent, $S\Delta q$ is indicated by placing the maximum permissible value of the rms slope, expressed in microradians, under the horizontal line as shown in Figure 8.



a) Rms slope



b) Areal rms slope

Figure 8 — Indication for an optically smooth surface; rms slope or areal rms slope of ≤0,7 µrad for a spatial band of 0,01 mm to 5 mm

A spatial band can be indicated under the horizontal line, as shown in Figure 8. Spatial bands shall be expressed in millimetres.

5.3.7 Indication of lay

In the event that the orientation of the surface texture parameter is significant, the addition of a surface lay symbol can be used. The letter C indicates a circular lay, while the letter R indicates a radial lay, as shown in Figure 9. Additional lay symbols are given in ISO 1302:2002, Table 2. If no indication of lay is given, then the surface parameter is assumed to apply for all orientations.

On rotationally symmetric parts, the lay indications C and R (for circular and radial) are recommended. On square or rectangular parts, the lay indications = and ⊥ are recommended.

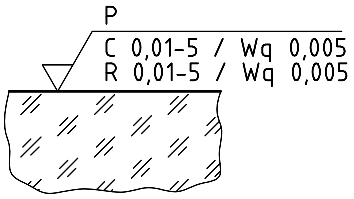


Figure 9 — Indication for optically smooth surface with *Wq* ≤ 0,005 µm for a spatial band of 0,01 mm to 5 mm, evaluated radially and circularly

5.4 Location

The indication of the surface roughness shall be located on the drawing as described in ISO 10110-1. In tabular drawings (see also ISO 10110-1), the texture symbol and indication can be shown either in the drawing field or in the appropriate surface fields. In alternate drawings the tip of the texture symbol shall be in contact with the line representing the surface or with a corresponding subsidiary line (see Figures 2 to 9, as well as the examples given in ISO 10110-1).

Annex A
(informative)

Relationship between surface texture and scattering characteristic of textured surfaces

It has been shown that there is an analytical expression relating surface texture to the angular distribution of light scattered by textured surfaces, see Reference [21]. Since scattered light can seriously compromise optical system performance and the measurement of surface texture or roughness tends to be easier than making scattered light measurements, it is useful to understand the relationship between surface roughness and scattered light.

It has also been shown experimentally that most polished surfaces scatter light according to a power law, see References [9] and [10]. Similarly a relationship between the two-dimensional power spectral density (PSD) of surface roughness or texture and the differential angular scatter has been obtained theoretically, see Reference [11]. Also the one-dimensional PSD, the raw data for which can be obtained with a one-dimensional profilometer, is simply related to the two-dimensional form for isotropic surfaces. It was shown that the one-dimensional PSD can be expressed as

$$PSD = \frac{A}{f^B}$$

where

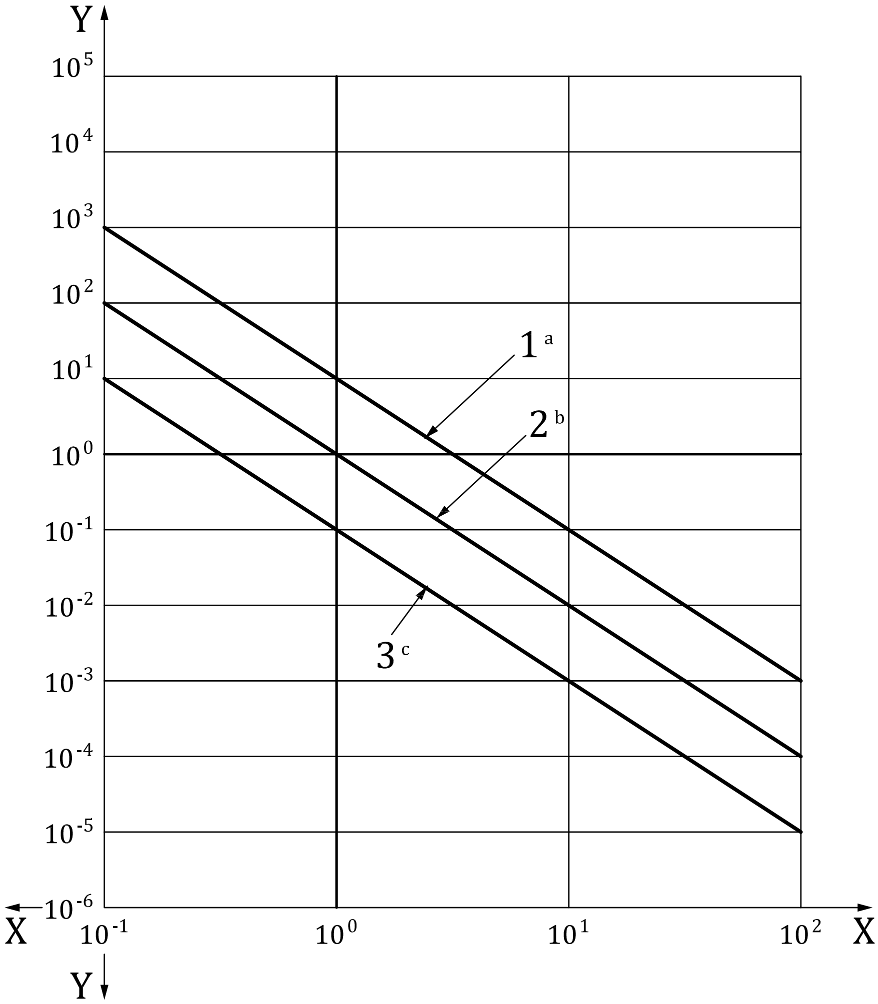
A is a constant, expressed in $nm^2 \times mm^{1-B}$;

f is the spatial frequency of the surface roughness, in reciprocal millimetres (mm^{-1});

B is the value of the exponent (or power) with which the PSD falls off with increasing spatial frequency. For most “real” surfaces, $1 < B < 3$.

This description of the PSD function is valid for a given range of spatial frequencies. The minimal spatial frequency is $1/D$, where D is the sampling length over which the sample was measured. The maximal spatial frequency is $1/C$, where C is the shortest lateral feature on the surface that the measuring instrument can resolve (C and D are expressed in millimetres).

Figure A.1 gives an example of three PSD functions for the case in which $B = 2$, and illustrates that the surface texture has smaller features as A is made smaller. These curves are for illustrative purposes only.



Key

X spatial frequency, in mm^{-1}

Y power spectral density, $nm^2 \times mm$

1 ordinary polish PSD

2 precision polish PSD

3 super polish PSD

a $A = 10\ nm^2 \times mm^{-1}$.

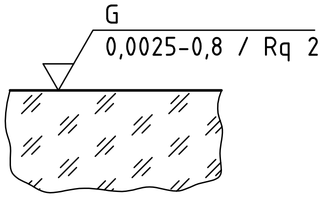
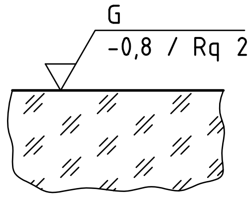
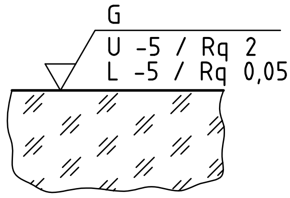
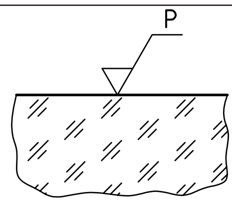
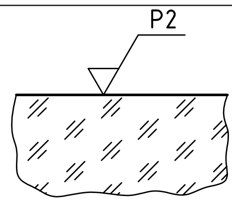
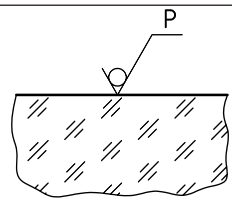
b $A = 1\ nm^2 \times mm^{-1}$.

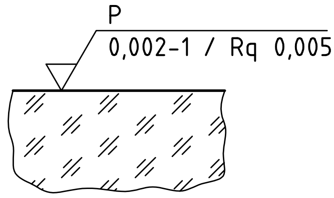
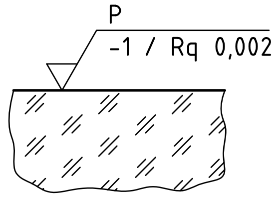
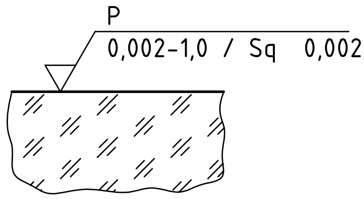
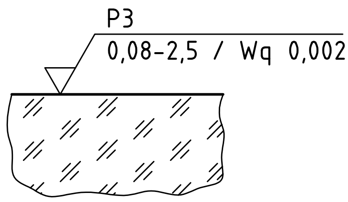
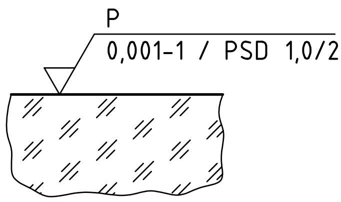
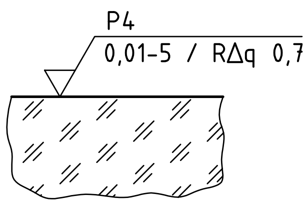
c $A = 0{,}1\ nm^2 \times mm^{-1}$.

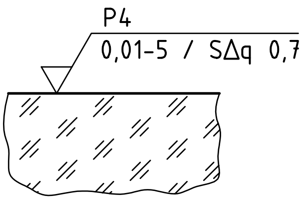
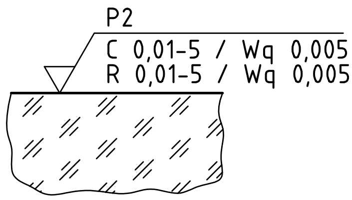
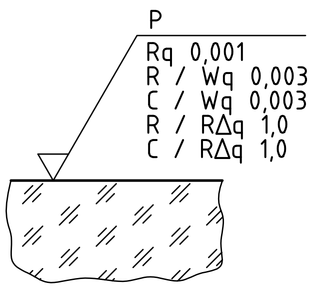
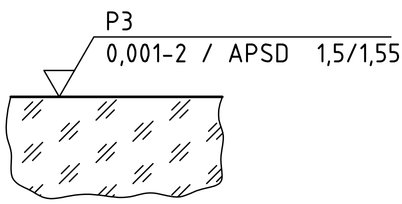
Figure A.1 — Examples of three PSD functions for *B* = 2

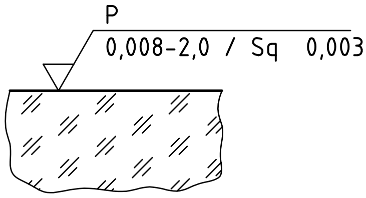
Annex B
(informative)

Examples of indication of surface texture requirements

Reference Number	Requirement	Example
B.1	Optical surface: — matt surface. Surface roughness: — a single, unilateral/upper specification limit; — $Rq \leq 2$ µm; — spatial band from 0,002 5 mm to 0,8 mm.	
B.2	Optical surface: — matt surface. Surface roughness: — a single, unilateral/upper specification limit; — $Rq \leq 2$ µm; — upper limit of spatial band 0,8 mm.	
B.3	Optical surface: — matt surface. Surface roughness: — bilateral specification limit; — upper specification limit $Rq = 2$ µm; — lower specification limit $Rq = 0{,}05$ µm; — upper limit of spatial band 5 mm.	
B.4	Optical surface: — optically smooth surface; — polish grade, no requirement; — numerical limit value of roughness, no requirement.	
B.5	Optical surface: — optically smooth surface; — polish grade 2.	
B.6	Optical surface: — optically smooth moulded surface; — numerical limit value of roughness, no requirement.	

Reference Number	Requirement	Example
B.7	Optical surface: — optically smooth surface. Surface roughness: — a single, unilateral/upper specification limit; — *Rq* ≤ 0,005 µm; — spatial band from 0,002 mm to 1 mm.	
B.8	Optical surface: — optically smooth surface. Surface roughness: — a single, unilateral/upper specification limit; — *Rq* ≤ 0,002 µm; — upper limit of spatial band 1 mm.	
B.9	Optical surface: — optically smooth surface. Surface roughness: — a single, unilateral/upper specification limit; — *Sq* ≤ 0,002 µm; — spatial band from 0,002 mm to 1 mm.	
B.10	Optical surface: — optically smooth surface; — polish grade 3. Surface waviness: — a single, unilateral/upper specification limit; — *Wq* ≤ 0,002 µm; — spatial band from 0,08 mm to 2,5 mm.	
B.11	Optical surface: — optically smooth surface. Surface power spectral density: — a single, unilateral/upper specification limit; — $PSD \leq 1{,}0/f^2$ ($nm^2 \times mm$); — spatial band from 0,001 mm to 1 mm.	
B.12	Optical surface: — optically smooth surface; — polish grade 4. Surface slope: — a single, unilateral/upper specification limit; — $R\Delta q \leq 0{,}7$ µrad; — Spatial band from 0,01 mm to 5 mm.	

Reference Number	Requirement	Example
B.13	Optical surface: — optically smooth surface; — polish grade 4. Surface slope: — a single, unilateral/upper specification limit; — $S\Delta q \leq 0{,}7$ µrad; — Spatial band from 0,01 mm to 5 mm.	
B.14	Optical surface: — optically smooth surface; — polish grade 2. Surface waviness: — two unilateral/upper specification limits; — $Wq \leq 0{,}005$ µm; — spatial band from 0,01 mm to 5 mm; — surface lay, radial from center and circular around centre.	
B.15	Optical surface: — optically smooth surface. Surface roughness: — a single, unilateral/upper specification limit; — $Rq \leq 0{,}001$ µm; — default spatial band from 0,002 5 mm to 0,08 mm; — surface lay, no requirement. Surface waviness: — two unilateral/upper specification limits; — $Wq \leq 0{,}003$ µm; — default spatial band from 0,08 mm to 2,5 mm; — surface lay radial from centre and circular around centre. Surface slope: — two unilateral/upper specification limits; — $R\Delta q \leq 1{,}0$ µrad; — default spatial band from 0,08 mm to 2,5 mm; — surface lay radial from centre and circular around centre.	
B.16	Optical surface: — optically smooth surface; — polish grade 3. Surface power spectral density: — a single, unilateral/upper specification limit; — 2D $PSD \leq 1{,}5/f^{1{,}55}$ (nm^2 × mm^2); — spatial band from 0,001 mm to 2 mm.	

Reference Number	Requirement	Example
B.17	Optical surface: — optically smooth surface. Surface roughness: — a single, unilateral/upper specification limit; — $Sq \leq 0{,}003$; — Spatial band 0,008 mm to 2,0 mm.	

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