INTERNATIONAL STANDARD

ISO 10110-8

Third edition
2019-11

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)

Contents

Page

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*, *S*Δ*q*, 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)

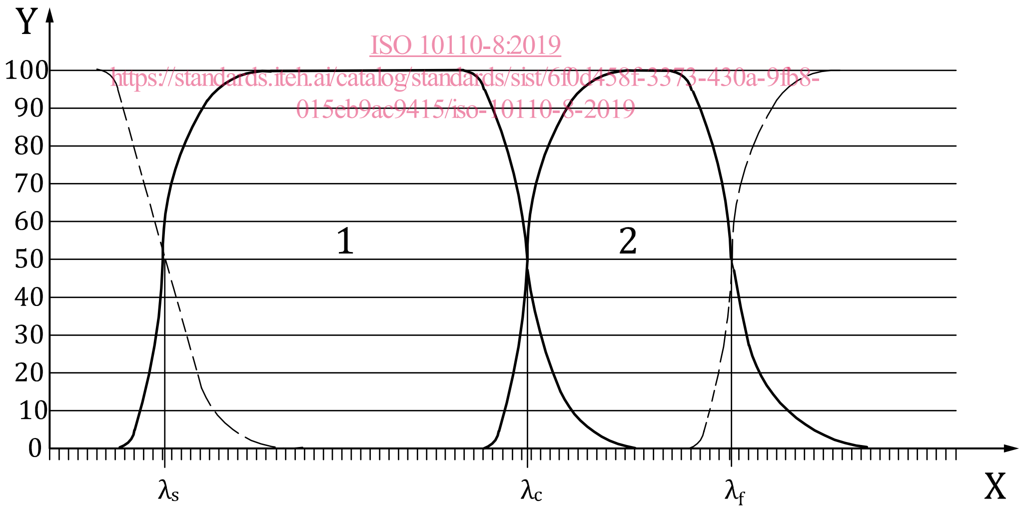
[SOURCE: ISO 4287:1997, 3.1.6, modified — The Notes to entry have been removed.]

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:

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

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*Δ*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.

