INTERNATIONAL STANDARD

ISO 10110-8

First edition
1997-11-01

199[illegible] 30B

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

Part 8: Surface texture

Optique et instruments d'optique — Indications sur les dessins pour éléments et systèmes optiques —

Partie 8: État de surface

DC-981123008

Reference number
ISO 10110-8:1997(E)

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.

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

International Standard ISO 10110-8 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 1, *Fundamental standards*.

ISO 10110 consists of the following parts, under the general title *Optics and optical instruments — Preparation of drawings for optical elements and systems*:

— *Part 1: General*

— *Part 2: Material imperfections — Stress birefringence*

— *Part 3: Material imperfections — Bubbles and inclusions*

— *Part 4: Material imperfections — Inhomogeneity and striae*

— *Part 5: Surface form tolerances*

— *Part 6: Centring tolerances*

— *Part 7: Surface imperfection tolerances*

— *Part 8: Surface texture*

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X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

— *Part 9: Surface treatment and coating*

— *Part 10: Table representing data of a lens element*

— *Part 11: Non-toleranced data*

— *Part 12: Aspheric surfaces*

— *Part 13: Laser irradiation damage threshold*

Annex A forms an integral part of this part of ISO 10110. Annexes B and C are for information only.

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

Part 8:
Surface texture

1 Scope

ISO 10110 specifies the presentation of design and functional requirements for optical elements in technical drawings used for manufacturing and inspection.

This part of ISO 10110 specifies rules for the indication of the texture of surfaces on optical elements.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10110. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10110 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1302:1992, *Technical drawings — Method of indicating surface texture.*

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

ISO 10110-10:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 10: Table representing data of a lens element.*

3 Definitions

For the purposes of this part of ISO 10110, the following definitions apply.

3.1 surface texture: Global statistical property relating to the profile of an optical surface.

NOTE — Localized defects, known as surface inperfections, are covered 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 the visible light.

NOTE — Matt surfaces are usually produced by brittle grinding of glass or other dielectric material, or by etching.

3.3 specular [optically smooth] surface: Optical surface for which the height variation of the surface texture is considerably smaller than the wavelength of the visible light.

NOTES

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

2 Specular optical surfaces are usually produced by polishing or moulding.

3.4 microdefect: Small irregularity (generally less than 1 µm in size) in a specular surface.

NOTES

1 Usually, microdefects are pits remaining after an incomplete polish, although they may also be due to mishandling and contamination during polishing. Microdefects are of concern because they produce large-angle scattering.

2 Microdefects are not considered surface imperfections as treated in ISO 10110-7 because they are reasonably uniformly distributed over the surface and thus have a global characteristic associated with texture.

4 Description of surface texture

4.1 General

Surface texture is a global statistical characteristic of the profile of the optical surface, and it is assumed for this part of ISO 10110 that the character and magnitude of the texture in any one area of the surface is similar to that in all other areas of the same surface. This assumption is made so that a measurement made in one part of the surface may be considered representative of the entire surface.

Unless stated otherwise, the indication of surface texture applies to surfaces before coating[1].

The texture is usually measured over a small part of the surface so that the long spatial periods normally associated with form error are not included in the designation of texture. Because the magnitude of the measured roughness is a function of the sampling length[2], this part of ISO 10110 provides for the indication of the sampling length.

This part of ISO 10110 makes use of the terminology of profilometry. 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. (The relationship between surface texture and optical scattering is discussed in the references in annex C.)

Surface texture specifications are applicable to matt or ground surfaces as well as to specular surfaces made by polishing or moulding. In this part of ISO 10110, texture also refers to microdefects such as pits left from an incomplete polish that are nominally uniformly distributed over a specular surface.

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

4.2 Description of matt surfaces

Matt surfaces shall be specified by indication of the root-mean-square (r.m.s.) height variation, Rq (see ISO 4287:1997, 5.11). This quantity depends on the sampling length. For this reason it may be necessary to specify a lower limit or, if desired, lower and upper limits of the sampling length.

In some cases, functional requirements may dictate a roughness criterion other than Rq. In such cases, that other criterion shall be indicated as shown in ISO 1302:1992, table B.2.

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1) This is a specific exception to the general statement in ISO 10110-1:1996, clause 3, first paragraph.

2) Sampling length is the length used for identifying the irregularities characterizing the surface texture (see ISO 4287:1997, 3.1.9).

4.3 Description of specular surfaces

There are three methods of describing specular surfaces: by means of the r.m.s. surface roughness, Rq; by indication of the density of microdefects; or by using a power spectral density (PSD) function.

4.3.1 R.M.S. surface roughness

Specular surfaces are commonly specified by indication of the r.m.s. surface roughness, Rq.

If the surface height variations obey certain statistical distribution properties, the r.m.s. value, Rq, can be related to the magnitude of the optical scattering (see annex B). Note that the r.m.s. description is incomplete without indicating lower and upper limits of the sampling length.

4.3.2 Quantification of microdefects

Microdefects can be understood as being very localized pits in an otherwise "smooth" surface. They are quantified by lightly drawing a sharp stylus of a mechanical profilometer across the surface to be measured and noting the number of times, N, that the stylus deviates markedly from the otherwise "smooth" surface in a 10 mm long scan. An optical profilometer, a microscope or a microscopic image comparator may also be used to quantify microdefects.

4.3.3 Power Spectral Density (PSD) function

The PSD function is the frequency spectrum of the surface roughness measured in inverse length units. It allows a complete description of the surface texture characteristics, and is particularly useful for specifying supersmooth surfaces used in high technology applications. 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 cubic micrometres, can be modeled by

$$\text{PSD} = A/f^B, \text{ for } \frac{1}{1000 \times D} < f < \frac{1}{1000 \times C} \qquad \ldots (1)$$

where

f is the spatial frequency of the roughness, (in μm^{-1});

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

C and D are the minimum and maximum spatial periods (sampling lengths) of the measurement, in millimetres;

A is a constant, expressed in μm^{3-B}.

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

In this way, the surface texture requirement may be given by specifying the four values A, B, C and D, for which equation (1) shall hold.

5 Indication in drawings

The symbols for indicating surface texture in drawings shall be those given in ISO 1302:1992, if necessary modified as described below.

5.1 Indication for matt surface texture

The matt surface texture is indicated according to ISO 1302:1992, 6.1 with the addition of the letter G (for "Ground"[3]) above the horizontal line, as shown in figure 1. The maximum permissible r.m.s. surface roughness

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

Rq max. in micrometres, is indicated above the triangle. When a single value of Rq is given, it represents the upper limit of the surface roughness parameter. If, in addition, the roughness is not permitted to lie below a certain value, a minimum r.m.s. surface roughness value Rq min. shall be specified. This value shall be indicated below the maximum value.

If desired, a lower limit of the sampling length may be indicated under the horizontal line, as shown in figure 1. If an upper limit is also to be specified, it shall be separated from the lower limit by a slash. Sampling lengths shall be expressed in millimetres.

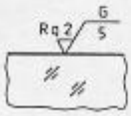

Figure 1 — Indication for ground surface with Rq = 2 µm and minimum sampling length of 5 mm

5.2 Indication for specular surface texture

5.2.1 General

The indication for specular surface texture shall include the letter P (for "Polished"[4]) above the horizontal line, as shown in figure 2. The use of the letter P alone means that no quantification of the microdefects is required but that the surface shall be specular. The quantitative aspect of surface texture shall be given in terms of r.m.s. roughness Rq, in terms of allowed microdefects, or in terms of PSD.

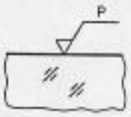

Figure 2 — Indication for specular surface without quantitative modifiers

5.2.2 Indication of polishing grade in terms of microdefects

The number of allowed microdefects is indicated by placing a grade number between 1 and 4 to the right of the letter P, as shown in figure 3. The range of the corresponding permissible number of microdefects is given by grade in table A.1.

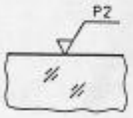

Figure 3 — Indication for specular surface with < 80 microdefects per 10 mm linear scan of the surface

4) The letter "P" is used to indicate all specular surfaces, including those not produced by polishing, e.g. moulded or float glass surfaces.

5.2.3 Indication of r.m.s. surface roughness

The r.m.s. surface roughness Rq is indicated by placing the maximum permissible value of the r.m.s. roughness, expressed in micrometres, above the triangle as shown in figure 4.

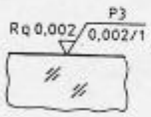

Figure 4 — Indication for specular surface with < 16 microdefects per 10 mm scan and $Rq \leq 0{,}002$ µm between sampling lengths of 0,002 mm and 1 mm

This indication can be complemented by an indication of the polishing grade in terms of microdefects according to 5.2.2.

5.2.4 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 4.3.3 and separated by a slash, above the triangle in the texture symbol as shown in figure 5. The minimum and maximum spatial periods (sampling lengths), C and D, expressed in millimetres, are placed under the horizontal line separated by a slash as in figure 5.

This indication can be complemented by an indication of the polishing grade in terms of microdefects according to 5.2.2.

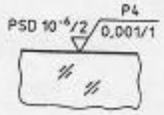

Figure 5 — Indication for polished surface with < 3 microdefects per 10 mm scan and a PSD $\leq 10^{-6}/f^2$ (µm³) between sampling lengths of 0,001 mm and 1 mm

5.3 Location

The tip of the texture symbol shall be in contact with the line representing the surface or with a corresponding subsidiary line (see figures 1 through 5, as well as the examples given in ISO 10110-1, annex A).

Also, if the data are presented in tabular form, the texture symbol shall be used in the corresponding drawing (see ISO 10110-10:1996, figures 2 and 3).

Annex A
(normative)

Specification of texture for specular surfaces in terms of microdefects

Table A.1 defines four polishing grades in terms of microdefects.

The fundamental investigation of microdefects is described in reference [4].

Table A.1

Polishing grade designation	Number N of microdefects per 10 mm of sampling length
P1	$80 \leq N < 400$
P2	$16 \leq N < 80$
P3	$3 \leq N < 16$
P4	$N < 3$

Annex B
(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 off textured surfaces[24, 25]. 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[24 to 28]. 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[109]. 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

$$\text{PSD} = Af^{B}$$

where

A is a constant, expressed in μm^{3-B};

f is the spatial frequency of the surface roughness, in reciprocal micrometres (μm^{-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 range of spatial frequencies related to the sampling lengths of the measurement. The minimal spatial frequency is $1/(1\,000D)$, where D is the sampling length over which the sample was measured. The maximal spatial frequency is $1/(1\,000C)$, where C is the shortest lateral feature on the surface that the measuring instrument can resolve (C and D are expressed in millimetres).

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

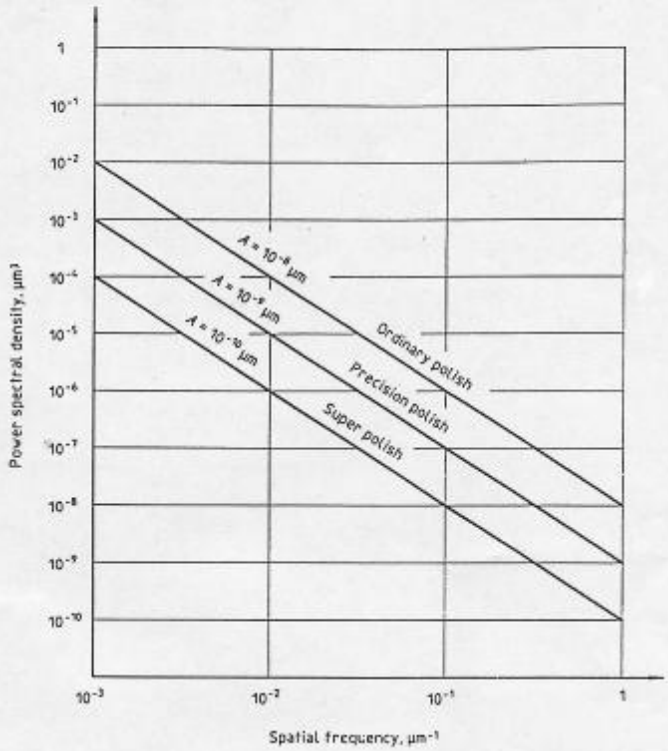

Figure B.1 — Examples of three PSD functions for $B = 2$

Annex C
(informative)

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ICS 01.100.20; 37.020

Descriptors: optics, optical equipment, drawings, technical drawings, presentation, surface condition.

Price based on 9 pages