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

Part 5: Surface form tolerances

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

Partie 5: Tolérances de forme de surface

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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 (see www.iso.org/directives).

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

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 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

This third edition cancels and replaces the second edition (ISO 10110-5:2007), which has been technically revised with the following changes:

a) "nanometres" have been introduced as the standard unit for specifying tolerances for certain types of surface form deviation replacing the former standard unit "fringe spacings";

b) expansion of the scope now including surfaces of higher order such as aspheric, non-circular cylindric, and general surfaces;

c) specification of deviations in tabular form has been added;

d) a definition of sagitta deviation has been added;

e) the name of quantity A has been changed to power deviation (reflecting the change in ISO 14999-4). For further details, see 5.2.3, NOTE 3;

f) an informative Annex B has been added giving a comparison of ISO 10110-5 and ISO 14999-4 regarding corresponding nomenclature, functions, and values.

ISO 10110 consists of the following parts, under the general title *Optics and photonics — 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; roughness and waviness*
— *Part 9: Surface treatment and coating*
— *Part 10: Table representing data of optical elements and cemented assemblies*
— *Part 11: Non-toleranced data*
— *Part 12: Aspheric surfaces*
— *Part 14: Wavefront deformation tolerance*
— *Part 17: Laser irradiation damage threshold*
— *Part 19: General description of surfaces and components*

Introduction

This part of ISO 10110 refers to deviations in the form (shape) of an optical surface and provides a means of specifying tolerances for certain types of surface form deviation in terms of nanometres.

As it is common practice to measure the surface form deviation interferometrically as the wavefront deformation caused by a single reflection from the optical surface at normal (90° to surface) incidence, it is possible to describe a single definition of interferometric data reduction that can be used in both cases, i.e. in surface form deviation as well as wavefront deformation. As the analysis of most measurements is software based, the deviations are expressed in nanometres. Interferometrical measurements, however, use the unit “fringe spacings”. One “fringe spacing” is equal to a surface form deviation that causes a deformation of the reflected wavefront of one wavelength. A value expressed in nanometres is an indication of the actual height deviation of the surface itself (and not that of the reflected wavefront).

The surface under test, together with the test glass is, for example, such an interferometer. The surface form deviation is represented by the wavefront deformation which is the difference between the wavefront reflected by the actual surface and that reflected by the test glass surface.

Due to the potential for confusion and misinterpretation, nanometres rather than fringe spacings are to be used. Where fringe spacings are used as units, the wavelength is also to be specified.

In addition, tolerances for slope deviations of surfaces can be given in units of mrad, μrad, arcmin, or arcsec.

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

Part 5: Surface form tolerances

1 Scope

This International Standard specifies the presentation of design and functional requirements for optical elements and systems in technical drawings used for manufacturing and inspection.

This part of ISO 10110 specifies rules for indicating the tolerance for surface form deviation.

NOTE The terminology of interferometry employing the unit “fringe spacings” is widely used for the specification of tolerances. However, the usage of non-interferometric methods for testing of optical parts has recently become more important. Therefore, unlike in the earlier versions of this part of ISO 10110, nanometres shall now be the preferred and standard unit to express surface form deviations. The usage of fringe spacings is still permitted given that the base wavelength is explicitly stated.

This part of ISO 10110 applies to surfaces of plano, spherical, aspheric, circular and non-circular cylindric, and toric form as well as to surfaces of other non-spherical shape such as generally described surfaces. It does not apply to diffractive surfaces, Fresnel surfaces, and micro-optical surfaces.

2 Normative references

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

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

ISO 10110-10, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 10: Table representing data of optical elements and cemented assemblies*

ISO 10110-19, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 19: General description of surfaces and components*

ISO 14999-4, *Optics and photonics — Interferometric measurement of optical elements and optical systems — Part 4: Interpretation and evaluation of tolerances specified in ISO 10110*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14999-4 and the following apply.

3.1
surface form deviation
function representing the distances normal to the surface between a nominal optical surface form and a measured form described as a measured wavefront deformation f_{WD} or $f_{\mathrm{WD,CY}}$ as defined in ISO 14999-4

Note 1 to entry: ISO 14999-4 provides the definitions for the deformation functions.

3.2
sagitta deviation
ΔZ
function representing the distances along the *z*-axis between a nominal optical surface form and a measured form

Note 1 to entry: Based on interferometric measurement, the values are available along the local surface normal and have to be converted to deviations in the *z* direction in order to compare them with ΔZ.

Note 2 to entry: For simple optical surfaces, the *z*-axis is often also the optical axis.

4 Specification of tolerances for surface form deviation

4.1 General

The tolerances for surface form deviation are indicated by specifying the maximum permissible values of the power deviation, irregularity, rotationally and/or translationally invariant irregularity. In addition, tolerances for root-mean-square (rms) measures of surface form deviation (rms total, rms irregularity, and rms rotationally and/or translationally varying wavefront irregularity) and tolerances for slope deviation (max and rms values) may be specified (see ISO 14999-4 for definitions). A surface form deviation based on a sagitta table can also be given in the *z*-direction and as irregularity as well as slope.

Both the surface form tolerances and the tolerances of the slope deviations can vary in different sections and different orientations (x, y) or (ρ, φ). In this case, the sampling length and the spatial sampling interval can also deviate from each other.

The surface form tolerance can also be defined as coefficients of a Zernike polynomial.

NOTE 1 ISO 10110-14 provides a means of specifying only one single tolerance for the wavefront deformation without any need to specify tolerances for individual surfaces.

NOTE 2 Methods for determining the amount of power deviation, irregularity, rotationally and/or translationally invariant irregularity, and slope deviation of a given surface are given in ISO 14999-4.

Specifying a slope deviation tolerance or rms slope is recommended for non-spherical surfaces like aspheric, non-circular cylindric, or general surfaces. Depending on the application and complexity, the permissible max slope deviation might also be indicated as an absolute quantity in direction (x, y) or (ρ, φ).

It is not necessary that tolerances are specified for all types of surface form deviation.

All deviations of the surface but one is defined perpendicular to the theoretical surface. The sagitta deviation, ΔZ, is defined along the *z*-axis.

4.2 Units

The maximum permissible values for power deviation, irregularity, and rotationally and/or translationally invariant irregularity shall be specified in units of nanometres or, if preferred, micrometers or fringe spacings. If a specification is to be given for one or more rms deviation types, it shall be given in units of nanometres or, if preferred, micrometers or fringe spacings.

To avoid confusion, the unit “wavelength of light” should never be used for surface form deviations.

When a surface is tested interferometrically by reflection at normal incidence, a surface form deviation of one-half the wavelength of light causes a wavefront deviation of one full wavelength. This results in an interference pattern in which the intensity varies from one bright fringe to the next or from one dark fringe to the next, i.e. one fringe spacing is visible. For the purpose of this part of ISO 10110, the words “fringe spacings” do not refer to the transverse distance between fringes, but to the fact that the number of fringe spacings visible in the interference pattern corresponds to the number of wavelengths of wavefront deviation.

NOTE 1 One fringe spacing is 1 × 1/2 × the wavelength (in nanometres) in which a surface form deviation is actually specified.

NOTE 2 The specification of a tolerance for an rms deviation type requires that the optical system is analysed digitally.

Deviations based on a sagitta table along the *z*-axis shall be given in metric units like µm or nm.

The maximum permissible values for max and rms slope deviation shall be specified with preferred units of mrad. The corresponding units of degree, *µ*rad, arc minutes (…'), and arc seconds (…'') can be used as well. The unit shall always be indicated.

4.3 Wavelength

Applying the unit fringe spacings the wavelength shall be given.

NOTE 1 In earlier versions of this part of ISO 10110, unless otherwise specified, the wavelength was the green spectral line of mercury (e-line), λ = 546,07 nm, according to ISO 7944.

NOTE 2 Specifications can be converted from one reference wavelength to another using Formula (1).

$$N_{\lambda 2} = N_{\lambda 1} \times (\lambda_1 / \lambda_2) \quad (1)$$

where $N_{\lambda 1}$ and $N_{\lambda 2}$ are the numbers of fringe spacings at λ_1 and λ_2, respectively.

5 Indication in drawings

5.1 General

The surface form tolerance is indicated by a code number and indications of the tolerances for power deviation, irregularity, rotationally and/or translationally invariant irregularity, max slope, and rms slope deviation types as appropriate. Irregularity, form deviation in *z*-direction, max slope, and rms slope deviation may also be indicated in a table in conjunction with the sagitta table. Both specifications can be used in combination. It shall be ensured that both are not contrary to each other.

The use of indications is not limited in general by the kind of form like spherical or cylindrical specified. However, not all specifications are helpful for all surface forms. All quantities shall have their units specified. If no unit is indicated, then fringe spacing is implied.

5.2 Structure of the indication based on code number

5.2.1 General

The indication shall consist of one basic form and may be supplemented by additional forms. Multiple forms shall be separated by a semicolon.

5.2.2 Code number

The code number for surface form tolerance is 3/.

5.2.3 Basic forms

3/A(B/C)

or

3/A(B/C) RMS*x* < D

where *x* is one of the letters t, i or a (see below quantity D).

or

3/RMS*x* < D

where *x* is one of the letters t, I, or a (see below quantity D).

or

3/AX;AY (B/CX;CY)

or

3/

NOTE In former editions, 3/— RMS_x was used.

Applying the unit fringe spacings, the indication "; λ = E" shall be added in order to specify the wavelength.

The quantity A is either

a) the maximum permissible power deviation (peak-to-valley value) PV(f_{WS}) as defined in ISO 14999-4, expressed in nanometres, micrometres, or fringe spacings, or

b) a dash (—) indicating that the total radius of curvature tolerance is given in the radius of curvature dimension (not applicable for planar surfaces).

The quantities AX, AY are either

a) the maximum permissible power deviation (peak-to-valley value) PV($f_{\mathrm{WC,x}}$) and PV($f_{\mathrm{WC,y}}$) for cylindric and similar surfaces as defined in ISO 14999-4, expressed in nanometres, micrometres, or fringe spacings, or

b) a dash (—) indicating that the entire radius of curvature tolerance is contained in the specification of the radius of curvature.

If no power deviation is allowed, then A, AX, or AY shall be 0. In this case, all the deviation including also that part that could be interpreted as a power deviation shall be included in irregularity B.

A shall be set to 0 in cases of surfaces without symmetry when no kind of power deviation is applicable.

NOTE 1 It is often the case that the tolerance for power deviation is calculated by converting a part of the tolerance shown against the radius of curvature tolerance into a tolerance for power deviation using the formulae given in Annex A.

NOTE 2 If no tolerance on the radius of curvature is specified combined with a dash for the power deviation, then defaults in ISO 10110-11 apply.

NOTE 3 Previous versions of this part of ISO 10110 used the term sagitta to represent this quantity A. This is not correct since the true sagitta deviation is the distance evaluated parallel to the *z*-axis. For better clarity, we have changed the name of quantity A everywhere to power deviation (reflecting the change in ISO 14999-4), so that the true sagitta can be used correctly.

NOTE 4 Care should be taken in the specification of quantity A for surfaces with large amounts of curvature as the value of the power can vary significantly compared to the measured value of the deviation of the radius of curvature.

The quantity B is either

a) the maximum permissible value (peak-to-valley value) PV(f_{WI}) of irregularity as defined in ISO 14999-4, expressed in nanometres, micrometres, or fringe spacings when A is used,

b) the maximum permissible value (peak-to-valley value) PV($f_{\mathrm{WI,CY}}$) of irregularity for cylindric and similar surfaces as defined in ISO 14999-4, expressed in nanometres, micrometres, or fringe spacings when AX and/or AY are used, or

c) a dash (—) indicating that no explicit irregularity tolerance is given.

The quantity C is either

a) the maximum permissible value (peak-to-valley) PV- (f_{WRI}) of rotationally invariant irregularity, expressed in nanometres, micrometers, or fringe spacings as defined in ISO 14999-4, or

b) a dash (—) indicating that no explicit rotationally invariant irregularity tolerance is given.

If no tolerance is given, the slash (/) is replaced by the closing parenthesis, i.e. 3/A(B).

The quantities CX and CY are either

a) the maximum permissible value (peak-to-valley) PV($f_{\mathrm{WTI,x}}$), PV($f_{\mathrm{WTI,y}}$) of translationally invariant irregularity for cylindric and similar surfaces, expressed in nanometres, micrometres, or fringe spacings as defined in ISO 14999-4. CX and CY are used for the symmetry specification across the x and y-axis, or

b) a dash (—) indicating that no explicit translationally invariant irregularity tolerance for both or one of them is given.

If no tolerance is given, the slash (/) is replaced by the closing parenthesis, i.e. 3/AX;AY(B).

If no tolerance is given for all three deviation types, then A, B, C, the slash (/) and the parentheses are replaced by a single dash (—), i.e. 3/—.

The quantity D is the maximum permissible value of the rms quantity of the type specified by *x* where *x* is one of the letters t, i, or a. These deviations are defined

a) for rotationally symmetric surfaces according to ISO 14999-4:

- for t (total): rms total rms(f_{WD})

- for i (irregular): rms irregularity rms(f_{WI})

- for a (asymmetric): rms rotationally varying (asymmetric) irregularity rms(f_{WRV})

b) for cylindric and similar surfaces according to ISO 14999-4:

- for t (total): rms total rms($f_{\mathrm{WD,CY}}$)

- for i (irregular): rms irregularity rms($f_{\mathrm{WI,CY}}$)

- for a (asymmetric): rms translationally varying (asymmetric) irregularity rms(f_{WTV})

The specification of more than one type of rms deviation is allowed. These specifications shall be separated by a semicolon as shown in Clause 6, Example 5.