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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 main task of technical committees is to prepare International Standards. 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.

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.

ISO 10110-5 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

This second edition cancels and replaces the first edition (ISO 10110-5:1996) which has been technically revised. It also incorporates the Technical Corrigendum ISO 10110-5:1996/Cor.1:1996.

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*

— *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*

Introduction

This part of ISO 10110 refers to deformation in the form (shape) of an optical surface and provides a means of specifying tolerances for certain types of surface deformation in terms of “fringe spacings”.

Because 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. One “fringe spacing” is equal to a surface deformation that causes a deformation of the reflected wavefront of one wavelength.

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

Because of the potential for confusion and misinterpretation, nanometres rather than fringe spacings should be used where possible. Where fringe spacings are used as units, the wavelength should also be specified. A value expressed in nanometres is (e.g. in the case of test glass testing) a converted value of one which is expressed in fringe spacings.

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

Part 5: Surface form tolerances

1 Scope

ISO 10110 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.

NOTE 1 The terminology of interferometry is used for the specification of tolerances and, in particular, for the units in which the tolerances are to be specified; however, this does not stipulate that only interferometric methods may be used for the actual testing of optical parts. Other non-interferometric methods may be used if the results are converted to the units specified here.

This part of ISO 10110 applies to surfaces of both spherical and aspheric form.

NOTE 2 ISO 10110-12 allows the surface form tolerance for aspheric surfaces to be specified without reference to this part of ISO 10110.

2 Normative references

The following referenced documents 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 7944:1998, *Optics and optical instruments — Reference wavelengths*

ISO 10110-1:2006, *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 14999-4:2007, *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 apply.

NOTE ISO 14999-4 provides the definitions for all the deformation functions.

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 sagitta deviation, irregularity, and/or rotationally invariant irregularity. In addition, tolerances for three root-mean-square measures of surface form deviation (rms total, rms irregularity and rms rotationally varying wavefront deviation) may be specified. See 3.3 of ISO 14999-4:2007 for definitions.

NOTE Methods for determining the amount of sagitta deviation, irregularity, and rotationally invariant irregularity of a given surface are given in ISO 14999-4.

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

4.2 Units

The maximum permissible values for sagitta deviation, irregularity, and rotationally symmetric irregularity shall be specified in units of fringe spacings or, if preferred, nanometres. If fringe spacing is used, then the surface form deviation is represented by the wavefront deviation. If nanometres are used, then actual height deviation of the surface is assumed. To avoid confusion, the unit “wavelength of light” should never be used for the surface 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.

If a specification is to be given for one or more rms deviation types, it shall be done in units of fringe spacings or, if preferred, nanometres.

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

NOTE 2 Note that the specification of a tolerance for an rms deformation type requires that the optical system be analysed digitally.

4.3 Wavelength

Unless otherwise specified, the wavelength is that of the green spectral line of mercury (e-line), λ = 546,07 nm, according to ISO 7944.

NOTE Specifications can be converted from one reference wavelength to another using the formula

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

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 sagitta deviation, irregularity, rotationally invariant irregularity, and rms deviation types, as appropriate.

All quantities shall have their units specified. If no unit is indicated, then fringe spacing is implied.

5.2 Code number

The code number for surface form tolerance is 3/.

5.3 Structure of the indication

The indication shall have one of three forms:

3/A(B/C); λ = E

or

3/A(B/C) RMSx < D; λ = E

(where x is one of the letters t, i or a, see 3.3 of ISO 14999-4:2007).

or

3/—RMSx < D; λ = E

(where x is one of the letters t, i or a).

The indication "; λ = E" (last element of the three forms of indication specified above) may be omitted provided the wavelength of specification is λ = 546,07 nm.

The quantity A is either

a) the maximum permissible sagitta deviation, as defined in 3.3.1 of ISO 14999-4:2007, expressed in nanometres 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).

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

The quantity B is either

a) the maximum permissible value of irregularity, as defined in 3.3.2 of ISO 14999-4:2007, expressed in nanometres or fringe spacings or

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

The quantity C is

the permissible rotationally invariant irregularity, expressed in nanometres or fringe spacings, as defined in 3.3.3 of ISO 14999-4:2007. If no tolerance is given, the slash (/) is replaced by the final parenthesis, i.e.

3/A(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 in 3.3.5, 3.3.6, and 3.3.8 of ISO 14999-4:2007, respectively. 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.

The quantity E is

the wavelength, in nanometres, in which the surface form deviation is specified.

The surface form tolerance indicated applies to the optically effective area, except when the indication is to apply to a smaller test field, for all possible positions within the optically effective area. In this case the diameter of the test field shall be appended to the tolerance indication as follows:

3/A(B/C) RMSx < D (all ∅)

See Clause 6, Example 3.

No provision is given for the specification of a PV-tolerance for the total surface deviation (that is, including both sagitta deviation and irregularity). If such a specification is necessary, this information shall be given in a note on the drawing; for example “Total surface deviation not to exceed 0,25 λ” or “Total surface deviation not to exceed 150 nm”.

NOTE 2 Such a specification might, for example, be useful for interferometer flats.

5.4 Location

The indication shall be shown in connection with a leader to the surface to which it relates and will be associated with centring errors and surface imperfections. An example of such an indication is given in ISO 10110-1:2006, Annex A.

Alternatively, for lens elements, the indication may be given in a table in accordance with ISO 10110-10.

If two or more optical elements are to be cemented (or optically contacted), the surface form tolerances given for the individual elements also apply for the surfaces of the optical sub-assembly, i.e. after cementing (or optically contacting), unless otherwise specified. See ISO 10110-1:2006, 4.8.3.

6 Examples of tolerance indications

EXAMPLE 1

3/3(1)

The tolerance for sagitta deviation is 3 fringe spacings. The irregularity may not exceed 1 fringe spacing.

EXAMPLE 2

3/5(—) RMSi < 0,05

The tolerance for sagitta deviation is 5 fringe spacings. No specific tolerance is given for irregularity or rotationally invariant irregularity, but the rms value of the irregularity may not exceed 0,05 fringe spacings.

EXAMPLE 3

3/3(1/0,5); λ = 632,8 nm (all ∅ 20)

The tolerance for sagitta deviation is 3 fringe spacings. The total irregularity may not exceed 1 fringe spacing. The rotationally symmetric irregularity may not exceed 0,5 fringe spacings. These tolerances apply for all possible test fields of 20 mm diameter within the total test area. The wavelength for all surface form deviation specifications is λ = 632,8 nm.

NOTE In case of nanometre indication: 3/949,4 nm (316,4 nm/158,2 nm) (all ∅ 20)

EXAMPLE 4

3/—(1)

No specific tolerance for sagitta deviation is given; the tolerance on the radius of curvature shall be taken from the radius of curvature indication. The total irregularity may not exceed 1 fringe spacing.

NOTE If no tolerance on the radius of curvature is specified, then ISO 10110-11:1996, Table 1, applies.

EXAMPLE 5

3/—RMSt < 0,07; RMSa < 0,035; λ = 405 nm

No specific tolerance for sagitta deviation, irregularity or rotationally invariant irregularity is given; the tolerance on the radius of curvature shall be taken from the radius of curvature indication; however, when the surface is compared with the desired theoretical surface, the rms total shall be less than 0,07 fringe spacings, and the rms asymmetric irregularity less than 0,035 fringe spacings.

NOTE If no tolerance on the radius of curvature is specified, then ISO 10110-11:1996, Table 1, applies.

EXAMPLE 6

3/ 600 nm (300 nm/150 nm) (all ∅ 20)

The tolerance for sagitta deviation is 600 nm. The total irregularity shall be less than 300 nm. The rotationally invariant irregularity shall be less than 150 nm. These tolerances apply for all possible test fields of 20 mm diameter within the total test area.

Annex A
(informative)

Relationship between sagitta deviation tolerance and radius of curvature tolerance

The maximum permissible number of fringe spacings, N, corresponding to a dimensional radius of curvature tolerance is given by the following formula, provided that the ratio ($\Delta R/R$) is small:

$$N \approx \left(2\Delta R / \lambda\right) \times \left\{1 - \sqrt{1 - \left[d / \left(2R\right)\right]^2}\right\}$$

If the ratio (d/R) is small, this formula may be approximated by

$$N \approx \left[d / \left(2R\right)\right]^2 \times \left(\Delta R / \lambda\right)$$

where

R is the radius of curvature;

ΔR is the dimensional radius of curvature tolerance;

d is the diameter of the test area;

λ is the wavelength (usually 546,07 nm).

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