International Standard

ISO 10110-5

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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Contents

Page

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

This fourth edition cancels and replaces the third edition (ISO 10110-5:2015), which has been technically revised.

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The main changes are as follows:

— permitted units were added (waves for deviation; µrad, °, ', '' for slope);

— multiple basic forms were added (e.g. both full aperture and all subaperture indications for irregularity);

— local slope was refined: circular subpupils for 2D slope (instead of square), and downsampling of the map prior to evaluation (provided that the downsampled resolution is still finer than the indicated slope sampling interval);

— new Zernike residual indication (for a simple mid spatial frequency specification);

— new Zernike coefficient indication (tabular form only);

— new local curvature indication;

— permission added to use trimmed PV estimators (PVr and PV%) to evaluate PV irregularity and PV total deviation unless specifically disallowed by a note on the drawing;

— indication code key (glossary) added;

— sampling length and interval for Peak and RMS slope indications were consolidated;

— examples for the new indications were added, and each specification form has a relevant example;

— consistency and clarity of Zernike polynomial notation were improved;

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— delimiter within forms changed from a semicolon to either a colon or one or more spaces (e.g. AX:AY instead of AX;AY) to avoid confusion with the semicolon used as the delimiter between forms.

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.

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Introduction

This document 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. Interferometric 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 that 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.

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

Part 5: Surface form tolerances

1 Scope

This document specifies rules for indicating the tolerance for surface form deviation, in the ISO 10110 series, which standardizes drawing indications for optical elements and systems.

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 document, nanometres are now the preferred and standard unit to express surface form deviations. The usage of fringe spacings is still permitted, provided that the base wavelength is explicitly stated.

This document applies to surfaces of plano, spherical, aspheric, cylindric, and toric form as well as to surfaces of other non-spherical shape such as generally described surfaces. It also applies to the substrates of diffractive surfaces; for transmitted or reflected wavefront specifications see ISO 10110-16 and ISO 10110-14.

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

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.

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

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

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

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.

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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, and other surface form errors (see 5.2). 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 a wavefront deformation tolerance for the entire optical element 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.

NOTE 3 The surface form tolerances apply to the finished (as-coated and/or cemented) optical component unless explicitly stated otherwise on the drawing (as per ISO 10110-1:2019, Clause 4).

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The surface form tolerances assume the part is in a ‘free’ state, undistorted by external forces (such as gravity) and mounting deformation. If mounting or gravity effects are expected to be significant, it is recommended to either compensate those effects (with an expected uncertainty of the compensation provided) or indicate the orientation and mounting of the part when it is measured.

Specifying a slope deviation or Zernike residual tolerance is recommended for non-spherical surfaces like aspheric, non-circular cylindric, or general surfaces. Depending on the application and complexity, the permissible maximum 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.

The sagitta deviation, ΔZ, is defined along the Z-axis. All other deviations of the surface are defined perpendicular to the theoretical surface.

4.2 Units

The maximum permissible values for power deviation, irregularity, rotationally and/or translationally invariant irregularity, total deviation, and any of the rms deviation types shall be specified in units of nanometres (…nm) or, if preferred, micrometres (…µm), waves (…λ or …wv), or fringe spacings (no unit or … fr). The use of nanometres is recommended. Fringe spacings (or “fringes” for short) require specification of a test wavelength as well as a scale factor, and make little sense for non-interferometric measuring techniques. Micrometres have a similar magnitude to fringes and make it more likely the specification could be mistaken as fringes on casual inspection. The unit “waves” also requires specification of the test wavelength and is not recommended to avoid confusion with other uses of the word “wavelength”.

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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 document, 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 The unit "fringe spacings" is a legacy of when optical surfaces were tested interferometrically and analysed visually, e.g. with a Newton test plate and green light from a Mercury lamp. While some surfaces are still tested this way, measuring surfaces with digital measurement systems (including non-interferometric techniques) is increasingly common. Furthermore, there is a greater variety of interferometric test configurations now than just a double-pass normal incidence test (e.g. for prisms, conic null tests, grazing incidence interferometry).

By default, the fringe spacing unit equals $\lambda/2$, where λ is the specified wavelength.

For a general interferometric test configuration, the fringe spacing is equal to $\lambda/[N \cos(\alpha)]$, where α is the angle of incidence of the test wavefront on the test surface, N is the number of passes the test wavefront makes with the test surface, and λ is the wavelength of light used in the test. For the 'typical' normal incidence surface test in reflection, $N = 2$ and $\alpha = 0$, resulting in the default expression above.

If units of fringe spacings are used for a surface that is not expected to be measured in reflection at normal incidence, a note shall be added to the drawing specifying both the test configuration and the fringe scale factor $[N \cos(\alpha)]$.

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 maximum and rms slope deviation shall be specified with preferred units of milliradians (…mrad), though other angular units are permitted (for example µrad, arcsec, arcmin). The angle unit shall always be indicated.

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NOTE 2 In earlier versions of ISO 10110-5 and ISO 14999-4, the slope was assumed to be in mrad (with no unit label).

NOTE 3 While the traditional mathematical definition of slope is unitless (the tangent of an angle, or the ratio between two lengths), our definition uses the angle itself (see ISO 14999-4:2026, 3.4.4 and 3.4.6). For typical slope deviation magnitudes, the slope angle ξ expressed in radians is practically identical to the traditional definition of slope ($\tan(\xi) \approx \xi$ when $\xi << 1$).

4.3 Wavelength

If using units of fringe spacings or waves, the wavelength shall be specified (preferably in nm). If different than the reference wavelength (defined in ISO 10110-1 and typically associated with the title field of the drawing), the wavelength shall be indicated in 3/. If the fringe and wavelength units are the same as the specified reference wavelength, the wavelength may be omitted in 3/.

NOTE 1 In earlier versions of this document, unless otherwise specified, the wavelength was the green spectral line of mercury (e-line), λ = 546,07 nm, in accordance with ISO 7944.

NOTE 2 Specifications can be converted from one reference wavelength to another; see ISO 14999-4:2026, 5.6.

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, maximum slope, and rms slope deviation, and more complex computations (e.g. based on Zernike polynomials) as needed for the optical

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