INTERNATIONAL STANDARD

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Optics and photonics — Interferometric measurement of optical elements and optical systems —

Part 4: Interpretation and evaluation of tolerances specified in ISO 10110

Optique et photonique — Mesurage interférométrique de composants et de systèmes optiques —

Partie 4: Directives pour l'évaluation des tolérances spécifiées dans l'ISO 10110

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 14999-4 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

ISO 14999 consists of the following parts, under the general title *Optics and photonics — Interferometric measurement of optical elements and optical systems*:

— *Part 1: Terms, definitions and fundamental relationships*

— *Part 2: Measurement and evaluation techniques*

— *Part 3: Calibration and validation of interferometric test equipment and measurements*

— *Part 4: Interpretation and evaluation of tolerances specified in ISO 10110*

Parts 1, 2 and 3 are Technical Reports.

Introduction

This part of ISO 14999 provides a theoretical frame upon which are based indications from ISO 10110-5 and/or ISO 10110-14.

ISO 10110-5 refers to deformations in the form of an optical surface, and provides a means for specifying tolerances for certain types of surface deformations in terms of “fringe spacings”.

ISO 10110-14 refers to deformations of a wavefront transmitted once through an optical system, and provides a means of specifying similar deformation types in terms of optical “wavelengths”.

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. One "fringe spacing" (as defined in ISO 10110-5) is equal to a surface deformation that causes a deformation of the reflected wavefront of one wavelength.

Certain scaling factors apply depending on the type of interferometric arrangement – for example, whether the test object is being measured in single pass or double pass.

Because of the potential for confusion and mis-interpretation, units of nanometres rather than units of “fringe spacings” or “wavelengths” should be used for the value of surface form deviation or the value of wavefront deformation, where possible. Where “fringe spacings” or “wavelengths” are used as units, the wavelength should also be specified.

Optics and photonics — Interferometric measurement of optical elements and optical systems —

Part 4: Interpretation and evaluation of tolerances specified in ISO 10110

1 Scope

This part of ISO 14999 applies to the interpretation of interferometric data relating to the measurement of optical elements.

This part of ISO 14999 gives definitions of the optical functions specified in the preparation of drawings for optical elements and systems, made in accordance with ISO 10110-5 and/or ISO 10110-14 as well as guidance for their interferometric evaluation with visual analysis.

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 10110-5:—[1)], *Optics and photonics — Preparation of drawings for optical elements and systems — Part 5: Surface form tolerances*

ISO 10110-14:—[2)], *Optics and photonics — Preparation of drawings for optical elements and systems — Part 14: Wavefront deformation tolerance*

3 Terms and definitions

3.1 Mathematical definitions

3.1.1
function
mathematical description of the measured wavefront deformation and its decomposition into components

NOTE The functions used in this part of ISO 14999 are scalar functions.

1) To be published (Revision of ISO 10110-5:1996 + 10110-5:1996/Cor.1:1996).

2) To be published (Revision of ISO 10110-14:2003).

3.1.2
peak-to-valley value
PV (f)
⟨of a function f⟩ maximum value of the function within the region of interest minus the minimum value of the function within the region of interest

3.1.3
root mean square value
rms (f)
⟨of a function f over a given area A⟩ value given by either of the following integral expressions:

a) Cartesian variables x and y:

$$\mathrm{rms}\,(f) = \left[\frac{\iint\limits_{x\,y} \left[f(x,y) \right]^2 \,\mathrm{d}x\,\mathrm{d}y}{\iint\limits_{x\,y} \mathrm{d}x\,\mathrm{d}y} \right]^{1/2} \quad \text{where } (x,y) \in A$$

b) Polar variables r and θ:

$$\mathrm{rms}\,(f) = \left[\frac{\iint\limits_{\theta\,r} \left[f(r,\theta) \right]^2 r\,\mathrm{d}r\,\mathrm{d}\theta}{\iint\limits_{\theta\,r} r\,\mathrm{d}r\,\mathrm{d}\theta} \right]^{1/2} \quad \text{where } (r,\theta) \in A$$

NOTE This integral may be approximated by the standard deviation provided that the measurement resolution is specified and is sufficient.

3.2 Definition of optical functions

NOTE The following optical functions are depicted in Figure 1. For the relationship of interferometric measurements to surface form deviation and transmitted wavefront deformation see Clause 4.

3.2.1
measured wavefront deformation
f_{MWD}
function representing the distances between the measured wavefront and the nominal theoretical wavefront, measured normal to the nominal theoretical wavefront

See Figure 1 a).

3.2.2
tilt
f_{TLT}
plane function representing the best (in the sense of the rms fit) linear approximation to the measured wavefront deformation f_{MWD}

See Figure 1 b).

3.2.3
wavefront deformation
f_{WD}
function resulting after subtraction of the tilt f_{TLT} from the measured wavefront deformation f_{MWD}

$$f_{WD} = f_{MWD} - f_{TLT}$$

See Figure 1 c).

3.2.4
wavefront spherical approximation
f_{WS}
function of spherical form that best (in the sense of the rms fit) approximates the wavefront deformation f_{WD}

See Figure 1 d).

3.2.5
wavefront irregularity
f_{WI}
function resulting after subtraction of the wavefront spherical approximation f_{WS} from the wavefront deformation f_{WD}

$$f_{WI} = f_{WD} - f_{WS}$$

See Figure 1 e).

3.2.6
wavefront aspheric approximation
f_{WRI}
rotationally invariant aspherical function that best (in the sense of the rms fit) approximates the wavefront irregularity, f_{WI}

See Figure 1 f).

3.2.7
rotationally varying wavefront deviation
f_{WRV}
function resulting after subtraction of the wavefront aspheric approximation f_{WRI} from the wavefront irregularity f_{WI}

$$f_{WRV} = f_{WI} - f_{WRI}$$

See Figure 1 g).

3.3 Definition of values related to the optical functions defined in 3.2

3.3.1
sagitta deviation
PV (f_{WS})
peak-to-valley value of the approximating spherical wavefront

NOTE PV (f_{WS}) corresponds to the quantity A in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.

3.3.2
irregularity
PV (f_{WI})
peak-to-valley value of the wavefront irregularity

NOTE PV (f_{WI}) corresponds to the quantity B in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.

3.3.3
rotationally invariant irregularity
PV (f_{WRI})
peak-to-valley value of the wavefront aspheric approximation

NOTE PV (f_{WRI}) corresponds to the quantity C in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.

3.3.4
rotationally varying irregularity
PV (f_{WRV})
peak-to-valley value of the rotationally varying wavefront deviation

3.3.5
rms total
rms (f_{WD})
root-mean-square value of the wavefront deformation

NOTE rms (f_{WD}) corresponds to the quantity RMSt in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.

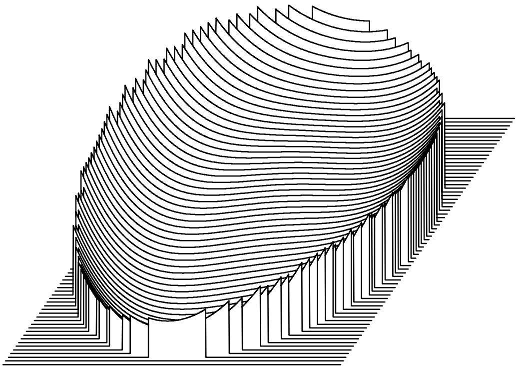
3.3.6
rms irregularity
rms (f_{WI})
root-mean-square value of the wavefront irregularity

NOTE rms (f_{WI}) corresponds to the quantity RMSi in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.

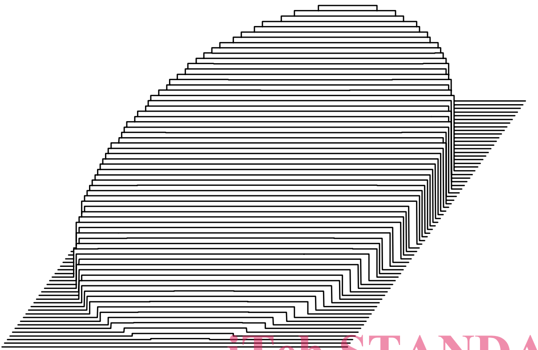
3.3.7
rms rotationally invariant irregularity
rms (f_{WRI})
root-mean-square value of the wavefront aspheric approximation

3.3.8
rms rotationally varying irregularity
rms (f_{WRV})
root-mean-square value of the rotationally varying wavefront deviation

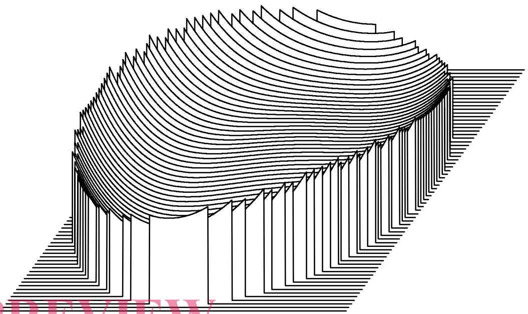
NOTE rms (f_{WRV}) corresponds to the quantity RMSa in ISO 10110-5:— and ISO 10110-14:—. In the case of ISO 10110-5, if the unit is not fringe spacing, the surface deviation is computed according to the test set-up used.



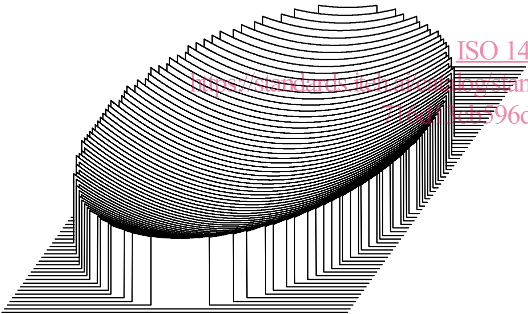
a) Measured wavefront deformation (f_{MWD})



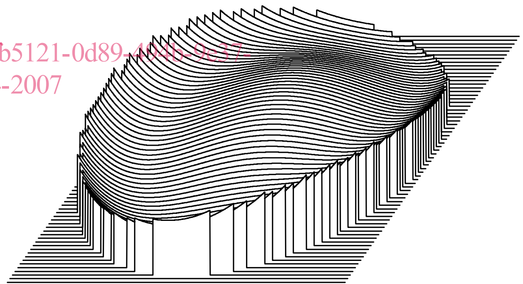
b) Tilt (f_{TLT})



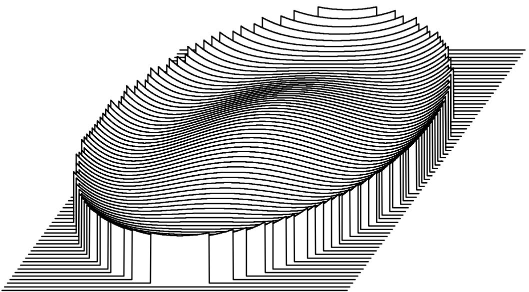
c) Wavefront deformation (f_{WD}) that determines the "RMSt"



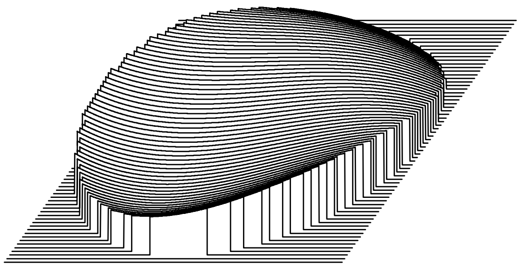
d) Wavefront spherical approximation (f_{WS}) that determines the sagitta deviation "A"



e) Wavefront irregularity (f_{WI}) that determines the irregularity "B" and "RMSi"



f) (Rotationally invariant) wavefront aspheric approximation (f_{WRI}) that determines the rotationally invariant irregularity "C"



g) Remaining rotationally varying wavefront deviation (f_{WRV}) that determines the "RMSa"

Figure 1 — Measured wavefront deformation and its decomposition into wavefront deformation types