INTERNATIONAL STANDARD

ISO 10110-12

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

Part 12:
Aspheric surfaces

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

Partie 12: Surfaces asphériques

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Reference number
ISO 10110-12:1997(E)

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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.

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 10110-12 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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Optics and optical instruments — Preparation of drawings for optical elements and systems —

Part 12:
Aspheric surfaces

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 presentation, dimensioning and tolerancing of optically effective surfaces of aspheric form.

This part of ISO 10110 does not apply to discontinuous surfaces such as Fresnel surfaces or gratings.

This part of ISO 10110 does not specify the method by which compliance with the specifications is to be tested.

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 1101:—[1]), *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings.*

ISO 10110-1:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 1: General.*

ISO 10110-5:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 5: Surface form tolerances.*

ISO 10110-6:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 6: Centring tolerances.*

1) To be published. (Revision of ISO 1101:1983)

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ISO 10110-7:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 7: Surface imperfection tolerances.*

ISO 10110-8:1997[2], *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 8: Surface texture.*

3 Mathematical description of aspheric surfaces

3.1 General

Aspheric surfaces are described in a right-handed, orthogonal coordinate system in which the z axis is the optical axis.

Unless otherwise specified, the z axis is in the plane of the drawing and runs from left to right; if only one cross-section is drawn, the y axis is in the plane of the drawing and is oriented upwards.

If two cross-sections are drawn, the xz cross-section shall appear under the yz cross-section (see figure 5). For clarity the x- and y-axes may be shown on the drawing.

The origin of the coordinate system is at the vertex of the aspheric surface (figure 1).

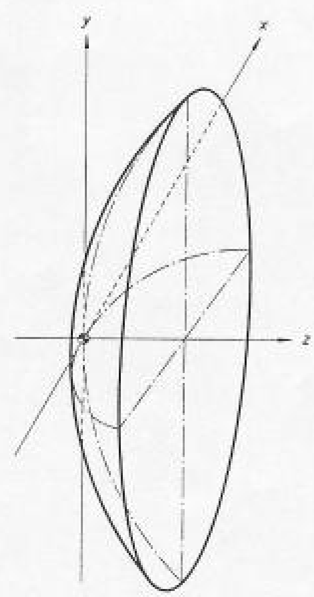

Figure 1 — Coordinate system

2) To be published.

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Surfaces fulfilling the equation

$z = f(x^2 + y^2)$

are of special importance; they are rotationally symmetric about the z axis.

Two types of surface are of particular importance because of their common application in applied optics:

— generalized surfaces of second order, and

— toric surfaces.

3.2 Special surface types

3.2.1 Generalized surfaces of second order

In the coordinate system given in 3.1, the equation of the surfaces of second order which fall within the scope of this part of ISO 10110 is

$$z = f(x, y) = c \cdot \frac{\frac{x^2}{a^2} + \frac{y^2}{b^2}}{1 + \sqrt{1 - \frac{x^2}{a^2} - \frac{y^2}{b^2}}} \qquad \ldots (1)$$

where

a and b are constants (possibly imaginary), with a^2 and b^2 real);

c is a real constant.

With the substitutions

$\frac{a^2}{c} = R_x$ (radius of curvature in the xz plane for $z = 0$),

$\frac{b^2}{c} = R_y$ (radius of curvature in the yz plane for $z = 0$),

$\kappa_x = \frac{a^2}{c^2} - 1$,

$\kappa_y = \frac{b^2}{c^2} - 1$

where κ_x, κ_y are the conic constants,

equation (1) becomes

$$z = f(x, y) = \frac{\frac{x^2}{R_x} + \frac{y^2}{R_y}}{1 + \sqrt{1 - (1 + \kappa_x)\left(\frac{x}{R_x}\right)^2 - (1 + \kappa_y)\left(\frac{y}{R_y}\right)^2}} \qquad \ldots (2)$$

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If the surface according to equation (2) is intersected with the planes $x = 0$ (or $y = 0$), then, depending on the value of κ_y (or κ_x), intersection lines of the following types are produced:

$\kappa > 0$	oblate ellipse;
$\kappa = 0$	circle;
$-1 < \kappa < 0$	prolate ellipse;
$\kappa = -1$	parabola;
$\kappa < -1$	hyperbola.

The following special cases of equation (2) should be mentioned:

a) $R = R_x = R_y$, $\kappa = \kappa_x = \kappa_y$ and $h^2 = x^2 + y^2$ gives

$$z = f(h) = \frac{h^2}{R + \sqrt{R^2 - (1+\kappa)\,h^2}} \quad \text{. . . (3)}$$

Equation (3) describes a surface rotationally symmetric about the z axis.

b) $$z = f(u) = \frac{u^2}{R_u + \sqrt{R_u^2 - (1+\kappa_u)\,u^2}} \quad \text{. . . (4)}$$

This equation describes a cylinder (not necessarily of circular cross-section) the axis of which for $u = x$ is perpendicular to the xz plane, and the axis of which for $u = y$ is perpendicular to the yz plane.

c) $$z = f(x, y) = c\sqrt{\frac{x^2}{a^2} + \frac{y^2}{b^2}} \quad \text{. . . (5)}$$

This equation describes a cone with its tip at the origin with elliptical cross-section (if $a \neq b$) or with circular cross-section (if $a = b$).

If necessary, equation (2) can be modified by the addition of a power series $f_1(x,y)$ (see annex A). The equation of the surface is then complete:

$$z = f(x, y) + f_1(x, y) \quad \text{. . . (6)}$$

where $f(x, y)$ represents the basic form according to equation (2).

NOTE — Care should be taken that the signs of the coefficients in $f_1(x, y)$ are in accordance with the conventions defined in figure 1.

3.2.2 Toric surfaces

A toric surface is generated by the rotation of a defining curve, contained in a plane, about an axis which lies in the same plane. The equation of a toric surface having its defining curve $z = g(x)$ in the xz plane and its axis of rotation parallel to the x axis is

$$z = f(x, y) = R_y \mp \sqrt{\left[R_y - g(x)\right]^2 - y^2} \quad \text{. . . (7)}$$

where R_y is the z-coordinate at which the axis of rotation intersects the z axis.

For the purpose of this part of ISO 10110, $g(x)$ is derived from equation (2) by setting $y = 0$.

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$$g(x) = \frac{x^2}{R_x + \sqrt{R_x^2 - (1+\kappa_x)\,x^2}} \qquad \ldots (8)$$

The equation of a toric surface having its defining curve in the yz plane and its axis of rotation parallel to the y axis may be obtained from equations (7) and (8) by interchanging x with y, R_x with R_y and κ_x with κ_y.

The following special case of equations (7) and (8) should be mentioned:

$\kappa_x = 0$ gives $g(x) = R_x - \sqrt{R_x^2 - x^2}$ and

$$z = f(x,y) = R_y - \sqrt{\left[R_y - R_x + \sqrt{R_x^2 - x^2}\right]^2 - y^2} \qquad \ldots (9)$$

Equation (9) describes a torus whose defining arc is a circle with radius R_x.

In analogy with 3.2.1 of this part of ISO 10110, $g(x)$ can be modified by addition of a power series $g_1(x)$ (see annex A.)

4 Indications in drawings

4.1 General

An aspheric lens or mirror shall be represented in the same manner as a spherical component (see ISO 10110-1), the indication of the radius on the drawing being replaced by the word "asphere" if $f_1(x, y) \neq 0$, or the type of asphere if the basic equation is not modified by a power series (e.g."toroid", "paraboloid", etc.).

The equation describing the aspheric surface shall be given in a note, except for cylindrical surfaces with circular cross-section.

For clarity, the form of the aspheric profile may be exaggerated in the drawing. In addition, an abridged sagitta table may be included on the drawing (see figure 2).

Surface form tolerances shall be indicated in one of the following ways:

a) in accordance with ISO 1101,

b) in accordance with ISO 10110-5

or

c) by a table specifying the permissible deviations of z, i.e. the differences between the nominal values of z according to equation (8) and the actual values of the workpiece (see figure 2).

In each of these three cases, the permissible slope deviation (that is, the local deviation of the surface normal from the nominal value) may additionally be specified.

If such a slope tolerance is specified, the slope sampling length shall also be given on the drawing. The slope sampling length is the transverse distance on the surface over which the slope is measured. Note that the slope deviation refers to the slope difference between the actual surface and the nominal aspheric surface calculated according to the defining equation.

For non-rotationally-symmetric surfaces, the slope tolerance may be different in different sections.

Centring tolerances shall be indicated in accordance with either ISO 1101 or ISO 10110-6.

Tolerances for surface imperfections and specifications of surface texture shall be indicated according to ISO 10110-7 and ISO 10110-8, respectively.

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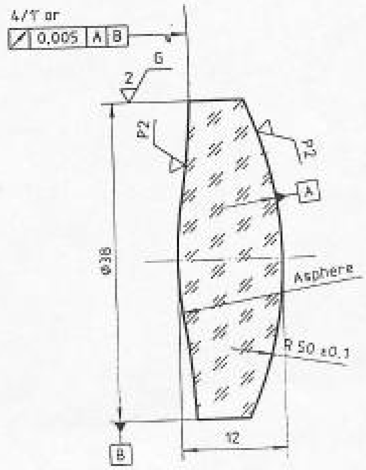
Dimensions in millimetres



$$z = \frac{h^2}{R\left(1+\sqrt{1-(1+\kappa)h^2/R^2}\right)} + \sum_{i=2}^{5}\left(A_{2i}\,h^{2i}\right)$$

h	z	Δz	Slope tolerance
0,0	0,000	0,000	0,3'
5,0	0,219	0,002	0,5'
10,0	0,825	0,004	0,5'
15,0	1,599	0,006	0,8'
19,0	1,934	0,008	1,0'

R = 56,031

K = − 3

A_4 = − 0,432 64E-05

A_6 = − 0,976 14 E-08

A_8 = − 0,108 52 E-11

A_{10} = − 0,122 84 E-13

Slope sampling length = 1 ± 0,1

Figure 2 — Lens with a rotationally symmetric aspheric surface

5 Examples

5.1 Parts with a symmetric aspheric surface, coincident mechanical and optical axes

In figure 2, the datum axis runs through the centre of curvature of the spherical surface and the central point of the right surface (according to ISO 10110-6).

The form tolerance of the aspheric surface is given in tabular form. Δz is the maximum permissible deviation, in millimetres, in the z direction for the given H coordinate. In addition, a slope error tolerance is indicated.

5.2 Parts with a symmetric aspheric surface, with the optical and mechanical axes not coincident

Figure 3 a) shows an off-axis paraboloid with a rectangular cross-section. The surface form tolerance and centring tolerance are indicated according to ISO 1101.

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The datum axis is given by the intersection of surfaces A and C. Datum C is the part width as shown.

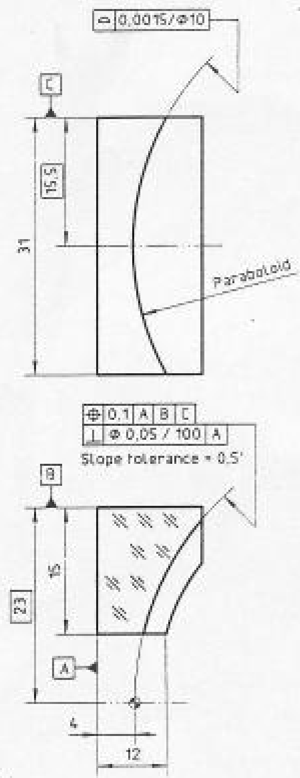
The vertex of the paraboloid shall lie within a cube of edge length 0,1 mm centred on the nominal position.

The rotation axis of the paraboloid shall lie, over a length of 100 mm, within a cylinder parallel to the datum axis, having a diameter of 0,05 mm.

The surface form tolerance of the optically effective surface is given according to ISO 1101:—[1], 14.6. In addition, the slope error tolerance is indicated.

Figure 3 b) shows the same optical element as figure 3 a); however, the surface form tolerance is indicated here according to ISO 10110-5.

Dimensions in millimetres



Slope sampling length = 2 ± 0,2

$z = \frac{h^2}{2R}$ $R = 35{,}741 \pm 0{,}2$

a) Surface form tolerance indication in accordance with ISO 1101

1) To be published (Revision of ISO 1101:1983)

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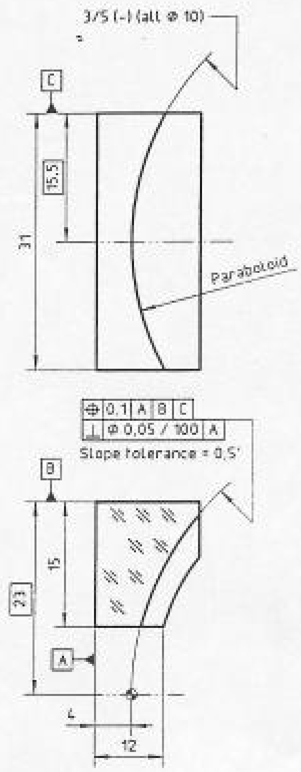
Dimensions in millimetres



Slope sampling length = 2 ± 0,2

$z = \dfrac{h^2}{2R}$ $\qquad$ $R = 35{,}741 \pm 0{,}2$

b) Surface form tolerance indication in accordance with ISO 10110-5

Figure 3 — Off-axis paraboloid

5.3 Parts with a non-rotationally-symmetric aspheric surface

Figure 4 shows a planocylinder lens with rectangular cross-section. The datum axis is given by the intersection of surfaces A and B.

The axis of the cylindrical surface shall be within a cylinder of diameter 0,05 mm.

The form error tolerance is specified according to ISO 1101:—[1]), 14.4 and additionally by different slope error tolerances in the two sections.

Figure 5 shows a planotoric lens with circular cross-section.

The datum axis is given by the edge cylinder B and the plano surface A.

The surface equation shown in the drawing indicates that defining arc and rotation axis of the surface lie in the xz-plane.

Different tolerances for the surface tilt angles are given in the two sections. Also the (local) slope angle tolerances are different in the two sections.

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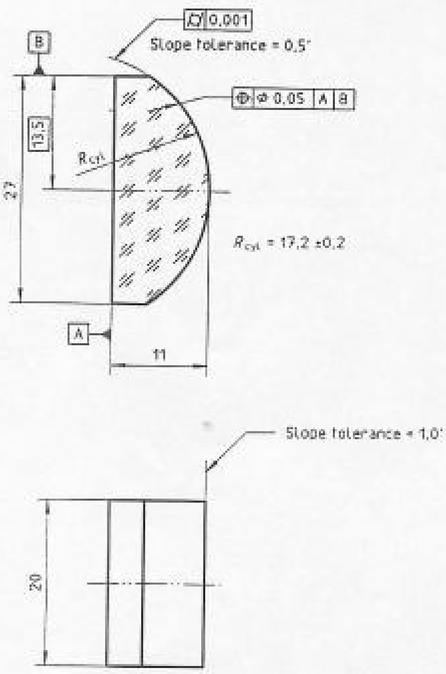
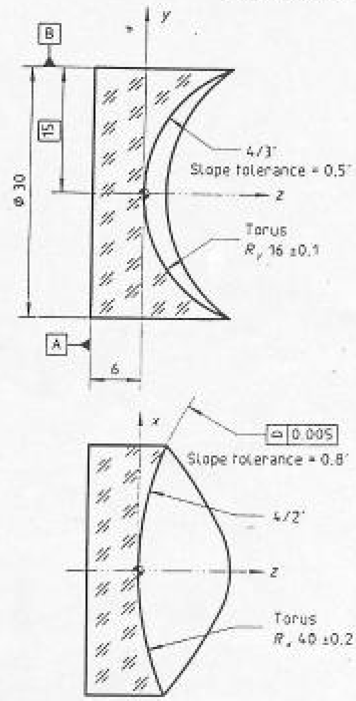
Dimensions in millimetres



Slope sampling length = 2 ± 0,2

Figure 4 — Planocylinder lens

Dimensions in millimetres



$$z = R_y - \sqrt{\left[R_y - R_x + \sqrt{R_x^2 - x^2}\right]^2 - y^2}$$

Slope sampling length = 3 ± 0,2

Figure 5 — Planotoric lens

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Annex A
(normative)

Summary of aspheric surface types

Class	Basic surface	Basic equation $f(x,y)$ =	Power series $f_1(x,y)$ = [for toric surfaces, $g_1(x)$]
Non-rotationally-symmetric surfaces	Ellipsoid Hyperboloid Paraboloid	$\dfrac{\dfrac{x^2}{R_x}+\dfrac{y^2}{R_y}}{1+\sqrt{1-(1+\kappa_x)\left(\dfrac{x}{R_x}\right)^2-(1+\kappa_y)\left(\dfrac{y}{R_y}\right)^2}}$	$A_4x^4+B_4y^4+A_6x^6+B_6y^6+\ldots$ $+C_3\lvert x\rvert^3+\ldots+D_3\lvert y\rvert^3+\ldots$
$R_x \neq R_y$ 1) $\kappa_x \neq \kappa_y$ $A_{2i} \neq B_{2i}$ $C_{2i-1} \neq D_{2i-1}$	Cone $(a \neq b)$	$c\sqrt{\dfrac{x^2}{a^2}+\dfrac{y^2}{b^2}}$	
	Cylinder	$\dfrac{u^2}{R_u\left[1+\sqrt{1-(1+\kappa_u)\left(\dfrac{u}{R_u}\right)^2}\right]}$	$A_4x^4+A_6x^6+\ldots+C_3\lvert x\rvert^3+\ldots$ for $u=x$ $B_4y^4+B_6y^6+\ldots+D_3\lvert y\rvert^3+\ldots$ for $u=y$
Surfaces rotationally symmetric about z axis	Ellipsoid Hyperboloid Paraboloid Sphere	$\dfrac{h^2}{R\left(1+\sqrt{1-(1+\kappa)\left(\dfrac{h}{R}\right)^2}\right)}$	$A_3h^3+A_4h^4+A_5h^5+\ldots$
$R_x = R_y = R$ $\kappa_x = \kappa_y = \kappa$ $h^2 = y^2 + x^2$	Cone $(a = b)$	$\dfrac{c}{a}\sqrt{h^2}$	where $h = \left\lvert\sqrt{x^2+y^2}\right\rvert$
	Plane (Schmidt surface)	0	
Surfaces of revolution; not coincident with coordinate axis	Toric surface	$f(x,y) = R_y \mp \sqrt{\left[R_y - g(x)\right]^2 - y^2}$ $g(x) = \dfrac{x^2}{R_x+\sqrt{R_x^2-(1+\kappa_x)x^2}}$	$g_1(x) = A_4x^4+A_6x^6+\ldots+C_3\lvert x\rvert^3+C_5\lvert x\rvert^5+\ldots$

1) If at least one of these inequalities is valid.

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