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

**Part 6:
Centring tolerances**

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

Partie 6: Tolérances de centrage



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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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 second edition cancels and replaces the first edition (ISO 10110-6:1996), which has been technically revised. It also incorporates ISO 10110-6:1996/Cor.1:1999.

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*

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

Part 6: Centring 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 centring tolerances for optical elements, subassemblies, and assemblies.

This part of ISO 10110 applies to plano surfaces, rotationally invariant surfaces, circular cylindrical, non-circular cylindrical, and non-symmetrical surfaces (general surfaces). General surfaces are described using ISO 10110-19.

2 Normative references

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

ISO 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 5459, *Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum systems*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5459 and the following apply.

3.1 optical surface

optically effective surface which deflects the incident light by reflection or refraction

Note 1 to entry: Optical surfaces can be of different degrees of complexity. Correspondingly, the number of the degrees of freedom needed for describing the orientation and location of the surface increases with complexity.

3.2 optical element

part with one or more *optical surfaces* (3.1) providing an optical function and which has a mechanical interface to the superior system

EXAMPLE One optical surface (e.g. parabolic mirror), two optical surfaces (e.g. lens element), or more than two optical surfaces (e.g. cube corner prism).

3.3

subassembly

combination of one or more *optical elements* (3.2) or of an optical element and a mechanical element including a mechanical interface to the superior system

EXAMPLE Doublets, triplets, cube or colour beamsplitters, or a lens element fixed in a barrel.

3.4

assembly

combination of *optical elements* (3.2), *subassemblies* (3.3), and/or mechanical parts

3.5

optical system

complete system providing a function with defined optical performance

3.6

optical axis

<optical system> theoretical axis which is given by the optical design and represents the central path for the main function of the *optical system* (3.5)

3.7

axis of symmetry

axis that connects the nominal centres of curvature of a series of *optical elements* (3.2)

Note 1 to entry: In a typical symmetrical optical system, the axis of symmetry and the *optical axis* (3.6) are the same.

Note 2 to entry: A symmetrical optical system which is used off axis has an optical axis which is not the axis of symmetry.

3.8

datum feature

real (non-ideal) integral feature used for establishing a *datum* (3.9)

Note 1 to entry: A datum feature should be accessible and of sufficient size to permit its use (such as the outer edge of the lens cylinder or a spherical surface).

Note 2 to entry: As datum features are subject to manufacturing imperfections and variations, it could be necessary, where appropriate, to specify tolerances of form to them (see ISO 5459).

[SOURCE: ISO 5459:2011, 3.2, modified — Note 1 and Note 2 from ISO 5459:2011, 3.2, are irrelevant for the purposes of this part of ISO 10110 and potentially confusing and therefore, have been omitted. For the purposes of this part of ISO 10110, instead, Note 1 to entry and Note 2 to entry have been added.]

3.9

datum

theoretically exact geometric reference (such as points, axes, planes, straight lines, etc.) to which toleranced features are related

Note 1 to entry: Datums can be based on one or more *datum features* (3.8) of a part.

3.10

common datum

datum (3.9) established from two or more *datum features* (3.8) considered simultaneously

Note 1 to entry: The two or more features are of equal order of priority (see ISO 5459).

[SOURCE: ISO 5459:2011, 3.9, modified — The Note from ISO 5459:2011, 3.9 is irrelevant for the purposes of this part of ISO 10110 and potentially confusing and therefore, has been omitted. For the purposes of this part of ISO 10110, instead, Note 1 to entry has been added.]

3.11**datum system**

group of two or more separate *datums* (3.9) used as a combined reference for a toleranced feature

Note 1 to entry: The sequence of the indicated datums is of considerable influence on the resulting reference (see ISO 5459).

3.12**datum axis**

theoretically exact axis based on one or more *datums* (3.9)

3.13**datum point**

specified point on the *datum axis* (3.12)

Note 1 to entry: A datum point serves as an additional reference to the location of an *optical system* (3.5). The indication of the datum point is described in 5.2.

3.14**cylindrical datum feature**

smallest circumscribed cylinder that contacts the edge of an *optical element* (3.2)

3.15**cylindrical datum**

axis of the *cylindrical datum feature* (3.14)

3.16**spherical surface datum feature**

best fit sphere of the *optical surface* (3.1) over the defined useable aperture

3.17**spherical datum**

point defined by the *spherical surface datum feature's* (3.16) centre of curvature

3.18**tilt angle**

<spherical surface> angle between the *datum axis* (3.12) and the normal to the surface at its intersection point with the datum axis

Note 1 to entry: See [Figure 1a](#)).

3.19**aspheric surface datum feature**

best fit asphere to the *optical surface* (3.1)

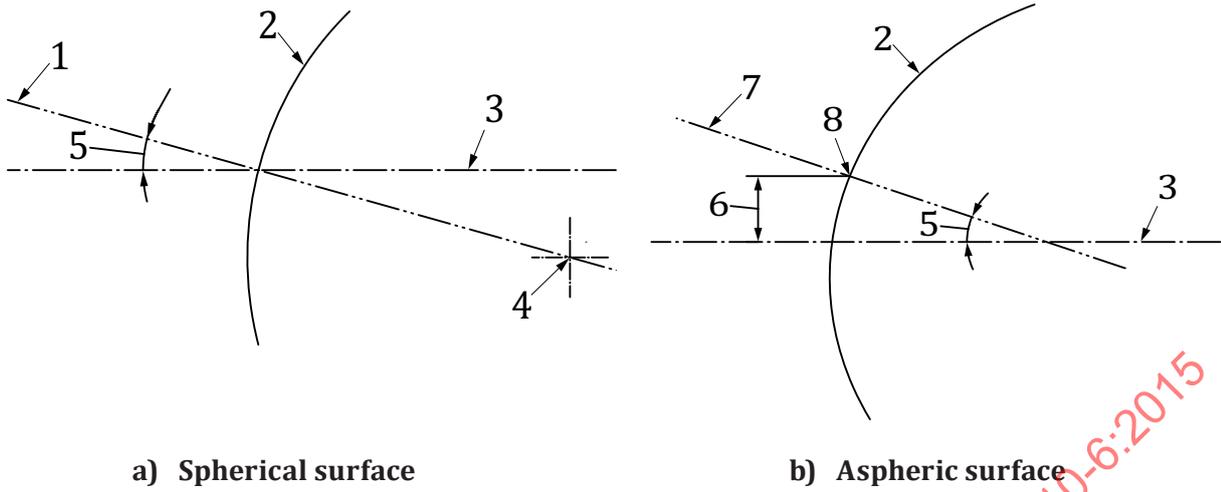
3.20**aspheric datum system**

combination of an axis defined by the *aspheric surface datum feature* (3.19) and the point of rotational symmetry which is the intersection of this axis with the best fit surface

Note 1 to entry: Depending on the grade of asphericity, it can be difficult to clearly differentiate between decentre and surface deviation (see Reference [3]).

3.21**tilt angle**

<aspheric surface> angle between the rotation axis of the aspheric surface and the *datum axis* (3.12) of the part, *subassembly* (3.3), or system to which the aspheric surface belongs



a) Spherical surface

b) Aspheric surface

Key

- 1 normal to the surface
- 2 surface
- 3 datum axis
- 4 centre of curvature
- 5 surface tilt angle
- 6 lateral displacement
- 7 aspheric datum axis
- 8 point of rotational symmetry

Figure 1 — Centring tolerances of a single spherical and aspheric surface

3.22

lateral displacement

<aspheric surface> distance from the point of rotational symmetry of the aspheric surface to the datum axis (3.12)

Note 1 to entry: See Figure 1b).

3.23

circular cylindrical surface datum feature

best fit circular cylinder to the optical surface (3.1)

Note 1 to entry: A circular cylindrical surface is a cylindrical surface whose cross-section perpendicular to its axis is a portion of a circle.

3.24

circular cylindrical datum

axis defined by the centre of curvature of the circular cylindrical surface datum feature (3.23)

3.25

tilt angle

<circular cylindrical surface> angle between the datum system (3.11) and the best fit circular cylinder to the surface at its intersection point with the datum axis

Note 1 to entry: Circular cylindrical surfaces typically require two tilt angles.

3.26**non-circular cylindrical surface datum feature**

best fit non-circular cylinder to the *optical surface* (3.1)

Note 1 to entry: A non-circular cylindrical surface is a surface formed by the translation of a non-circular curve along a linear axis.

Note 2 to entry: The best fit defines the symmetry plane of the non-circular cylinder.

3.27**non-circular cylindrical datum system**

combination of the plane of symmetry defined by the *non-circular cylindrical surface datum feature* (3.26) and the line of intersection of this plane and the best fit surface

3.28**tilt angles**

<non-circular cylindrical surface> angles between the *non-circular cylindrical datum system* (3.27) and the *datum system* (3.11) of the part, *subassembly* (3.3), or system to which the surface belongs

Note 1 to entry: Non-circular cylindrical surfaces typically require three tilt angles.

3.29**lateral displacement**

<non-circular cylindrical surface> distances from the *non-circular cylindrical datum system* (3.27) to the *datum system* (3.11) of the part, *subassembly* (3.3), or system to which the surface belongs

Note 1 to entry: Non-circular cylindrical surfaces typically require one lateral displacement value.

3.30**non-symmetrical surface**

generalized surface defined by a function

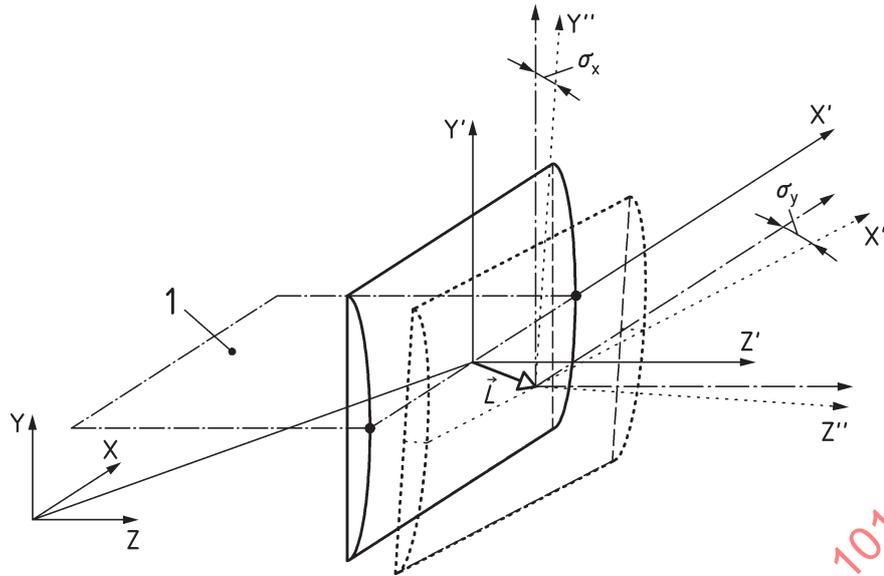
3.31**non-symmetrical surface datum feature**

best fit of the defining function to the *optical surface* (3.1)

Note 1 to entry: Depending on the defining function of the surface, it can be difficult to clearly differentiate between decentre and surface deviation.

3.32**non-symmetrical datum system**

combination of three axes defined by the *non-symmetrical surface datum feature* (3.31)



Key

1	plane of symmetry
XYZ	optical system coordinate system
X'Y'Z'	datum system (optical element coordinate system)
X''Y''Z''	non-circular cylindrical system (measured element coordinate system)
— · — · — · —	L_x, L_y, L_z displaced datum system (displaced element coordinate system)
\vec{L}	vector displaying the lateral displacement with components L_x, L_y, L_z of non-circular cylindrical datum system (measured element coordinate system)

NOTE Z'' is tilted by σ_x and σ_y ; arbitrarily in this case $\sigma_z = 0$, in general σ_z also with a tilt.

Figure 2 — Non-circular cylindrical surface definition of tilt angles and lateral displacements

3.33 tilt angle

<non-symmetrical surface> angle between the *non-symmetrical datum system* (3.32) and the *datum system* (3.11) of the part, *subassembly* (3.3), or system to which the surface belongs

Note 1 to entry: *Non-symmetrical surfaces* (3.30) typically require three tilt angles.

3.34 lateral displacement

<non-symmetrical surface> distances from the *non-symmetrical datum system* (3.32) to the *datum system* (3.11) of the part, *subassembly* (3.3), or system to which the surface belongs

Note 1 to entry: *Non-symmetrical surfaces* (3.30) typically require three lateral displacements.

3.35 tilt angle

<optical element or subassembly> angle between the *datum axis* (3.12) of the element or *subassembly* (3.3) and the system datum axis of which the element or subassembly is a part

Note 1 to entry: See Figure 3.

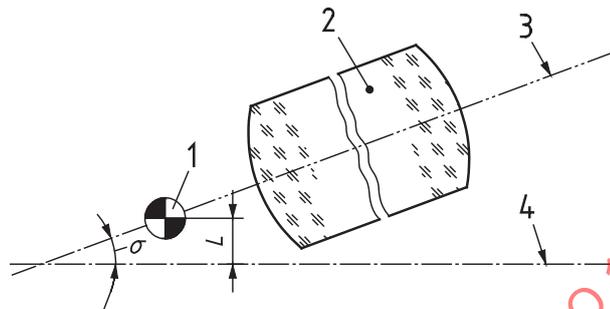
Note 2 to entry: Non-symmetrical optical subassemblies typically require three tilt angles.

3.36**lateral displacement**

<optical element or subassembly> distance between the *datum axis* (3.12) of the element or subassembly and the datum axis of the system which the element or *subassembly* (3.3) is a part of measured at the *datum point* (3.13) of the subassembly

Note 1 to entry: Figure 3 shows an example for a rotationally invariant optical subassembly.

Note 2 to entry: Non-symmetrical optical subassemblies typically require three lateral displacements.

**Key**

- 1 datum point of the subassembly
- 2 subsystem
- 3 datum axis of the subassembly
- 4 datum axis of the system
- σ tilt angle
- L lateral displacement

Figure 3 — Tilt angle and lateral displacement of a rotationally invariant optical subassembly

3.37**surface axial runout**

total cyclical variation (wobble) of the surface parallel to the *datum axis* (3.12) as the surface is rotated about the datum axis taken at the edge of the test diameter expressed in units of millimetres

Note 1 to entry: Runout = test diameter * tangent of surface tilt. Test is specified at the test diameter.

Note 2 to entry: Practical considerations can dictate measurement at a different diameter. The runout tolerance shall then be scaled in direct proportion to the diameter at which it is applied. Best practice is to measure at the greatest practical diameter.

Note 3 to entry: The surface axial runout is only defined for rotationally invariant surfaces. The result is ambiguous for aspheres.

3.38**circular runout of edge cylinder**

total cyclical variation at target line on edge cylinder taken perpendicular to *datum axis* (3.12) as surface is rotated about datum axis, expressed in units of millimetres

Note 1 to entry: Circular runout is twice the *lateral displacement* (3.36).

Note 2 to entry: The runout is only defined for rotationally invariant surfaces. The result is ambiguous for aspheres.

3.39**beam deviation**

angular tilt of a pencil of light incident along the *datum axis* (3.12) after transmission through the element

Note 1 to entry: Alternatively, a *lateral displacement* (3.36) in units of millimetres applied at the focal spot.

Note 2 to entry: Best measurement practice is to rotate the element about the datum axis and take half the full cone angle of the transmitted beam's orbit.

Note 3 to entry: The beam deviation is only defined for rotationally invariant surfaces.

4 Specification of centring tolerances

4.1 General

For individual spherical surfaces, the centring error consists of a surface tilt angle as defined in [3.18](#). For aspheric surfaces, elements, and subassemblies, the centring error consists of a tilt angle between two datum axes and a lateral displacement as defined in [3.19](#), [3.20](#), [3.21](#), and [3.22](#).

For circular cylindrical, non-circular cylindrical and non-symmetrical surfaces, elements, and subassemblies, the centring error consists of up to three tilt angles and up to three lateral displacements as defined in [3.25](#), [3.28](#), [3.29](#), [3.33](#), and [3.34](#) respectively.

4.2 Individual spherical surfaces

For individual spherical surfaces, the maximum permissible tilt angle or axial runout or circular runout with respect to the datum axis (see [3.18](#), [3.37](#), or [3.38](#)) shall be indicated.

4.3 Individual aspheric surfaces

For individual aspheric surfaces, the maximum permissible value of the tilt angle, as defined in [3.21](#), or axial runout, as defined in [3.37](#), and the lateral displacement, as defined in [3.22](#), shall be indicated.

NOTE The surface axial runout is only defined for rotationally invariant surfaces. The result is ambiguous for aspheres.

Alternatively, the centring tolerances for aspheric surfaces may be specified in accordance with ISO 1101 (see Reference [\[1\]](#)).

4.4 Individual circular cylindrical surfaces

For individual circular cylindrical surfaces, the maximum permissible values of up to three tilt angles as defined in [3.25](#) shall be indicated.

Alternatively, the centring tolerances for circular cylindrical surfaces may be specified in accordance with ISO 1101 (see Reference [\[1\]](#)).

4.5 Individual non-circular cylindrical surfaces

For individual non-circular cylindrical surfaces, the maximum permissible values of up to three tilt angles, as defined in [3.28](#), and the maximum permissible value of the lateral displacement of the vertex line, as defined in [3.29](#), shall be indicated.

Alternatively, the centring tolerances for non-circular cylindrical surfaces may be specified in accordance with ISO 1101 (see Reference [\[1\]](#)).

4.6 Individual non-symmetrical surfaces

For individual non-symmetrical surfaces, the maximum permissible values of three tilt angles, as defined in [3.33](#) and of three lateral displacements, as defined in [3.34](#), shall be indicated.

Alternatively, the centring tolerances for non-symmetrical surfaces may be specified in accordance with ISO 1101.

4.7 Optical elements and subassemblies

For rotationally invariant elements, the maximum permissible values of the tilt angles, as defined in 3.35, and the lateral displacements, as defined in 3.36, or the beam deviation, as defined in 3.39, shall be indicated. For subassemblies, the maximum permissible values of the tilt angles, as defined in 3.35, and the lateral displacements, as defined in 3.36, shall be indicated.

4.8 Cement wedge in cemented optical assemblies

For cemented optical subassemblies, a tolerance for the wedge angle of the cement layer can be indicated.

NOTE This applies for subassemblies where the cemented surfaces are plano or spherical.

4.9 Surfaces without optical function

The centring tolerance for optical element surfaces that have no optical function (such as an edge cylinder) shall be specified according to the rules in ISO 1101 (see Figure 15 and Figure 16). Alternatively, the notation of 5.3.4 may be used.

4.10 Field stops, reticles, etc

The centring tolerance for field stops, reticles, etc. shall be specified as in ISO 1101 (see Figure 17).

5 Indication in drawings

5.1 Datum axis

The datum axis shall be established by the application of datum triangles to one or more datum features in accordance with ISO 1101 and ISO 5459 [see Figure 4 a) and Figure 5].

In drawings where centring tolerances of individual surfaces are indicated, the two cases for which the datum axis need not be indicated are the following:

- when the datum axis is established by a single datum feature that is the outer cylinder of the element [see Figures 4 b), d), and f)];
- when the datum axis is a common datum established by a spherical surface and the datum point on the cylinder axis established at the intersection of that surface with the outer edge of the lens cylinder [see Figure 6 b)].

5.2 Datum point

The datum point shall be indicated by the following symbol:



The datum point need not be indicated if it coincides with the intersection point of the datum axis and the first (counted in the direction of light) optical surface of the optical system to which it relates.

For single rotationally invariant aspheric surfaces, the datum point coincides with the point of rotational symmetry of the surface; it is not necessary to indicate it.

5.3 Centring tolerance

5.3.1 The indication for centring tolerances consists of a code number, one or up to six tolerance values (see [Figure 19](#)), and, if necessary, references to more than one datum system (see [Figure 18](#)).

For the indication of cement wedge angle tolerances, the triangular delta symbol (Δ) shall precede the tolerance value.

5.3.2 The code number for centring tolerances is 4. The code number for beam deviation tolerances is 14.

5.3.3 Tolerance values shall be specified in minutes (') or seconds (") of arc for angular dimensions including the unit or in the SI unit radian (preferred values of the prefix include milli, micro and nano), and in millimetres for linear dimensions.

5.3.4 Structure of the indication: The indication shall have one of the following forms:

For spherical surfaces:

$$4/\sigma$$

where

σ is the maximum permissible tilt angle at the datum axis.

For aspheric surfaces and rotationally invariant subassemblies:

$$4/\sigma(L)$$

where

σ is the maximum permissible tilt angle at the datum axis;

L is the maximum permissible lateral displacement.

For cemented assemblies where the cemented surfaces are plano or spherical:

$$4/\Delta\tau$$

where

τ is the maximum permissible cement wedge angle.

For circular and non-circular cylindrical and non-symmetrical surfaces:

$$4/\sigma_x, \sigma_y, \sigma_z (L_x, L_y, L_z)$$

where

σ_i are the maximum permissible tilt angles of the non-symmetrical datum system around the i -axis of the system datum;

L_i are the maximum permissible lateral displacements of the non-symmetrical datum system along the i -axis of the system datum.

If tolerance values are not indicated, they shall be replaced by a dash (—).

For rotational invariant surfaces:

$$4/a < A$$

where

A is the maximum permissible axial runout tolerance at the full clear aperture (see 3.37).

$$4/c < B$$

where

B is the maximum permissible circular runout tolerance at edge (see 3.38).

For rotational invariant elements:

$$14/\rho$$

where

ρ is the maximum permissible transmitted beam deviation through the element or subassembly.

5.3.5 The centring tolerances refer to the datum axis of the optical element or subassembly. If more than one datum axis is indicated in the drawing, the reference letters of the appropriate datum system shall be appended to the tolerance values (see Figure 18).

5.4 Location

The centring tolerance indication shall be shown in connection with a leader to the surface or optical system to which it refers as shown in Figure 4 to Figure 8 and examples in ISO 10110-1.

Alternatively, the indication may be given in a table in accordance with ISO 10110-10. In optical layout drawings when the centring tolerances are given in a table and if no datum axis is indicated, all centring tolerances refer to the theoretical optical axis. An example of the indication of tilt angle and lateral displacement tolerances of subassemblies in a layout-drawing is given in ISO 10110-1, Figure 30.

6 Examples

Examples of indicating centring tolerances for single optical elements are shown in Figure 4 to Figure 8, Figure 15 and Figure 16, and in Figure 19 and Figure 20. Examples for optical subassemblies and assemblies are shown in Figure 9 to Figure 14 and in Figure 17 and Figure 18.

In the example shown in Figure 4 a), c), and e), the datum axis is explicitly indicated as the axis of the outer cylinder. In the abbreviated indication shown in Figure 4 b), d), and f), the tilt angle tolerances for both surfaces are indicated, but the datum axis does not have to be indicated. In this case, the datum axis is the axis of the outer cylinder as shown in Figure 4 a), c), and e).

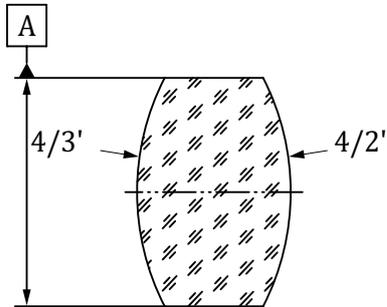
The datum axis in Figure 5 is the line joining the centre of curvature of the left surface and the axis of the outer cylinder as determined only at the circular target line B1. The circular target line B1, also referred to as the gauge line, is located at a distance "a" from the vertex of the spherical surface. Circular target lines and cylindrical target areas (a band instead of a line) may be used to limit the area on the outer cylinder that is used to establish the datum axis on rotationally invariant parts.

NOTE Use of lens barrel cylinder as sole datum is only practical if the cylinder is of sufficient length, e.g. edge thickness $> \varnothing/2$. For instance, it is well-suited for relay lenses in endoscopy.

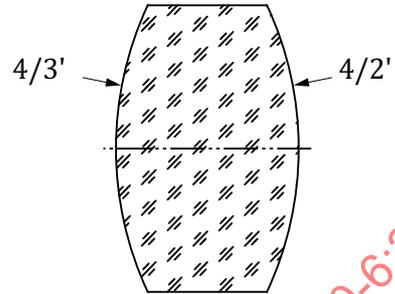
In Figure 6 a), the datum axis is the line joining the centre of curvature and the axis of the outer cylinder as determined only at the circular target line B1 which is located at the intersection of the left spherical

surface with the outer cylinder (see ISO 5459). If no datum axis is indicated and only one tilt angle tolerance is specified [as shown in Figure 6 b)], the datum axis is defined as in Figure 6 a).

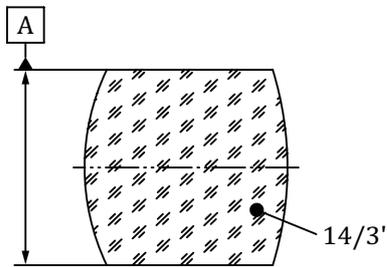
In Figure 7, the datum axis is established first by the plane of datum A and secondly by datum B which is the axis of the outer cylinder.



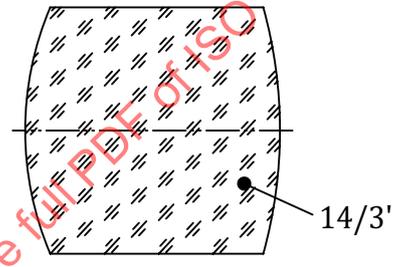
a) Explicit indication



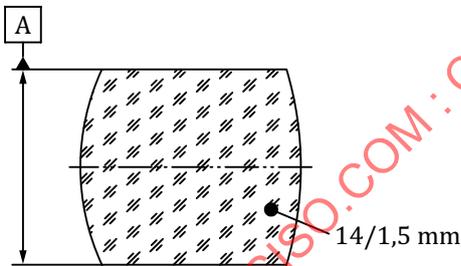
b) Abbreviated indication



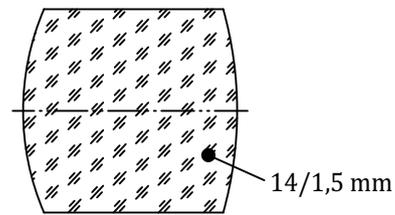
c) Explicit indication for beam deviation



d) Abbreviated indication for beam deviation



e) Explicit indication for beam deviation



f) Abbreviated indication for beam deviation

Figure 4 — Datum axis established by the axis of the outer cylinder of the element

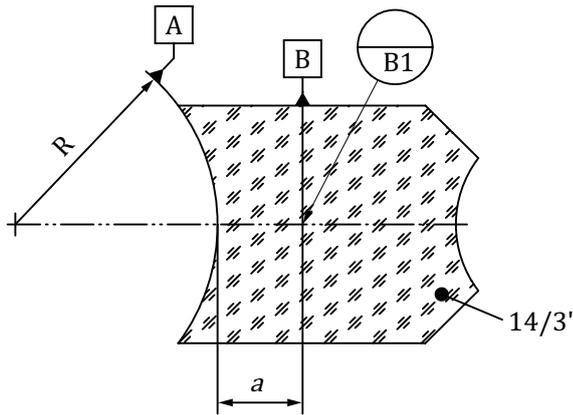
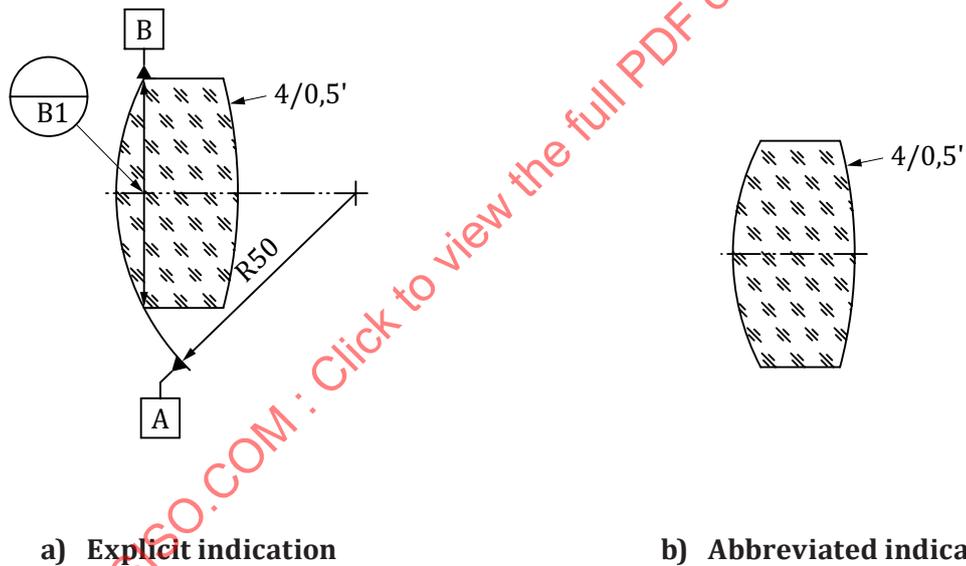


Figure 5 — Example for the indication of a tolerance for beam deviation as defined in 3.39 (datum axis established by the centre of curvature of the left surface and the axis of the outer cylinder determined at the circular target line B1 which is located at a distance a from the vertex of the left spherical surface)



a) Explicit indication

b) Abbreviated indication

Figure 6 — Datum axis established by the centre of curvature of surface A and the outer cylinder axis determined at the circular target line B1 which is located at the intersection of the left spherical surface with the outer cylinder

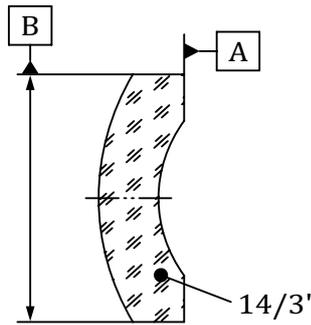


Figure 7 — Datum axis established by the plane of surface A and the axis of the outer cylinder

Figure 8 shows the indication of a centring tolerance for an aspheric surface in accordance with 4.3. Datum A is the primary datum while datum B is the axis of the smallest circumscribed outer cylinder perpendicular to plane A.

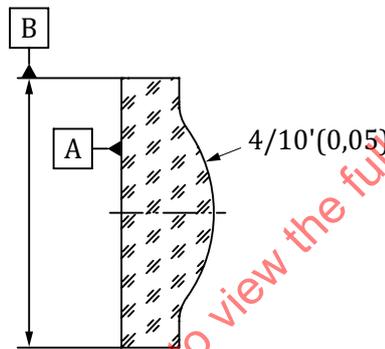


Figure 8 — Centring tolerance for an aspheric surface

The datum axes in Figure 9 and Figure 12 are defined similarly to those in Figure 4.

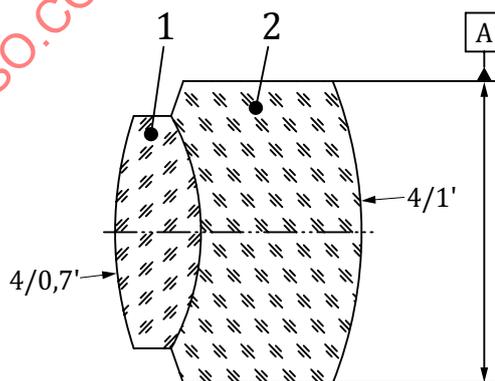


Figure 9 — Datum axis established by the outer cylinder

The definitions of the datum axes in Figure 10 and Figure 13 are the same as those in Figure 6.

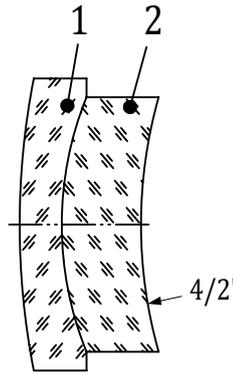


Figure 10 — Optical subassembly [datum axis established as in [Figure 6b](#)]

In [Figure 11](#), the datum axis is the line joining the centres of curvature of the surfaces of lens 2 (i.e. the optical axis of lens 2). Additionally, the indication of a cement wedge tolerance is shown.

[Figure 12](#) gives an example for the indication of a tolerance for the surface axial runout as defined in [3.37](#).

[Figure 14](#) shows a datum axis established by the mechanical surfaces of the lens mount. Here, a plane is established by datum feature A and the cylinder's axis is established by datum B. It is analogous to [Figure 7](#).

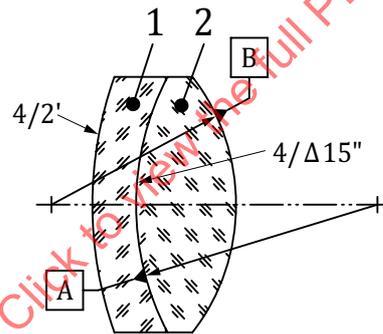


Figure 11 — Datum axis established by the centres of curvature of two surfaces

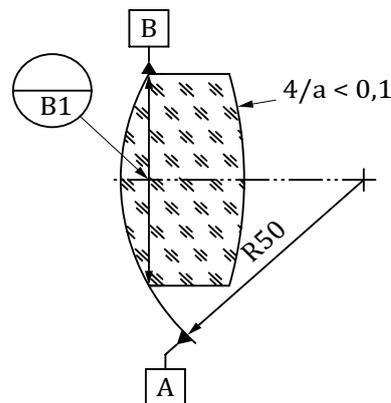


Figure 12 — Indication of a tolerance for the surface axial runout

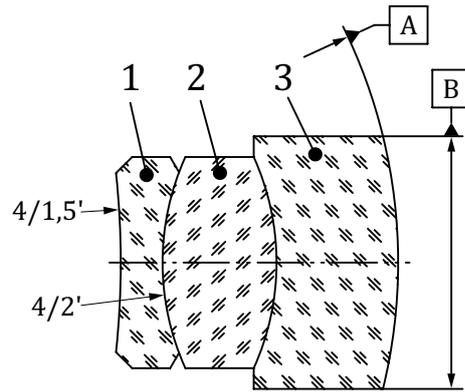


Figure 13 — Tolerance indication of the tilt angle of a cemented surface. Datum axis established as shown in [Figure 6](#)

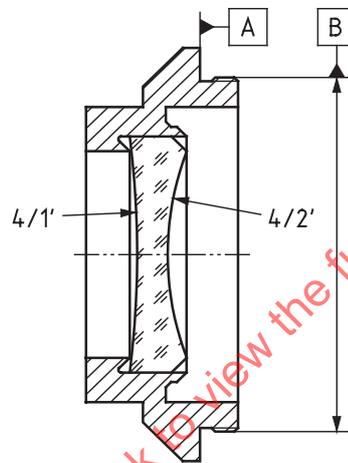


Figure 14 — Datum axis established by datum features on the mechanical mount

[Figure 15](#), [Figure 16](#), and [Figure 17](#) show centring tolerance indications for features with and without optical function in accordance with ISO 1101. [Figure 15](#) additionally shows the indication of a tolerance for the maximum circular runout of the edge cylinder as defined in [3.38](#).

In [Figure 18](#), two different datum systems are used according to the successive manufacturing steps of the compound element.

In [Figure 19](#), centring tolerance indications for a cylindrical lens element are shown.