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

Part 16: **Diffractive surfaces**

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

Partie 16: Surfaces diffractives

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Foreword

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

A list of all parts in the ISO 10110 series can be found on the ISO website.

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

Part 16:
Diffractive surfaces

1 Scope

This document provides general methods of describing surfaces adding a diffractive optical function on optical surfaces, such as planes, spheres, aspheres or general optical surfaces, in the ISO 10110 series, which standardizes drawing indications for optical elements and systems. The subject of this document is the presentation, description and dimensioning of diffractive surfaces in technical drawings. A diffractive surface contains diffractive structures, which are very small structures on or in the surface; ; which use the wave properties of the light and work with diffraction and interference. The diffractive optical function is realized by relief structures on or in the surface or by variations of the index of refraction in the coating material. Diffractive surfaces may be also situated inside of optical assemblies.

This document does not apply to diffractive surfaces with random surface texture, for example stochastic antireflective structures. Also not addressed by this document are all types of 3-dimensionally extended diffractive structures: Bragg gratings, volume holograms (HOE) and acousto-optic modulators.

This document does not address the methods to test and qualify the specifications.

This document does not address tools and methods for manufacturing diffractive surfaces.

Due to the large variety of diffractive optical elements for many purposes, this document is divided in several sub clauses. Common diffractive properties and specifications will be described in the beginning of this document. Specific properties and specifications of several basic types are described in the Annex to this document.

The three most applied types of diffractive structures are linear diffractive structures, concentric circular structures and more complex computer generated diffractive structures.

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

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

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

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

ISO 15902, *Optics and photonics — Diffractive optics — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15902 and the following apply.

IEC maintain terminological databases for use in standardization at the following addresses:

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

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

3.1
diffractive structures
structures on or in the optical surface with which use the wave properties of light and work with diffraction and interference

Note 1 to entry: This part of ISO 10110 does not include random surface textures or coatings which may also have a diffractive optical function.

3.2
diffractive surface
surface of an optical element, which contains diffractive structures

3.3
diffractive region
single closed diffractive structured part of a diffractive surface

3.4
diffractive test region
used part of a diffractive region, where the desired specifications have to be valid

3.5
base surface
finished surface of the substrate before realizing diffractive structures

Note 1 to entry: The base surface is an intermediate surface state in the technological sequence, which may not exist in some manufacturing processes.

3.6
diffraction grating
regular periodic diffractive structure, which is unambiguously mathematically describable

3.7
linear grating
diffraction grating with translation invariant profile in one dimension (which consists of parallel straight equal lines or grooves)

3.8
circular grating
diffraction grating with rotational invariant profile (which consists of concentric circular lines or grooves)

3.9
CGH
computer-generated hologram
diffractive optical element which is computer designed and fabricated under computer control

Note 1 to entry: Only 2-dimensional CGHs are addressed by this standard.

Note 2 to entry: Since CGH is a definition of a surface structure through a production technology, the resulting diffractive structure can be a linear or circular grating. However, it can also be used to fabricate more complex structures. In most cases when referring to a CGH, more complex diffractive structures are meant.

[SOURCE: ISO 15902:2019, 3.2.8]

3.10
transmission grating
diffraction grating, where incident light and diffracted light are situated on different sides

3.11
reflection grating
diffraction grating, where incident light and diffracted light are situated on the same side

3.12
amplitude grating
diffraction grating, which consists of lines of non-transparent material on or in the surface, which form periodically light gaps

3.13
phase grating
diffraction grating, which works with periodically different retardation of the lightwaves

Note 1 to entry: Phase gratings are subclassified into surface relief gratings and index gratings.

3.14
surface relief grating
diffraction grating, which consists of periodically groves in the surface (periodically changing thickness)

3.15
index grating
diffraction grating, which consists of a thin smooth coating on the surface with periodically changing refractive index

3.16
DOE
DOE (diffractive optical element)
optical element for which the phenomenon of the diffraction of optical radiation is the operating principle, usually characterized in terms of its periodic spatial structure

Note 1 to entry: All DOEs containing 2-dimensional diffractive structures are addressed by this standard.

Note 2 to entry: DOE is the generic term for all optical elements described by this standard.

[SOURCE: ISO 15902:2019, 3.2.1]

3.17
reference axis
theoretical axis of the base surface, given by the optical designer which does not depend on symmetries of the base surface and which usually represents the centre of the optical path for the main function

Note 1 to entry: In the case of a rotationally invariant base surface the reference axis is the optical axis.

3.18
local reference axis
theoretical axis of the diffractive structure, given by the optical designer which does not depend on symmetries of the diffractive structure

Note 1 to entry: The intersection point of the local reference axis with the base surface is the origin of the coordinate system of the diffractive structure.

3.19
global coordinate system
coordinate system of the part

Note 1 to entry: Often, the coordinate system of the part is also the coordinate system of the base surface.

Note 2 to entry: The global coordinate system notation is described in ISO 10110. It may be preferred to define the global coordinate system origin to be the coordinate system origin of the base surface; e.g. the point of intersection of the reference axis and the base surface.

3.20
local coordinate system
coordinate system of the diffractive surface

Note 1 to entry: The origin of the local coordinate system is the intersection point of the local reference axis with the base surface, where the diffractive structure is located.

4 Coordinate systems

4.1 General

The diffractive structure is referenced with the coordinate systems used in the process chain, e.g. to define centring tolerances according to ISO 10110-6. A diffractive structure can have 2 essential coordinate systems as shown in Figure 1:

— The local coordinate system with the origin of the mathematical description of the diffractive structure;

— The global coordinate system of the optical component (e.g.: the optical axis)

Specifications shall be available for the clear orientation of the local coordinate system of the diffractive structure according to its position and orientation relative to the global coordinate system. A diffractive structure has 2 or 3 degrees of freedom for referencing onto the base surface. Two lateral coordinates specify the position of the origin of the diffractive structure with respect to the origin of the base surface. A third lateral coordinate is not necessary, because diffractive structures are always located onto the surface of the base surface. If the diffractive structure is rotationally variant, the azimuthal orientation of the local coordinate system onto the base surface shall be specified by an angle or a preferred direction. This angle, if necessary, is the third degree of freedom.

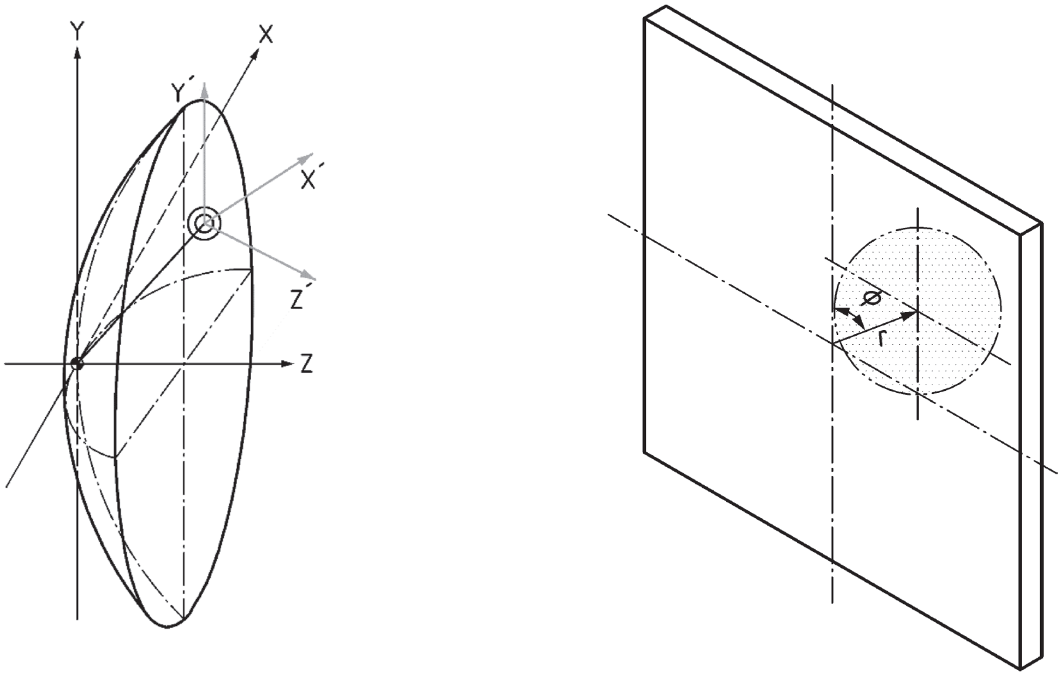
Reference marks in the form of crosses, circles, or lines and combinations of the specified structures can also be specified in this way.

4.2 Description of global and local coordinate systems

The coordinate system of the optical surface consists of three axes (X, Y, Z) orthogonal to each other and follows the right hand rule (right-handed system). The local coordinate origin of the diffractive structure shall be referenced with respect to the global coordinate system of the diffractive part. The local coordinate system of the diffractive structure has its origin onto the base surface. The local coordinate system has three axes (X’, Y’, Z’) and follows also the right hand rule.

The direction of the local Z’ coordinate is parallel to the normal of the local base surface at [X, Y]. The local Z’ direction indicates the local reference axis of the diffractive structure, Y' and X' lie within the tangential plane of the local base surface at X, Y. Figure 1 shows the coordinate system of the base surface and the local coordinate system of the diffractive structure.

The general coordinate transformation shall be done in accordance with ISO 10110-1. Further restriction is that the coordinate system of the diffractive structure is located on the base surface of the optical part.



a) cartesian coordinate system

b) polar coordinate system

Figure 1 — Coordinate system of the base surface and the local origin of the diffractive structure. The origin of the local coordinate system is always on the base surface, therefore two position coordinates are sufficient to describe the position on the base surface. The reference axis is labelled with Z, the local reference axis is Z’

If global reference axis and local reference axis are not identical then a coordinate transformation rule shall be indicated on the drawing or as a supplement to the optical drawing. This transformation rule includes a sketch of the optical part where the local reference axis and the global reference axis can be seen (Figure 2). Second a calculation table shall be given, which describes the transformation sequence mathematically (Table 1). And third, one or more tables with explicit data points shall be given. The purpose of these tables is to confirm the correct calculation of the coordinate transformation. The tables shall state clearly to which surface and to which reference axis the table is referring to. The surface types are defined in Section 3. Examples of such a table can be seen from Table 2 to Table 4. If necessary it is allowed to define multiple reference axes and multiple local reference axes. For all defined axes a coordinate transformation shall be given to indicate the correct positions. If the order of the coordinate transformation from one axis to the next axis is important, the correct order shall be indicated either on the drawing or in the tables.

NOTE A similar type of table is known as “sagitta table” in the optical community and also used in other standards for example ISO 10110-12 on “aspherical surfaces” and ISO 10110-19 on “general surfaces”.

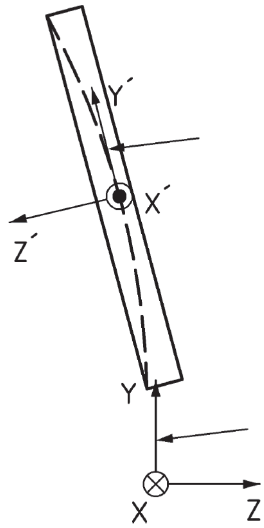


Figure 2 — Coordinate systems as 2 dimensional image with right handed coordinate system arrow markers (top: local reference axis; bottom: reference axis)

Table 1 — Example for a coordinate transformation table

Transformation sequence: 1. Translation 2. rot. around Z 3. rot. around Y 4. rot. around X	**Coordinate transformation**					
	Translations in [mm]			**Rotation around in [°]**		
	X	Y	Z	X	Y	Z
Reference axis to local ref. axis #1						
Reference axis to local ref. axis #2						
…………						
Reference axis to local ref. axis #...						

Table 2 — Table for X’ coordinate

X’ coordinate of the base surface with respect to local reference coordinate system #1 [mm] (parameters from reference coordinate system)								
Y ↓	X →	...	-20	-10	0	10	20	...
...								
-20								
-10								
0								
10								
20								
...								

Table 3 — Table for Y’ coordinate

Y’ coordinate of the base surface with respect to local reference coordinate system #1 [mm]. (parameters from reference coordinate system)								
Y ↓	X →	...	-20	-10	0	10	20	...
...								

Table 3 *(continued)*

-20							
-10							
0							
10							
20							
...							

Table 4 — Table for Z’ coordinate

Z’ coordinate of the base surface with respect to local reference coordinate system #1 [mm]. (parameters from reference coordinate system)							
Y ↓ X →	...	-20	-10	0	10	20	...
...							
-20							
-10							
0							
10							
20							
...							

4.3 Sign convention

As described in later clauses of this document, the various diffractive structures are specified by mathematical equations. To achieve clear surface specifications, the following sign conventions for the constants, vectors, and coefficients shall be used.

The sagitta of a point on the diffractive surface is positive if it lies in the positive Z direction from the XY plane and negative if it lies in the negative Z direction from the XY plane.

5 Drawing specifications

5.1 General

Diffractive structures do not have influence on shape and size. They mean a modification of properties and functionality of the optical surface, similar to an optical coating. Therefore, diffractive structures shall be indicated with a symbol in accordance with Table 5. The combination of the symbols from Table 5 at the same surface is allowed and often necessary.

It is mandatory to present each diffractive optical element in face view on the diffractive surface and at least in one side view.

In addition, the drawing should contain a table defining the surface shape at reference points of the diffractive surface. If the base surface, which carries the diffractive structure, is not spherical, then also a sagitta table of this base surface shall be given on the drawing. When a sagitta table is given on the drawing, it shall have an unique title to identify the mathematical formula from where the table entries are calculated and shall be clearly referenced to the coordinate system used (X, Y, Z) and/or (X', Y', Z'). (see Table 1 to Table 4)

NOTE 1 Recommended reference points are discontinuities, inflection point, fiducials or datum-points. For example the zone positions.

NOTE 2 The diffractive surface form is a combination of the base surface and the diffractive structure. Therefore, the sagitta table of the base surface is only for comparison of mathematical descriptions. The same applies for sagitta tables of the pure diffractive structure.

A note shall be added to the drawing indicating the selected form of mathematical description or a corresponding data file with the corresponding constants, vectors, and coefficients.

If there is no data file for exchanging data between CAD and other systems, the mathematical description shall be specified on the drawing. If there is a data file for exchanging data between CAD and other systems, it shall be specified on the 2D drawing of the individual part near the diffractive surface. An unambiguous file name (e.g. date stamp, version number) including data file extension shall be given. An example of the representation is shown in Annex B.3. Diffractive surfaces can be manufactured by various tools and technologies, however these are not subject of this standard.

5.2 Symbols and abbreviations

Table 5 — Symbols for marking of diffractive structures on drawings

Symbol	Meaning
	Diffractive structure
LG	Linear grating
CG	Concentric circular grating
CGH	Computer generated hologram
TG	Transmission grating
RG	Reflection grating
AG	Amplitude grating
SG	Surface relief grating
IG	Index grating

5.3 Marking and Hatching

In the side view the diffractive symbol has to be drawn outside at the diffractive surface (see Figure 3). If diffractive structures are specified in the table field, this symbol shall be located at the beginning of the specification. When diffractive structures are specified in the drawing field, this symbol shall be located outside the element and tangent to the diffractively structured surface. There are two exceptions from this rule, where the symbol has to be placed inside at the diffractive surface: Diffractive structures with lacquer layer outside and diffractive structures inside of an optical assembly (see Figure 4).

