INTERNATIONAL STANDARD

ISO 11151-2

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Lasers and laser-related equipment — Standard optical components —

Part 2: Components for the infrared spectral range

Lasers et équipements associés aux lasers — Composants optiques standards —

Partie 2: Composants pour la plage spectrale infrarouge

Reference number
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Contents

Page

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 3.

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 part of ISO 11151 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11151-2 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 9, *Electro-optical systems*.

ISO 11151 consists of the following parts, under the general title *Lasers and laser-related equipment — Standard optical components*:

— *Part 1: Components for UV, visible and near-infrared spectral ranges*

— *Part 2: Components for the infrared spectral range*

Annexes A and B of this part of ISO 11151 are for information only.

Introduction

Lasers are used in a wide variety of applications, including medicine, materials processing, information technology and metrology. Most lasers contain optical windows and mirrors (intracavity) and most laser systems use a variety of windows, beamsplitters, deflectors, mirrors and lenses. Those components used in high power laser applications must withstand high peak power and/or energy densities to avoid laser-induced damage, thus their component specifications are more demanding than those used in low power applications.

Lasers and laser-related equipment — Standard optical components —

Part 2: Components for the infrared spectral range

1 Scope

This part of ISO 11151 specifies requirements for laser components used in the infrared spectral range, from wavelengths 2,10 µm to 15,0 µm, and facilitates the supply of spare parts:

— by specifying preferred dimensions and tolerances, thereby reducing the variety of types;

— by standardizing the specifications and removing barriers to trade;

— by establishing an agreed designation for item orders.

This part of ISO 11151 covers planar, plano-spherical and spherical substrates, lenses and optical components that are designed specifically as standardized optical components normally offered via catalogue from suppliers and intended for use with lasers.

This part of ISO 11151 includes component descriptions, materials employed, physical dimensions and manufacturing tolerances (including surface finish, figure and parallelism). Although most, but not all of these components will be coated (fully reflecting, partially reflecting or anti-reflecting) before incorporation into the laser system, this part of ISO 11151 does not include recommendations for the specification of coatings.

NOTE For optical components used in the ultra-violet, visible and near infrared spectral ranges (190 nm to 2 100 nm), refer to ISO 11151-1. For the specification and testing of optical coatings, refer to the ISO 9211 series.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11151. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11151 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 9211-1:1994, *Optics and optical instruments — Optical coatings — Part 1: Definitions.*

ISO 9211-2:1994, *Optics and optical instruments — Optical coatings — Part 2: Optical properties.*

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

3 Code for components covered

Table 1 specifies codes for the components to which this part of ISO 11151 is applicable.

Table 1 — Component codes

Component form	Code
Optical flats	IOF
Circular windows — flat	IWC
Elliptical windows — flat	IWE
Rectangular windows — flat	IWR
Output couplers — flat	IOC
Mirrors — flat	IMF
Mirrors — convex	IMX
Mirrors — concave	IMV
Plano-convex lenses	IPX
Plano-concave lenses	IPV
Symmetric biconvex lenses	IBX
Symmetric biconcave lenses	IBV

4 Materials

This part of ISO 11151 covers components employed in the infrared wavelength region from 2,10 µm to 15 µm. A wide range of materials may be used, such as:

— zinc selenide, ZnSe;

— potassium chloride, KCl;

— germanium, Ge;

— gallium arsenide, GaAs;

— silicon, Si;

— copper, Cu.

In view of the wide variety of materials available, the use of specific code numbers for each material has not been formalized. Manufacturers and designers shall therefore specifiy the exact materials used/required. The material specification shall be given as stated in subclause 4.7 of ISO 10110-1:1996. If birefringent materials are used/specified, the orientation of the optical axis relative to the geometric axes of the components shall be stated.

5 Requirements for quality

Preferred specifications and classes for material and surface quality are set out in Tables 2 to 6, using terminology in accordance with parts 1 to 7 of ISO 10110. The same quality standards apply to all components of a given diameter, except that the material tolerances are inapplicable in the case of total reflector substrates.

The requirement of quality for components to be used with infrared lasers is in general high, therefore this part of ISO 11151 only promulgates one class of quality[1)] .

For this reason there is no difference between a flat circular window, IWC, specification and an output coupler, IOC, specification in this waveband. It should be noted that the surface dig and pit critical dimensions for laser-induced damage are λ/10 to 10λ, where λ is the wavelength of operation of the laser.

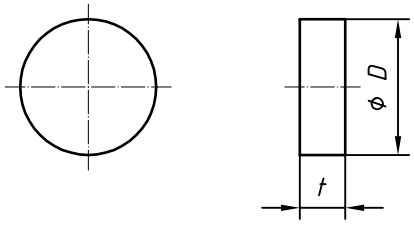
Table 2 — Material and surface fabrication tolerances for lenses, windows and beamsplitters

Diameter mm	**Stress birefringence** 0/...	**Bubbles and inclusions** 1/...	**Inhomogeneity and striae** 2/...	**Surface form** 3/...	**Centring** 4/...	**Surface imperfection** 5/...
5 to 15	15	3 × 0,063	0;2	–(0,4/0,4)	3′	2 × 0,025
>15 to 30	15	4 × 0,063	0;2	–(0,6/0,6)	3′	3 × 0,040
>30 to 51	15	4 × 0,100	0;2	–(1,0/1,0)	3′	4 × 0,063
>51 to 102	15	5 × 0,100	0;2	–(1,0/1,0)	3′	5 × 0,100

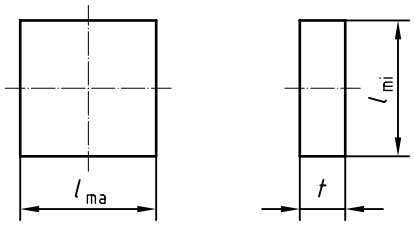
Table 3 — Material and surface fabrication tolerances for total reflector substrates

Diameter mm	**Stress birefringence** 0/...	**Bubbles and inclusions** 1/...	**Inhomogeneity and striae** 2/...	**Surface form** 3/...	**Centring** 4/...	**Surface imperfection** 5/...
5 to 15	NA	NA	NA	–(0,4/0,4)	5′	2 × 0,025
>15 to 30	NA	NA	NA	–(0,6/0,6)	5′	3 × 0,040
>30 to 51	NA	NA	NA	–(1,0/1,0)	5′	4 × 0,063
>51 to 102	NA	NA	NA	–(1,0/1,0)	5′	5 × 0,100
NA: not applicable.						

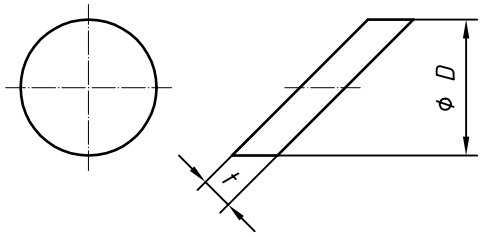
[1)] The quoted grade values assume that most of the incident radiation is scattered out of the beam by the imperfection. This is the case where the radiometric obscuration equals the area obscuration. If the imperfection is partially transmitting, its actual area could be larger than is suggested by these values. A method for measuring the surface imperfections is described in ISO 14997.



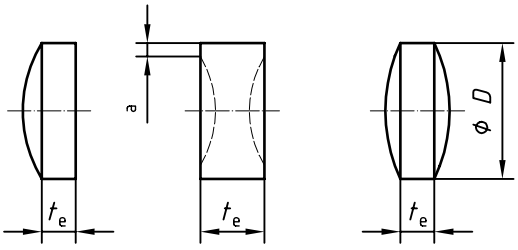
a) Form IWC (i.e. circular window, flat)



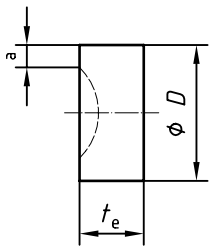
b) Form IWR (i.e. rectangular window, flat)



c) Form IWE (i.e. elliptical window, flat)



d) Forms IPX, IBV and IBX



e) Form IMV

Key

D	Diameter
t	Thickness
l_{mi}	Minor edge length
l_{ma}	Major edge length
t_e	Edge thickness

[a] Annulus width may be specified.

Figure 1 — Schematic presentation of different component types

6 Dimensional tolerances

6.1 Preferred dimensions

It is strongly recommended that all dimensions for components be specified in metric units. However it is recognized that, at least for the time being, there is also a market for components whose dimensions are specified in imperial units. Preferred dimensions for this latter class are given in annex A.

It should be noted that while the nomenclature (see clause 8) has been designed so that non-preferred dimensions can be included if strictly necessary, it is strongly recommended that both designers and manufacturers adopt preferred dimensions. The preferred (metric) dimensions and dimensional tolerances are listed in Table 4 using reference terminology as defined in Figure 1.

6.2 Diameter of circular optical components

These include circular windows, mirrors and lenses. The preferred diameters are given in Table 4.

6.3 Mirror and output coupler curvature

Although many laser mirrors and windows are optically flat, it is also recognized that there may be a requirement for both plano-convex and plano-concave components. These should be specified using the radius of curvature (half the equivalent lens focal length). The radius of curvature is the 'second dimension' as specified in clause 8. There are no basic limits on the radius of curvature except it cannot be smaller than the substrate radius. The standard tolerance for the radius of curvature is ± 2 %.

6.4 Rectangular and elliptical windows

The preferred dimensions and tolerances are listed in Table 4 using terminology specified in Figure 1. The minor dimension is specified together with the diameter of circular components and the major dimension is specified as the second dimension. In the case of elliptical windows, this second dimension is the angle at which the component is to be used. The tolerances for all linear dimensions is 0,00/–0,20 mm.

Table 4 — Standardized dimensions for the diameter of circular components and edge length of rectangular components

Dimensions in millimetres

Diameter or minor edge length	Major edge length	Edge thickness	Tolerance of diameter or edge length
12,5	20	a	–0,20
25	40	a	–0,20
30	48	a	–0,20
40	63	a	–0,20
50	80	a	–0,20
75	120	a	–0,20
100	160	a	–0,20

a Shall be specified separately depending on the material (see 6.6).

6.5 Focal length

The manufacturer shall specify the effective focal length as an element of the designation. The effective focal length shall be specified, in millimetres, at 10,6 µm. The standard tolerance is ± 2 %. Preferred values for the effective focal lengths of lenses are given in Table 5, and for the radii of curvature of total reflector substrates in Table 6. The edge thickness is standardized for plano-convex and plano-concave lenses only. For other lenses the edge thickness may be specified differently.

The manufacturer shall additionally state the back focal length (distance from the secondary vertex to the rear focal point).

NOTE 1 There are no basic limits on the focal length except that the radii of curvature cannot be less than half the lens diameter. For simple plano-concave and plano-convex lenses the equation relating the refractive index, n, and the radius of curvature, r, to the focal length, f, (in air) is, in the case of a thin lens:

$$r = (n - 1)\, f$$

For simple symmetric biconcave and biconvex lenses, the equation is:

$$r = 2(n - 1)\, f$$

For thick lenses, see relevant text books.

NOTE 2 Effective focal length in the direction of beam propagation (application direction) is calculated for homogeneous irradiation of 90 % of the diameter of the aperture.

Table 5 — Preferred effective focal lengths for lenses

Effective focal length mm								
25	50	75	100	125	150	200	250	500

Table 6 — Preferred radii of curvature of total reflector substrates

Radius of curvature mm										
250	500	750	1 000	2 000	2 500	5 000	10 000	15 000	20 000	30 000

6.6 Thickness

This part of ISO 11151 does not specify the thickness of lenses and mirrors used in the infrared because of the range of thermomechanical properties of the substrate materials. However, the manufacturer shall specify the edge thickness as an element of the designation (see clause 8). The edge thickness is measured in millimetres. The standard tolerance for lens and mirror edge thickness is ± 0,3 mm.

7 Testing area

The testing area for surface quality, specified in Table 2, is the central area of the optical component, defined as 90 % of the component diameter (or side length, for rectangular and elliptical components).

8 Designation for ordering

The designation system is composed as follows:

ISO 11151-2/(component code) (diameter)/(2nd dimension)/(edge thickness)

EXAMPLE 1 The designation of a flat circular window for use within a laser cavity of 25 mm diameter and 10 mm thickness is ISO 11151-2/IWC25//10. This designation is made up in the following fashion:

Designation	Meaning
IWC**//**	Component code for an IR-transmitting flat circular window
***25//**	Specifies 25 mm diameter, 0,00/–0,20 mm tolerance
*****//10	Specifies 10,0 mm thickness, ± 0,3 mm tolerance

EXAMPLE 2 The designation of a symmetric bi-convex lens with 50 mm diameter, 500 mm effective focal length and 4 mm edge thickness is ISO 11151-2/IBX50/500/4. This designation is made up thus:

IBX**/***/*	Component code for symmetric biconvex lens for use in the IR
50//*	Specifies 50 mm diameter, 0,00/–0,20 mm tolerance
*****/500/*	Specifies 500 mm effective focal length, ± 2 % tolerance
*****/***/4	Specifies 4 mm edge thickness, ± 0,3 mm tolerance

EXAMPLE 3 The designation of a 15 mm (minor diameter) flat elliptical window, with 24 mm major edge length, 2 mm thick, is ISO 11151-2/IWE15/57°/2. This designation is made up thus:

IWE**/**/*	Component code for an IR-transmitting flat elliptical window
***15/**/*	Specifies 15 mm minor dimension, 0,00/–0,20 mm tolerance
*****/57°/*	Specifies use at 57° angle of incidence
*****/**/2	Specifies 2 mm thickness, ± 0,3 mm tolerance

EXAMPLE 4 The designation of a flat rectangular window with dimensions of 10 mm × 16 mm × 2 mm is ISO 11151-2/IWR10/16/2. This designation is made up thus:

IWR**/**/*	Component code for an IR-transmitting flat rectangular window
***10/**/*	Specifies 10 mm minor dimension, 0,00/–0,20 mm tolerance
*****/16/*	Specifies 16 mm major dimension, 0,00/–0,20 mm tolerance
*****/**/2	Specifies 2 mm thickness, ± 0,3 mm tolerance

EXAMPLE 5 The designation of a concave laser cavity mirror of 25 mm diameter, 10 mm thickness with a radius of curvature of 50 mm is ISO 11151-2/IMV25/50/10. This designation is made up thus:

IMV**/**/**	Component code for concave laser cavity mirror
***25/**/**	Specifies 25 mm diameter, 0,00/–0,20 mm tolerance
*****/50/**	Specifies 50 mm radius of curvature, ± 2 % tolerance
*****/**/10	Specifies 10 mm edge thickness, ± 0,3 mm tolerance

9 Coating

The designation put forward in clause 8 does not specifically mention the coating of the lens, window or mirror. This coating, unless an uncoated substrate is desired, shall be specified in detail. Minimum specifications include coating-type (anti-reflectance, partial reflectance, total reflectance), wavelength, reflectance, angle of incidence and absorption characteristics. These aspects shall be covered in accordance with ISO 9211-1 and ISO 9211-2.

10 Packaging

Some infrared optical materials are hazardous, toxic and/or hygroscopic. In consequence, all optical components shall be carefully packaged in accordance with legal regulations and additionally be labelled with the following information:

a) component designation;

b) material;

c) coating details (if applied);

d) handling and storage instructions;

e) potential hazards (e.g. toxic/carcinogenic).

If coating or components are either toxic , hazardous or hygroscopic, this shall be clearly indicated on the label.

Annex A
(informative)

Imperial units

It is strongly recommended that all designers and manufacturers use metric units. This is particularly important in avoiding duplication of manufacturing facilities and to minimize component fabrication costs. However, it is realized that certain countries/firms have designs, jigs and components in accordance with dimensions in imperial units. The preferred imperial dimensions and tolerances for components covered by this part of ISO 11151 are set out in Tables A.1 and A.2.

Table A.1 — Preferred dimensions and diameter tolerances

Imperial dimension inches	**Metric equivalent** mm	**Diameter tolerance** mm
1/2	12,7	–0,20
1	25,4	–0,20
1 1/2	38,0	–0,20
2	50,8	–0,20
3	76,2	–0,20
4	101,6	–0,20

The specification of a flat circular window for use within a laser cavity of 1 inch diameter and 0,25 inch thickness is:

ISO 11151-2/IWC25,4//6,3

Table A.2 — Preferred effective focal lengths

Effective focal length mm								
25,4	50,8	76,2	101,6	127,0	152,4	203,2	254,0	508,0

Annex B
(informative)

Configuration for relieving stress in copper mirrors

B.1 Introduction

When fabricating mirrors from soft material such as copper, special precautions are needed to prevent mechanical deformation, both when initially mounting the mirror and as the mirror is thermally stressed by the laser beam. For use with high-power laser radiation, direct water cooling through cooling channels fabricated directly into the mirror substrate may be required to prevent deformation.

This annex describes one approach to mounting a copper mirror, using a flange machined into the mirror itself. Using this approach, a reduction of deformation of a factor of > 100 was achieved. Specifically, with CO_2 laser power of 15 kW impinging upon a mirror with a super-enhanced coating, deformation was < 0,5 µm. With an uncoated copper mirror, deformation was approximately 1,5 µm.

B.2 Mirror configuration

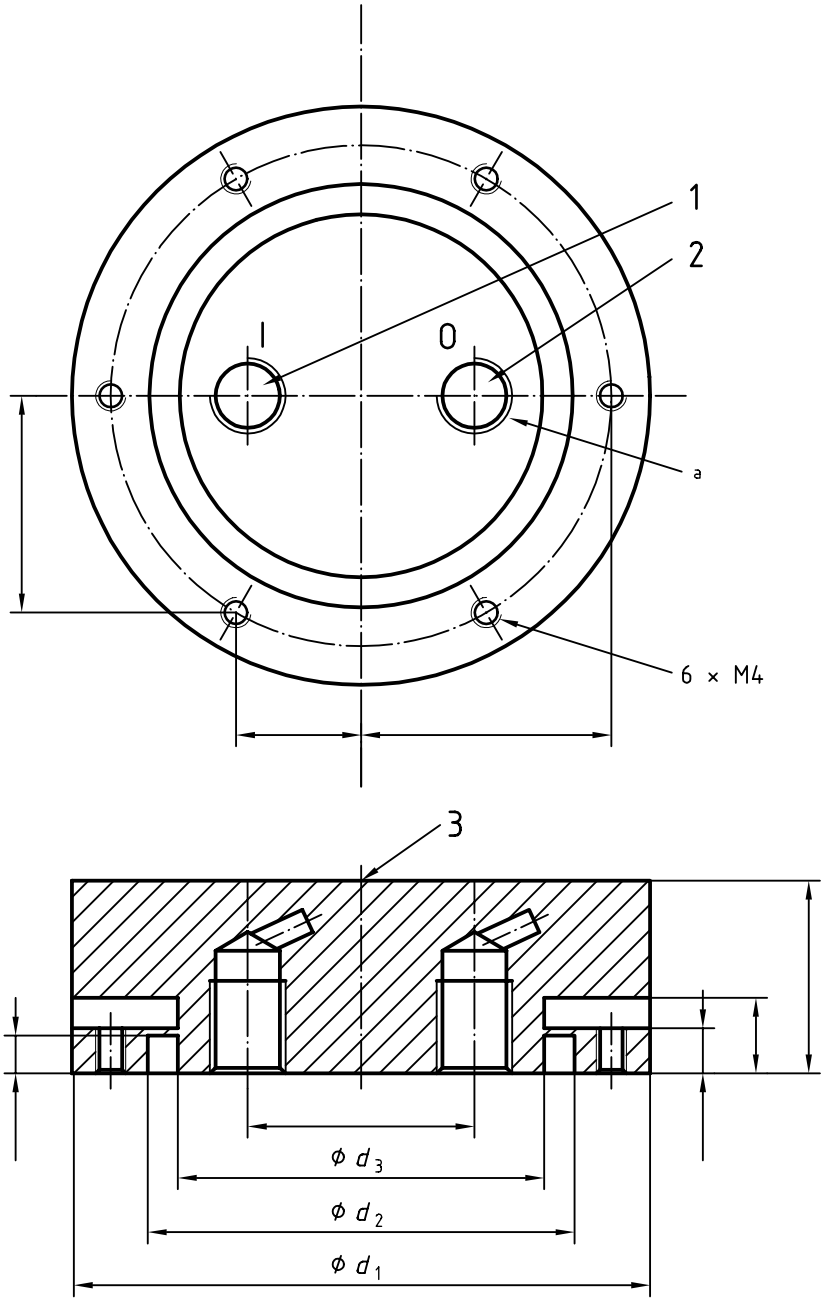
Set-up for the mirror flange tested is shown in Figure B.1. This design decouples the mounting flange containing the mounting threads (or holes) from the mirror body. Since water cooling is required with high-power lasers, threaded holes are shown for input and output cooling connectors. The water-cooling channels themselves are not shown, because the layout is dependent upon the application.

Table B.1 indicates recommended thicknesses for copper mirrors.

Table B.1 — Recommended thickness for copper mirrors

Dimensions in millimetres

Diameter	Without flange and without water cooling	With flange, with or without water cooling
12,5	6	NA
25	6	NA
50	10	25
75	15	25
100	20	25
NA: not applicable.		



Key

1	Cooling water inlet (marked "I")
2	Cooling water outlet (marked "O")
3	Mirror surface
d_1 to d_3	Diameters

a ISO 228-1-G1/8

Drawing does not show spiral tubing for water cooling.

Figure B.1 — Schematic drawing of the mirror flange

Bibliography

[1] ISO 10110-2:1996, *Optics and optical instruments — Preparation of drawings for optical* elements and *systems — Part 2: Material imperfections — Stress birefringence.*

[2] ISO 10110-3:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 3: Material imperfections — Bubbles and inclusions.*

[3] ISO 10110-4:1997, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 4: Material imperfections — Inhomogeneity and striae*.

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

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

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

[7] ISO 11151-1:2000, *Lasers and laser-related equipment — Standard optical components — Part 1: Components for UV, visible and near-infrared spectral ranges.*

[8] ISO 14997:—[2)], *Optics and optical instruments — Test methods for surface imperfections of optical elements*.

[2)] To be published.

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