INTERNATIONAL STANDARD

ISO 12123

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Optics and photonics — Specification of raw optical glass

Optique et photonique — Spécification d'un verre d'optique brut

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12123 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

This second edition cancels and replaces the first edition (ISO 12123:1996) and ISO 12123:1996/Amd.1:2005, which have been technically revised and substantially expanded to cover not only the specification of bubbles and inclusions, but also the specification of other important characteristics of raw optical glass.

Optics and photonics — Specification of raw optical glass

1 Scope

This International Standard gives rules for the specification of raw optical glass. It serves as a complement to ISO 10110, which provides rules specifying finished optical elements. Since raw optical glass may be quite different in shape and size from the optical elements, its specification also differs from that of optical elements.

This International Standard provides guidelines for the essential specification characteristics of raw optical glass in order to improve communication between glass suppliers and optical element manufacturers. For specific applications (e.g. lasers, the infrared spectral range), specifications based on this International Standard will have to be supplemented.

NOTE Additional information on how to translate optical element specifications into raw optical glass specifications is given in Annex A.

2 Normative references

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

ISO 7944, *Optics and optical instruments — Reference wavelengths*

ISO 9802, *Raw optical glass — Vocabulary*

ISO 10110 (all parts), *Optics and photonics — Preparation of drawings for optical elements and systems*

ISO 11455, *Raw optical glass — Determination of birefringence*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9802 and the following apply.

3.1
refractive index
n
ratio of the velocity of the electromagnetic waves at a specific wavelength in a vacuum to the velocity of the waves in the medium

See ISO 7944.

NOTE For practical reasons, this document refers to the refractive index in air.

3.2
principal refractive index
refractive index in the middle range of the visible spectrum commonly used to characterize an optical glass

NOTE 1 This principal refractive index is usually denoted as n_d, the refractive index at the wavelength 587,56 nm, or n_e, the refractive index at the wavelength 546,07 nm.

NOTE 2 The specific values for different glass types refer to standard environmental conditions (20 °C and 1 013 hPa according to ISO 1[1]). For common daily business other reference temperatures are acceptable and will have to be quoted on demand.

3.3
refractive index variation
maximum difference of refractive index between samples of optical glasses

3.4
dispersion
measure of the change of the refractive index with wavelength

3.5
Abbe number
most common characterization of the dispersion of optical glasses

EXAMPLE 1 The Abbe number for the d-line is defined as

$$\nu_\mathrm{d} = \frac{(n_\mathrm{d} - 1)}{(n_\mathrm{F} - n_\mathrm{C})}$$

where

n_F is the refractive index at wavelength 486,13 nm;

n_C is the refractive index at wavelength 656,27 nm.

EXAMPLE 2 The Abbe number for the e-line is defined as

$$\nu_\mathrm{e} = \frac{(n_\mathrm{e} - 1)}{(n_\mathrm{F'} - n_\mathrm{C'})}$$

where

n_F is the refractive index at wavelength 479,99 nm;

n_C is the refractive index at wavelength 643,85 nm.

3.6
glass type
usually a letter/number designation used in the manufacturer's catalogue to designate or characterize the glasses offered

NOTE 1 The letter/number designation is the manufacturer's option and is usually a proprietary trade name, and therefore indeterminate. For example, borosilicate crown glass is designated N-BK by one manufacturer, but S-BSL and BSC by others.

NOTE 2 An alternative way to specify the glass type is the six-figure number called glass code, for N-BK7 e.g. 517642. It refers to the optical position of the individual glass types. The first three digits refer to the refractive index n_d, the second three digits to the Abbe number ν_d. This glass code, however, does not denominate a glass type unequivocally. The same glass code may be valid for glass types of very different chemical compositions and hence other properties may differ also very significantly.

3.7
transmittance
ratio of the transmitted luminous flux to the incident luminous flux of a collimated, monochromatic beam that passes, at normal incidence, through a plane parallel polished plate

3.8
spectral transmittance
measure of the variation of the transmittance with wavelength

3.9
spectral internal transmittance
ratio of the transmitted luminous flux to the incident luminous flux excluding reflection losses at the surfaces

3.10
UV cut-off edge
UVC 80/10
term describing the position and the slope of the transmittance cut-off edge in the short wavelength range and given by the wavelengths at 80 % and 10 % internal transmittance

3.11
colour code
CC
position and slope of the transmittance cut-off edge in the short wavelength range, given by the wavelengths at 80 % and 5 % transmittance including reflection losses

3.12
optical homogeneity
measure of the refractive index variation within a single piece of optical glass given by the difference between the maximum and minimum values of the refractive index within the optical glass

3.13
striae

short range deviations of refractive index in glass, resembling bands in which the refractive index fluctuates with a typical period of fractions of one millimetre to several millimetres

3.14
inclusion
term covering all localized bulk material imperfections including, but not limited to, bubbles, striae knots, small stones, sand and crystals

3.15
bubble
gaseous void in the bulk optical material, of generally circular cross section

NOTE Bubbles and solid inclusions are treated the same in assessing the quality of optical glass.

3.16
stress birefringence
birefringence caused by residual stresses within the glass, generally as a result of different cooling histories of different partial volumes of a given piece of glass during the forming and/or annealing process, and producing an optical path difference between the ordinary and extraordinary rays for plane polarized light passing through the glass

NOTE The optical path difference is proportional to the magnitude of mechanical stress.

4 Tolerances

4.1 Principal refractive index

The preferred tolerance ranges for the principal refractive index are given in Table 1.

Table 1 — Tolerances for principal refractive index

Principal refractive index tolerance limits
±0,002 0
±0,001 0
±0,000 5
±0,000 3
±0,000 2

4.2 Refractive index variation

Fine annealed raw glasses will be arranged in delivery lots based on the refractive index variation. Therefore, the refractive index variation shall also be specified. All parts of a delivery lot shall meet the tolerances for refractive index given in Table 2.

Table 2 — Tolerances for refractive index variation within a delivery lot

Refractive index variation tolerance limits
$\pm 30 \times 10^{-5}$
$\pm 10 \times 10^{-5}$
$\pm 5 \times 10^{-5}$
$\pm 2 \times 10^{-5}$

4.3 Abbe number

The tolerances for the Abbe number are given in Table 3.

Table 3 — Tolerances for Abbe number

Abbe number tolerance limits
±0,8 %
±0,5 %
±0,3 %
±0,2 %

4.4 Spectral internal transmittance

Spectral internal transmittance data shall be reported for thicknesses of 10 mm, and optionally 5 mm or 25 mm thicknesses. The reference thickness shall be listed in the manufacturer's catalogue or data sheet. The data shall be the typical spectral internal transmittance for a given glass type. It may be the median value of several different melts. If the buyer's requirement for melt data or minimum values for spectral internal transmittance are critical, the requirement shall be specified on the drawing or in the purchase order.

4.5 UV cut-off edge and colour code

4.5.1 General

For the description of the UV transmittance cut-off edge the so-called colour code is used. Its advantage is that it may be measured easily and cost-effectively. On the other hand, especially high index glass types hardly reach the 80 % transmittance level because of their high reflection losses. Therefore, their quality is not described very distinctly and adequately to their application as coated elements in any case. The 5 % limit may lead to ambiguous results with glass types showing fluorescence in the UV-region. Such problems may be avoided by use of the UV cut-off edge UVC 80/10.

4.5.2 UV cut-off edge

The UV cut-off edge lists the wavelengths λ_{80} and λ_{10}, in which the internal transmittance (excluding reflection losses) is 0,80 and 0,10 at 10 mm thickness. The reflection losses may be calculated using catalogue refractive index data. A UVC 80/10 measurement result, for example, may be quoted as 332/303 indicating the internal transmittances of 80 % at λ_{80} = 332 nm and of 10 % at λ_{10} = 303 nm.

4.5.3 Colour code

The colour code lists the wavelengths λ_{80} and λ_{5}, at which the transmittance (including reflection losses) is 0,80 and 0,05 at 10 mm thickness. The values are rounded to 10 nm and are written by eliminating the last digit. For example, colour code 33/30 indicates λ_{80} = 330 nm and λ_{5} = 300 nm.

4.6 Optical homogeneity

The refractive index homogeneity that is achievable from a given glass type depends on the volume and the form of the individual glass pieces. Therefore, if it is necessary to specify the optical homogeneity of the raw glass, then this should be done with respect to the final dimensions of the optical elements to be manufactured out of the raw glass parts. In general the optical homogeneity values specified are peak-to-valley values and contain all aberrations. In many cases it is acceptable to subtract certain aberration terms that are of no importance or can easily be corrected (e.g. focal terms). This should be specified in advance.

Table 4 gives the preferred homogeneity tolerances. Lower homogeneity grades are already covered by the variation tolerances.

Table 4 — Tolerances for the homogeneity of optical raw glass

Homogeneity tolerance limits (peak-to-valley)	Generally applicable for
100×10^{-6}	common application sizes
40×10^{-6}	
10×10^{-6}	partial volumes of the raw glass
4×10^{-6}	
2×10^{-6}	partial volumes of the raw glass but not for all glass types
1×10^{-6}	

4.7 Striae

Striae tolerances of optical raw glasses are defined in terms of wavefront deviations.

Striae are generally detected by means of the shadowgraph method using comparison standards. The wavefront deviation of the comparison standard is certified in advance using an interferometer set-up. Table 5 gives the striae wavefront deviation tolerance limits.

Table 5 — Striae wavefront deviation tolerances

Striae wavefront deviation tolerance limit per 50 mm path length (nm)	**Generally applicable for**
< 60	raw glass
< 30	
< 15	partial volumes of the raw glass
< 10	

Striae are highly directionally dependent. If striae are perceived during a test, they are usually no longer detectable if inspected in a direction perpendicular to the original test direction.

Striae in optical raw glasses are in general band-like, therefore the striae wavefront deviation is dependent on the sampling thickness to a certain extent. In general the raw glass parts are inspected through the total thickness. The thickness of the finished parts is in most cases only a fraction of the initial thickness therefore the striae wavefront deviation will also be much lower. A reference thickness of 50 mm is therefore introduced to specify striae quality of general purpose raw glass.

For extremely low striae content glass pieces, it is necessary to know the optical path length and direction for the final application in order to perform adequate inspection.

In special cases the measurement can also be carried out in two directions.

4.8 Bubbles and inclusions

Inclusions in glass, such as stones or crystals are treated as bubbles of equivalent cross sectional area.

The characterization of the bubble content of a glass is performed by reporting the total cross section in mm^2 of a 100 cm^3 glass volume, calculated as the sum of the detected cross sections of bubbles. Additionally, the maximum permissible number per 100 cm^3 and the size-dependent diameter of bubbles is defined for each cross section. The evaluation includes all bubbles and inclusions with dimensions $\geqslant$ 0,03 mm equivalent diameter.

Standard permissible quantities of bubbles and inclusions in raw optical glass are given in Table 6. The rows of the table define different bubble and inclusion quality grades of optical glass combining the maximum permitted cross section and number per glass volume. It is acceptable to specify any combination of cross section and number per volume.

For strips and blocks, from which much smaller finished parts are normally produced, occasional, individual bubbles or inclusions having greater dimensions are permitted, if the limit values for the total cross section area and quantity per volume are maintained.

Bubbles and inclusions may be distributed. Instead of one bubble or inclusion with a prescribed size, a larger number of bubbles or inclusions of smaller dimensions is permissible.

The inclusion quality will be assessed by visual inspection. In critical cases measurements will be performed.

Table 6 — Permissible bubbles and inclusions within optical raw glass

Maximum permissible cross section of any bubbles and inclusions (mm^2 per 100 cm^3) **in a given glass volume**	**Maximum allowable number** (per 100 cm^3)
0,5	140
0,25	70
0,1	30
0,03	10

Concentrations of bubbles and inclusions in the final part are not allowed. A concentration occurs when there are multiple bubbles or inclusions and more than 20 % of the total number of bubbles or inclusions occurs in any 5 % of the sample area. However, when the total number of bubbles or inclusions found in the sample is ten or less, there must be two or more bubbles or inclusions falling within a 5 % area to constitute a concentration.

4.9 Stress birefringence

The size and distribution of permanent internal stresses in glasses depend on the annealing conditions (e.g. annealing rate and temperature distribution around the glass being annealed), the glass type and the dimensions. The stresses cause birefringence that is dependent on the glass type.

Stress birefringence is measured as optical path difference using the de Sénarmont and Friedel method and is stated in nanometres per centimetre based on the test thickness. A detailed description of the measurement method is given in ISO 11455.

The preferred tolerance limits are given in Table 7.

The stress birefringence in raw optical glass parts is, in most cases, larger than in the final product.

In raw glass destined to be hot processed, higher stresses are permitted, as long as they do not restrict mechanical processing.

Table 7 — Stress birefringence preferred tolerance limits for optical raw glass

<table>
<tr><th>Stress birefringence preferred tolerance limits (nm/cm)</th><th>Generally applicable for</th></tr>
<tr><td>⩾ 20</td><td rowspan="5">raw glass</td></tr>
<tr><td>< 20</td></tr>
<tr><td>⩽ 12</td></tr>
<tr><td>⩽ 6</td></tr>
<tr><td>⩽ 4</td></tr>
<tr><td>⩽ 2</td><td>cut parts from the raw glass</td></tr>
</table>