भारतीय मानक
Indian Standard

IS 5920 (Part 12) : 2024
ISO 10110-18 : 2018

प्रकाशिकी और फोटोनिक्स — प्रकाशीय तत्वों और प्रणालियों के लिए आरेखण तैयार करना

भाग 12 तनन द्विप्रतिरोध, बुलबुले और समावेशन, एकरूपता और स्ट्राई

Optics and Photonics — Preparation of Drawings for Optical Elements and Systems

Part 12 Stress Birefringence, Bubbles and Inclusions, Homogeneity and Striae

ICS 37.020; 01.100.20

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www.bis.gov.in www.standardsbis.in

September 2024 **Price Group 11**

Optics and Photonics Sectional Committee, PGD 39

NATIONAL FOREWORD

This Indian Standard (Part 12) which is identical to ISO 10110-18 : 2018 'Optics and photonics — Preparation of drawings for optical elements and systems — Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Optics and Photonics Sectional Committee and approval of the Production and General Engineering Division Council.

This standard specifies the indication of tolerances for four categories of imperfections within optical materials — stress birefringence, bubbles and inclusions, homogeneity, and striae. Tolerances are applied either to a finished optical part, a finished system of optical parts, or to the raw material used to manufacture an optical part.

IS 5920 (Part 1) supersedes the originally published Indian Standard IS 5920 : 1970 'Recommendation for the preparation of drawing for optical elements and system'.

This standard has been published in thirteen parts. The other parts in this series are:

Part 1	General
Part 2	Surface form tolerances
Part 3	Centering tolerances
Part 4	Surface imperfections
Part 5	Surface texture
Part 6	Surface treatment and coating
Part 7	Non-tolerance data
Part 8	Aspheric surfaces
Part 9	Wave front deformation tolerance
Part 10	Diffractive surfaces
Part 11	Laser irradiation damage threshold
Part 13	General description of surfaces and components

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current-practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standards	*Corresponding Indian Standards*	*Degree of Equivalence*
ISO 9802 Raw optical glass — Vocabulary	PGD 39 (24216)/ISO 9802 : 2022 Raw optical glass — Vocabulary	Identical
ISO 10110-1 Optics and photonics — Preparation of drawings for optical elements and systems — Part 1: General	IS 5920 (Part 1) : 2024/ISO 10110-1 : 2019 — Optics and photonics — Preparation of drawings for optical elements and systems: Part 1 General	Identical

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Introduction

The ISO 10110 series is composed of separate parts. It standardizes drawing indications for optical elements and systems. This document (Part 18) standardizes drawing indications for the tolerancing of material imperfections.

Material imperfections require tolerances because they can degrade the quality of an optical part. This document provides notations for material imperfections in optical elements. This includes the specification of a tolerance for stress birefringence, bubbles and inclusions, refractive index homogeneity, and striae. It includes the notations and grades formerly described in ISO 10110-2, ISO 10110-3, and ISO 10110-4, and provides complete backward compatibility to drawings developed using those standards.

A drawing notation standard, such as this document for specifying all optical material tolerances, should accommodate all common specification methods to allow broad adoption and application. In some cases, material tolerances are specified on the final part, and in other cases material tolerances are specified on the raw material or blank used to make the final part.

Even on a single part, different tolerances may be specified and controlled in different ways. For example, it might be desirable to specify the bubbles and inclusions of a finished doublet assembly in addition to a specification on the individual elements. Additionally, for that same doublet, it might be prudent to specify raw material tolerances and accept the manufacturer’s material quality certifications for stress birefringence, refractive index homogeneity and striae, which are much more difficult to validate on a finished part or assembly.

In this document, every effort has been made to provide flexibility in the notation to allow the materials to be specified in the most sensible means for the given application. In each case the user is allowed to either specify the material imperfection tolerance for the finished part, using the “0/”, “1/”, and “2/” notations, or to specify the quality of the material blank used in the manufacture of the part, using the “00/”, “01/” and “02/” notations. If the specification is intended to apply to the finished assembly, the notations “10/”, “11/”, and “12/” are used.

Indian Standard

OPTICS AND PHOTONICS — PREPARATION OF DRAWINGS FOR OPTICAL ELEMENTS AND SYSTEMS

PART 12 STRESS BIREFRINGENCE, BUBBLES AND INCLUSIONS, HOMOGENEITY AND STRIAE

1 Scope

This document specifies the indication of tolerances for four categories of imperfections within optical materials — stress birefringence, bubbles and inclusions, homogeneity, and striae — in the ISO 10110 series, which standardizes drawing indications for optical elements and systems.

Tolerances are applied either to a finished optical part, a finished system of optical parts, or to the raw material used to manufacture an optical part.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 9802, *Raw optical glass — Vocabulary*

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

ISO 10110-11, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 11: Non-toleranced data*

ISO 12123, *Optics and photonics — Specification of raw optical glass*

ISO 14999-4:2015, *Optics and photonics — Interferometric measurement of optical elements and optical systems — Part 4: Interpretation and evaluation of tolerances specified in ISO 10110*

3 Terms and definitions

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

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

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

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

3.1 Terms for stress birefringence

3.1.1
birefringence
variation of the refractive index with the orientation of polarization inside optical materials

3.1.2
stress birefringence
birefringence caused by mechanical stress within the optical material

Note 1 to entry: The formula relating the stress optical constant and stress birefringence is given in Annex A.

3.2 Terms for bubbles and inclusions

3.2.1
bubble
gaseous void, of generally circular cross section, in the bulk material

3.2.2
inclusion
localized bulk material imperfection including, but not limited to, bubbles, striae, knots, small stones, sand and crystals

3.2.3
grade number of a bubble or inclusion
unitless numeric label derived from a value in an R5 Renard sequence and specifying the square root of a projected area

Note 1 to entry: The grade number can be interpreted as an equivalent size, which is the approximate diameter of a circle that contains the specified area. The actual diameter of the circle is nearly 13 % larger than indicated by the grade number when units of linear dimension are appended.

3.2.4
negligible bubble or inclusion
bubble or inclusion whose grade number is 16 % of the maximum permissible grade or less

3.3 Terms for homogeneity and striae

3.3.1
homogeneity
gradual variation of the refractive index within a single piece of optical material

3.3.2
striae
short spatial range variation of refractive index with typical spatial extent from below one millimetre up to several millimetres

4 Specification of raw material and finished assemblies

4.1 Raw material

By prefixing the digit zero “0” to any of the indication codes, e.g. “00/”, “01/”, or “02/” rather than “0/", "1/", or “2/”, the designer directs the specification to the raw material rather than to the finished part. Unless otherwise noted, this shall mean that the manufacturer’s quality certifications for the raw material that was used to manufacture the part will be accepted as proof that the part itself is in accordance with the specification.

ISO 12123 on raw optical glass defines specifications and quality grades for raw optical glass materials that shall be used whenever possible, even when tolerancing finished components.

4.2 Finished assemblies

By prefixing the digit one “1” to any of the indication codes, e.g. “10/”, “11/”, or “12/” rather than “0/”, “1/”, or “2/”, the designer directs the specification to a finished assembly of components rather than to a single component in the assembly.

5 Stress birefringence

5.1 Principle of specification

Stress birefringence is the optical path difference (OPD), in nanometres, between orthogonal polarizations of a light beam as it propagates one centimetre through the material (nanometres per centimetre).

NOTE Guidance for typical tolerances for stress birefringence for some applications is given in Annex B.

5.2 Indication in drawings

5.2.1 Indication codes

The indication code for stress birefringence in the finished part is "0/". The indication code for stress birefringence in the raw material is "00/" and for a finished assembly is "10/".

5.2.2 Structure of the indication

0/*A* or 00/*A* or 10/*A*

where *A* is the maximum allowable OPD in nm/cm.

5.3 Examples of indications for stress birefringence

EXAMPLE 1 0/2

The stress birefringence allowed in the finished part shall be less than or equal to 2 nm/cm.

EXAMPLE 2 00/20

The stress birefringence of the raw material used to manufacture the part shall be less than or equal to 20 nm/cm.

EXAMPLE 3 10/20

The stress birefringence in a finished assembly shall be less than or equal to 20 nm/cm.

6 Bubbles and inclusions

6.1 General

Bubble is used as the generic term for bubbles and/or inclusions, unless otherwise indicated.

6.2 Principle of specification

Specify the maximum size grade of a permissible bubble. Specify the maximum number of maximum grade bubbles. Control the total accumulated area obscured by all allowed bubbles.

Standard bubble grades are defined in Table 1. They were derived by rounding the values of a Renard sequence (R5) of size.

Table 1 — Standard bubble grades

Grade Number no units	Size (square root of area) mm	Area mm^2
0,006[a]	0,006[a]	$3{,}60 \times 10^{-5}$ [a]
0,010[a]	0,010[a]	$1{,}00 \times 10^{-4}$ [a]
0,016[a]	0,016[a]	$2{,}6 \times 10^{-4}$ [a]
0,025[a]	0,025[a]	$6{,}25 \times 10^{-4}$ [a]
0,040	0,040	$1{,}60 \times 10^{-3}$
0,063	0,063	$3{,}97 \times 10^{-3}$
0,10	0,10	$1{,}00 \times 10^{-2}$
0,16	0,16	$2{,}56 \times 10^{-2}$
0,25	0,25	$6{,}25 \times 10^{-2}$
0,40	0,40	$1{,}60 \times 10^{-1}$
0,63	0,63	$3{,}97 \times 10^{-1}$
1,0	1,0	$1{,}00 \times 10^{0}$
1,6	1,6	$2{,}56 \times 10^{0}$
2,5	2,5	$6{,}25 \times 10^{0}$
4,0	4,0	$1{,}60 \times 10^{1}$

a Bubbles smaller than 0,030 mm equivalent size are not typically relevant to the specification of raw optical glass.

NOTE Annex C contains guidance for typical specifications in several applications.

6.3 Indication in drawings

6.3.1 Indication codes

The indication code for bubbles in the finished part is “1/”. The indication code for bubbles in the raw material is “01/”. The indication code for bubbles throughout a finished assembly is “11/”.

6.3.2 Structure of the indication

$1/N \times A$ or $01/N \times A$ or $11/N \times A$

where

- A is the grade number of the largest permissible bubble;
- N is the maximum permissible number of largest permissible bubbles;
- $\times$ is the multiply symbol to separate and relate N and A.

6.4 Accumulation rule

The sum of the projected areas of all bubbles with grade numbers less than or equal to A and greater than 0,16 A shall not exceed

$N \times A^2$ mm^2

where

N is the maximum number of the maximum size bubble that is indicated in the specification;

A^2 is the square of the grade number of the largest permissible bubble.

The accumulation rule allows more bubbles of smaller sizes, but their summed cross sectional areas shall remain below the maximum total areal limit established by the indicated specification.

6.5 Concentration rule

Concentrations of bubbles are not allowed.

A concentration occurs when more than 20 % of the number of allowed maximum grade bubbles is found in any 5 % sub-area of the test region. The 5 % sub-area shall have a similar form as the test region.

If the total number of allowed bubbles is less than 10, then a concentration occurs when two or more bubbles of allowed maximum grade fall within a 5 % sub-area of the test region.

For any bubbles with a grade of one to three grades smaller (down to 0,16 A) than the maximum allowed grade and within 5 % of the test region, accumulate the grade numbers to find the equivalent number of bubbles of maximum grade, rounding up. Then evaluate as described for maximum grade bubbles.

6.6 Examples of indications for bubbles

EXAMPLE 1 1/1 × 0,25

The largest permissible grade number of any bubble in the finished part is 0,25. The sum of the projected areas of all bubbles less than or equal to grade number 0,25 and greater than grade number 0,04 — which is 0,16 × 0,25 — shall be less than or equal to 0,062 5 mm^2.

EXAMPLE 2 01/3 × 0,5

The largest permissible grade number of any bubble in the raw material used to manufacture the part is 0,5. The maximum allowed number of maximum size bubbles is 3. The sum of the projected areas of all bubbles less than or equal to grade number 0,5 and greater than grade number 0,08 — which is 0,16 × 0,5 — shall be less than or equal to 0,75 mm^2.

EXAMPLE 3 11/1 × 0,25

The largest permissible grade number of any bubble throughout a finished assembly is 0,25. The sum of the projected areas of all bubbles less than or equal to grade number 0,25 and greater than grade number 0,04 — which is 0,16 × 0,25 — shall be less than or equal to 0,062 5 mm^2.

7 Homogeneity and striae

7.1 General

The two different specifications for permissible homogeneity and striae imperfections appear under the same indication code and are separated by a semicolon. Within the indication, the specification for homogeneity precedes the specification for striae. The basic specification may be modified with a focus term for homogeneity and a multi-directional term for homogeneity or striae.

7.2 Indication in drawings

7.2.1 Indication codes

The indication code for homogeneity and striae is “2/” for the finished part, “02/” for the raw material used to manufacture the finished part, or “12/” for a finished assembly.

7.2.2 Structure of the indication

Basic structure of the indication:

2/*A*; *B* or 02/*A*; *B* or 12/*A*; *B*

Standard quality classes for *A* are defined in Table 2. Standard quality classes for *B* are defined in Table 3 and Table 4.

Optional Focus term, "–F", added to the indication for homogeneity:

2/*A* – F; *B* or 02/*A* – F; *B* or 12/*A* – F; *B*

Use the focus term, F, where the focus term, F, is the Zernike Polynomial Term Z(2, 0) as defined in ISO 14999-4:2015, Annex B, Table B.1.

Optional Multi-dimensional term, "$\times\perp n$", term added to the indication for homogeneity or striae:

$2 / A \times\perp n; B \times\perp n$ or $02 / A \times\perp n; B \times\perp n$ or $12 / A \times\perp n; B \times\perp n$

where for basic and optional indications

A is a variable and is to be replaced with the specification for homogeneity in terms of quality class;

B is a variable and is to be replaced with the specification for striae in terms of quality class;

–F is not a variable and indicates that the focus term may be removed from the wavefront map of the homogeneity;

$\times\perp n$ contains the variable *n* and indicates that the specification applies in *n* orthogonal dimensions.

7.3 Homogeneity

7.3.1 Principle of specification

The magnitude of homogeneity is specified as the difference between the maximum and minimum values of the refractive index.

NOTE Annex D offers some guidance for the specification of homogeneity in several common applications.

7.3.2 Quality classes

This document defines six quality classes for homogeneity as given in Table 2.

Table 2 — Six quality classes that may be used for A, the specification for homogeneity (finished parts, finished assemblies, and/or raw material)

Legacy class indicator	New class indicator	Maximum permissible peak-to-valley variation of refractive index 10^{-6}
0	NH100	100
1	NH040	40
2	NH010	10
3	NH004	4
4	NH002	2
5	NH001	1

The legacy class indicators are backwards compatible with the previous ISO 10110-4 standard. New class indicators are taken from ISO 12123.

7.3.3 Focus term

The designer may further qualify the specification for homogeneity to exclude the focus term that is generated with a wavefront map of the homogeneity. The indication "–F" shall be appended to allow the exclusion of the focus term.

Care should be exercised when manufacturing a finished part from raw material that passed the homogeneity specification by excluding the focus term.

7.4 Striae

7.4.1 Principles of specification

Two methods of specifying striae are allowed. The first method, specification by density, is the method used in the older standard for striae, ISO 10110-4. The second method, specification by wavefront deviation, is the method described in ISO 12123.

NOTE Annex E offers some guidance for the specification of striae tolerances in several common applications.

7.4.2 Density classes for striae

Striae imperfections in finished parts may be specified by the density of striae that cause optical path differences of at least 30 nm. Their density is measured in terms of the areal percentage of the test region that they obscure.

Four classes are predefined on the basis of density.

The specification of maximum density is not useful for very weak striae. Therefore, a fifth class for designating the highest of quality does not restrict the specification to striae that cause optical path differences of at least 30 nm.

The classes are defined in Table 3.

Table 3 — Five density classes for the specification of striae for finished parts, finished assemblies, and/or raw material

Class indicator	Density of striae causing optical path difference of at least 30 nm % of test region obscured
1	≤10
2	≤5
3	≤2
4	≤1
5	Extremly free of striae Restriction to striae exceeding 30 nm does not apply Further information to be supplied in a note to the drawing.

Striae density classification is not supported by all manufacturers. Care should be used with this method of specification.

7.4.3 Wavefront deviation classes for striae

Striae tolerances are defined in terms of wavefront deviation for 50 mm of material path.

Striae are generally detected by means of the shadowgraph method using comparison standards. Table 4 gives the striae wavefront deviation tolerance classes.

To specify extremely low striae content in raw material, it is necessary to know the optical path length and direction for the final application in order to perform adequate inspection.

Table 4 — Striae wavefront deviation tolerances

Striae wavefront deviation using shadowgraph classes	Striae wavefront deviation using ISO 12123 classes	Striae wavefront deviation tolerance limit per 50 mm path length nm
D	SW60	≤60
C	SW30	≤30
B	SW15	≤15
A	SW10	≤10

7.4.4 Comparison of density and wavefront quality classes for striae

Striae imperfections may be specified by the density of striae that cause optical path differences of at least 30 nm. Their density is measured in terms of the percentage of the test region that they occupy. Alternatively, striae imperfections may be specified in terms of the wavefront deviation per 50 mm of material path. These two types of classifications are mutually independent; one cannot be considered a good predictor of the other.

7.4.5 Multiple orthogonal directions

In exceptional cases, e.g. for large prisms, the designer may further qualify the specification for striae by requiring that the tolerance apply to 2 or 3 orthogonal directions by appending the indication $\times \perp n$. The variable *n* may take on the value of either 2 or 3. A note is needed to define the directions of interest.

If the indication for multiple orthogonal directions is not included, then the specification applies in only one direction.

7.5 Examples of indications for homogeneity and striae

EXAMPLE 1 2/2; 3

The finished part's homogeneity shall be better than or equal to 10×10^{-6} and the density of striae that cause OPD of at least 30 nm shall be 2 % or less of the test region. This is an example of an old specification that uses legacy class indicators for homogeneity and for striae.

EXAMPLE 2 02/NH004 – *F*; SW15

The raw material's homogeneity shall be better than or equal to 4×10^{-6} when the focus term is excluded; and the maximum wavefront deviation caused by striae shall not exceed 15 nm per 50 mm of path length.

EXAMPLE 3 2/NH010; *B*

The finished part's homogeneity shall be better than or equal to 10×10^{-6}; and the striae shall be grade B or better when evaluated by the shadowgraph method.

EXAMPLE 4 12/NH004 – *F*; SW15 × ⊥2

An entire finished assembly's homogeneity shall be better than or equal to 4×10^{-6} when the focus term is excluded; and the maximum wavefront deviation caused by striae shall not exceed 15 nm per 50 mm of path length in the 2 orthogonal directions that are identified on the drawing.

8 Indications for “no requirement” or “default”

If no specification for a kind of imperfection is needed, then enter a dash, “–”, in the specification field after the indication code and “no requirement” shall apply.

If a default specification is desired for a kind of imperfection, then do not enter a specification or a dash, “–”, in the specification field after the indication code. The default specification according to ISO 10110-11 shall apply.

When a raw material specification is indicated, it shall be assumed that the quality for the same property need not be evaluated in the finished part or assembly. Therefore, when a raw material specification is indicated and the same imperfection for the finished part or assembly is not redundantly indicated, then “no requirement” regarding that imperfection shall apply to the finished part or assembly.

9 Indications on drawings

9.1 Table field

If tabulating the indications, then the indication shall be entered in a table constructed according to ISO 10110-1, with the following exception.

If an indication refers to the raw material, rather than to the finished part, a thin horizontal line shall divide the column for the material specification. The upper region shall contain the specifications for the finished part; the lower region shall contain the specifications for the raw material.

9.2 Drawing field

The indication shall be entered in the drawing field of the drawing near the optical element to which it refers. The indication shall be connected to the element by a leader line that terminates in an arrow on the surface or in a dot inside the cross section of the element (see ISO 10110-1), or for the specification of a finished assembly, indicate it near the optical axis.

10 Indications for other optical material tolerances

If additional material tolerances listed in ISO 12123 are required which have not been described explicitly in this document, it is recommended that they be indicated in the raw material section (on a tabular drawing), or in the material description part of the title block.

11 Examples of indications on drawings

11.1 Example 1: Raw material properties in the drawing region

Figure 1 demonstrates the indication of a tolerance for homogeneity and striae in the raw material used to manufacture the biconvex lens element. Up to 100×10^{-6} in variation of refractive index in the raw material is allowed. Striae with wavefront OPD of up to 60 nm per 50 mm are allowed in the raw material.

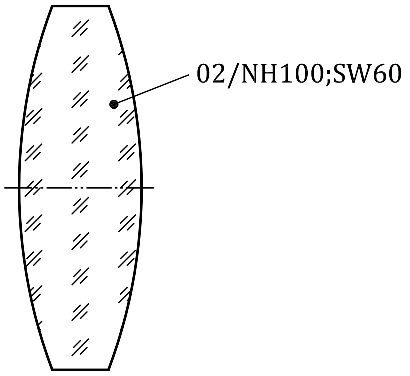


Figure 1 — Homogeneity and striae specified for raw material used to make a finished lens element

11.2 Example 2: Finished part bubble specification

Figure 2 demonstrates the indication of a bubble specification. Up to three bubbles of grade 0,16 are permitted in the finished element. The maximum permitted cross sectional area of all bubbles with grades greater than 0,026 (0,16 × 0,16 = 0,026) and less than or equal to 0,16 is $3 \times 0{,}16^2 = 0{,}077\ \text{mm}^2$.

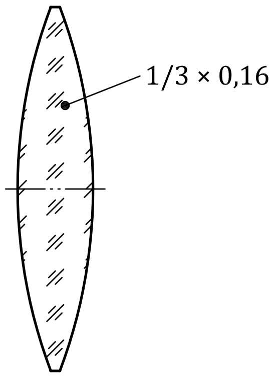


Figure 2 — Bubbles and inclusions specified for a finished biconvex lens element

11.3 Example 3: Finished part, all three properties

Figure 3 demonstrates the indication of all three bulk tolerances for the finished part. Stress birefringence may be as high as 12 nm/cm; up to three bubbles of grade 0,16 are allowed; homogeneity may be as poor as 40×10^{-6} after subtraction of the focus term; and maximum wavefront OPD caused by striae shall be less than or equal to 30 nm/50 mm.

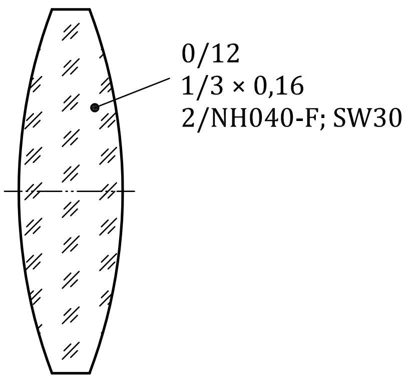


Figure 3 — All three bulk properties specified for a finished part

11.4 Example 4: System example

Figure 4 demonstrates a bubble tolerance for a system after assembly. Up to three bubbles of grade 0,16 are allowed for the entire cemented doublet. It is to be inspected for bubbles as if it were one piece of glass.

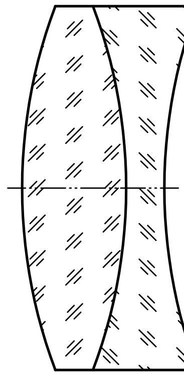
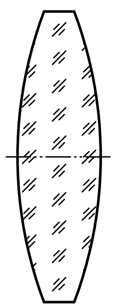


Figure 4 — Bubble specification for a system

11.5 Example 5: Tabulation example

Figure 5 demonstrates a tabulated drawing in which a biconvex element is specified directly with a bubble tolerance of up to three bubbles of grade 0,16.

The stress birefringence, homogeneity, and striae specifications are referenced to the raw material and use values for standard grades as published in ISO 12123.



Left Surface	Material	Right Surface
	1/3 × 0,16	
	00/12 02/NH040-F; SW30	

Figure 5 — Location for a raw material indication when tabulating specifications

Annex A
(informative)

Stress optical constant and stress birefringence

For stressed materials, the optical path difference (OPD) Δs between orthogonal polarizations of transmitted light over the thickness of the sample is a measure of birefringence. It is given in nanometres by

$$\Delta s = a \cdot \sigma \cdot K$$

where

a is the optical path length;

σ is the stress;

K is the material-specific stress optical constant (the value of K is material-specific).

To calculate OPD in nanometres when the optical path length through the material is expressed in centimetres, the stress should be expressed in MPa, and the stress optical constant should be expressed in 10^{-7} MPa^{-1}.

Annex B
(informative)

Guidance for stress birefringence in optical glass

B.1 Values for typical applications

Table B.1 represents common values for stress birefringence that have been successfully used for finished parts in several applications during the past 100 years. See Table B.1.

Table B.1 — Examples of stress birefringence tolerances in some common applications

Maximum permissible stress birefringence (OPD in nm/cm of material path)	Representative applications
2	polarization instruments, interference instruments
5	precision optics, astronomical optics
10	photography, microscopy
20	magnifying glasses, view finders
without requirement	illuminators

B.2 Guidance for the selection of raw glass

B.2.1 Introduction

Selection of raw optical glass for lenses can often be based upon the size of the finished part. Table B.2 gives some guidance based upon the experience of the past 100 years.

Table B.2 — Approximate dimensions for small, medium, and large lenses

	Diameter mm	Thickness mm
Large	>50	>10
Medium	>10 and <50	>5 and <10
Small	<10	<5

B.2.2 Large lenses

For large lenses made out of fine annealed strip or block glass that has been individually inspected, if the raw material blank is much thicker than the element, then stress birefringence in the raw material may be twice as high as that specified for the element.

B.2.3 Medium lenses

Usually, the fine annealed optical glass default is sufficient for medium-sized lenses. A special specification is needed only for very critical requirements.

B.2.4 Small, thin lenses

Usually, the coarse annealed optical glass default is sufficient for small thin lenses. Due to the small thickness of the element no significant stress birefringence will evolve in a standard precise pressing process.

Annex C
(informative)

Guidance for bubble grades in optical glass

C.1 Accumulation chart with traditional bubble grades

The specification for bubble grade defines the maximum size of allowable bubbles. It also defines the maximum number of these bubbles. However, larger numbers of smaller bubbles are allowed as defined in the accumulation rule for bubbles (see 6.4). Table C.1 provides a quick reference to the number of smaller bubbles allowed by a given specification $N \times A$.

Table C.1 — Example accumulation for bubbles

Specified grade (*A*)	Multiplication factor for number of smaller grades 2,5	6,3	16
0,006[a]			
0,010[a]	0,006[a]		
0,016[a]	0,010[a]	0,006[a]	
0,025[a]	0,016[a]	0,010[a]	0,006[a]
0,040	0,025[a]	0,016[a]	0,010[a]
0,063	0,040	0,025[a]	0,016[a]
0,10	0,063	0,040	0,025[a]
0,16	0,10	0,063	0,040
0,25	0,16	0,10	0,063
0,40	0,25	0,16	0,10
0,63	0,40	0,25	0,16
1,0	0,63	0,40	0,25
1,6	1,0	0,64	0,40
2,5	1,6	1,0	0,63
4,0	2,5	1,6	1,0

[a] Grades that are not typically considered by optical glass manufacturers when assessing the bubble quality of raw optical glass.

Use Table C.1 by finding the grade number *A* in the indicated specification (Specified grade "*A*") in Column 1. The three smaller grades included in the accumulation appear in the same row to the right. To calculate the number of allowable bubbles of a smaller grade — if all of the bubbles present belong to that smaller grade — multiply the number, *N*, in the indication by the corresponding "multiplication factor for smaller grades" at the top of the smaller grade's column, and round down to the nearest whole number.

For example, consider the case in which the specification is $1/3 \times 0{,}40$:

1) if only grade 0,40 bubbles appear, then as many as 3 are permissible;

2) if only grade 0,25 bubbles appear, then as many as 7 are permissible;

3) if only grade 0,16 bubbles appear, then as many as 18 are permissible; and

4) if only grade 0,10 bubbles appear, then as many as 48 are permissible.

C.2 Values for typical applications

C.2.1 Introduction

The standard bubble grades follow a sequence known as a Renard R5 sequence. Each equivalent size is 1,6 times larger or smaller than its neighbour. Such a sequence divides a factor of 10 into 5 equal logarithmic parts.

Since a bubble's tendency to scatter light is approximately proportional to its cross sectional area, which is the square of its equivalent size, a bubble in one grade scatters about 2,5 times more or less light than a bubble in a neighbouring grade.

For optical glass, melting and refining processes are optimized for smallest possible number and size of bubbles. Today, there are hardly any bubbles with size <0,03 mm in any glass. Most small, thin lenses are free from bubbles. Unavoidably, some small bubbles will usually appear in large elements. If the element is near an image plane, these bubbles may become visible. Otherwise, they simply scatter tiny amounts of light.

C.2.2 Tolerances for typical applications

Historical precedent during the past 100 years, see Table C.2.

Table C.2 — Typical bubble tolerances for some common applications

Bubble specification	Representative applications
1/0	small lenses in digital cameras and mobile phone cameras
1/1 × 0,16	medium-sized lens for precision optics
1/3 × 0,16	medium-sized lens for photographic optics
1/4 × 0,25	large lens for photographic optics
without requirement	illumination optics

C.3 Guidance for the selection of raw glass

C.3.1 Introduction

Modern manufacturing techniques lead to the following guideline (see Table C.3) with regard to the final size of a lens.

Table C.3 — Approximate dimensions for small, medium, and large lenses

	Diameter mm	Thickness mm
Large	>50	>10
Medium	>10 and <50	>5 and <10
Small	<10	<5

C.3.2 Large lenses

Fine annealed strip or block glass will be inspected individually. The position of the element in the raw glass form will be optimized for minimum bubble content.

C.3.3 Medium lenses

Usually, the optical glass default is sufficient. Special specification is needed only for critical requirements.

C.3.4 Small, thin lenses

Usually, the optical glass default is sufficient.

Annex D
(informative)

Guidance for homogeneity in optical glass

D.1 Introduction

Homogeneity strongly depends on the size of the glass item. In small thin lenses made from state-of-the-art optical glass, homogeneity is expected to be far better than needed. With increasing size (medium-sized lenses) residual variations begin to sum up but are mostly still beneath a level critical for common applications. Large elements with long light paths intended for precision optics may become subject to individual specification requirements, especially when they are so large that their surfaces approach the natural cast surfaces of the raw glass form to within less than about 10 mm. The definition of homogeneity as the maximum variation (peak-to-valley, p-v) value is the most stringent way to specify homogeneity. It is more stringent than usually needed. The focus term of wavefront distortion normally forms a significant part of p-v. Generally, it can be easily corrected in practice and thus may be neglected in the specification for many, but not all cases. Omitting this term explicitly from a p-v specification can be decisive for the successful deliverability of raw glass.

If it is necessary to specify the optical homogeneity of an element it is highly recommended not to transfer the element specification to the total raw glass form as a whole but to the diameter or maximum edge length of the element.

D.2 Change in homogeneity class notation from ISO 10110-4

The homogeneity classes defined in ISO 10110-4 have not changed; however, the notation and the style of explanation has changed under the premise of full equivalence. Plus-minus (±) terminology was used in ISO 10110-4, but peak-to-valley terminology is used in this document and in ISO 12123. See Table D.1.

Table D.1 — Conversion from ISO 10110-4 notation for homogeneity

ISO 10110-4		ISO 10110-18 and ISO 12123	
Grade	Homogeneity tolerance limits (± method)	Grade	Homogeneity tolerance limits (peak-to-valley)
0	$\pm 50 \times 10^{-6}$	NH100	100×10^{-6}
1	$\pm 20 \times 10^{-6}$	NH040	40×10^{-6}
2	$\pm 5 \times 10^{-6}$	NH010	10×10^{-6}
3	$\pm 2 \times 10^{-6}$	NH004	4×10^{-6}
4	$\pm 1 \times 10^{-6}$	NH002	2×10^{-6}
5	$\pm 0,5 \times 10^{-6}$	NH001	1×10^{-6}

D.3 Values for typical applications

See Table D.2.

Table D.2 — Typical homogeneity specifications for representative applications

Homogeneity specification	Representative applications
2/NH100;	illumination optics
2/NH040;	medium size lens for precision optics
2/NH010;	large lens for photographic optics
2/NH004;	large lens for precision optics
2/NH002;	large lens for an interferometric measurement device
2/NH001;	large lens for microlithography optics

D.4 Guidance for the selection of raw glass

D.4.1 Introduction

With modern manufacturing processes for optical glass, the following guidelines usually avoid unnecessarily tight and expensive specifications for raw glass with regard to homogeneity of lenses. See Table D.3.

Table D.3 — Approximate dimensions for small, medium, and large lenses

	Diameter mm	Thickness mm
Large	>50	>10
Medium	>10 and <50	>5 and <10
Small	<10	<5

D.4.2 Large lenses

Fine annealed strip or block glass will be inspected individually. The position of the element in the raw glass form will be optimized for best homogeneity. Usually interferometric measurements are made at 632 nm wavelength and cannot be made up to the very edge but only to a circular rim zone of 10 mm.

D.4.3 Medium lenses

Usually, the optical glass default is sufficient. A special specification is needed only for critical requirements.

D.4.4 Small, thin lenses

Usually, the optical glass default is sufficient.

Annex E
(informative)

Guidance for striae in optical glass

E.1 Introduction

Optical glass melting and refining processes are optimized for low content of striae. The default quality over a 50 mm glass path length already represents high quality. Usually optical wavefront distortions caused by striae decrease roughly proportionally to glass thickness and are effective only in narrow angle ranges below ±5 degrees. For thin lenses, striae distortions lie fairly below 10 nm and thus below the detection limit. This also holds for most medium-sized lenses. With large prisms light path lengths of more than 50 mm easily occur together with different travelling directions. Here wavefront distortions might be summed up leading to light ray deflections higher than tolerable. See Table E.1 for typical striae specifications in representative applications.

E.2 Values for typical applications

Table E.1 — Typical striae specifications for representative applications

Striae specification	Representative applications
2/;SW60	small lenses in digital cameras and mobile phone cameras.
2/;SW30	medium-sized lenses for precision optics.
2/;SW15	large lens for photographic optics.
2/;SW10 × ⊥2	large prism for precision optics. Requirement applies to 2 orthogonal directions
without requirement	illumination optics

E.3 Guidance for the selection of raw glass

E.3.1 Introduction

With modern manufacturing processes for optical glass, the following guidelines usually avoid unnecessarily tight and expensive specifications for raw glass with regard to striae in lenses. See Table E.2.

Table E.2 — Approximate dimensions for small, medium, and large lenses

	Diameter mm	Thickness mm
Large	>50	>10
Medium	>10 and <50	>5 and <10
Small	<10	<5

E.3.2 Large lenses

Fine annealed strip or block glass will be inspected individually. The position of the element in the raw glass form will be optimized for minimum striae content. Large prisms may require inspection in two or more perpendicular directions.

E.3.3 Medium lenses

Usually, the optical glass default is sufficient. Special specifications are needed only for critical requirements.

E.3.4 Small, thin lenses

Usually, the optical glass default is sufficient.

Bibliography

[1] ISO 3, *Preferred numbers — Series of preferred numbers*

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 10110-11 Optics and photonics — Preparation of drawings for optical elements and systems — Part 11: Non-toleranced data	IS 5920 (Part 7) : 2024/ ISO 10110-11 : 2019 — Optics and photonics — Preparation of drawings for optical elements and systems: Part 7 Non-toleranced data	Identical
ISO 12123 Optics and photonics — Specification of raw optical glass	PGD 39 (24214)/ISO 12123 : 2018 Optics and photonics — Raw optical glass — Specification	Identical

The Committee has reviewed the provisions of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard.

International Standard	*Title*
ISO 14999-4 : 2015	Interferometric measurement of optical elements and optical systems — Part 4: Interpretation and evaluation of tolerances specified in ISO 10110

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (second revision)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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This Indian Standard has been developed from Doc No.: PGD 39 (23514).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi