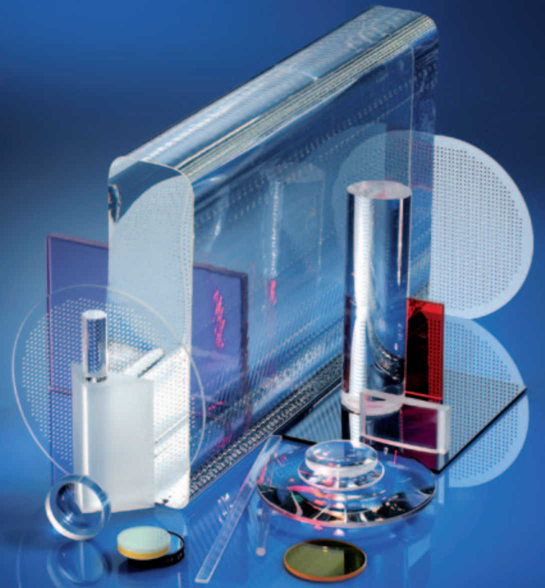
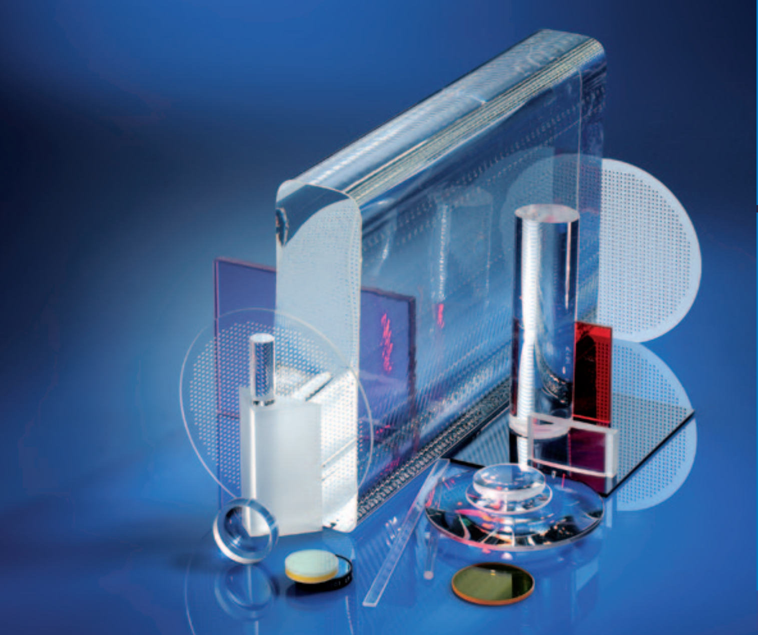


SCHOTT
glass made of ideas

Optical Glass

Description of Properties
2011



SCHOTT
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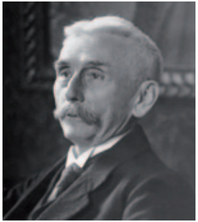
Foreword & Overview

SCHOTT Advanced Optics –
Your Partner for Excellence in Optics.

SCHOTT, an international technology group, has been developing and manufacturing glass, specialty materials and components for more than 125 years.

Today, the Advanced Optics unit of SCHOTT offers optical materials, components and filters and has been a trailblazer for various applications. With a product portfolio of over 100 optical glasses, special materials (e.g. active laser glass, IR-Materials, sapphire), ultra-thin glass, high-precision optical components, wafers, and optical filter glasses, Advanced Optics develops customized solutions all over the world for applications in optics, lithography, astronomy, opto-electronics, life sciences, research, and more.

Advanced Optics masters the entire value chain: from customer-specific glass development and its production all the way to high-precision optical product finishing, processing and measurement.



Otto Schott (1851–1935)

For more information on Advanced Optics, visit our website: *http://www.us.schott.com/advanced_optics/english/index.html*

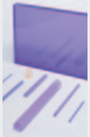
Product Portfolio of Advanced Optics:

Advanced Optics offers a broad variety of optical materials, filters and components. Here, you will find a concise overview of our main products and applications:

MATERIALS

Optical Glass
SCHOTT offers a wide range of high-quality optical glasses to meet the needs of a broad variety of optical and industrial applications. The portfolio includes lead and arsenic free N-glasses, glasses suitable for precision molding (low Tg glass) as well as glass types with lead oxide as an essential component for outstanding optical properties. In addition, we also offer special versions e.g. "HTultra" glasses with superior transmission.

Low Tg Optical Glass
These special lead and arsenic-free low Tg glasses are suited for precision molding processes (P-glasses). The glass compositions of these glasses have been developed to have low tendencies to devitrification and show less vehement reactions with mold materials inside the molding temperature range.



Active and Passive Laser Glasses
SCHOTT offers cutting edge silicate and phosphate laser glasses for security, medical (dermatology), and a variety of high energy applications. These glasses are offered as finished components with custom polishing or coating.

Radiation Resistant Glass
SCHOTT offers a variety of radiation resistant glass types covering main parts of the Abbe Diagram. These products are suited for earth orbit based applications with lifetimes of up to 10 years.

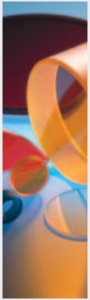
Radiation Shielding Glass
Radiation shielding glass has been developed specifically for nuclear technology. Some of our glass types contain lead in order to exploit its high radiation absorption.

Technical Glass
SCHOTT's technical glass is designed to meet specific requirements. High electrical resistance for hermetic sealings, superior durability for corrosive environments and high glass transformation temperature all make it the ideal choice for temperature applications.

IR-Materials*
SCHOTT offers chalcogenide glasses with excellent transmission and low thermal change in refractive index. Polycrystalline ZnS FLIR and CLEAR is produced using a CVD process. It is available in large sizes and custom shapes and formats such as windows, domes, or lens blanks. *IR Materials partly provided by our partner VITRON Spezialwerkstoffe GmbH

ZERODUR®
A zero expansion glass-ceramic for demanding applications in which critical geometry and distance accuracy need to be controlled perfectly under temperature changes, with extraordinary properties: extremely low thermal expansion coefficient, excellent homogeneity of thermal expansion, good workability, polishability to high accuracy and excellent chemical stability.

FILTERS



Optical Filter Glasses
Optical filter glasses ("color glass") absorb the undesirable light spectrum ("colors") and are thus relatively insensitive to a change in the angle of incidence of light, and typically very durable in mechanical terms, as the filter glass can also be hardened. Optical filters, such as IR-cut filters, for example, only admit the light visible to the human eye and block the infrared light spectrum (IR), in particular. SCHOTT offers more than 55 different filter glasses that enable applications in analytics, photography, medical technology and laser protection.

Interference Filters –
Customer-specific filter functions

Interference filters use the wave characteristic of light – interference. Band-pass, long-pass, short-pass, and band block filters can be produced by means of thin optical layers. These thin layers are applied under high vacuum using a vapor deposition process. Decorative and protective coatings are also available. SCHOTT uses different technologies for this, such as reactive vapor depositions, reactive ion plating and magnetron sputtering. Our custom designed interference filters are used for applications in medical technology, for analysis of drinking water and clarified water, for fluorescence microscopy, and more. Post-processed filters – cemented or framed, are also available.

COMPONENTS

Windows & Substrates

SCHOTT is a specialist when it comes to producing plane parallel polished substrates of the highest precision. Substrates with diameters up to 625 mm, surface flatness up to $\lambda/20$, roughness below 8 Angstrom, scratch & digs up to 5-2 can be reached. Coatings are also available.

Lenses

Lenses are essential to any optical system. SCHOTT offers various types of lenses: spherical, cylindrical, aspherical (molded or CNC machined, polished, coated), singlets, doublets, and triplets. Diameters of up to 200 mm, surface flatness of up to $\lambda/10$, scratch & digs up to 10-5, and centering better than 30 arc seconds can be achieved.

Prisms

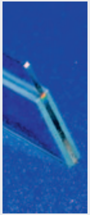
SCHOTT offers prisms as transparent optical elements with flat polished surfaces that refract, reflect or disperse light. SCHOTT supplies all types of prisms: right angle prisms, porro prisms, roof prisms and more in sizes up to 200 mm, surface flatness up to $\lambda/10$, and scratch & digs up to 10-5. Different customer-specific coatings are also available.

Precision CNC Machined Parts

CNC machined parts are optical components which have been processed to complex forms such as laser gyroscope bodies, lithography plates or light weighted mirrors. Coupled with the use of CAD software, nearly all geometrical forms can be achieved with very high accuracy.

Coatings

SCHOTT applies standard and custom-designed coatings. Different coating technologies are available in-house for a typical wavelength spectrum of between 200 nm and 3000 nm. Our portfolio ranges from anti-reflective coatings, mirrors, dielectric beam splitters, and polarizers to high-end interference filters with sharp edges and strong blocking ranges. All types of materials can be coated, for instance fused silica, optical filter glass, and optical glass.



Sub-Assembly

SCHOTT supplies optical and opto-mechanical mounted parts based on customer requirements: e.g. filter assemblies, head-up displays for aviation, prism assemblies, objective lenses. We assure that requirements such as high precision and quality, solid assembling, vacuum tightness and optical properties (such as transmission and reflection) can be met.

Optical Glass Catalog

In this **catalog**, you will find an overview of our optical glasses and materials that cover the needs of a wide range of applications from consumer products to optical systems at the cutting edge of research.

We address the following categories:

→ Lead and arsenic free N-glasses
→ Low Tg glass types suited for the precision molding process
→ Classical glass types with lead oxide as an essential component for outstanding optical properties
→ Radiation resistant glass types
→ Optical glasses with enhanced transmission values in the visible spectral range, especially in the blue-violet area: HT & HTultra glasses

While addressing these different categories, SCHOTT distinguishes between **Preferred Materials**, usually kept in stock for immediate delivery, and **Inquiry Glass Types**, which can be ordered, althogh SCHOTT does not guarantee their availability from stock. Details are listed in the data section of the catalog.

TIE available

Relevant definitions for the materials listed in this catalog:

The cerium-stabilized **radiation resistant glass** types are used to maintain transmittance in an ionizing radiation environment and also rank among our inquiry glasses.
The optical data of the materials listed in this catalog are meant for use in optical applications and therefore refer to air.
For the use of materials in lithography for which transmittance data below 250 nm is required, we kindly ask that you contact us directly to discuss technical aspects in greater detail. This also applies for **i-line glasses**, which are used for lithography due to their superb transmit-

tance in the near-UV range and in optical homogeneity. Upon request, we would be happy to provide you with the respective data sheets and technical support.

Supply Forms

SCHOTT offers **different supply forms** of the materials available. Detailed information is included in chapter 7.

Quality Management

We manufacture, process and distribute our materials in accordance with our Integrated Management System for Safety and Environmental Protection (IMSU) to prevent environmental pollution and conserve natural resources. In addition, SCHOTT recently implemented parts of the new ISO 12123 "Optics and Photonics – Specification of Raw Optical Glass" which is being taken into account in this updated version of this catalog. References are shown in the descriptions.

Further Product Information

One of SCHOTT's main concerns is providing professional support in addition to supplying current products. Extensive technical mentoring, detailed product information and application support before and after a product is purchased and joint developments to a customized solutions describe our uniqueness. We offer detailed data sheets, databases for use with optical design programs and survey diagrams for all materials listed in this catalog. Electronic versions of technical information or so-called TIEs are also available.

The stamp shown here is placed within this catalog and indicates the availability of a relevant TIE. An overview is shown on page 65 of this catalog. Detailed technical information can be found under: *http://www.us.schott.com/advanced_optics/english/tools_downloads/download/index.html*

1 Optical Properties

1.1 Refractive Index, Abbe Number, Dispersions, Glass Designations

TIE available

The most common identifying features for characterizing an optical glass are the refractive index n_d in the middle range of the visible spectrum and the Abbe number $\nu_d = (n_d - 1)/(n_F - n_C)$ as a measure for dispersion. The difference $n_F - n_C$ is referred to as the principal dispersion.

Optical glass can also be designated by a numerical code, often called the glass code. Here, SCHOTT uses a nine-digit code. The first six digits correspond to the common international glass code. They indicate the optical position of the individual glass. The first three digits reflect the refractive index n_d, the second three digits the Abbe value ν_d. The additional three digits show the density of the glass.

Table 1.1: Examples of glass codes

Glass type	n_d	ν_d	Density	Glass code
N-SF6	1.80518	25.36	3.37	805254.337 lead and arsenic free glass
SF6	1.80518	25.43	5.18	805254.518 classical lead silicate glass

When specifying optical systems, the values based on the e-line n_e and $\nu_e = (n_e - 1)/(n_{F'} - n_{C'})$ are other commonly established quantities.

Preferred optical glasses are grouped as families in the n_d/ν_d or n_e/ν_e diagram. The glass families are listed in the data section in the order of decreasing Abbe values.

1.2 Tolerances for Refractive Index and Abbe Number

The tolerances for the refractive index and Abbe number are listed in table 1.2. The standard delivery quality for fine annealed glass is step 3 for n_d and step 3 for ν_d. We supply material in tighter steps upon demand.

Table 1.2: Tolerances for refractive index and Abbe number (according to ISO 12123)

	n_d	ν_d
Step 1	± 0.0002	± 0.2%
Step 2	± 0.0003	± 0.3%
Step 3	± 0.0005	± 0.5%
Step 4	–	± 0.8%

All deliveries of fine annealed optical glass and cut blanks are made in lots of single batches (see fig.: 1.1).

The batch may be a single block or several strips. The delivery lots are identified by a delivery lot number.

The delivery lots are formed based on the specified maximum allowed refractive index and Abbe number deviation of single batches from the nominal values in the data sheets (tolerances according table 1.2) and the refractive index variation from batch to batch as specified in table 1.3.

As the batches may have different fine annealing histories, such delivery lots are not suitable for repressing.

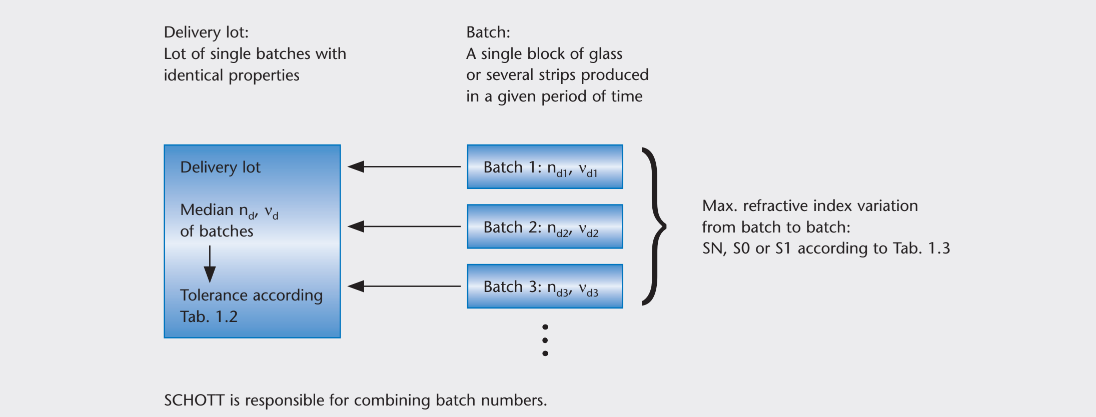
All parts of a delivery lot of fine annealed optical glass, cut blanks or pressings meet the normal quality of refractive index variation as listed in the following table 1.3. If requested, parts can also be supplied in lots with tighter refractive index variations than indicated in table 1.3.

Table 1.3: Tolerance of refractive index variation within a lot of fine annealed glass (according to ISO 12123) and within a lot of pressings

Fine annealed glass, cut blanks		**Pressings**	
Designation	**Refractive index variation**	**Designation**[1)]	**Refractive index variation**
SN	$\pm 1 \cdot 10^{-4}$	LN	$\pm 2 \cdot 10^{-4}$
S0	$\pm 5 \cdot 10^{-5}$	LH1	$\pm 1 \cdot 10^{-4}$
S1	$\pm 2 \cdot 10^{-5}$	LH2	$\pm 5 \cdot 10^{-5}$

[1)] All variation tolerances for pressings upon request only

Fig. 1.1: Delivery lot composition of glass for hot processing and fine annealed glass



1.3 Test Reports for Refractive Indices and Dispersions

1.3.1 Standard test reports

We provide standard test reports according to ISO 10474 for all deliveries of fine annealed optical glass. The information they contain is based on sampling tests and refers to the median position of the optical values of a delivery lot. The value of the individual part may deviate from the reported median value by the tolerance of refractive index variation.

Measurements are performed with an accuracy of $\pm 3 \cdot 10^{-5}$ for refractive index and $\pm 2 \cdot 10^{-5}$ for dispersion. Numerical data is listed down to five decimal places.

Table 1.4: Refractive index and dispersion information in standard test reports

n_d	ν_d	$n_F - n_C$	$n_F - n_d$	$n_{F'} - n_{C'}$	$n_g - n_F$
n_e	ν_e	$n_d - n_C$	$n_F - n_e$	$n_{F'} - n_e$	

Test certificates that are even more accurate can be provided for individual glass parts upon request ($\pm 2 \cdot 10^{-5}$ for refractive index and $\pm 1 \cdot 10^{-5}$ for dispersion). These certificates also list the constants of the Sellmeier dispersion formula for the applicable spectral range evaluated from a complete measurement series.

1.3.2 Precision test certificates UV-VIS-IR

Precision test certificates are issued upon request and always refer to individual glass parts.

Within the visible spectral range, these certificates contain the same quantities as the test reports for standard accuracy, however the dispersion data is reported down to six decimal places. Upon request, refractive index data can be provided for an expanded spectral range of 185 nm to 2325 nm and the constants of the Sellmeier dispersion formula can be listed for the applicable spectral range.

Measurement is done using a prism goniometer. The accuracy is $\pm 1 \cdot 10^{-5}$ for refractive index and $\pm 3 \cdot 10^{-6}$ for dispersion. Accuracy of up to $\pm 4 \cdot 10^{-6}$ for the refractive index and $\pm 2 \cdot 10^{-6}$ for the dispersion measurement, independent of the glass type and measurement wavelength, can be provided upon request.

The standard measurement temperature is 22 °C. The measurement temperature can be changed to a constant value between 18 °C and 28 °C upon request. The standard measurement atmosphere is air at a pressure of about 1013.3 hPa. The actual measurement temperature and pressure are indicated on the individual test certificates. Measurement in nitrogen is possible upon special request.

1.4 Refractive Index Homogeneity

The refractive index homogeneity is a measure for designating deviations in the refractive index in individual pieces of glass. Pieces of glass with a high homogeneity of refractive index can be obtained by undertaking special efforts in the area of melting and fine annealing. The refractive index homogeneity that can be achieved depends on the type of glass, the volume and the shape of the individual glass piece.

The required optical homogeneity should be specified with respect to the application and the final dimensions of the part. In general, the optical homogeneity values specified are peak to valley values calculated from measured wave front deviations containing all of the aberrations.

In many cases, you can subtract certain aberration terms of negligible impact on the application. For example, focal aberrations (expressed by the focal term) can often be corrected by adapting the geometry of the final part. This should be specified in advance.

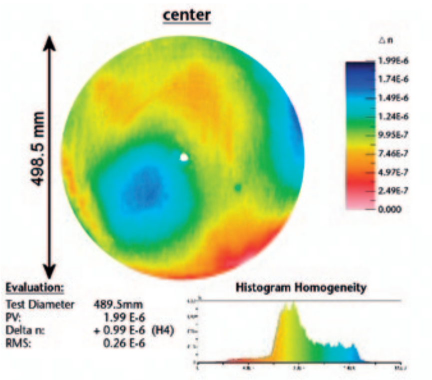
The gradient of homogeneity distribution can be evaluated in terms of refractive index variation per cm aperture upon request. This too should be specified in advance.

Increased requirements for refractive index homogeneity comprise five classes in accordance with the standard ISO 10110 Part 4 (see table 1.5). The maximum variation of refractive index is expressed in peak to valley values in accordance with ISO 12123.

Table 1.5: Homogeneity of optical glasses

Homogeneity class	**Maximum variation of refractive index**	**Applicability, deliverability**
H 1	$40 \cdot 10^{-6}$	For individual cut blanks
H 2	$10 \cdot 10^{-6}$	For individual cut blanks
H 3	$4 \cdot 10^{-6}$	For individual cut blanks, not in all dimensions
H 4	$2 \cdot 10^{-6}$	For individual cut blanks, not in all dimensions, not for all glass types
H 5	$1 \cdot 10^{-6}$	For individual cut blanks, not in all dimensions, not for all glass types

Fig. 1.2: H4 quality of a 1 m diameter N-BK7® blank measured with a central aperture of 500 mm



1.5 Internal Transmittance, Color Code

TIE available

According to general dispersion theory, internal transmittance, i.e. the light transmittance excluding reflection losses, is closely related to the optical position of the glass type. Using the purest raw materials and sophisticated melting technology, it is possible to approach the dispersion limits for internal transmittance in the short wave spectral range.

SCHOTT seeks to achieve the best possible internal transmittance within economically reasonable limits.

The internal transmittance and color code listed in the data section represent median values from several melts of one glass type. Minimum values for internal transmittance can also be maintained for all glass types upon special request. Prior clarification of the delivery situation is necessary. The internal transmittance at 400 nm for a sample thickness of 10 mm is listed in the data section.

Some glasses are available with improved transmittance in the visible spectrum, especially in the blue-violet range. These products are marked with the suffix HT (high transmittance) or HTultra (ultra high transmittance) and will be shown separately in the data section (like N-SF6HT or SF57HTultra). For HT and HTultra grade, the internal transmittance in the visible spectrum includes guaranteed minimum values.

The limit of the transmittance ranges of optical glasses towards the UV area is of particular interest in high index glasses because it moves closer to the visible spectral range with increases in the refractive index. A simple description of the position and slope of the UV absorption curve is shown by the color code.

The color 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 off to 10 nm and denoted by eliminating the first digit. For example, color code 33/30 means $\lambda_{80} = 330$ nm and $\lambda_5 = 300$ nm.

For high index glass types with $n_d > 1.83$, the data of the color codes (marked by *) refers to the transmittance values 0.70 and 0.05 (λ_{70} and λ_5) because of the high reflection loss of this glass. The tolerance of the color code is usually within ±10 nm.

1.6 Measurement Capabilities for Optical Properties

Table 1.6 provides an overview of the measurement accuracy for the measurement procedures used to characterize optical properties in quality assurance of optical glass.

	Measurement	Accuracy		Equipment	Spectral Range	Sample	
						Shape	Format
Refractive index measurement		refr. index	dispersion	V-block refractometer	g, F´, F, e, d, C´, C (ν_d, ν_e)	cube	$20 \cdot 20 \cdot 5$ mm³
	Standard measurement	$\pm 3 \cdot 10^{-5}$	$\pm 2 \cdot 10^{-5}$				
	Standard measurement with increased accuracy	$\pm 2 \cdot 10^{-5}$	$\pm 1 \cdot 10^{-5}$		i, h, g, F´, F, e, d, C´, C, r, t (ν_d, ν_e)	cube	
	Precision measurement	$\pm 0.4 \cdot 10^{-5}$	$\pm 0.2 \cdot 10^{-5}$	Spectrometer	185–2325 nm	prism	side: 30 mm height: 22 mm
	Internal transmittance	$\pm$ 0.5% T $\pm$ 0.3% T		Spectral photometer	250–2500 nm 400–700 nm	cube	$30 \cdot 30 \cdot$ thickness mm³
	Refractive index homogeneity	~10 nm wavefront pv		Interferometer	633 nm	rectangular circular	up to ~1000 mm diameter
	Temperature coefficients of refraction	$\pm 5 \cdot 10^{-7} \cdot K^{-1}$		Spectral goniometer	i, h, g, F´, e, d, C´, t, 1060 -100 °C bis +140 °C	half prism single sided metallized	side: 30 mm height: 22 mm
	High accuracy Stress birefringence	1 nm absolute (1 mm spatial resolution)		Imaging polarimeter	587 nm	arbitrary shape	up to 300 mm diameter

2 Internal Properties

2.1 Striae

TIE available

Deviations of the refractive index in glass of short range are called striae. They resemble layers in which the refractive index deviates by a typical difference of tenths to several millimeters.

The standard ISO 10110 Part 4 contains a classification with reference to striae. Since it refers to finished optical components, it is only applicable to optical glass in its original form of supply to a limited extent. It assigns the striae to classes 1–4 based on their area in terms of the optically effective total surface of the component. Thus, it only considers striae that deforms a plane wave front by more than 30 nm.

The fifth class specifies glass that is extremely free of striae. It also includes striae below 30 nm wave front distortion and advises the user to make arrangements with the glass manufacturer.

The production formats of all optical glasses from SCHOTT meet the requirements of classes 1–4 of ISO 10110 Part 4. The tested glass thickness is usually much thicker than that of the finished optical components. Therefore, the effective striae quality in the optical system is *much better*.

Striae in all optical glasses are detected by means of the shadowgraph method using comparison standards with known wavefront deviations. The tolerance limits in accordance with ISO 12123 are shown in table 2.1.

Table 2.1: Tolerance limits (according to ISO 12123)

Striae class	Striae wavefront deviation tolerance limit per 50 mm path length [nm]	Generally applicable for
Standard	< 30	raw glass
VS1 / VS2	not visible	cut blanks

Quality step VS1 specifies optical glass with increased striae selection. For optical glass in this quality category, no striae have been detected by the sensitive shadow method. For prism applications, SCHOTT offers quality step VS2. For such glass parts, no striae have been detected by the shadow method in two directions perpendicular to one another.

2.2 Bubbles and Inclusions

TIE available

Optical glass is remarkably free of bubbles. However, due to the glass composition and the need for an economical manufacturing process, bubbles cannot be completely avoided in glass.

The bubble content is expressed by the total cross section in mm^2 in a glass volume of 100 cm^3, calculated from the sum of the detected cross section of bubbles. Inclusions in glass, such as stones or crystals, are treated as bubbles that have the same cross section. The evaluation considers all bubbles and inclusions $\geq$ 0.03 mm.
The bubble classes, maximum allowable quantities and diameters of bubbles and inclusions are listed in table 2.2. In the increased quality steps VB (increased bubble selection) and EVB (extra increased bubble selection), the glasses can only be supplied as fabricated pieces of glass.

In accordance with ISO 10110 Part 3, bubbles may be distributed. Instead of a bubble with a given dimension, a larger quantity of bubbles of smaller dimensions is allowed.

Special applications, such as high energy lasers, beam splitter prisms or streak imaging cameras and high pitch gratings, only tolerate glasses that have a small number of tiny bubbles/inclusions. We can offer glass that meets these requirements upon request.

Table 2.2: Tolerances for bubbles and inclusions in optical glasses

Bubble class		**B0**	**B0**	**B0**	**B1**	**B1**	**B1**
Quality step			**VB**	**EVB**		**VB**	**EVB**
Maximum allowable cross section of all bubbles and inclusions in mm^2 per 100 cm^3 of glass volume		0.03	0.01	0.006	0.1	0.03	0.02
Maximum allowable quantity per 100 cm^3		10	4	2	30	10	4
Maximum allowable	50	0.10	0.10	0.10	0.15	0.15	0.10
diameter of bubbles	100	0.15	0.15	0.10	0.20	0.15	0.10
or inclusions in mm	200	0.20	0.15	0.10	0.30	0.20	0.10
within parts of **diameter**	300	0.25	0.20	0.10	0.40	0.25	0.10
or max. edge length	500	0.40	–	–	0.60	–	–
in mm	800	0.55	–	–	0.80	–	–

2.3 Stress Birefringence

TIE available

The size and distribution of permanent inherent stress in glass depends on the annealing conditions, the glass type, and the dimensions. The extent to which stress causes birefringence depends on the glass type.

Stress birefringence is measured as a path difference using the de Sénarmont and Friedel method and is listed in nm/cm based on the test thickness. Its accuracy is 3–5 nm for simple geometric test sample forms. Measurement is performed on round discs at a distance of 5% of the diameter from the edge. For rectangular plates, the measurement is performed at the center of the longer side at a distance of 5% of the plate width. A detailed description of the method can be found in ISO Standard 11455.

The manual de Sénarmont and Friedel method is insufficient for measurements of low stress birefringence and low thickness. In these cases, we have systems for measuring with an accuracy of 1 nm or less.

With our annealing methods, we are able to achieve both high optical homogeneity and very low stress birefringence. The pieces of glass that are delivered generally have symmetrical stress distribution. The glass surface is usually under compression. Stress birefringence can be reduced significantly by cutting block or strip glass. If the optical elements are much smaller than the raw glass format they are made of, then the remaining stress birefringence will be even much lower than the limiting values shown in table 2.3.

The limit values for stress birefringence in parts larger than 600 mm are available upon request.

Higher stresses are allowed in glass used for reheat pressing. This has no effect on mechanical processing.

Table 2.3: Limit values of stress birefringence in cut blanks for various dimensions (Ø: diameter or maximum length, d: thickness)

	Stress birefringence		
Dimensions	**Fine annealing [nm/cm]**	**Special annealing (SK) [nm/cm]**	**Precision annealing (SSK) [nm/cm]**
Ø ≤ 300 mm d ≤ 60 mm	≤ 10	≤ 6	≤ 4
Ø: > 300 – 600 mm d: > 60 – 80 mm	≤ 12	≤ 6	≤ 4

3 Chemical Properties

TIE available

The five test methods described below are used to assess the chemical durability of polished glass surfaces.

3.1 Climatic Resistance

Climatic resistance describes the behavior of optical glasses at high relative humidity and high temperatures. A film of white stains can develop on the surface of sensitive glasses that generally cannot be wiped off.

An accelerated procedure according to ISO/WD 13384 is used to test the climatic resistance of the glass, in which polished, uncoated glass plates are exposed to water vapor saturated atmosphere, the temperature of which alternates between 40 °C and 50 °C. This produces a periodic change from moist condensation on the glass surface and subsequent drying.

The glass plates are removed from the climatic chamber after 30 hours of exposure time. The difference ΔH between the haze before and after testing is used as a measure of the resulting surface change. The measurements are performed using a spherical hazemeter. Classification is done based on the increase of transmittance haze ΔH after a 30-hour test period. Table 3.1 lists the climatic resistance classes.

Table 3.1: Classification of optical glasses into climatic resistance classes CR 1–4

Climatic resistance class CR	1	2	3	4
Increase in haze ΔH	$< 0.3\,\%$	$\geq 0.3\,\%$ $< 1.0\,\%$	$\geq 1.0\,\%$ $< 2.0\,\%$	$\geq 2.0\,\%$

The glasses in class CR 1 show no visible attacks after being exposed to climatic change for 30 hours. Under normal humidity conditions during the fabrication and storing of optical glass in class CR 1, no surface attack can be expected. On the other hand, class CR 4 optical glasses should be manufactured and stored with caution because these glasses are highly sensitive to environmental influences.

When storing optical polished elements, we recommend applying a protective coating and/or ensuring that relative humidity is kept as low as possible.

3.2 Stain Resistance

The test procedure provides information on possible changes in the glass surface (stain formation) under the influence of slightly acidic water (for example perspiration, acidic condensation) without vaporization.

The stain resistance class is determined using the following procedure: The plane polished glass sample to be tested is pressed onto a test cuvette, which has a spherical depression of max. 0.25 mm depth that contains a few drops of a test solution.

Test solution I: sodium acetate buffer pH = 4.6
Test solution II: sodium acetate buffer pH = 5.6

Interference color stains develop as a result of decomposition of the surface of the glass by the test solution. The measure for classifying the glass is the time that elapses before the first brown-blue stain occurs at a temperature of 25 °C. Changes in color correspond to certain thicknesses of the surface layer that were previously determined on reference samples. A brown-blue change in color indicates a chemical change in the surface layer of 0.1 µm thickness insofar as the glass is able to form layers. Table 3.2 lists the stain resistance classes.

Stain resistance class FR 0 contains all glasses that show virtually no interference colors, even after 100 hours of exposure to test solution I. Glasses in classification FR 5 must be handled with particular care during processing.

Table 3.2: Classification of optical glasses into stain resistance classes FR 0–5

Stain resistance class FR	**0**	**1**	**2**	**3**	**4**	**5**
Test solution	I	I	I	I	II	I/II
Time (h)	100	100	6	1	1	0.2
Stain development	no	yes	yes	yes	yes	yes
Color change	no	yes/no	yes	yes	yes	yes

3.3 Acid Resistance

Acid resistance describes the behavior of optical glass that comes in contact with larger quantities of acidic solutions (for example: perspiration, laminating substances, carbonated water, etc.). Acid resistance is determined according to ISO 8424 (1996).

Acid resistance is denoted by either a two or three digit number. The first or first two digits indicate the acid resistance class SR. The last digit, which is separated by a decimal point, indicates the visible surface changes that occurred as a result of exposure. The last digit is discussed in chapter 3.5.

The time required to dissolve a layer with a thickness of 0.1 µm at 25 °C serves as a measure of acid resistance. Two aggressive solutions are used to determine acid resistance. A strong acid (nitric acid, c = 0.5 mol/l, pH 0.3) is used for the more resistant glass types, whereas glasses with lower acid resistance are exposed to a weak acidic solution with a pH value of 4.6 (sodium acetate buffer).

The layer thickness is calculated from the weight loss per surface area and the density of the glass. Table 3.3 lists the acid resistance classes.

Class SR 5 forms the transition point between the more acid resistant glasses in SR 1–4 and the more acid sensitive glasses in SR 51–53. Class SR 5 includes glasses for which the time for removal of a layer thickness of 0.1 µm at a pH value of 0.3 is less than 0.1 h and at a pH value of 4.6 is greater than 10 hours.

Table 3.3: Classification of optical glasses into acid resistance classes SR 1–53

Acid resistance class SR	**1**	**2**	**3**	**4**	**5**		**51**	**52**	**53**
pH value	0.3	0.3	0.3	0.3	0.3	4.6	4.6	4.6	4.6
Time (h)	> 100	10–100	1–10	0.1–1	< 0.1	> 10	1–10	0.1–1	< 0.1

3.4 Alkali and Phosphate Resistance

Both test methods are used to classify the resistance of glasses to aqueous alkaline solution in excess and use the same classification scheme.

The alkali resistance indicates the sensitivity of optical glass in contact with warm, alkaline liquids, such as cooling liquids in grinding and polishing processes. Alkali resistance is determined according to ISO 10629 (1996).

Phosphate resistance describes the behavior of optical glass during cleaning with washing solutions (detergents) that contain phosphates. Phosphate resistance is determined according to ISO 9689 (1990).

Both alkali and phosphate resistance are denoted using two digits separated by a decimal point. The first digit lists the alkali resistance class AR or the phosphate resistance class PR, and the decimal indicates the visible surface change that occurs as a result of exposure.

The alkali resistance class AR indicates the time needed to remove a 0.1 μm layer thickness of glass in an alkaline solution (sodium hydroxide, c = 0.01 mol/l, pH = 12) at 50 °C.

The phosphate resistance class PR indicates the time needed to remove a 0.1 μm layer thickness of glass in a solution that contains alkaline phosphate (pentasodium triphosphate $Na_5P_3O_{10}$, c = 0.01 mol/l, pH = 10) at a temperature of 50 °C. The layer thickness is calculated from the weight loss per surface area and the density of the glass. Table 3.4 lists the alkali and phosphate resistance classes.

Table 3.4: Classification of the optical glasses to alkali resistance classes AR 1–4 and phosphate resistance classes PR 1–4

Alkali resistance class AR, Phosphate resistance class PR	1	2	3	4
Time (h)	> 4	1–4	0.25–1	< 0.25

Glasses in class 1 are more resistant to the test solutions than the glasses in class 4. The digit behind the classification identifies the visible surface change that occurs following exposure. The digits are covered in chapter 3.5.

3.5 Identification of Visible Surface Changes

Changes in the surface of the exposed samples are evaluated qualitatively with the naked eye. The definition of the digits behind the classification for acid, alkali, and phosphate resistance is as follows:

- .0 no visible changes
- .1 clear, but irregular surface (wavy, pockmarked, pitted)
- .2 staining and/or interference colors (slight, selective leaching)
- .3 tenacious thin whitish layer (stronger, selective leaching, cloudy/hazy/dullish surface)
- .4 adhere loosely, thick layer, such as insoluble, friable surface deposits (maybe a cracked and/or peelable surface, surface crust, or cracked surface; strong attack)

3.6 Environmental Aspects, Hazardous Substances, RoHS

We manufacture, process and distribute our range of materials in accordance with our Integrated Management System for Safety and Environmental Protection (IMSU) and Environmental, Health and Safety Management System (EHS) to prevent environmental pollution, conserve natural resources and follow the procedure and philosophy of our Quality Management System.

Raw materials are handled, batches are melted and hot forming takes place in accordance with established safety procedures. Sludge from cutting, grinding and polishing is treated according to the waste disposal procedures prescribed by local authorities. Glass parts survive their end of usage life by far without releasing any of their chemical components. Their disposal is a rare and dispersed event to prevent any critical levels from accumulating.

All optical materials in this catalog comply with the requirements of the European Directive 2002/95/EC (RoHS). The optical materials featured in our catalog do not contain any mercury (Hg), chromium VI (CrVI), cadmium or the flame retardants PBB and PBDE whatsoever. N- and P-glass types comply with the limit value of 0.1 % for lead specified in the directive 2005/618/EC that states the admissible limits for the hazardous substances quoted in RoHS. The classical glass types may contain lead oxide in significant amounts. They are in compliance with RoHS due to the exemption documented in the Commission decision 2011/65/EU. In addition, all materials discussed in this catalog comply with the requirements of the European Regulation 2006/1907/EC (REACH: Registration, Evaluation and Authorization of Chemical Substances).

4 Mechanical Properties

TIE available

4.1 Knoop Hardness

Knoop Hardness expresses the amount of surface changes in a material after indentation of a test diamond at given pressure and time. The standard ISO 9385 describes the measurement procedure for glasses. In accordance with this standard, the values for Knoop Hardness HK are listed in the data sheets for a test force of 0.9807 N (corresponds to 0.1 kp) and an effective test period of 20 s. The test is performed on polished glass surfaces at room temperature. The data for hardness values are rounded off to 10 HK 0.1/20. Micro hardness is a function of the magnitude of the test force and decreases with increasing test force.

4.2 Grindability (ISO 12844)

The grindability according to ISO 12844 allows for a comparison to made between the grinding processes used with different glasses. Twenty samples of the glass to be classified are ground for 30 seconds in a standardized diamond pellet tool under predetermined conditions. The removed volume of glass is then compared to that of the reference glass, N-SK16. The value for N-SK16 is arbitrarily set to 100.

Classification takes place according to the following scheme.

Table 4.1: Grindability (according to ISO 12844)

Grindability class	Grindability	
HG 1	≤ 30	
HG 2	> 30	≤ 60
HG 3	> 60	≤ 90
HG 4	> 90	≤ 120
HG 5	> 120	≤ 150
HG 6	> 150	
The grindability of N-SK16 is defined as 100.		

According to this scheme, the removal of glass volume during grinding is less in the lower classifications and higher in the upper classifications than for the reference glass N-SK16.

4.3 Viscosity

Glasses run through three viscosity ranges between the melting temperature and room temperature: the melting range, the super cooled melt range, and the solidification range. The viscosity of glass constantly increases during cooling of the melt ($10^0 - 10^4$ dPa·s). A transition from a liquid to a plastic state can be observed between 10^4 and 10^{13} dPa·s.

The so-called softening point EW identifies the plastic range in which glass parts rapidly deform under their own weight. This is the temperature $T_{10}{}^{7.6}$ at which glass exhibits a viscosity of $10^{7.6}$ dPa·s. The glass structure can be described as solidified or "frozen" above 10^{13} dPa·s. At this viscosity, the internal stress in glass equalizes in approx. 15 minutes.

Another way to identify the transformation range is to observe the change in the rate of relative linear thermal expansion. In accordance with ISO 7884-8, this can be used to determine the so-called transformation temperature Tg. It generally lies close to $T_{10}{}^{13}$.

Precision optical surfaces may deform and refractive indices may change if a temperature of $T_{10}{}^{13}-200K$ is exceeded during any type of thermal treatment.

4.4 Coefficient of Linear Thermal Expansion

The typical curve of linear thermal expansion of glass starts near absolute zero with an increase in slope to approximately room temperature. Then, a nearly linear increase to the beginning of the noticeable plastic behavior follows. The transformation range is characterized by a distinct bending of the expansion curve that results from the increasing structural movement in the glass. Above this range, expansion again shows a nearly linear increase, but with a noticeably greater rate of increase.

Due to the dependence of the coefficient of linear thermal expansion α on temperature, two average linear thermal expansion coefficients α are usually shown for the following temperature ranges:

α (–30 °C; +70 °C) as the relevant information for characterizing glass behavior at room temperature (listed in the data section).

α (+20 °C; +300 °C) as the standard international value for comparison purposes for orientation during the melting process and for temperature change loading.

5 Thermal Properties

TIE available

5.1 Thermal Conductivity

The range of values for thermal conductivity for glasses at room temperature extends from 1.38 W/(m·K) (pure quartz glass) to about 0.5 W/(m·K) (glasses with high lead concentrations). The most commonly used silicate glasses have values between 0.9 and 1.2 W/(m·K).

The thermal conductivities shown in the data sheets apply for a glass temperature of 90 °C.

5.2 Heat Capacity

The mean isobaric specific heat capacity c_p (20 °C; 100 °C) is listed for some glasses as measured from the heat transfer of a hot glass at 100 °C in a liquid calorimeter at 20 °C. The range of values for c_p (20 °C; 100 °C) and the true heat capacity c_p (20 °C) for silicate glasses lies between 0.42 and 0.84 J/(g·K).

6 Delivery Quality

6.1 Quality Management and Quality Assurance

Advanced Optics Business Segment of SCHOTT AG in Mainz operates a global Quality Management System on the basis of ISO9001/ISO14001. The certification is performed by Lloyd's Register Quality Assurance, Cologne/Germany.

The research laboratories of Advanced Optics in Mainz for the measurement of physical and chemical properties are accredited by the German authority GAZ Association for the Accreditation and Certification GmbH on the basis of the standard series ISO 17025:2005-08. Regular round robin tests are performed with the PTB, "Physikalisch-Technische Bundesanstalt" in Braunschweig, Germany. The PTB is a national metrology institute that provides scientific and technical services (*http://www.ptb.de/index en.html*), an institution similar to the NIST in the United States.

Optical glass as a technical material requires well-defined reproducible properties that a designer can rely on. Quality assurance of these properties is based on sample-based statistical measurement, partly 100 % measurement, of the optical and internal quality properties during continuous production of optical glass and on customer-specific individual measurement of cut blanks.

Professional work with high-quality materials requires precise knowledge of their properties. Hence, as Fraunhofer has already realized, progress in the production of optical glasses and their applications is always limited by the measurement capabilities. Ever growing quality demands for industrial and research applications require constant improvement of measurement technology, which is still going on.

6.2 Standard Delivery Quality

If no special quality steps are requested, the glass will be delivered in refractive index/Abbe number step 3/3 with a standard test report. The standard test report refers to a delivery lot that fulfills the standard variation tolerance. The refractive index variation from batch to batch within a lot will not exceed $\pm 1 \cdot 10^{-4}$ ($\pm 2 \cdot 10^{-4}$ for pressings, if requested). The glass is tested for bubbles and inclusions, striae, and stress birefringence.

Production of optical glass is a stable process, with only small variations in the chemical, mechanical and thermal properties of the glass. These properties are statistically controlled datasheet reference values and not measured individually upon order.

6.3 Enhanced Delivery Quality

Additional quality steps are offered based on the following table.

Table 6.1: Additional quality steps for various forms of supply

	Glass for hot processing	Pressings	Fine annealed glass	Cut blanks
Refractive index – Abbe number steps	2, 1 3, 2, 1	2, 1 3, 2, 1	2, 1 3, 2, 1	2, 1 3, 2, 1
Test certificates	Annealing schedule	Standard (S)	Standard (S)	Standard (S)
Measurement accuracy, measurement ranges	With data on the annealing rates for the achievable refractive index – Abbe number steps after fine annealing	If variation tolerance is requested	Standard with enhanced accuracy (SE)	Standard with enhanced accuracy (SE), precision (PZ), dn/dT (DNDT)
Refractive index scattering	S0, S1	LH1, LH2	S0, S1	S0, S1
Homogeneity	–	–	–	H1–H5
Stress birefringence	–	SK	SK	SK, SSK
Striae	–	VS1	–	VS1, VS2
Bubbles/inclusions	–	VB, EVB	–	VB, EVB
Remarks			One surface can be worked	Striae and homogeneity measured in the same direction

The quality steps listed within a form of supply can be combined with one another. However, melts that are suited for various combinations are not always available.

We recommend checking availability with us as early as possible.

Requirements that exceed the quality steps mentioned can also be met. Please ask for further details.

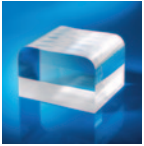
7 Forms of Supply and Tolerances

Advanced Optics masters the entire value chain: from customer-specific glass development and its production all the way to high-precision optical product finishing, processing and measurement. By leveraging our extensive capabilities in the area of processing (polishing, coating, bonding, etc.), we offer a wide variety of custom-made optical components such as lenses (aspherical, spherical, cylindrical), prisms, mirrors, wafers, substrates and more.

Here, you will find a selection of available supply forms:

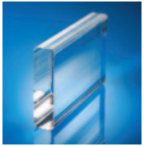
7.1 Raw Glass

7.1.1 Blocks



Blocks have up to five unworked, as-cast surfaces. Usually, at least one surface has been worked. The edges are rounded. Blocks are fine annealed and thus suited for cold working.
Described by: *Length, width, thickness*

7.1.2 Strips



Strips normally have unworked or ground surfaces and broken or cut ends. Strips are either coarse annealed or fine annealed. Coarse annealed strips are only suited for reheat pressings.
Described by: *Length, width, thickness*

7.2 Cut Blanks

7.2.1 Plates

Plates are quadrilateral fabricated parts. All six sides are worked; the edges have protective bevels.
Described by: *Length, width, thickness*

We achieve surface roughnesses of R_a = 20–25 µm with standard processing. Plates with closer dimensional tolerances and finer surfaces are possible upon request.

Table 7.1: Dimensional tolerances and minimum dimensions for plates

Maximum edge length [mm]	Admissible tolerances				Minimum thickness[1) [mm]
	For edge length		For thickness		
	Standard [mm]	Precision [mm]	Standard [mm]	Precision [mm]	
> 3–80	± 0.2	± 0.1	± 0.3	± 0.15	2
> 80–120	± 0.3	± 0.15	± 0.5	± 0.25	4
> 120–250	± 0.5	± 0.25	± 0.5	± 0.25	6
> 250–315	± 0.9	± 0.45	± 0.8	± 0.4	8
> 315–400	± 1.2	± 0.6	± 0.8	± 0.4	8
> 400–500	± 1.3	± 0.65	± 0.8	± 0.4	20
> 500–630	± 1.5	± 0.75	± 0.8	± 0.4	20
> 630–800	± 1.8	± 0.9	± 0.8	± 0.4	20
> 800–1000	± 2.0	± 1.0	± 0.8	± 0.4	20
> 1000	Inquire	Inquire	Inquire	Inquire	

[1) Lower thicknesses than listed are possible. Please ask for details.

7.2.2 Round plates

Round plates are cylindrical parts for which the diameter is larger than the thickness. Round plates are machined on all surfaces.
Described by: *Diameter, thickness*

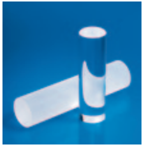
We achieve surface roughness of R_a = 20–25 µm with standard processing. Round plates with closer dimensional tolerances and finer surfaces are possible upon request.

Table 7.2: Dimensional tolerances and minimum dimensions for round plates

Diameter [mm]	Admissible tolerances				Minimum thickness[1)] [mm]
	For diameter		For thickness		
	Standard [mm]	Precision [mm]	Standard [mm]	Precision [mm]	
> 3–80	± 0.2	± 0.1	± 0.3	± 0.15	2
> 80–120	± 0.3	± 0.15	± 0.5	± 0.25	4
> 120–250	± 0.3	± 0.15	± 0.5	± 0.25	6
> 250–500	± 0.5	± 0.25	± 0.8	± 0.4	20
> 500–800	± 0.8	± 0.4	± 0.8	± 0.4	20
> 800–1250	± 1.0	± 0.5	± 0.8	± 0.4	40
> 1250	Inquire	Inquire	Inquire	Inquire	

[1)] Lower thicknesses than listed are possible. Please ask for more details.

7.2.3 Worked rods

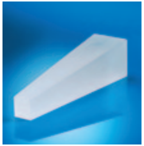


Worked rods are cylindrical parts that are machined on all sides. The length of a rod is always greater than its diameter.
Described by: *Diameter, length*

Table 7.3: Dimensions and tolerances for worked rods in the 6–80 mm diameter range

Diameter [mm]	**Standard tolerance [mm]**	**Tolerances, drilled and rounded per ISO 286**				**Length range [mm]**	**Tolerance for length [%]**
		[mm]	**[mm]**	**[mm]**	**[mm]**		
6–10	± 0.2	h11 +0/–0.09	h10 +0/–0.058	h9 +0/–0.036	h8 +0/–0.022	max. 130	± 2
> 10–18	± 0.2	h11 +0/–0.11	h10 +0/–0.070	h9 +0/–0.043	h8 +0/–0.027	max. 130	± 2
> 18–30	± 0.2	h11 +0/–0.13	h10 +0/–0.084	h9 +0/–0.052	h8 +0/–0.033	max. 130	± 2
> 30–50	± 0.2	h11 +0/–0.16	h10 +0/–0.100	h9 +0/–0.062	h8 +0/–0.039	max. 130	± 2
> 50–80	± 0.3	h11 +0/–0.19	h10 +0/–0.120	h9 +0/–0.074		max. 130	± 2

7.2.4 Cut prisms



Cut prisms are prisms produced by cutting and can be ground on all sides. Equilateral and non-equilateral prisms can be produced in various forms (ridge, penta, triple prisms …) using different fabrication technologies.
Described by: *Drawing*

Table 7.4: Dimensions and tolerances for cut prisms

Maximum edge length [mm]	Tolerances for dimensions [mm]	Tolerances for width [mm]
< 50	+1.0/–0	± 0.5
50–100	+1.5/–0	± 1.0
> 100	+2.0/–0	± 1.0

7.3 Pressings

7.3.1 Pressed blanks

Pressed blanks are hot formed parts with mainly round cross sections, defined radii and bevels.

Described by:
Diameter, center thickness, radius 1, radius 2, bevels

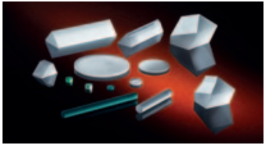


Table 7.5: Dimensions and tolerances for pressed blanks (according to DIN 58 926, Part 2)

Diameter [mm]	Tolerances for diameter [mm]	Tolerances for thickness [mm]	Minimum center thickness [mm]	Minimum edge thickness [mm]	Maximum edge thickness [mm]
5–18	± 0.075	±0.3	2	1	0.6·Ø
> 18–30	± 0.11	±0.3	3	1.5	0.45·Ø
> 30–60	± 0.14	±0.3	4	3	0.4·Ø
> 60–90	± 0.175	±0.3	5	4	0.3·Ø
> 90–120	± 0.25	±0.4	6	5	0.3·Ø
> 120–140	± 0.3	±0.4	7	5	0.3·Ø
> 140–180	± 0.4	±0.4	7	6	0.3·Ø
> 180–250	± 0.5	±0.5	10	8	0.3·Ø
> 250–320	± 0.6	±0.6	10	8	0.3·Ø

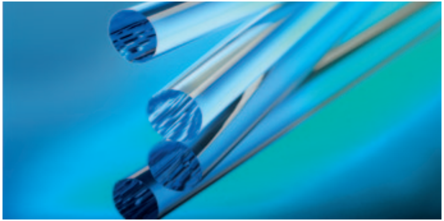
7.3.2 Pressed prisms

Pressed prisms are hot formed parts with angled, prismatic shapes. Other dimensions are possible upon request.
Described by: *Drawing*

Table 7.6: Dimensions and tolerances for pressed prisms

Maximum edge length [mm]	Tolerances for edge length [mm]	Tolerances for center thickness [mm]	Angular	Socket [mm]
5–30	±0.2	±0.3		2
> 30–60	±0.3	±0.4		2
> 60–90	±0.4	±0.5	±0.5°	2.5
> 90–150	±0.5	±0.5		2.5
> 150–180	±0.7	±0.7		3
> 180–305	±1.0	±1.0		4

7.4 Optical Glass Rods for Miniaturized Ball Lenses, Discs & More!



SCHOTT offers the widest range of rods with different geometries, formats and materials.

Optical glass rods from SCHOTT for applications that use small optical components such as ball lenses, rod lenses, aspheres and discs are manufactured with the help of different unique processes.

*Table 7.7: Optical Glass Rods – Specifications**

	Fire polished surface		Matt surface	
Description	**Standard Quality**	**Premium Quality**	**Standard Quality**	**Premium Quality**
Diameter/Tolerance	± 5% of nominal diameter	± 3% of nominal diameter	± 0.1 mm	± 0.05 mm
Straightness deviation	max. 0.1 mm/100 mm	max. 0.1 mm/100 mm	max. 0.05 mm/100 mm	max. 0.03 mm/100 mm
Length tolerance	+ 5 mm	+ 2 mm	+ 5 mm	+ 2 mm
Diameter range	< 1.0–7.0 mm	< 1.0–7.0 mm	2.0–12.5 mm	2.0–12.5 mm
Surface quality	fire polished	fire polished	matt	matt
Length	up to 1000 mm		up to 150 mm	

* Reference to round shape and glass type P-LASF47

8 Optical Glasses for Precision Molding

TIE available

Precision molding technology for direct pressing of aspherical lenses or freeform surfaces in general has become more and importance in recent years all over the world. During the precision molding process, a glass preform with exceptionally high surface quality is shaped into its final aspherical geometry, while conserving the surface quality of the preform. The molding process is a low temperature molding process with temperatures that typically range between 500 °C and 700 °C. Low temperature processes help to extend the operating lifetime of the mold material.

P-glasses are newly developed low transformation temperature glasses especially for use in precision molding. The letter "P" indicates that these glasses are produced exclusively for precision molding and are lead and arsenic free. In addition, several traditional optical glasses have been identified to be suited for precision molding mainly because of their low glass transition temperatures.

Glasses for precision molding in general are coarse annealed glasses. They are produced in refractive index/Abbe number step 3/3 based on 2 K/h reference annealing rate. The actual refractive index of the glass within the delivery lot will differ from this value, however.

The rapid cooling rate of a precision molding process leads to an index drop that lowers the refractive index of the glass significantly compared to the initial value. The index drop is defined as the difference between the refractive index of the glass after molding and the initial refractive index based on a 2 K/h reference annealing rate.
The data section contains the n_d and Abbe number values after molding using a SCHOTT reference process. Some of these values are preliminary data based on a theoretical reference annealing rate of 5000 K/h. The catalog n_d serves as an initial refractive index based on a reference annealing rate of 2 K/h to calculate the index drop.

Furthermore, the index drop can be calculated based on a higher initial reference annealing rate of 25 K/h. For this purpose, the n_d reference value based on an annealing rate of 25 K/h is listed.

The index drop for a given glass type depends on the specific process and geometry of the part and will differ slightly from the values displayed in the data section.

In case the refractive index after molding does not meet specific customer requirements, specific index adjustments to the given process conditions are possible upon request.

The optical glasses available that are suited for use in precision molding are displayed in the data section of this catalog, which contains the newly developed P-glasses but also the traditional glasses that are suited for precision molding. The data section on low Tg glasses also contains additional information. Acid resistance according to JOGIS (Japanese Optical Glass Industrial Standard), grindability (abrasion) according to JOGIS and the yield point/sag temperature of the glass.

9 Product Range of Optical Materials

9.1 Preferred Materials

The materials listed in the first part of the data section are preferred materials. They are produced before any specific customer orders have been received and are usually kept in stock for immediate delivery. We guarantee reliable long-term supply of these materials. Preferred materials are thus recommended for use of designs in new optical systems and listed in our so-called positive list of optical glasses. The current version of the positive list of optical glasses can be found on our website.

9.2 Inquiry Glasses

The second part of the data section is comprised of inquiry glasses that are produced on a regular basis in response to specific requests. With some of these glasses, we might have stock available from previous long running projects. However, stock is not generated on purpose without receiving orders from our customers. But even if they are not available on stock, glasses will be manufactured and delivered upon request.

10 Collection of Formulas and Wavelength Table

Relative partial dispersion Px, y for the wavelengths x and y based on the blue F and red C hydrogen line

$$P_{x,y} = (n_x - n_y)/(n_F - n_C) \quad (10.1)$$

or based on the blue F′ and red C′ cadmium line

$$P'_{x,y} = (n_x - n_y)/(n_{F'} - n_{C'}) \quad (10.2)$$

Linear relationship between the Abbe number and the relative partial dispersion for "normal glasses"

$$P_{x,y} \approx a_{xy} + b_{xy} \cdot \nu_d \quad (10.3)$$

Deviation ΔP from the "normal lines"

$$P_{x,y} = a_{xy} + b_{xy} \cdot \nu_d + \Delta P_{x,y} \quad (10.4)$$

$$\Delta P_{C,t} = (n_C - n_t)/(n_F - n_C) - (0.5450 + 0.004743 \cdot \nu_d) \quad (10.5)$$

$$\Delta P_{C,s} = (n_C - n_s)/(n_F - n_C) - (0.4029 + 0.002331 \cdot \nu_d) \quad (10.6)$$

$$\Delta P_{F,e} = (n_F - n_e)/(n_F - n_C) - (0.4884 - 0.000526 \cdot \nu_d) \quad (10.7)$$

$$\Delta P_{g,F} = (n_g - n_F)/(n_F - n_C) - (0.6438 - 0.001682 \cdot \nu_d) \quad (10.8)$$

$$\Delta P_{i,g} = (n_i - n_g)/(n_F - n_C) - (1.7241 - 0.008382 \cdot \nu_d) \quad (10.9)$$

The position of the normal lines was determined based on value pairs of the glass types K7 and F2.

Sellmeier dispersion formula

$$n^2(\lambda)-1 = B_1\,\lambda^2/(\lambda^2-C_1)+B_2\,\lambda^2/(\lambda^2-C_2)+B_3\,\lambda^2/(\lambda^2-C_3) \quad (10.10)$$

When calculating the refractive index using the Sellmeier coefficients from the SCHOTT data sheets, the wavelength λ needs to be entered in units of μm.

Change in refractive index and Abbe number during annealing at different annealing rates

$$n_d(h_x) = n_d(h_0)+m_{nd}\cdot\log(h_x/h_0) \quad (10.11)$$

$$\nu_d(h_x) = \nu_d(h_0)+m_{\nu d}\cdot\log(h_x/h_0) \quad (10.12)$$

$$m_{\nu d} = (m_{nd}-\nu_d[h_0]\cdot m_{nF-nC})/((n_F-n_C)+2\cdot m_{nF-nC}\cdot\log(h_x/h_0)) \quad (10.13)$$

h_0	Beginning annealing rate
h_x	New annealing rate
m_{nd}	Annealing coefficient for the refractive index, depending on glass type
$m_{\nu d}$	Annealing coefficient for the Abbe number, depending on glass type
m_{nF-nC}	Annealing coefficient for the principal dispersion, depending on glass type

Measurement accuracy of the Abbe number

$\sigma_{\nu d} \approx \sigma_{nF-nC} \cdot \nu_d / (n_F - n_C)$ (10.14)

Spectral internal transmittance

$\tau_{i\lambda} = \Phi_{e\lambda} / \Phi_{i\lambda}$ (10.15)

Spectral transmittance

$\tau_{\lambda} = \tau_{i\lambda} \cdot P_{\lambda}$ (10.16)

P_{λ} factor of reflection

Fresnel reflectivity for a light beam with normal incidence, irrespective of polarization

$R = ((n-1)/(n+1))^2$ (10.17)

Reflection factor that considers multiple reflections

$P = (1-R)^2/(1-R^2) = 2n/(n^2+1)$ (10.18)

n Refractive index for the wavelength λ

Converting of internal transmittance to another layer thickness

$log\ \tau_{i1} / log\ \tau_{i2} = d_1 / d_2$ or (10.19)

$\tau_{i2} = \tau_{i1}^{(d2/d1)}$ (10.20)

τ_{i1}, τ_{i2} Internal transmittances at the thicknesses d_1 and d_2

Stress birefringence, difference in optical path

$\Delta s = 10 \cdot K \cdot d \cdot \sigma$ in nm (10.21)

K Stress optical constant, dependent on glass type in 10^{-6} mm^2/N

d Length of light path in the sample in cm

σ Mechanical stress (positive for tensile stress) in N/mm^2 (= MPa)

Homogeneity from interferometrically measured wave front deviations

$$\Delta n = \Delta W / (2 \cdot d) \qquad (10.22)$$

$$= \Delta W\,[\lambda] \cdot 633 \cdot 10^{-6} / (2 \cdot d[mm])$$

when listing the wave front deformation in units of the wavelength and a test wavelength of 633 nm (He-Ne laser)

ΔW Wave front deformation with double beam passage (interferometric testing)

d Thickness of test piece

Note: The formulas have been chosen carefully and listed.
Nevertheless, SCHOTT cannot be held responsible for errors resulting from their use.

Table 10.1: Wavelengths for selecting frequently used spectral lines

Wavelength [nm]	Designation	Spectral line used	Element
2325.42		Infrared mercury line	Hg
1970.09		Infrared mercury line	Hg
1529.582		Infrared mercury line	Hg
1060.0		Neodymium glass laser	Nd
1013.98	t	Infrared mercury line	Hg
852.11	s	Infrared cesium line	Cs
706.5188	r	Red helium line	He
656.2725	C	Red hydrogen line	H
643.8469	C′	Red cadmium line	Cd
632.8		Helium-neon gas laser	He-Ne
589.2938	D	Yellow sodium line	Na
		(center of the double line)	

Wavelength [nm]	Designation	Spectral line used	Element
587.5618	d	Yellow helium line	He
546.0740	e	Green mercury line	Hg
486.1327	F	Blue hydrogen line	H
479.9914	F′	Blue cadmium line	Cd
435.8343	g	Blue mercury line	Hg
404.6561	h	Violet mercury line	Hg
365.0146	i	Ultraviolet mercury line	Hg
334.1478		Ultraviolet mercury line	Hg
312.5663		Ultraviolet mercury line	Hg
296.7278		Ultraviolet mercury line	Hg
280.4		Ultraviolet mercury line	Hg
248.3		Ultraviolet mercury line	Hg

11 Technical Information Electronic – TIE

The relevant TIEs can be found under
http://www.us.schott.com/advanced_optics/english/tools_downloads/download/index.html

Title		
TIE-25:	Striae in optical glass	(Chapter 2.1)
TIE-26:	Homogeneity of optical glass	(Chapter 1.4)
TIE-27:	Stress in optical glass	(Chapter 2.3)
TIE-28:	Bubbles and inclusions in optical glass	(Chapter 2.2)
TIE-29:	Refractive index and dispersion	(Chapter 1.1)
TIE-30:	Chemical properties of optical glass	(Chapter 3.1)
TIE-31:	Mechanical and thermal properties of optical glass	(Chapter 4.1, 4.2, 4.4, 5.1, 5.2)
TIE-35:	Transmittance of optical glass	(Chapter 1.5)
TIE-40:	Optical glass for precision molding	(Chapter 8)
TIE-42:	Radiation resistant optical glasses	(Foreword & Overview)

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Optical Glass

Properties
2011

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-FK5 487704.245	1.48749	70.41	0.006924	1.48914	70.23	0.006965	1.48410	1.48535	1.49266	1.49593	1.49894	0.5290	0.0036
N-FK51A 487845.368	1.48656	84.47	0.005760	1.48794	84.07	0.005804	1.48379	1.48480	1.49088	1.49364	1.49618	0.5359	0.0342
N-PK51 529770.386	1.52855	76.98	0.006867	1.53019	76.58	0.006923	1.52527	1.52646	1.53372	1.53704	1.54010	0.5401	0.0258
N-PK52A 497816.370	1.49700	81.61	0.006090	1.49845	81.21	0.006138	1.49408	1.49514	1.50157	1.50450	1.50720	0.5377	0.0311
N-PSK3 552635.291	1.55232	63.46	0.008704	1.55440	63.23	0.008767	1.54811	1.54965	1.55885	1.56302	1.56688	0.5365	−0.0005
N-PSK53A 618634.357	1.61800	63.39	0.009749	1.62033	63.10	0.009831	1.61334	1.61503	1.62534	1.63007	1.63445	0.5424	0.0052

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
2	1	4	2	2.3	9.2	466	672	2.45	520	3	1	0.998	30/27
1	0	52.3	2.2	4.3	12.7	464	527	3.68	345	6	1	0.997	34/28
1	0	52.3	3.3	4.3	12.4	487	568	3.86	415	6	1	0.994	34/29
1	0	52.3	3.3	4.3	13.0	467	538	3.70	355	6	1	0.997	34/28
3	0	2.2	2	2	6.2	599	736	2.91	630	2	1	0.994	33/28
1	1	53.3	2.3	4.3	9.6	606	699	3.57	415	6	1	0.985	36/31

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-BK7® 517642.251	1.51680	64.17	0.008054	1.51872	63.96	0.008110	1.51289	1.51432	1.52283	1.52668	1.53024	0.5349	−0.0009
N-BK7HT 517642.251	1.51680	64.17	0.008054	1.51872	63.96	0.008110	1.51289	1.51432	1.52283	1.52668	1.53024	0.5349	−0.0009
N-BK10 498670.239	1.49782	66.95	0.007435	1.49960	66.78	0.007481	1.49419	1.49552	1.50337	1.50690	1.51014	0.5303	−0.0008
N-K5 522595.259	1.52249	59.48	0.008784	1.52458	59.22	0.008858	1.51829	1.51982	1.52910	1.53338	1.53734	0.5438	0.0000
K7 511604.253	1.51112	60.41	0.008461	1.51314	60.15	0.008531	1.50707	1.50854	1.51748	1.52159	1.52540	0.5422	0.0000
K10 501564.252	1.50137	56.41	0.008888	1.50349	56.15	0.008967	1.49713	1.49867	1.50807	1.51243	1.51649	0.5475	−0.0015
N-ZK7 508612.249	1.50847	61.19	0.008310	1.51045	60.98	0.008370	1.50445	1.50592	1.51470	1.51869	1.52238	0.5370	−0.0039

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	2.3	2.3	7.1	557	719	2.51	610	3	0	0.997	33/29
1	0	1	2.3	2.3	7.1	557	719	2.51	610	3	0	0.998	33/29
1	0	1	1	1	5.8	551	753	2.39	560	4	1	0.996	31/27
1	0	1	1	1	8.2	546	720	2.59	530	3	1	0.995	34/30
3	0	2	1	2.3	8.4	513	712	2.53	520	3	1	0.996	33/30
1	0	1	1	1.2	6.5	459	691	2.52	470	4	1	0.994	33/30
1	0	2	1.2	2.2	4.5	539	721	2.49	530	4	1	0.990	34/29

BK
K
ZK

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-BAK1 573576.319	1.57250	57.55	0.009948	1.57487	57.27	0.010039	1.56778	1.56949	1.58000	1.58488	1.58941	0.5472	0.0002
N-BAK2 540597.286	1.53996	59.71	0.009043	1.54212	59.44	0.009120	1.53564	1.53721	1.54677	1.55117	1.55525	0.5437	0.0004
N-BAK4 569560.305	1.56883	55.98	0.010162	1.57125	55.70	0.010255	1.56400	1.56575	1.57649	1.58149	1.58614	0.5487	−0.0010
N-SK2 607567.355	1.60738	56.65	0.010722	1.60994	56.37	0.010821	1.60230	1.60414	1.61547	1.62073	1.62562	0.5477	−0.0008
N-SK2HT 607567.355	1.60738	56.65	0.010722	1.60994	56.37	0.010821	1.60230	1.60414	1.61547	1.62073	1.62562	0.5477	−0.0008
N-SK4 613586.354	1.61272	58.63	0.010450	1.61521	58.37	0.010541	1.60774	1.60954	1.62059	1.62568	1.63042	0.5448	−0.0004
N-SK5 589613.330	1.58913	61.27	0.009616	1.59142	61.02	0.009692	1.58451	1.58619	1.59635	1.60100	1.60530	0.5400	−0.0007
N-SK11 564608.308	1.56384	60.80	0.009274	1.56605	60.55	0.009349	1.55939	1.56101	1.57081	1.57530	1.57946	0.5411	−0.0004
N-SK14 603606.344	1.60311	60.60	0.009953	1.60548	60.34	0.010034	1.59834	1.60008	1.61059	1.61542	1.61988	0.5415	−0.0003
N-SK16 620603.358	1.62041	60.32	0.010285	1.62286	60.08	0.010368	1.61548	1.61727	1.62814	1.63312	1.63773	0.5412	−0.0011

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
2	1	3.3	1.2	2	7.6	592	746	3.19	530	2	1	0.996	33/29
2	0	1	1	2.3	8.0	554	727	2.86	530	2	1	0.997	32/28
1	0	1.2	1	1	7.0	581	725	3.05	550	2	0	0.992	36/33
2	0	2.2	1	2.3	6.0	659	823	3.55	550	2	0	0.994	35/30
2	0	2.2	1	2.3	6.0	659	823	3.55	550	2	0	0.996	34/30
3	1	51.2	2	2	6.5	658	769	3.54	580	3	1	0.990	36/32
3	1	4.4	2	1.3	5.5	660	791	3.30	590	3	1	0.992	34/29
2	0	2	1	2.3	6.5	610	760	3.08	570	2	1	0.990	34/29
4	2	51.3	2	2.3	6.0	649	773	3.44	600	3	1	0.990	35/29
4	4	53.3	3.3	3.2	6.3	636	750	3.58	600	4	1	0.988	36/30

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-KF9 523515.250	1.52346	51.54	0.010156	1.52588	51.26	0.010258	1.51867	1.52040	1.53114	1.53620	1.54096	0.5558	−0.0014
N-BALF4 580539.311	1.57956	53.87	0.010759	1.58212	53.59	0.010863	1.57447	1.57631	1.58769	1.59301	1.59799	0.5520	−0.0012
N-BALF5 547536.261	1.54739	53.63	0.010207	1.54982	53.36	0.010303	1.54255	1.54430	1.55510	1.56016	1.56491	0.5532	−0.0004
N-SSK2 622533.353	1.62229	53.27	0.011681	1.62508	52.99	0.011795	1.61678	1.61877	1.63112	1.63691	1.64232	0.5526	−0.0016
N-SSK5 658509.371	1.65844	50.88	0.012940	1.66152	50.59	0.013075	1.65237	1.65455	1.66824	1.67471	1.68079	0.5575	−0.0007
N-SSK8 618498.327	1.61773	49.83	0.012397	1.62068	49.54	0.012529	1.61192	1.61401	1.62713	1.63335	1.63923	0.5602	0.0002
N-LAK7 652585.384	1.65160	58.52	0.011135	1.65425	58.26	0.011229	1.64628	1.64821	1.65998	1.66539	1.67042	0.5433	−0.0021
N-LAK8 713538.375	1.71300	53.83	0.013245	1.71616	53.61	0.013359	1.70668	1.70897	1.72297	1.72944	1.73545	0.5450	−0.0083

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	1	1	9.6	476	640	2.50	480	1	1	0.986	37/34
1	0	1	1	1	6.5	578	661	3.11	540	2	1	0.985	37/33
1	0	1	2	1	7.3	558	711	2.61	600	2	1	0.983	37/34
1	0	1.2	1	1	5.8	653	801	3.53	570	3	1	0.981	37/33
2	3	52.2	2.2	3.2	6.8	645	751	3.71	590	5	1	0.959	38/34
1	0	1	1.3	1	7.2	616	742	3.27	570	3	1	0.950	39/35
3	2	53.3	3.3	4.3	7.1	618	716	3.84	600	5	0	0.988	35/29
3	2	52.3	1	3.3	5.6	643	717	3.75	740	2	0	0.977	37/30

KF
BALF
SSK
LAK

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-LAK9 691547.351	1.69100	54.71	0.012631	1.69401	54.48	0.012738	1.68497	1.68716	1.70051	1.70667	1.71239	0.5447	–0.0071
N-LAK10 720506.369	1.72003	50.62	0.014224	1.72341	50.39	0.014357	1.71328	1.71572	1.73077	1.73779	1.74438	0.5515	–0.0072
N-LAK12 678552.410	1.67790	55.20	0.012281	1.68083	54.92	0.012396	1.67209	1.67419	1.68717	1.69320	1.69882	0.5485	–0.0024
N-LAK14 697554.363	1.69680	55.41	0.012575	1.69980	55.19	0.012679	1.69077	1.69297	1.70626	1.71237	1.71804	0.5427	–0.0079
N-LAK21 640601.374	1.64049	60.10	0.010657	1.64304	59.86	0.010743	1.63538	1.63724	1.64850	1.65366	1.65844	0.5411	–0.0017
N-LAK22 651559.377	1.65113	55.89	0.011650	1.65391	55.63	0.011755	1.64560	1.64760	1.65992	1.66562	1.67092	0.5467	–0.0031
N-LAK33A 754523.422	1.75393	52.27	0.014424	1.75737	52.04	0.014554	1.74707	1.74956	1.76481	1.77187	1.77845	0.5473	–0.0086
N-LAK33B 755523.422	1.75500	52.30	0.014436	1.75844	52.07	0.014566	1.74814	1.75062	1.76589	1.77296	1.77954	0.5473	–0.0085
N-LAK34 729545.402	1.72916	54.50	0.013379	1.73235	54.27	0.013493	1.72277	1.72509	1.73923	1.74575	1.75180	0.5443	–0.0079

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
3	3	52	1.2	4.3	6.3	656	722	3.51	700	3	0	0.980	37/31
2	2	52.3	1	3	5.7	636	714	3.69	780	2	0	0.959	39/34
3	1	53.3	3.3	4.3	7.6	614	714	4.10	560	6	1	0.976	37/31
3	2	52.3	1	3	5.5	661	734	3.63	730	2	0	0.981	37/30
4	2	53.2	4.3	4.3	6.8	639	716	3.74	600	5	0	0.979	37/31
2	2	51.2	1	2.3	6.6	689		3.77	600	4	0	0.985	36/30
1	1	51	1	2	5.8	669	744	4.22	740	2	0	0.976	38/30
1	1	51.3	1	2	5.8	668	750	4.22	797		0	0.980	37/28
1	0	52.3	1	3.3	5.8	668	740	4.02	740	2	0	0.981	37/28

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
LLF1 548458.294	1.54814	45.75	0.011981	1.55099	45.47	0.012118	1.54256	1.54457	1.55725	1.56333	1.56911	0.5660	–0.0009
N-BAF4 606437.289	1.60568	43.72	0.013853	1.60897	43.43	0.014021	1.59926	1.60157	1.61624	1.62336	1.63022	0.5733	0.0030
N-BAF10 670471.375	1.67003	47.11	0.014222	1.67341	46.83	0.014380	1.66339	1.66578	1.68083	1.68801	1.69480	0.5629	–0.0016
N-BAF51 652450.333	1.65224	44.96	0.014507	1.65569	44.67	0.014677	1.64551	1.64792	1.66328	1.67065	1.67766	0.5670	–0.0012
N-BAF52 609466.305	1.60863	46.60	0.013061	1.61173	46.30	0.013211	1.60254	1.60473	1.61856	1.62521	1.63157	0.5678	0.0024

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	2	1	8.1	431	628	2.94	450	3	1	0.997	33/31
1	0	1	1.2	1.3	7.2	580	709	2.89	610	3	1	0.946	39/35
1	0	4.3	1.3	1	6.2	660	790	3.75	620	4	1	0.950	39/35
2	0	5.4	1.3	1	8.4	569	712	3.33	560	5	1	0.954	39/34
1	0	1	1.3	1	6.9	594	716	3.05	600	3	1	0.950	39/35

LLF
BAF

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
LF5 581409.322	1.58144	40.85	0.014233	1.58482	40.57	0.014413	1.57489	1.57723	1.59231	1.59964	1.60668	0.5748	–0.0003
N-F2 620364.265	1.62005	36.43	0.017020	1.62408	36.16	0.017258	1.61229	1.61506	1.63310	1.64209	1.65087	0.5881	0.0056
F2[H] 620364.360	1.62004	36.37	0.017050	1.62408	36.11	0.017284	1.61227	1.61503	1.63310	1.64202	1.65064	0.5828	0.0002
F5 603380.347	1.60342	38.03	0.015867	1.60718	37.77	0.016078	1.59616	1.59875	1.61556	1.62381	1.63176	0.5795	–0.0003
N-BASF2 664360.315	1.66446	36.00	0.018457	1.66883	35.73	0.018720	1.65607	1.65905	1.67862	1.68838	1.69792	0.5890	0.0057
N-BASF64 704394.320	1.70400	39.38	0.017875	1.70824	39.12	0.018105	1.69578	1.69872	1.71765	1.72690	1.73581	0.5769	–0.0006

[H] Also available in HT or HTultra quality

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
2	0	1	2.3	2	9.1	419	585	3.22	450	2	1	0.997	34/31
1	0	1	1	1	7.8	569	686	2.65	600	2	1	0.946	39/36
1	0	1	2.3	1.3	8.2	434	594	3.60	420	2	0	0.994	35/32
1	0	1	2.3	2	8.0	438	608	3.47	450	3	0	0.993	35/32
1	0	1	1	1	7.1	619	766	3.15	580	3	1	0.891	41/36
1	0	3.2	1.2	1	7.3	582	712	3.20	650	4	0	0.924	40/35

LF
F
BASF

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-LAF2 744449.430	1.74397	44.85	0.016588	1.74791	44.57	0.016780	1.73627	1.73903	1.75659	1.76500	1.77298	0.5656	−0.0027
N-LAF7 750348.373	1.74950	34.82	0.021525	1.75459	34.56	0.021833	1.73972	1.74320	1.76602	1.77741	1.78854	0.5894	0.0042
LAFN7 750350.438	1.74950	34.95	0.021445	1.75458	34.72	0.021735	1.73970	1.74319	1.76592	1.77713	1.78798	0.5825	−0.0025
N-LAF21 788475.428	1.78800	47.49	0.016593	1.79195	47.25	0.016761	1.78019	1.78301	1.80056	1.80882	1.81657	0.5555	−0.0084
N-LAF33 786441.436	1.78582	44.05	0.017839	1.79007	43.80	0.018038	1.77751	1.78049	1.79937	1.80837	1.81687	0.5626	−0.0071
N-LAF34 773496.424	1.77250	49.62	0.015568	1.77621	49.38	0.015719	1.76515	1.76780	1.78427	1.79196	1.79915	0.5518	−0.0085
N-LAF35 743494.412	1.74330	49.40	0.015047	1.74688	49.16	0.015194	1.73620	1.73876	1.75467	1.76212	1.76908	0.5523	−0.0084
N-LAF36[i] 800424.443	1.79952	42.37	0.018871	1.80400	42.12	0.019090	1.79076	1.79390	1.81387	1.82345	1.83252	0.5659	−0.0067

[i] Will become inquiry glass as of 2014/01/01; not recommended for new design

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}{}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
2	3	52.2	1	2.2	8.1	653	742	4.30	530	6	1	0.933	40/34
1	2	51.3	1.2	1.2	7.3	568	669	3.73	530	5	1	0.752	46/36
3	1	53.3	2.2	4.3	5.3	500	573	4.38	520	3	0	0.937	40/35
1	1	51.3	1	1.3	6.0	653	729	4.28	730	2	1	0.966	39/32
1	2	52.2	1	3	5.6	600	673	4.36	730	1	0	0.963	39/32
1	1	51.3	1	1	5.8	668	745	4.24	770	2	0	0.980	38/30
2	1	52.3	1	3.3	5.3	589	669	4.12	660	2	0	0.976	38/30
1	2	52.3	1	3.3	5.7	579	670	4.43	680	1	0	0.946	40/33

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-LASF9 850322.441	1.85025	32.17	0.026430	1.85650	31.93	0.026827	1.83834	1.84255	1.87058	1.88467	1.89845	0.5934	0.0037
N-LASF9HT 850322.441	1.85025	32.17	0.026430	1.85650	31.93	0.026827	1.83834	1.84255	1.87058	1.88467	1.89845	0.5934	0.0037
N-LASF31A 883408.551	1.88300	40.76	0.021663	1.88815	40.52	0.021921	1.87298	1.87656	1.89950	1.91050	1.92093	0.5667	–0.0085
N-LASF40 834373.443	1.83404	37.30	0.022363	1.83935	37.04	0.022658	1.82380	1.82745	1.85114	1.86275	1.87393	0.5786	–0.0024
N-LASF41 835431.485	1.83501	43.13	0.019361	1.83961	42.88	0.019578	1.82599	1.82923	1.84972	1.85949	1.86872	0.5629	–0.0083
N-LASF43 806406.426	1.80610	40.61	0.019850	1.81081	40.36	0.020089	1.79691	1.80020	1.82122	1.83137	1.84106	0.5703	–0.0052
N-LASF44 804465.444	1.80420	46.50	0.017294	1.80832	46.25	0.017476	1.79609	1.79901	1.81731	1.82594	1.83405	0.5572	–0.0084
N-LASF45 801350.363	1.80107	34.97	0.022905	1.80650	34.72	0.023227	1.79066	1.79436	1.81864	1.83068	1.84237	0.5859	0.0009
N-LASF45HT 801350.363	1.80107	34.97	0.022905	1.80650	34.72	0.023227	1.79066	1.79436	1.81864	1.83068	1.84237	0.5859	0.0009
N-LASF46A 904313.445	1.90366	31.32	0.028853	1.91048	31.09	0.029287	1.89064	1.89526	1.92586	1.94129	1.95645	0.5953	0.0042
N-LASF46B 904313.451	1.90366	31.32	0.028852	1.91048	31.09	0.029289	1.89065	1.89526	1.92586	1.94130	1.95647	0.5956	0.0045

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	2	1	1	7.4	683	817	4.41	515	4	1	0.799	41/36*
1	0	2	1	1	7.4	683	817	4.41	515	4	1	0.843	40/36*
1	0	2.3	1	1	6.7	719	830	5.51	650	2	1	0.933	38/33*
1	1	51.2	1	1.3	5.8	590	677	4.43	580	1	0	0.891	39/35*
1	1	4	1	1	6.2	651	739	4.85	760	2	0	0.948	37/32*
1	1	51.3	1	2	5.5	614	699	4.26	720	2	1	0.919	42/34
1	1	4	1	1	6.2	655	742	4.44	770	2	0	0.963	40/31
1	0	3.2	1	1	7.4	647	773	3.63	630	3	0	0.857	44/35
1	0	3.2	1	1	7.4	647	773	3.63	630	3	0	0.886	43/35
1	0	3	1	1	6.0	638	733	4.45	666	1	0	0.815	41/37*
1	0	3.3	1	1	6.0	611	703	4.51	712		0	0.847	40/36*

* Wavelength for transmittance 0.7 and 0.05

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-SF1 717296.303	1.71736	29.62	0.024219	1.72308	29.39	0.024606	1.70651	1.71035	1.73605	1.74919	1.76224	0.6037	0.0097
N-SF2 648338.272	1.64769	33.82	0.019151	1.65222	33.56	0.019435	1.63902	1.64210	1.66241	1.67265	1.68273	0.5950	0.0081
N-SF4 755274.315	1.75513	27.38	0.027583	1.76164	27.16	0.028044	1.74286	1.74719	1.77647	1.79158	1.80668	0.6096	0.0118
N-SF5 673323.286	1.67271	32.25	0.020858	1.67763	32.00	0.021177	1.66330	1.66664	1.68876	1.69998	1.71106	0.5984	0.0088
N-SF6 805254.337	1.80518	25.36	0.031750	1.81266	25.16	0.032304	1.79114	1.79608	1.82980	1.84738	1.86506	0.6158	0.0146
N-SF6HT 805254.337	1.80518	25.36	0.031750	1.81266	25.16	0.032304	1.79114	1.79608	1.82980	1.84738	1.86506	0.6158	0.0146
N-SF6HTultra 805254.337	1.80518	25.36	0.031750	1.81266	25.16	0.032304	1.79114	1.79608	1.82980	1.84738	1.86506	0.6158	0.0146
N-SF8 689313.290	1.68894	31.31	0.022005	1.69413	31.06	0.022346	1.67904	1.68254	1.70589	1.71775	1.72948	0.5999	0.0087
N-SF10 728285.305	1.72828	28.53	0.025524	1.73430	28.31	0.025941	1.71688	1.72091	1.74800	1.76191	1.77578	0.6066	0.0108
N-SF11 785257.322	1.78472	25.68	0.030558	1.79192	25.47	0.031088	1.77119	1.77596	1.80841	1.82533	1.84235	0.6156	0.0150
N-SF14 762265.312	1.76182	26.53	0.028715	1.76859	26.32	0.029204	1.74907	1.75356	1.78405	1.79986	1.81570	0.6122	0.0130

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	1	1	9.1	553	660	3.03	540	5	1	0.867	41/36
1	0	1	1.2	1	6.7	608	731	2.72	539		1	0.928	40/36
1	0	1.3	1	1	9.5	570	661	3.15	520	6	1	0.830	43/36
1	0	1	1	1	7.9	578	693	2.86	620	3	1	0.905	40/36
1	0	2	1	1	9.0	589	683	3.37	550	4	0	0.821	44/37
1	0	2	1	1	9.0	589	683	3.37	550	4	0	0.877	44/37
1	0	2	1	1	9.0	589	683	3.37	550	4	0	0.887	43/37
1	0	1	1	1	8.6	567	678	2.90	600	4	1	0.901	41/36
1	0	1	1	1	9.4	559	652	3.05	540	5	1	0.837	42/36
1	0	1	1	1	8.5	592	688	3.22	615	4	1	0.815	44/37
1	0	1	1	1	9.4	566	657	3.12	515	5	0	0.891	42/36

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-SF15 699302.292	1.69892	30.20	0.023142	1.70438	29.96	0.023511	1.68854	1.69222	1.71677	1.72933	1.74182	0.6038	0.0108
N-SF57 847238.353	1.84666	23.78	0.035604	1.85504	23.59	0.036247	1.83099	1.83650	1.87432	1.89423	1.91440	0.6216	0.0178
N-SF57HT 847238.353	1.84666	23.78	0.035604	1.85504	23.59	0.036247	1.83099	1.83650	1.87432	1.89423	1.91440	0.6216	0.0178
N-SF57HTultra 847238.353	1.84666	23.78	0.035604	1.85504	23.59	0.036247	1.83099	1.83650	1.87432	1.89423	1.91440	0.6216	0.0178
N-SF66 923209.400	1.92286	20.88	0.044199	1.93322	20.70	0.045076	1.90368	1.91039	1.95739	1.98285		0.6394	0.0307
SF1 717295.446	1.71736	29.51	0.024307	1.72310	29.29	0.024687	1.70647	1.71031	1.73610	1.74916	1.76201	0.5983	0.0042
SF2 648339.386	1.64769	33.85	0.019135	1.65222	33.60	0.019412	1.63902	1.64210	1.66238	1.67249	1.68233	0.5886	0.0017
SF4 755276.479	1.75520	27.58	0.027383	1.76167	27.37	0.027829	1.74300	1.74730	1.77636	1.79121	1.80589	0.6036	0.0062
SF5 673322.407	1.67270	32.21	0.020885	1.67764	31.97	0.021195	1.66327	1.66661	1.68876	1.69986	1.71069	0.5919	0.0023
SF6 805254.518	1.80518	25.43	0.031660	1.81265	25.24	0.032201	1.79117	1.79609	1.82970	1.84707	1.86436	0.6102	0.0092
SF6HT 805254.518	1.80518	25.43	0.031660	1.81265	25.24	0.032201	1.79117	1.79609	1.82970	1.84707	1.86436	0.6102	0.0092

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}{}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	1	1	8.0	580	692	2.92	610	3	1	0.857	42/37
1	0	1	1	1	8.5	629	716	3.53	520	4	0	0.733	42/37*
1	0	1	1	1	8.5	629	716	3.53	520	4	0	0.793	41/37*
1	0	1	1	1	8.5	629	716	3.53	520	4	0	0.830	40/37*
1	0	1	1	1	5.9	710	806	4.00	440	3	1	0.504	45/39*
2	1	3.2	2.3	3	8.1	417	566	4.46	390	1	1	0.967	39/34
1	0	2	2.3	2	8.4	441	600	3.86	410	2	0	0.981	37/33
1	2	4.3	2.3	3.3	8.0	420	552	4.79	390	1	1	0.954	40/35
1	1	2	2.3	3	8.2	425	580	4.07	410	2	1	0.980	37/33
2	3	51.3	2.3	3.3	8.1	423	538	5.18	370	1	0	0.915	42/36
2	3	51.3	2.3	3.3	8.1	423	538	5.18	370	1	0	0.941	41/36

* Wavelength for transmittance 0.7 and 0.05

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
SF10 728284.428	1.72825	28.41	0.025633	1.73430	28.19	0.026051	1.71681	1.72085	1.74805	1.76198	1.77579	0.6046	0.0085
SF11 785258.474	1.78472	25.76	0.030467	1.79190	25.55	0.030997	1.77125	1.77599	1.80834	1.82518	1.84208	0.6147	0.0142
SF56A 785261.492	1.78470	26.08	0.030092	1.79180	25.87	0.030603	1.77136	1.77605	1.80800	1.82449	1.84092	0.6098	0.0098
SF57 847238.551	1.84666	23.83	0.035536	1.85504	23.64	0.036166	1.83102	1.83650	1.87425	1.89393	1.91366	0.6160	0.0123
SF57HTultra 847238.551	1.84666	23.83	0.035536	1.85504	23.64	0.036166	1.83102	1.83650	1.87425	1.89393	1.91366	0.6160	0.0123

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	1.2	2	7.5	454	595	4.28	430	1	0	0.862	41/37
1	0	1	1.2	1	6.1	503	635	4.74	450	1	1	0.525	44/39
1	1	3.2	2.2	3.2	7.9	429	556	4.92	380	1	1	0.857	42/37
2	5	52.3	2.3	4.3	8.3	414	519	5.51	350	1	0	0.847	40/37*
2	5	52.3	2.3	4.3	8.3	414	519	5.51	350	1	0	0.924	39/36*

* Wavelength for transmittance 0.7 and 0.05

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-KZFS2 558540.255	1.55836	54.01	0.010338	1.56082	53.83	0.010418	1.55337	1.55519	1.56612	1.57114	1.57580	0.5419	–0.0111
N-KZFS4 613445.300	1.61336	44.49	0.013785	1.61664	44.27	0.013929	1.60688	1.60922	1.62380	1.63071	1.63723	0.5590	–0.0100
N-KZFS5 654397.304	1.65412	39.70	0.016477	1.65803	39.46	0.016675	1.64649	1.64922	1.66667	1.67511	1.68318	0.5710	–0.0060
N-KZFS8 720347.320	1.72047	34.70	0.020763	1.72539	34.47	0.021046	1.71099	1.71437	1.73637	1.74724	1.75777	0.5833	–0.0021
N-KZFS11 638424.320	1.63775	42.41	0.015038	1.64132	42.20	0.015198	1.63069	1.63324	1.64915	1.65670	1.66385	0.5605	–0.0120
KZFS12[i] 696363.384	1.69600	36.29	0.019179	1.70055	36.06	0.019425	1.68717	1.69033	1.71065	1.72059	1.73017	0.5778	–0.0050

[i] Will become inquiry glass as of 2012/01/01; not recommended for new design

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	4	52.3	4.3	4.2	4.4	491	600	2.55	490	3	1	0.985	34/30
1	1	3.4	1.2	1	7.3	536	664	3.00	520	3	1	0.979	36/32
1	0	1	1	1	6.4	584	739	3.04	555		1	0.976	37/32
1	0	1	1	1	7.8	509	635	3.20	570	4	1	0.963	38/33
1	1	3.4	1	1	6.6	551		3.20	530	3	1	0.987	36/30
4	1	53.3	4.3	4.3	5.2	492	549	3.84	440	4	1	0.919	40/35

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
P-BK7 516641.243	1.51640	64.06	0.008061	1.51832	63.87	0.008115	1.51248	1.51392	1.52243	1.52628	1.52982	0.5335	–0.0025
P-PK53[i] 527662.283	1.52690	66.22	0.007957	1.52880	65.92	0.008022	1.52309	1.52447	1.53288	1.53673	1.54029	0.5408	0.0084
P-SK57Q1 586595.301	1.58600	59.50	0.009849	1.58835	59.26	0.009928	1.58127	1.58299	1.59340	1.59817	1.60260	0.5414	–0.0024
P-SK57 587596.301	1.58700	59.60	0.009849	1.58935	59.36	0.009928	1.58227	1.58399	1.59440	1.59917	1.60359	0.5412	–0.0024
P-SK58A 589612.297	1.58913	61.15	0.009634	1.59143	60.93	0.009707	1.58449	1.58618	1.59636	1.60100	1.60530	0.5386	–0.0023
P-SK60 610579.308	1.61035	57.90	0.010541	1.61286	57.66	0.010628	1.60530	1.60714	1.61828	1.62340	1.62815	0.5427	–0.0037
P-SF8 689313.290	1.68893	31.25	0.022046	1.69414	31.01	0.022386	1.67901	1.68252	1.70591	1.71778	1.72950	0.5991	0.0079
P-LAK35 693532.385	1.69350	53.20	0.013036	1.69661	52.95	0.013156	1.68732	1.68955	1.70334	1.70974	1.71569	0.5482	–0.0061
P-SF69 723292.293	1.72250	29.23	0.024718	1.72883	29.00	0.025116	1.71144	1.71535	1.74158	1.75502	1.76840	0.6050	0.0104
P-LAF37 755457.399	1.75550	45.66	0.016546	1.75944	45.42	0.016722	1.74775	1.75054	1.76804	1.77633	1.78414	0.5590	–0.0080

[i] Will become inquiry glass as of 2014/01/01; not recommended for new design

n_d ref.*1	After Molding*2		SR-J	WR-J	α (–30/+70)	α (20/300)	T_g	AT	ρ	HK	Abrasion Aa	B	τ_i (10/400)	FC
	n_d	ν_d												
1.51576	1.5144*3	63.9*3	1	4	6.0	7.3	498	546	2.43	627	66	1	0.997	33/30
1.52567	1.5232	66	3	1	13.3	16.0	383	418	2.83	335	977	1	0.994	36/31
1.58496	1.5833	59.4	4	1	7.2	8.9	493	522	3.01	535	124	1	0.994	34/31
1.58596	1.5843	59.4	4	1	7.2	8.9	493	522	3.01	535	124	1	0.994	34/31
1.58795	1.5860	60.8	4	2	6.8	8.4	510	551	2.97	662	102	1	0.994	35/31
1.60918	1.6068	57.7	4	3	7.1	8.9	507	547	3.08	601	86	1	0.997	33/29
1.68623	1.6814	31.7	1	1	9.4	11.1	524	580	2.90	533	200	1	0.924	40/36
1.69234	1.6904	53.0	4	3	8.1	9.7	508	544	3.85	616	119	0	0.988	36/29
1.72006	1.7155	29.7	1	1	9.0	11.1	508	547	2.93	612	142	1	0.915	41/36
1.75396	1.7508	45.5	4	1	6.3	7.8	506	546	3.99	697	67	0	0.980	37/31

*1 n_d reference value (annealing rate 25 K/h) *2 as pressed at SCHOTT; for details please consult SCHOTT *3 preliminary data

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
P-LASF47 806409.454	1.80610	40.90	0.019709	1.81078	40.66	0.019941	1.79696	1.80023	1.82110	1.83112	1.84064	0.5671	–0.0079
P-LASF50 809405.454	1.80860	40.46	0.019985	1.81335	40.22	0.020223	1.79934	1.80266	1.82382	1.83399	1.84367	0.5680	–0.0078
P-LASF51 810409.458	1.81000	40.93	0.019792	1.81470	40.68	0.020025	1.80082	1.80411	1.82506	1.83512	1.84467	0.5670	–0.0080
P-SF67[ii] 907214.424	1.90680	21.40	0.042374	1.91675	21.23	0.043191	1.88833	1.89480	1.93985	1.96401		0.6334	0.0256
P-SF68 005210.619	2.00520	21.00	0.047867	2.01643	20.82	0.048826	1.98449	1.99171	2.04262	2.07018		0.6392	0.0308
N-FK51A 487845.368	1.48656	84.47	0.005760	1.48794	84.07	0.005804	1.48379	1.48480	1.49088	1.49364	1.49618	0.5359	0.0342
N-FK5 487704.245	1.48749	70.41	0.006924	1.48914	70.23	0.006965	1.48410	1.48535	1.49266	1.49593	1.49894	0.5290	0.0036
N-PK52A 497816.370	1.49700	81.61	0.006090	1.49845	81.21	0.006138	1.49408	1.49514	1.50157	1.50450	1.50720	0.5377	0.0311
N-PK51 529770.386	1.52855	76.98	0.006867	1.53019	76.58	0.006923	1.52527	1.52646	1.53372	1.53704	1.54010	0.5401	0.0258

[ii] Will become inquiry glass as of 2016/01/01; not recommended for new design

n_d ref.*1	After Molding*2		SR-J	WR-J	α (–30/+70)	α (20/300)	T_g	AT	ρ	HK	Abrasion Aa	B	τ_i (10/400)	FC
	n_d	ν_d												
1.80449	1.8016	40.8	3	1	6.0	7.3	530	580	4.54	620	70	1	0.967	39/33
1.80699	1.8036*3	40.3*3			5.9	7.3	527	571	4.54	655	62	1	0.967	39/32
1.80842	1.8056	40.8	3	1	6.0	7.4	526	570	4.58	722	66	1	0.967	39/33
1.90439	1.8998	21.6	1	1	6.2	7.4	539	601	4.24	440	309	1	0.276	48/39*
2.00365	1.9958	20.9	4	1	8.4	9.7	428	468	6.19	404	298		0.007	49/41*
1.48597	1.4847	84.2	3	1	12.7	14.8	464	503	3.68	345	528	1	0.997	34/28
1.48666	1.485	70.2	5	4	9.2	10.0	466	557	2.45	520	109	1	0.998	30/27
1.49640	1.4952	81.3	4	1	13.0	15.0	467	520	3.70	355	526	1	0.997	34/28
1.52784	1.5267	76.7	3	1	12.4	14.1	487	528	3.86	415	592	1	0.994	34/29

*1 n_d reference value (annealing rate 25 K/h) *2 as pressed at SCHOTT; for details please consult SCHOTT *3 preliminary data
* Wavelength for transmittance 0.7 and 0.05

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-KZFS2 558540.255	1.55836	54.01	0.010338	1.56082	53.83	0.010418	1.55337	1.55519	1.56612	1.57114	1.57580	0.5419	–0.0111
N-KZFS4 613445.300	1.61336	44.49	0.013785	1.61664	44.27	0.013929	1.60688	1.60922	1.62380	1.63071	1.63723	0.5590	–0.0100
N-KZFS11 638424.320	1.63775	42.41	0.015038	1.64132	42.20	0.015198	1.63069	1.63324	1.64915	1.65670	1.66385	0.5605	–0.0120
N-KZFS5 654397.304	1.65412	39.70	0.016477	1.65803	39.46	0.016675	1.64649	1.64922	1.66667	1.67511	1.68318	0.5710	–0.0060
N-KZFS8 720347.320	1.72047	34.70	0.020763	1.72539	34.47	0.021046	1.71099	1.71437	1.73637	1.74724	1.75777	0.5833	–0.0021
N-LAF33 786441.436	1.78582	44.05	0.017839	1.79007	43.80	0.018038	1.77751	1.78049	1.79937	1.80837	1.81687	0.5626	–0.0071
N-LASF46B 904313.451	1.90366	31.32	0.028852	1.91048	31.09	0.029289	1.89065	1.89526	1.92586	1.94130	1.95647	0.5956	0.0045
SF57 847238.551	1.84666	23.83	0.035536	1.85504	23.64	0.036166	1.83102	1.83650	1.87425	1.89393	1.91366	0.6160	0.0123
SF57HTultra 847238.551	1.84666	23.83	0.035536	1.85504	23.64	0.036166	1.83102	1.83650	1.87425	1.89393	1.91366	0.6160	0.0123

n_d ref.*1	After Molding*2		SR-J	WR-J	α (–30/+70)	α (20/300)	T_g	AT	ρ	HK	Abrasion Aa	B	τ_i (10/400)	FC
	n_d	ν_d												
1.55666	1.5534	53.7	6	6	4.4	5.4	472	533	2.54	490	70	1	0.985	34/30
1.61227	1.6100*3	44.5*3	6	4	7.3	8.2	536	597	3.00	520	130	1	0.979	36/32
1.63658	1.6341*3	42.3*3			6.6	7.6	551		3.20	530	74	1	0.987	36/30
1.65272	1.6498*3	39.8*3	1	1	6.4	7.4	584	648	3.04	555	122	1	0.976	37/32
1.71896	1.7158*3	34.8*3	1	1	7.8	9.4	509	561	3.20	570	152	1	0.963	38/33
1.78425	1.7811	43.9	6	1	5.6	6.7	600	628	4.36	730	67	0	0.963	39/32
1.90165	1.8977	31.4	1	2	6.0	7.1	611	649	4.51	712	55	0	0.847	40/36*
1.84608	1.8447	23.6	6	1	8.3	9.2	414	449	5.51	350	344	0	0.847	40/37*
1.84608	1.8447	23.7	6	1	8.3	9.2	414	449	5.51	350	344	0	0.924	39/36*

*1 n_d reference value (annealing rate 25 K/h) *2 as pressed at SCHOTT; for details please consult SCHOTT *3 preliminary data
* Wavelength for transmittance 0.7 and 0.05

Inquiry glasses
classic glasses

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
FK3 464658.227	1.46450	65.77	0.007063	1.46619	65.57	0.007110	1.46106	1.46232	1.46978	1.47315	1.47625	0.5329	–0.0003
N-SK10 623570.364	1.62278	56.98	0.010929	1.62539	56.70	0.011029	1.61759	1.61947	1.63102	1.63638	1.64137	0.5474	–0.0005
N-SK15 623580.362	1.62296	58.02	0.010737	1.62552	57.75	0.010832	1.61785	1.61970	1.63105	1.63629	1.64116	0.5453	–0.0009
N-BAF3 583466.279	1.58272	46.64	0.012495	1.58569	46.35	0.012637	1.57689	1.57899	1.59222	1.59857	1.60463	0.5669	0.0015
BAFN6 589485.317	1.58900	48.45	0.012158	1.59189	48.16	0.012291	1.58332	1.58536	1.59823	1.60436	1.61017	0.5625	0.0002
N-LAF3 717480.414	1.71700	47.96	0.014950	1.72055	47.68	0.015112	1.71001	1.71252	1.72834	1.73585	1.74293	0.5603	–0.0028
SFL57 847236.355	1.84666	23.62	0.035841	1.85510	23.43	0.036489	1.83089	1.83643	1.87451	1.89456	1.91488	0.6218	0.0177
SFL6 805254.337	1.80518	25.39	0.031708	1.81265	25.19	0.032260	1.79116	1.79609	1.82977	1.84733	1.86500	0.6159	0.0148
N-SF19 667331.290	1.66679	33.12	0.020131	1.67154	32.86	0.020435	1.65769	1.66092	1.68228	1.69309	1.70377	0.5976	0.0095
N-PSK53 620635.360	1.62014	63.48	0.009769	1.62247	63.19	0.009851	1.61547	1.61717	1.62749	1.63223	1.63662	0.5423	0.0053
KZFSN5 654396.346	1.65412	39.63	0.016507	1.65803	39.40	0.016701	1.64644	1.64920	1.66668	1.67512	1.68319	0.5700	–0.0071

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
2	3	52.4	2	1	8.2	362	622	2.27	380		1	0.994	33/30
3	3	52.2	2	2.2	6.8	633	758	3.64	550	3	1	0.988	36/32
3	3	52.2	2	3.2	6.7	641	752	3.62	620	3	1	0.984	36/31
1	0	1	1	1	7.2	583	714	2.79	560	2	1	0.959	39/35
2	0	2	2	1	7.8	549		3.17	540		1	0.971	38/33
2	3	52.3	1.2	3.3	7.6	646	740	4.14	580	5	1	0.954	39/34
1	0	1.3	1	1.3	8.7	598	700	3.55	580	3	1	0.525	44/38*
1	0	2	1	1	9.0	585		3.37	570		0	0.850	45/37
1	0	1	1.2	1	7.2	598	707	2.90	630	3	1	0.901	40/36
2	1	52.3	1.2	4.3	9.4	618	709	3.60	440	6	1	0.985	36/31
3	2	52.3	4.3	4.3	4.5	501		3.46	460	5	1	0.976	37/34

* Wavelength for transmittance 0.7 and 0.05

Glass type	n_d	ν_d	$n_F - n_C$	n_e	ν_e	$n_{F'} - n_{C'}$	n_r	n_C	$n_{F'}$	n_g	n_h	$P_{g,F}$	$\Delta P_{g,F}$
N-SF64 706302.299	1.70591	30.23	0.023350	1.71142	29.99	0.023720	1.69544	1.69914	1.72392	1.73657	1.74912	0.6028	0.0099
N-SF56 785261.328	1.78470	26.10	0.030071	1.79179	25.89	0.030587	1.77137	1.77607	1.80800	1.82460	1.84126	0.6139	0.0140
LASF35 022291.541	2.02204	29.06	0.035170	2.03035	28.84	0.035721	2.00628	2.01185	2.04916	2.06805	2.08663	0.5982	0.0033
BK7G18 520636.252	1.51975	63.58	0.008174	1.52170	63.36	0.008233	1.51579	1.51724	1.52587	1.52981	1.53345	0.5376	0.0007
LF5G19 597399.330	1.59655	39.89	0.014954	1.60010	39.60	0.015153	1.58970	1.59214	1.60799	1.61578	1.62330	0.5803	0.0036
LF5G15 584408.322	1.58397	40.83	0.014301	1.58736	40.55	0.014484	1.57739	1.57974	1.59489	1.60228		0.5759	0.0008
K5G20 523568.259	1.52344	56.76	0.009222	1.52564	56.47	0.009308	1.51906	1.52065	1.53040	1.53494	1.53919	0.5500	0.0017
LAK9G15 691548.353	1.69064	54.76	0.012612	1.69364	54.53	0.012721	1.68462	1.68680	1.70013	1.70630	1.71205	0.5462	−0.0055
F2G12 621366.360	1.62072	36.56	0.016979	1.62474	36.30	0.017212	1.61298	1.61573	1.63373	1.64261	1.65121	0.5831	0.0008
SF6G05 809253.520	1.80906	25.28	0.032015	1.81661	25.08	0.03257	1.79491	1.79988	1.83387			0.6121	0.0108

CR	FR	SR	AR	PR	α (–30/+70)	T_g	$T_{10}^{7.6}$	ρ	HK	HG	B	τ_i (10/400)	FC
1	0	1	1.2	1	8.5	572	685	2.99	620	4	1	0.850	42/37
1	0	1	1.3	1	8.7	592	691	3.28	560	5	1	0.799	44/37
1	0	1.3	1	1.3	7.4	774		5.41	810	1	2	0.634	45/37*
	0	1	2		7.0	585	722	2.52	580		0	0.764	41/37
2–3	2	3.4	2.2	3	10.7	474	606	3.30	410	2	1	0.276	45/39
2	0	1	1.3	2.3	9.3	407	578	3.22	446		1	0.569	43/37
	0	1	1		9.0	483	679	2.59	510		1	0.821	41/37
1–2	2	53.0	1.3	4.3	6.3	634	710	3.53	721		2	0.292	46/38
1	0	1	1.3	2.3	8.1	435	604	3.60	428		1	0.325	45/39
4	3	51.3	2.3	3.3	7.8	427	529	5.20	360		1		52/46*

* Wavelength for transmittance 0.7 and 0.05

Glossary

Glass Code	–	International glass code of refractive index n_d and Abbe number ν_d with density
n_x, ν_x, $n_x - n_y$	–	Refractive index, Abbe number, and dispersion at various wavelengths
$P_{g,F}$, $\Delta P_{g,F}$	–	Relative partial dispersion and deviation of relative partial dispersion from the normal line between g and F line
CR	–	Climatic resistance class (ISO/WD 13384)
FR	–	Stain resistance class
SR	–	Acid resistance class (ISO 8424)
AR	–	Alkali resistance class (ISO 10629)
PR	–	Phosphate resistance class (ISO 9689)
α **(–30/+70)**	–	Coefficient of linear thermal expansion between –30 °C and +70 °C in 10^{-6}/K
T_g	–	Transformation temperature in °C (ISO 7884-8)
$T_{10^{7.6}}$	–	Temperature of the glass at a viscosity of $10^{7.6}$ dPa s
ρ	–	Density in g/cm^3
HK	–	Knoop hardness (ISO 9385)
HG	–	Grindability class (ISO 12844)
B	–	Bubble class
τ_i **(10/400)**	–	Internal transmittance at 400 nm; glass thickness: 10 mm
FC	–	Color Code: Wavelength for transmittance 0.80 (at*: 0.70) and 0.05; glass thickness: 10 mm (JOGIS)

Only precision molding glasses:

Abrasion Aa	–	Grindability according to JOGIS
n_d **ref.**	–	n_d reference value (annealing rate 25 K/h)
n_d, ν_d **after molding**	–	As pressed at SCHOTT (preliminary data based on annealing rate of 5000 K/h)
SR-J	–	Acid resistance class according to JOGIS
WR-J	–	Water resistance class according to JOGIS
AT	–	Yield point/sag temperature in °C
α **(20/300)**	–	Coefficient of linear thermal expansion between +20 °C and +300 °C in 10^{-6}/K
JOGIS	–	Japanese Optical Glass Industrial Standards

The data listed is the most accurate data currently available.
We reserve the right to make changes due to technical progress.

Notes

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