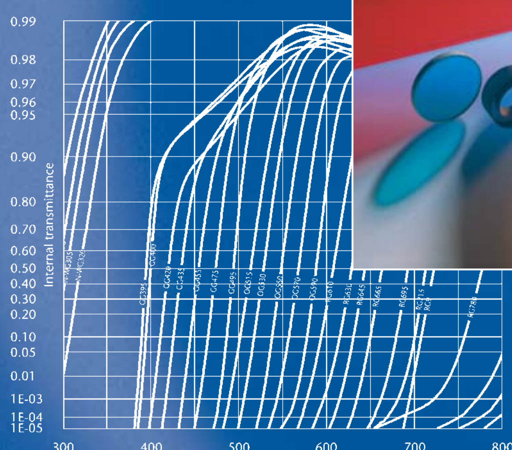
Definitions

Glass Filters



SCHOTT
glass made of ideas

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Foreword

For more than 40 years SCHOTT’s optical filter glass catalog has helped system designers and optical engineers to devise solutions for applications for a wide variety of market needs. During these years, the catalog has undergone many changes, as newly developed glass types were added, and others modified to keep up with the advancing technology.

Although the basic principles and equations remain the same, the look, feel and function of our optical filter glass catalog has been tailored and personalized to help simplify system design and to make it a more user-friendly experience. The layout of the individual data sheets has been standardized. These data sheets now comprise 2 pages and have been ameliorated by integration of two graphical representations of the spectral internal transmittances for the corresponding reference thickness. The first one comprises the wavelength range from 200 to 1200 nm. The second one gives a condensed overview within the range from 200 to 5200 nm. For the complete data sheets of our preferred glass type range, please see our website at http://www.us.schott.com/optics_devices or CD-ROM enclosed. In the data section we have extended the wavelength range of all graphs up to 1200 nm. Further, all long pass filters are now represented in one graph. As the data sheets contain now also the transmission graphs we have omitted the additional graph of the KG-glass types showing the spectral curves in the infrared (1000 to 4600 nm).

On the CD-ROM you will also find an improved calculation program with additional features superseding the FILTER 99 program.

You may notice that we have revised our product spectrum of color and filter glasses. The new product range is described in detail in the data section of our catalog.

As you read through this new version, keep in mind that its intent is to educate in the most important criteria regarding the materials and characteristics of the filters themselves, and that additional information is available on each section. As such, we urge you to contact our regional sales staffs around the world with questions and comments, to help grow the relationships that we have developed with our customers over the years.

For our long-standing customers, we hope that this new version finds its honorary place next to the many previous printings of our filter catalog, and is as much use as our older versions have been over the years. And for those who are reading this SCHOTT optical filter glass catalog for the first time, we look forward to helping you with your design needs and building a strong working relationship which will last for years to come.

1. General information on the catalog data

All data listed in this catalog not containing tolerances are to be understood as reference values. Guaranteed values are only those values listed in the data section of the catalog under ”Limit Values of τ_i“, ”Tolerance Ranges of τ_i“ and ”Tolerances for Long Pass Filters“. The graphically depicted internal transmittance curves serve as an initial overview to aid you in finding the most suitable filter type for your application.

Unless otherwise indicated, all data are valid for a temperature of 20°C.

Upon inquiry, the reference values can be more closely specified and the guaranteed values can be adapted to your requirements, where possible.

We constantly strive to improve our products to your advantage through innovation and new technical developments. We therefore reserve the right to change the optical and non-optical data of our color filter glass without prior notice.

The publication of this catalog renders all previous filter glass catalogs obsolete.

Our new catalog was composed with the utmost care. We assume no liability in the unlikely event that there are content and printing errors.

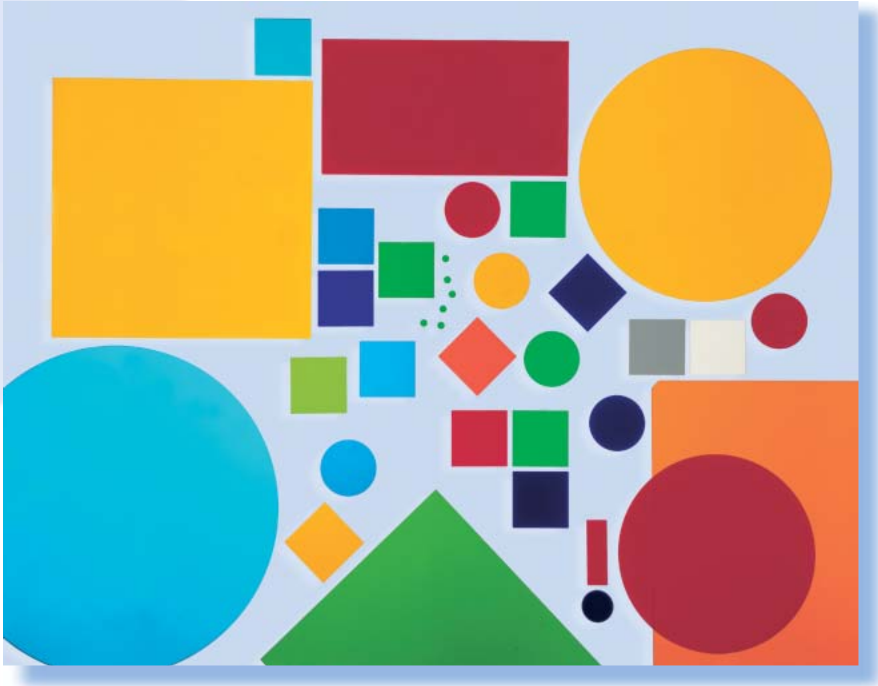
2. SCHOTT glass filter catalog: product line

The filter glass product line of SCHOTT comprises the following filter types in the wavelength range above 200 nm:
Band pass filters, that selectively transmit a desired wavelength range,
Long pass filters, that block an undesired shorter wavelength range,
Short pass filters, that block an undesired longer wavelength range, and
Neutral density filters, that exhibit nearly constant transmission, especially in the visible range.

Filter glass is manufactured and supplied in different thicknesses, which multiply the number of filter effects. By combining different filters together you can achieve additional filter effects.

Special emphasis was placed on qualitative and quantitative descriptions of glass and filter properties which are important for the user. These include chemical resistance, bubble quality, and tolerances of transmission properties, among other things.

The curves in the data section group similar color glass types together, thus simplifying your search for the most suitable filter glass for your application. These values are understood to be guidelines and should only serve to provide initial orientation.



3. Applications for SCHOTT glass filters

All glass filter types can be used as **substrates for thin film coating** to manufacture socalled interference filters. Thus the specific advantages of the individual components (absorption properties of optical glass filters and the reflection properties of interference coatings) can be combined in one optical filter.
SCHOTT has a wide range of thin film coating capabilities, so that in nearly every case an optimal filter solution according to special customer's requirements can be offered.

Optical glass filters are used in widely differing application areas. From the industrial measurement, regulation, and control technology to analytical measurement methods in production, research and development, as well as environmental protection and medicine, optical glass filters are important components in transmitting and blocking certain specific spectral ranges.

The filter glass types KG1, KG2, KG3, and KG5 exhibit high transmission in the visible range and effective absorption of infrared radiation (heat radiation) in the long wave spectral region and therefore make excellent **heat absorption filters (heat protection filters).** These filters are also used as **heat protection filters in photocopiers.** KG3 and KG5, which stand out because of their high transmission of visible light and effective absorption in the infrared range (especially 1064 nm for Nd : YAG-Laser) are used as components in protective glasses and windows for lasers.

An additional application area is the use of these filters in **operating room lamps.** The essentially colorlessness of the KG filters in the visible range hinders any undesirable color falsification in operating rooms.

In general it can be said that the heat protection filters of the KG group can be used wherever good transmission in the visible range is required with simultaneously effective absorption of undesirable heat radiation.

Long pass filters exhibit low transmission in the short wavelength spectral region (blocking range) and high transmission in the long wavelength region (pass range).

SCHOTT offers an entire spectrum of optical glass filters with long pass characteristic and cut-offs from the ultraviolet to the near infrared (the N-WG, GG, OG, and RG filter glass groups).

The customer may select these for his application according to the spectral range he wants to pass or block. Long pass filters are often used as blocking filters for shorter wavelengths, for example in interference band pass filters.

The RG filters (such as RG780, RG830, and RG850) which appear black to the eye, serve for the **separation of visible radiation and infrared radiation.** While they almost totally absorb the visible radiation, the highest possible levels of the longer wavelength infrared radiation can pass through the filter.

There are many **sensor** applications in the near infrared region, where undesirable visible radiation can distort measurements or even make them impossible and must therefore be totally eliminated.

An additional area where the RG filter glasses are used is in infrared lighting technology. Lamps that are equipped with these filters only emit infrared radiation and appear black to the observer, even when operating, because the visible radiation is indeed absorbed. Therefore these lamps are especially suitable for use in darkness and do not emit any disturbing radiation or make themselves visible. These filters, combined with infrared sensitive cameras, allow **surveillance systems (object protection)** to operate unnoticed.

Ultraviolet transmitting filter glasses of the UG group find wide use in UV-lighting situations. In this area, the simultaneous presence of visible radiation is frequently undesirable.

Especially in the **excitation of materials with ultraviolet radiation** for producing visible luminescence the filter must guarantee a sufficiently strong suppression of the visible radiation of the radiation source. This can be achieved in UG5 and UG11, for example, by an appropriate selection of the filter thickness. UG5 filter glass is especially suited for the 254 nm line of a low pressure mercury lamp, while UG11 is frequently used for the selection of the 365 nm mercury line.

Neutral density glasses, with the designation NG, have, as their name suggests, a very constant transmission over a large spectral range, especially in the visible range. The degree of desired filtering can be regulated by the use of different NG filter types and by thickness within a particular filter type. Their use is indicated when the user requires a **defined attenuation of the intensity of radiation sources over a large spectral range.**

Different filter glasses in the BG group are utilized for **correction of the sensitivity of silicon receivers,** the maximum sensitivity of which is in the range from approx. 800 nm to 900 nm, depending on the type of receiver. The increase in sensitivity from the blue to the near infrared in detection leads to an overevaluation of the longwave (red) area. By selecting suitable BG glasses this can be compensated for to a certain extent.

BG39 is suited for **video cameras,** whereby the infrared sensitivity must be suppressed to approx. 1100 nm.

The examples cited only present a small picture of the many possible applications for optical glass filters.

If you have questions on this, please contact us so that we may cooperate with you in working out an optimum solution to your special application requirement.

4. Material: filter glass

Our filter glass types contain no more than 0.05 weight percent thorium oxide or other radioactive material. Negligible inherent radioactivity can be present as in many everyday substances as a result of the natural radioactivity of raw materials.

4.1 Group names

Filter glasses are distinguished by more or less selective absorption of optical radiation. The filters only appear colored if their filter action is within the visible spectral range.

Our filter glasses are classified into the following groups:

UG	Black and blue glasses, UV transmitting
BG	Blue, blue-green, and multiband glasses
VG	Green glass
GG	Nearly colorless to yellow glasses, IR transmitting
OG	Orange glasses, IR transmitting
RG	Red and black glasses, IR transmitting
NG	Neutral density glasses with uniform attenuation in the visible range
N-WG	Colorless glasses with different cutoffs in the UV, transmitting in the visible range and the IR
KG	Virtually colorless glasses with high transmission in the visible and absorption in the IR (heat protection filters)

4.2. Classification

The various filter glass types can be divided into three classes:

4.2.1 Base glasses
Colorless (uncolored) optical glasses with different location of the cutoff in the UV (see N-WG glasses)

4.2.2 Ionically colored glasses
Ions of heavy metals or rare earths can influence the coloration of glasses when in true solution. This coloration depends on the nature and quantity of the coloring substances, on the oxidation state of the coloring substances, and on the base glass composition (see UG, BG, VG, NG, and KG glasses as well as glass types RG9, and RG1000).

4.2.3 Colloidally colored glasses

The colorants in these glasses are in most cases rendered effective by a secondary heat treatment ("striking") of the initially (nearly) colorless glass. Particulary important glasses in this class are the yellow, orange, red, and black filter glasses with their steep absorption edges. As with the ionically colored glasses, their color is dependent upon the type and concentration of the colorants, the base glass, and, to a large extent, their thermal history during the secondary heat treatment (see GG, OG and RG glasses with the exception of RG1000).

The filter glass type RG9 presents a mixture of an ionically colored and colloidally colored glass. The shortwave absorption edge comes from the colloidal glass character, and the longer wavelength behavior is determined by ionic coloring.

4.3 Reproducibility of transmission

The spectral properties of the base and ionically colored filter glasses are nearly constant within the individual melts. Based on slight deviations in the properties and pureness of the raw materials and batch composition, there can be deviations from melt to melt. The colloidally colored glasses also exhibit deviations within a melt due to technically unavoidable temperature gradients during the striking process.

In the data section the manufacturing based maximum deviations of transmission are listed for each glass type (refer to "Limit Values of τ_i", "Tolerance ranges of τ_i" and "Tolerances for long pass filters"). These spectral properties are measured and documented for each production batch. These results are permanently retrievable. Through selection and reservation of suitable melts and through variation in the filter glass thickness, tighter tolerances than normally listed in the specifications can usually be achieved.

4.4 Thermal toughening

In most cases, absorbing filter glass is heated unevenly by the illuminating radiation. The low thermal conductivity of filter glass prevents rapid thermal equilibrium.

Thus, temperature gradients arise both between front and rear side and especially between the center and the edges of the filter glass. This produces flexural stresses within the filter glass based on the different thermal expansion.

An improved resistance to larger temperature gradients or rapid temperature changes and an increase in the flexural strength can be achieved through thermal toughening of the filter glass. The improved thermal resistance of toughened filter glass causes a slight deformation and possibly a slight change in the spectral values.

Thermal toughening is required for filter glasses placed in front of intense light sources in order to increase their breaking strength. It must be assured that the temperature of the glass does not exceed a temperature of Tg – 300 °C, or, for short periods, Tg – 250 °C (the transformation temperature Tg is listed for each color glass type in the data section). Otherwise, thermal toughening will relax as a function of temperature and time.

Already at the stage of designing lamps, adequate measures have to be taken to minimize temperature gradients – especially between the center and the edges of the glass plate (uniform illumination). This is the only way to avoid large temperature gradients that cause undesirably high tensile stresses in the normally colder edge zone of the filter glass. When installing filters into mounts and / or lamp housings, it must be assured that no additional mechanical forces can act onto the glasses. Direct metal-to-glass contact must be avoided; insulating intermediate layers made from suitable material are recommended.

5. Filter glass properties

In order to develop an assortment of filter glasses, some with extreme filtering properties, in the largest possible spectral area, numerous colorants with different concentrations and many different base glasses had to be developed. In the data section, the following important properties are mostly quantitatively listed for each filter glass type. These are typical values.

5.1 Mechanical density ρ [g/cm³]

This is defined as the quotient of mass and volume. Most filter glass types have a density between 2.4 and 2.8 g/cm³.

5.2 Transformation temperature Tg [°C]

The transformation range of a filter glass is the boundary region between brittle and liquid behavior. It is characterized by the precisely determined transformation temperature Tg which is defined according to ISO 7884-8. The value T= Tg – 200°C should not be exceeded during filter operation because otherwise the glass and filter properties can permanently change.

5.3 Thermal expansion α [10^{-6}/K]

The coefficient of linear thermal expansion α gives the relative change in length of a glass sample when heated by one Kelvin (K). It is a function of the temperature and is therefore given for two temperature ranges.

$\alpha_{-30/+70°C}$ [10^{-6}/K] applies as a mean for 20°C, and
$\alpha_{20/300°C}$ [10^{-6}/K] is an internationally used value for comparative purposes.

The second value is approximately 10% higher than the first. Due to the relatively low transformation temperatures for BG 39 and BG 40, the value listed is $\alpha_{20/200°C}$.

5.4. Chemical Resistance

For various chemical demands, especially during different processing steps, we use the resistance classes that apply to optical glass. The greater the resistance of the glass, the smaller the class number. The resistance classes are listed in the data section for all filter glasses.
Exact descriptions of the individual test procedures are available upon request.

5.4.1 Stain Resistance, Classification into Stain Resistance Classes FR 0 – 5

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

The stain resistance class is determined according to 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 containing a few drops of test solution I or II.

Test solution I: Standard Acetate 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 glasses is the time that elapses before the first brown-blue stain occurs at a temperature of 25 °C. This change in color indicates a chemical change in the previously defined surface layer of 0.1 μm thickness insofar the glass can form layers at all.

Table 1: Classification of filter glasses into stain resistance classes FR 0 – 5.

Stain Resistance Classes FR	0	1	2	3	4	5
Test solution	I	I	I	I	II	II
Time (h)	100	100	6	1	1	0.2
Color change	no	yes	yes	yes	yes	yes

5.4.2 Acid Resistance (ISO 8424: 1987), Classification into Acid Resistance Classes SR 1 – 4, 5, 51 – 53

Acid resistance classifies the behavior of glass surfaces that come in contact with large quantities of acidic solutions (from a practical standpoint for example, perspiration, laminating substances, carbonated water, etc.).

Acid resistance is denoted by a two or a three digit number. The first or the first two digits indicate the acid resistance class SR. The last digit (separated by decimal point) tells the change in the surface visible to the unaided eye that occurs through exposure (see 5.4.4).

The time t required to dissolve a layer with a thickness of 0.1 μm serves as a measure of acid resistance. Two aggressive solutions are used in determining acid resistance. A strong acid (nitric acid, c = 0.5 mol/l, pH 0.3) at 25 °C is used for the more resistant glass types. For glasses with less acid resistance, a weakly acidic solution with a pH value of 4.6 (standard acetate) is used, also at 25 °C.

Class SR 5 forms the transition point between the two groups. It 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.

Acid Resistance Classes 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

Table 2: Classification of filter glasses into acid resistance classes SR 1 – 53.

5.4.3 Alkali Resistance (ISO 10629), Classification into Alkali Resistance Classes AR 1–4

The alkali resistance indicates the sensitivity of filter glasses in contact with warm, alkaline liquids, such as cooling liquids in grinding and polishing processes.

The alkali resistance is denoted using two digits separated by a decimal point. The first digit lists the alkali resistance class AR and the decimal indicates the surface changes visible to the unaided eye that occur through exposure.

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

The layer thickness is calculated from the weight loss per surface area and the density of the glass.

Alkali Resistance Classes AR	1	2	3	4
Time (h)	> 4	1 – 4	0.25 – 1	< 0.25

Table 3: Classification of filter glasses into alkali resistance classes AR 1 – 4

5.4.4 Identification of visible surface changes

Meaning of the digits behind the classification for acid and alkali resistance:

- .0 no visible changes
- .1 clear, but irregular surface
- .2 interference colors (light, selective leaching)
- .3 firmly adhered thin white layer (stronger, selective leaching, cloudy surface)
- .4 loosely adhering, thicker layers, for example, insoluble reaction products on the surface (this can be a projecting and/or flaking crust or a projecting surface; strong attack)

5.5 Long term changes in polished filter glasses

After a certain amount of time, the surface of highly sensitive glasses exhibits a slightly cloudy coating. Initially this coating can be removed with glass polishing compounds. More severe attacks ruin the surface polish quality. This effect is favored by humidity. With respect to this behavior, the color filter glasses can be classified into three groups:

Group 1
No substantial surface change occurs in most of the filter glass types. These types are not specially identified in the data section. Only under extreme conditions, such as when subjected to a continuous spray of sea water, or when used in rain or in water, a change in the surface is possible.

Group 2 Symbol: [!]
In the filter glass types BG40, KG1, KG2, KG3, and KG5, there is virtually no long term change when used and stored in moderate climates or in closed work and store rooms (constant temperature below 35°C, relative humidity less than 80%). If there exists the possibility of wetting, a desiccant should be used. For use and storage in open air and tropical climates, it is advisable to apply a protective coating (SCHOTT can do this.)

Group 3 Symbol: [!!]
In filter glass types UG5, UG11, and BG39, a change in the glass surface is possible within a few months during normal storage. For this reason, we recommend a protective coating or lamination to a durable filter glass from Group 1 (SCHOTT can do both).

5.6 Internal quality

The internal quality of the filter glasses is characterized by the following features.

5.6.1 Bubble content
SCHOTT filter glasses are distinguished by a particularly small number of bubbles. However, it is not entirely possible to avoid bubbles in the glass due to unusual glass compositions and production processes. Insofar as the transparency allows, the bubble content of a filter glass is characterized by stating the total cross-sectional area of the bubbles in mm^2 relative to 100 cm^3 of filter glass volume, calculated from the sum of the cross-sectional areas of detected individual bubbles.

Inclusions in the filter glass, such as small stones or crystals, are treated as bubbles of the same cross-sectional area. Only bubbles and inclusions having a diameter ≥ 0.03 mm are covered in the assessment. The bubble classes are shown in table 4:

Bubble class	Total cross-section of all bubbles/ inclusion ≥ 0.03 mm in mm^2 per 100 cm^3 of glass volume	
B0		≤ 0.03
B1	> 0.03	≤ 0.10
B2	> 0.10	≤ 0.25
B3	> 0.25	≤ 0.50

Table 4: The bubble classes of color filter glasses

Upon request and according to availability, filter glass types with better bubble classes than listed in the data section, can be supplied.

In accordance with ISO 10110 Part 3 the bubble area may be distributed: Instead of one bubble of given area, a larger number of smaller bubbles is allowable.

5.6.2 Striae

Striae are locally limited areas than can be detected due to their refractive index which differs from the base glass. Classes of striae are defined in ISO 10110 Part 4. For appropriate requirements and to the extent the transparency allows, the socalled shadow method can be used to check for striae. Our standard quality can contain individual fine striae.
Upon special request, the most striae-free glass available can be supplied (polished filters only).

5.6.3 Homogeneity of refractive index

The variation of the refractive index within a glass filter or a raw block is a measure of the optical homogeneity. The better the homogeneity, the smaller the variation in refractive index. Insofar as the transparency of the filter glass type allows, quantitive homogeneity measurements can be performed. The homogeneity that can be achieved in doing this depends on the dimension, among other things.

6. Filter attributes

6.1 Refractive index

In imaging optics, light refraction and its spectral dependence (dispersion) are the most important properties; they are determined by wavelength dependent refractive index n (λ). The refractive indices are basically listed as reference values to two decimal places for the helium d-line (λ = 587.6 nm) and usually for several additional wavelengths in the transmission range of the filter glass.

6.2 Reflection factor

Due to reflection at the two glass surfaces of a filter in contact with air, the radiation is attenuated by the reflection factor P(λ) (reflection loss). P is the Greek letter "rho". For incoherent radiation, perpendicular incidence, and considering multiple reflections, equation 1 approximately applies independently of glass filter thickness.

$$P(\lambda) = \frac{2n(\lambda)}{n^2(\lambda)+1} \qquad ①$$

6.3 Transmittance and internal transmittance

Optical radiation filters are characterized by the spectral transmission. The two most important filter data are the spectral transmittance $\tau(\lambda)$ and the spectral internal transmittance $\tau_i(\lambda)$.

$$\tau(\lambda) = \frac{(\phi_{e\lambda})_\tau}{\phi_{e\lambda}} \qquad ②$$

The spectral transmittance $\tau(\lambda)$ in equation 2 is the ratio of the transmitted spectral flux $(\varphi_{e\lambda})_\tau$ to the incident radiation flux $\varphi_{e\lambda}$. So, $\tau(\lambda)$ describes the transmittance of the absorbing glass filter considering the reflection losses at the front and rear sides of the filter.

$$\tau_i(\lambda) = \frac{(\phi_{e\lambda})_{ex}}{(\phi_{e\lambda})_{in}} \qquad ③$$

The spectral internal transmittance $\tau_i(\lambda)$ in equation 3 is the ratio of the emerging spectral radiant flux $(\varphi_{e\lambda})_{ex}$ to the penetrated radiation flux $(\varphi_{e\lambda})_{in}$. $\tau_i(\lambda)$ describes the transmittance of the absorbing glass filter without considering reflection losses.

The Bouguer-Lambert law (equation 4) applies for perpendicular radiation incidence, assuming homogeneous absorption, for the dependence of the spectral internal transmittance on filter thickness.

$$\tau_{id_1}(\lambda) = \tau_{id_2}(\lambda)^{d1/d2} \quad ④$$

τ_{id1} (λ): Internal transmittance at the wavelength λ and with filter thickness d_1.
τ_{id2} (λ): Internal transmittance at the wavelength λ and with filter thickness d_2.

By taking reflection losses into account, the transmittance is obtained by multiplying the internal transmittance and the reflection factor P (λ).

$$\tau(\lambda) = P(\lambda) \cdot \tau_i(\lambda) \quad ⑤$$

Generally, the description for the dependence of the spectal transmittance on thickness is:

$$\tau_{d_1}(\lambda) = P(\lambda) \cdot \tau_{id_2}(\lambda)^{d1/d2} \quad ⑥$$

By using equation 6, the thickness d_1 can be derived from a given desired transmittance τ_{d1} (λ) (equation 7).

$$d_1 = d_2 \frac{\lg\tau_{d_1}(\lambda) - \lg P(\lambda)}{\lg\tau_{id_2}(\lambda)} \quad ⑦$$

6.4 Derived filter data

In addition to $\tau(\lambda)$ und $\tau_i(\lambda)$, the following filter characteristics derived from them are useful:

$$\text{Spectral optical density } D(\lambda) = \lg \frac{1}{\tau(\lambda)} \quad ⑧$$

$$\text{Spectral absorbance (extinction) } A(\lambda) = \lg \frac{1}{\tau_i(\lambda)} \quad ⑨$$

$$\text{Spectral diabatie } \theta(\lambda) = 1 - \lg\left(\lg \frac{1}{\tau_i(\lambda)}\right) = \lg \frac{10}{A(\lambda)} \quad ⑩$$

6.5 Internal transmittance curves

The $\tau_i(\lambda)$ values for the appropriate reference thicknesses are graphically presented in the data section of the printed catalog. The wavelength from 200 nm to 1200 nm is shown as the abscissa. $\tau_i(\lambda)$ is shown as the ordinate in a lg-lg-scale (see spectral diabatie). Presented this way, the curve shapes are independent of the thickness of the filter glass. The values are reference values and should only serve for initial orientation purposes.

6.6 Spectral characterization of filters

Optical filters are described by their spectral characteristics and can be divided into several groups. The most important types are defined and explained below.

6.6.1 Long pass filters

A long pass filter is characterized by the fact that a range of low transmission (blocking range) in the short wavelength region is joined to an area of high transmission (pass band) in the long wavelength region (see figure 1).

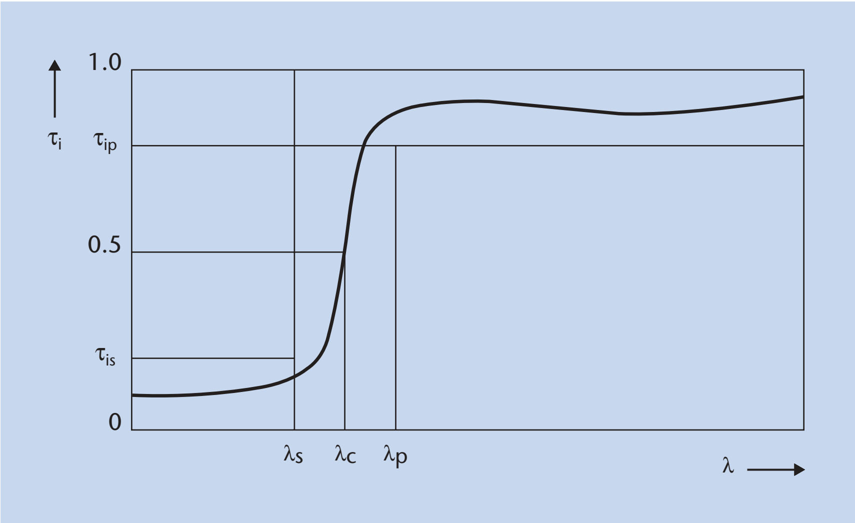


Figure 1: Long pass filter

The important properties applicable to filter glasses are:

λ_c: Edge wavelength at which point the spectral internal transmittance is one-half of the maximum value of the pass range.

λ_s: The limit of the blocking range. Below this wavelength, the internal transmittance τ_{is} not exceeded for a certain spectral region.

λ_p: The limit of the pass range. Above this wavelength, the spectral internal transmittance does not fall below τ_{ip} within a certain spectral range. The pass range can be divided into several sub-ranges, e. g. into two ranges with τ_{ip1}= 0.90 and τ_{ip2} = 0.97.

6.6.2 Short pass filters

In principle, the same comments which apply to the long pass filters apply to the short pass filters, only their pass range is at lower wavelengths than the blocking range.

6.6.3 Band pass filters

Band pass filters are characterized by the fact that they connect a region of high transmission (pass band) and shorter and longer wavelength regions with low transmission (blocking ranges).

The most important characteristics are:

τ_{max}: Maximum of the spectral transmittance in the pass range

λ_m: Center wavelength (spectral position):
If those wavelengths in which the spectral transmittance $t_{max}/2$ are identified as $\lambda'_{1/2}$ and $\lambda''_{1/2}$, then $\lambda_m = (\lambda'_{1/2} + \lambda''_{1/2})/2$

HW: Half-width: Curve width at $\tau_{max}/2$

6.6.4 Neutral density filters

Neutral density filters exhibit nearly constant spectral transmittance in a limited spectral range, for example from 400 nm to 700 nm, and are therefore only slightly wavelength dependent.

7. Neutral density filter set

Filters having spectrally constant transmission in various attenuation steps are frequently required for certain applications within the visible spectrum from approx. 400 nm to 700 nm.

The NG glasses, which are splendidly suited for such purposes, offer a simple solution for this.

Neutral filter sets are composed of filter glass types NG11, NG4, and NG9. The thicknesses of the filters vary between approx. 0.8 mm and 4.5 mm. By using the three filter types the values of the spectral optical density at the wavelength 546 nm – short form: D (546 nm) – can be adjusted between 0.15 and 5.0, and that of the spectral transmittance at 546 – short form: τ (546 nm) can be adjusted between 0.708 and $1\cdot10^{-5}$. The graduation is shown in table 5.

Table 5: Neutral density filter set

Filters in the neutral density filter set		
Filter glass type	D (546 nm)	τ (546 nm)
NG11	0.15	0.708
NG11	0.3	0.50
NG4	0.6	0.25
NG4	1.0	0.10
NG4	1.3	0.05
NG9	1.6	0.025
NG9	2.0	0.01
NG9	2.3	$5\cdot10^{-3}$
NG9	2.6	$2.5\cdot10^{-3}$
NG9	3.0	$1\cdot10^{-3}$
NG9	3.3	$5\cdot10^{-4}$
NG9	3.6	$2.5\cdot10^{-4}$
NG9	4.0	$1\cdot10^{-4}$
NG9	4.3	$5\cdot10^{-5}$
NG9	4.6	$2.5\cdot10^{-5}$
NG9	5.0	$1\cdot10^{-5}$

The target thicknesses of the individual filter glasses are determined from suitable sample measurements of the appropriate melts of the filter type. During the fabrication of the polished filter the target thickness is maintained to ±0.05 mm. The deviations in the target density and target transmission listed in table 6 result from this manufacturing tolerance alone.

Filter glass type	Δ D (546 nm)	Δ τ (546 nm) / τ (546 nm)
NG11	± 0.006	± 0.013
NG4	± 0.03	± 0.06
NG9	± 0.07	± 0.17

Table 6:
Deviation in target density and target transmission with a thickness tolerance of ±0.05 mm.

In addition, further deviations may arise through unavoidable measurement errors that may become evident through relative density deviations of approx. ±4.5% in NG9, for example. If the goal is the precise and graduated attenuation of only one wavelength, such as in laser systems, then basically thicker glasses must be used with narrower thickness tolerances. We will advise you in all of your special questions.

8. Filter properties

8.1 Dependence of spectral transmittance on temperature

The edge position λ_C of long pass filters shifts to higher wavelengths with increasing temperature. In the data section the temperature coefficient of the edge position $\Delta \lambda_C / \Delta T$ [nm /K] is listed for all long pass filters. These are average values in the temperature range from 10°C to 90°C.

For the band pass filters and filters with flat curve flanks, the changes in spectral transmittance as a function of temperature are relatively small. We will provide additional information upon request.

8.2 Luminescence

The more or less pronounced luminescence of the filter glasses is only interesting for practical purposes if these filters are to be used to measure the luminescence of materials. In doing this, the application of filter glasses as excitation filters, i.e. for spectral isolation of the exciting radiation, presents no problem in most cases.

In this connection, reference is made to our low-luminescence glass-plastic laminated KV filters (long pass filters) that, with edge positions between 370 nm and 550 nm, have proven to be very good blocking filters for luminescence investigations.

8.3 Transmission changes caused by intense ultraviolet radiation

Prolonged exposure to intense light sources with high ultraviolet radiation can cause permanent changes (reductions) in the transmissions of filter glasses. In glass technology this effect is called “solarization”. It is mainly a function of the intensity and spectral distribution of the radiation. The more shortwave the radiation is, the higher is the solarization effect.

The solarization effect itself manifests mainly by a shift of the shortwave-located edge to longer wavelengths and a reduction of the transmission in the pass range. Depending on the spectral distribution, intensity and duration of the irradiation, a saturation effect will set in. If the transmittance curve, resulting from such an effect, is acceptable for the application, such a glass can be “aged” prior to use by exposing it to an appropriate pre-irradiation. KG heat protection filters for xenon lamps are an important example for such an application.

Since the solarization of a filter glass is strongly dependent upon the spectral distribution and intensity of the light source, the duration and the geometrical arrangement of the irradiation, no detailed information is given regarding solarization. Filter glasses that are prone to higher solarization are identified with the letter V in the data section.

8.4 Color

Color is a sensation perceived by the human eye when observing an illuminated filter glass. It is a function of the spectral transmission of the filter and the spectral distribution of the illuminating light source. Color stimulus is measurable and is defined by three numerical values in accordance with color metric conventions set forth by the CIE (see publication CIE N° 15.2 (1986)). It is defined (see figure 2):

as the coordinates (chromaticity coordinates) x and y of the color locus F (x,y) in the CIE chromaticity diagram or
as the dominant wavelength λ_d and the excitation purity $P_e = \overline{DF} : \overline{DS}$,
the third parameter is the brightness (standard tristimulus value) Y.

The following values are listed in the data sheets for our "colored" filter glasses, which excludes the black, neutral density, and clear glasses:
x, y, Y, λ_d, and P_e.

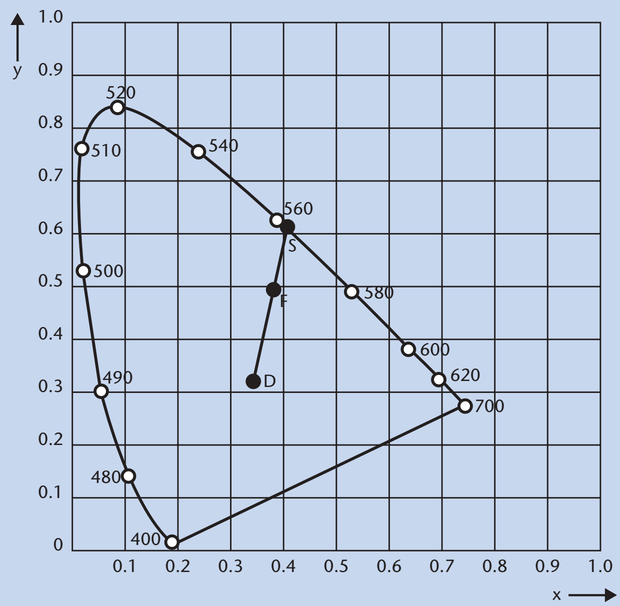
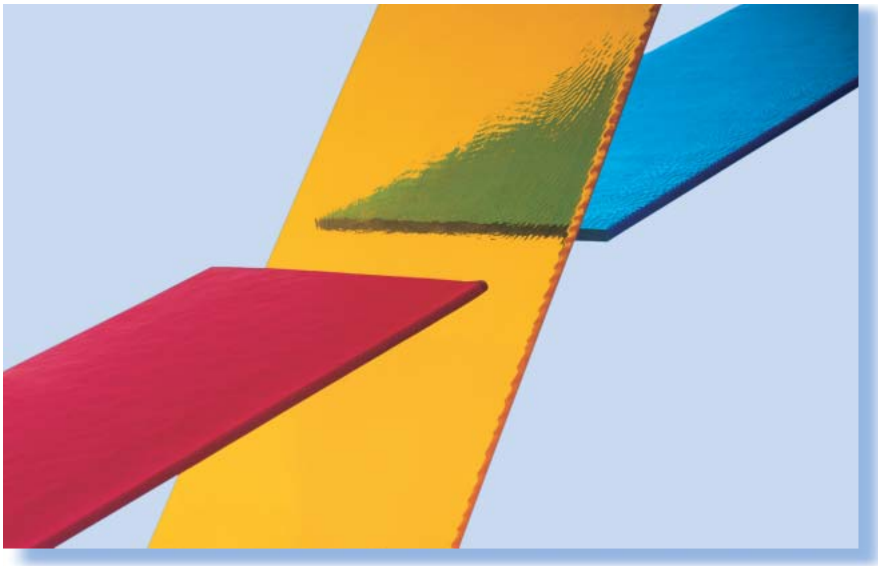


Figure 2:
The color of filter glasses according to CIE.
D: Color locus of the radiation source, for example D65
S: Point at which the extension of $\overline{DF}$ intersects the spectrum locus at λ_d

These apply to:

- Filter glass thickness of 1, 2, and 3 mm
- Illumination with the illuminants:
  - Standard illuminant A (Planckian radiator at 2856 K), incandescent lamp
  - Planckian radiator at 3200 K, halogen lamp light
  - Standard illuminant D65, standard daylight
- 2°-standard observer
- 20° C temperature

The tristimulus values listed in the data sheets are reference values only.



9. Forms of supply

Our line of polished filter and cut filter glass mainly comprises dimensions that are produced to specific customer specifications. However, it should be mentioned here that the standard formats described in the following section can be supplied on short notice.

9.1 Polished filters

Filters are supplied in the form of edge-machined, polished plates or discs. See section 10.1 for dimensional tolerances.

The standard polish quality corresponds to a polished surface (P2 according to ISO 10110 Part 8). Higher polish quality is available upon request.

The filters can be thermally toughened for special applications (see section 4.4).

In consideration of the variety of possible applications, the range of filter glasses is not limited to certain standard sizes and thicknesses, rather they can be produced to specification, subject to each individual glass type's maximum allowable dimensions and thickness.

Standard format polished filter glasses, edge-machined with dimension of 50 mm x 50 mm (standard size in the US: 50.8 mm x 50.8 mm) ± 0.2 mm with thickness 1 ± 0.1; 2 ± 0.2 and 3 ± 0.2 mm can be supplied upon short notice.

9.2 Cut filter glass

With machined edges
Rectangular plates and round discs with ground surfaces and machined edges. See section 10.2 for dimensional tolerances.

Without machined edges
Rectangular plates with ground surfaces and without machined edges. See section 10.2 for dimensional tolerances.

Standard formats without machined edges
Plates with dimension of 165 mm x 165 mm +3/–0 mm with the thickness of 3.5 ± 0.5 mm and 4.5 ± 0.5 mm.

10. Dimensional tolerances

10.1 Polished filters

The tolerances listed in table 7 apply to polished filters with machined edges.

Dimension	Range in mm	Tolerance in mm
Diameter or edge length	6–50	± 0.2
Thickness	0.5–1.0	± 0.1
	> 1.0	± 0.2
Diameter or edge length	> 50–100	± 0.3
Thickness	1–10	± 0.2
	> 10	± 0.3
Diameter or edge length	> 100–150	± 0.4
Thickness	1.5–10	± 0.2
	> 10	± 0.3
Diameter or edge length	> 150	± 0.4
Thickness	2–10	± 0.3
	> 10	± 0.4
Larger dimension and narrower dimensional tolerances can be supplied on request.		

Table 7: Dimensional tolerances for polished glass filters with machined edges.

The minimum thicknesses listed in table 8 apply for thermally toughened filters.

Diameter or edge length in mm	Minimum thickness in mm
up to 100	1.0
> 100 – 150	1.5
> 150 – 200	2.0

Table 8: Minimum thickness for thermally toughened filters.

10.2 Cut filter glass

With machined edges

The tolerances listed in table 9 apply.

Diameter or edge length	Range in mm	Tolerance in mm
Diameter or edge length	6–50	± 0.2
Thickness	≥ 3	± 0.3
Diameter or edge length	> 50–80	± 0.3
Thickness	≥ 3	± 0.3
Diameter or edge length	> 80–120	± 0.5
Thickness	≥ 3	± 0.5
Diameter or edge length	> 120	± 0.5
Thickness	≥ 3	± 0.5
Larger dimension and narrower dimensional tolerances can be supplied on request.		

Table 9: Dimensional tolerances for cut filter glass with machined edges.

Without machined edges

This form of supply is shipped with scribe-cut or machine-cut edges; tolerances can be as high as 3 mm, depending on thickness.

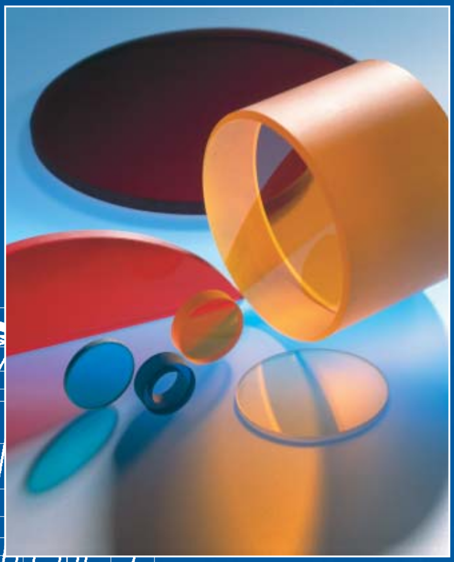
For your notes

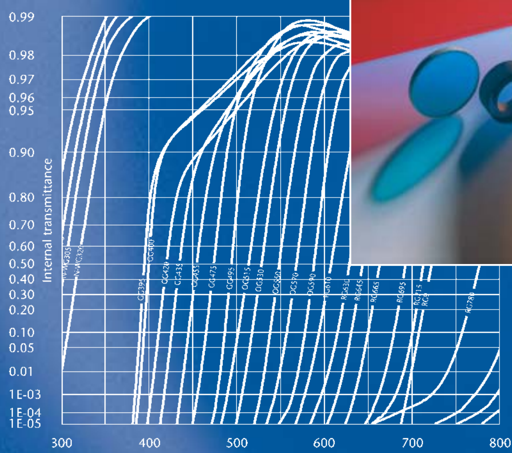
For your notes

For your notes

Data

Glass Filters | Status December 2004





SCHOTT
glass made of ideas

Table of Contents

11. Filter glass product range: product line

The color filter glass product line comprises 50 filter glass types. The old WG types were replaced by the new developed types N-WG280, N-WG295, N-WG305, and N-WG320. These types are lead-free and arsenic-free. Our current product line consists of the following filter glass types:

UG1	BG3	VG9	GG395	OG515	RG9	NG1	N-WG280	KG1
UG5	BG7		GG400	OG530	RG610	NG3	N-WG295	KG2
UG11	BG18		GG420	OG550	RG630	NG4	N-WG305	KG3
	BG25		GG435	OG570	RG645	NG5	N-WG320	KG5
	BG36		GG455	OG590	RG665	NG9		
	BG38		GG475		RG695	NG11		
	BG39		GG495		RG715			
	BG40				RG780			
	BG42				RG830			
					RG850			
					RG1000			

Table 10: Product line

Some filter glass types listed in the 1997 catalog are no longer being produced due to insufficient demand and to streamline the product line. Types, the production of which has been discontinued, but are replaced by new similar types (see table 10), are not listed below explicitely.

BG 4	VG 6	GG 385	NG 10	WG 225	KG 4	FG 3
BG 12	VG 14		NG 12			FG 13
BG 20						
BG 23						
BG 24A						
BG 26						
BG 28						
BG 34						

Table 11: Glasses that are no longer produced and are not replaced by new similar types

These filter glass types will continue to be manufactured if there is sufficiently large demand. We will gladly discuss minimum purchase quantities and costs with you.

12. Filter glass product range: specified values (spectral values guaranteed)

Limit values of τ_i

Filter glass type	Thickness [mm]	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm]))	τ_i (λ[nm])
UG1	1	≥ 0.80(365)	≤ 0.10(405)	≤ 0.06(694)	≤ 0.53(750)				
UG5	1	≥ 0.80(254)	≥ 0.94(308)	≤ 0.50(405)	≤ 0.05(546)	≤ 0.05(633)	≤ 0.85(725)		
UG11	1	≥ 0.06(254)	≥ 0.90(334)	≤ 0.001(405)	≤ 0.26(694)	≤ 0.32(725)			
BG3	1	≥ 0.94(365)	≤ $5 \cdot 10^{-5}$ (633)						
BG7	1	≥ 0.25(365)	≥ 0.78(488)	≤ 0.08(633)					
BG18	1	≥ 0.30(350)	≥ 0.65(405)	≥ 0.88(514)	≤ 0.25(633)	≤ 0.03(694)	≤ $5 \cdot 10^{-4}$ (1060)		
BG25	1	≤ 0.80(334)	≥ 0.93(405)	≤ 0.39(488)	≤ 0.36(725)				
BG38	1	≥ 0.80(350)	≥ 0.93(405)	≥ 0.95(514)	≤ 0.67(633)	≤ 0.32(694)	≤ 0.06(1060)		
BG39	1	≥ 0.60(350)	≥ 0.85(405)	≥ 0.93(514)	≤ 0.30(633)	≤ 0.03(694)	≤ 0.001(1060)		
BG40	1	≥ 0.80(350)	≥ 0.93(405)	≥ 0.97(514)	≤ 0.57(633)	≤ 0.16(694)	≤ 0.02(1060)		
BG42	1	≥ 0.40(350)	≥ 0.65(405)	≥ 0.88(514)	≤ 0.27(633)	≤ 0.03(694)	≤ 0.002(1060)		
VG9	1	≤ 0.21(450)	≥ 0.67(514)	≤ 0.15(633)	≤ 0.07(725)	≤ 0.18(1060)			
RG9	3	≤ 0.45(720)	≥ 0.92(800)	≤ 0.40(1060)					
KG1	2	≥ 0.89(365)	≥ 0.92(500)	≥ 0.88(600)	≤ 0.68(700)	≤ 0.33(800)	≤ 0.10(900)	≤ 0.02(1060)	≤ 0.06(2200)
KG2	2	≥ 0.93(365)	≥ 0.94(500)	≥ 0.92(600)	≤ 0.83(700)	≤ 0.55(800)	≤ 0.28(900)	≤ 0.12(1060)	≤ 0.20(2200)
KG3	2	≥ 0.86(365)	≥ 0.88(500)	≥ 0.83(600)	≤ 0.55(700)	≤ 0.14(800)	≤ 0.03(900)	≤ 0.001(1060)	≤ 0.01(2200)
KG5	2	≥ 0.80(365)	≥ 0.86(500)	≥ 0.80(600)	≤ 0.43(700)	≤ 0.09(800)	≤ 0.008(900)	≤ $1 \cdot 10^{-4}$ (1060)	≤ 0.001(2200)

Table 12.1: Filter glass product range: specified values (spectral values guaranteed)

Tolerance ranges of τ_i

Filter glass type	Thickness [mm]	τ_i (λ[nm])	τ_i (λ[nm])	τ_i (λ[nm])
NG1	1	< $1 \cdot 10^{-4}$ (546)		
NG3	1	0.06 ± 0.02(405)	0.10 ± 0.02(546)	0.17 ± 0.03(694)
NG4	1	0.27 ± 0.03(405)	0.31 ± 0.03(546)	0.39 ± 0.04(694)
NG5	1	0.56 ± 0.03(405)	0.57 ± 0.03(546)	0.62 ± 0.03(694)
NG9	1	0.025 ± 0.01(405)	0.04 ± 0.02(546)	0.08 ± 0.02(694)
NG11	1	0.76 ± 0.02(405)	0.77 ± 0.02(546)	0.79 ± 0.02(694)

Table 12.2: Filter glass product range: specified values (spectral values guaranteed)

Tolerances for long pass filters

Filter glass type	Thickness [mm]	λ_c (τ_i = 0.50)[nm]	λ_s ($\tau_{is} = 1 \cdot 10^{-5}$)[nm]	λ_p (τ_{ip})[nm]	λ_{p1} (τ_{ip1})[nm]	λ_{p2} (τ_{ip2})[nm]
GG395	3	395 ± 6	340	480(0.92)		
GG400	3	400 ± 6	340	480(0.93)		
GG420	3	420 ± 6	360	530(0.93)		
GG435	3	435 ± 6	370	520(0.92)		
GG455	3	455 ± 6	390	530(0.92)		
GG475	3	475 ± 6	410	550(0.92)		
GG495	3	495 ± 6	430	560(0.92)		
OG515	3	515 ± 6	440	580(0.93)		
OG530	3	530 ± 6	460	600(0.93)		
OG550	3	550 ± 6	480	620(0.93)		
OG570	3	570 ± 6	500	640(0.93)		
OG590	3	590 ± 6	510	660(0.93)		
RG610	3	610 ± 6	530	690(0.94)		
RG630	3	630 ± 6	540	710(0.94)		
RG645	3	645 ± 6	560	720(0.94)		
RG665	3	665 ± 6	580	750(0.96)		
RG695	3	695 ± 6	610	780(0.96)		
RG715	3	715 ± 9	620	810(0.96)		
RG780	3	780 ± 9	610	900(0.97)		
RG830	3	830 ± 9	670	950(0.97)		
RG850	3	850 ± 9	700		950(0.90)	1200(0.97)
RG1000	3	1000 ± 6	730	1300(0.90)		
N-WG280	2	280 ± 6	230	380(0.99)		
N-WG295	2	295 ± 6	250	400(0.99)		
N-WG305	2	305 ± 6	260	420(0.99)		
N-WG320	2	320 ± 6	280	470(0.99)		

Table 12.3: Filter glass product range: specified value (spectral values guaranteed)

13. Filter glass product range: reference values

Filter glass type	Density ρ [g/cm³]	Reflection factor P for λ = 587.6 nm	Refractive index n for λ = 587.6 nm	Bubble class	Stain resistance FR	Acid resistance SR	Alkali resistance AR	Transformation temperature Tg [°C]	Thermal expansion $\alpha_{-30/+70°C}$ $[10^{-6}/K]$	Thermal expansion $\alpha_{20/300°C}$ $[10^{-6}/K]$	Temperature coefficient T_K [nm/°C]	Notes
UG1	2.77	0.91	1.54	1	0	1.0	1.0	603	7.9	8.9		V
UG5	2.85	0.91	1.54	2	0	3.0	2.0	462	8.1	9.4		V, [!!]
UG11	2.92	0.91	1.56	2	0	3.0	2.2	545	7.8	9.0		V, [!!]
BG3	2.56	0.92	1.51	1	0	1.0	1.0	478	8.8	10.2		V
BG7	2.61	0.92	1.52	1	0	1.0	1.0	468	8.5	9.9		
BG18	2.68	0.91	1.54	2	0	2.0	2.0	482	7.4	8.8		
BG25	2.56	0.92	1.51	1	0	1.0	1.0	487	8.7	10.1		V
BG36	3.59	0.88	1.69	3	1	52.2	1.2	657	6.1	7.2		
BG38	2.66	0.92	1.53	2	0	2.0	2.0	482	7.5	8.9		
BG39	2.74	0.91	1.54	2	0	5.1	3.0	322	11.6	13.1*		[!!]
BG40	2.74	0.92	1.53	2	0	5.1	3.0	313	11.9	13.7*		[!]
BG42	2.69	0.91	1.54	2	0	2.0	2.0	475	7.3	8.7		
VG9	2.87	0.91	1.55	1	0	1.0	1.0	462	9.2	10.6		
GG395	2.55	0.92	1.52	3	0	1.0	1.0	538	7.8	9.0	0.07	
GG400	2.55	0.92	1.52	3	0	1.0	1.0	537	7.9	9.1	0.07	
GG420	2.55	0.92	1.52	3	0	1.0	1.0	535	7.8	9.0	0.07	
GG435	2.55	0.92	1.52	3	0	1.0	1.0	537	7.8	9.1	0.08	
GG455	2.56	0.92	1.52	3	0	1.0	1.0	529	8.2	9.5	0.09	
GG475	2.56	0.92	1.52	3	0	1.0	1.0	531	8.2	9.4	0.09	
GG495	2.56	0.92	1.52	3	0	1.0	1.0	535	8.1	9.4	0.10	
OG515	2.56	0.92	1.51	3	0	1.0	1.0	509	7.9	9.0	0.11	
OG530	2.56	0.92	1.51	3	0	1.0	1.0	506	7.9	9.0	0.11	
OG550	2.56	0.92	1.51	3	0	1.0	1.0	507	7.9	9.0	0.12	
OG570	2.56	0.92	1.51	3	0	1.0	1.0	510	7.9	9.0	0.12	
OG590	2.56	0.92	1.51	3	0	1.0	1.0	506	7.9	9.0	0.13	

Table 13: Filter glass product range: reference values

*$\alpha_{20/200°C}$

Filter glass type	Density ρ [g/cm³]	Reflection factor P for λ = 587.6 nm	Refractive index n for λ = 587.6 nm	Bubble class	Stain resistance FR	Acid resistance SR	Alkali resistance AR	Transformation temperature Tg [°C]	Thermal expansion $\alpha_{-30/+70°C}$ [10^{-6}/K]	Thermal expansion $\alpha_{20/300°C}$ [10^{-6}/K]	Temperature coefficient T_K [nm/°C]	Notes
RG9	2.58	0.92	1.52	3	0	1.0	1.0	519	7.9	9.0	0.06	
RG610	2.65	0.92	1.52	3	0	1.0	1.0	520	8.0	9.2	0.14	
RG630	2.65	0.92	1.52	3	0	1.0	1.0	527	8.0	9.2	0.14	
RG645	2.65	0.92	1.52	3	0	1.0	1.0	519	8.0	9.2	0.16	
RG665	2.77	0.91	1.54	3	0	1.0	1.0	527	8.1	9.4	0.17	
RG695	2.76	0.91	1.54	3	0	1.0	1.0	532	8.1	9.4	0.18	
RG715	2.76	0.91	1.53	3	0	1.0	1.0	532	8.1	9.4	0.18	
RG780	2.94	0.91	1.56	3	5	53.4	1.3	552	9.5	10.5	0.22	
RG830	2.94	0.91	1.56	3	5	53.4	1.3	554	9.5	10.5	0.23	
RG850	2.93	0.91	1.56	3	5	53.4	1.3	554	9.5	10.5	0.24	
RG1000	2.73	0.91	1.54	3	0	1.0	1.0	476	9.0	10.3	0.41	
NG1	2.47	0.92	1.52	2	1	2.2	1.0	471	6.6	7.2		
NG3	2.44	0.92	1.51	2	1	2.2	1.0	462	6.5	7.3		
NG4	2.43	0.92	1.51	2	1	2.2	1.0	483	6.7	7.2		
NG5	2.43	0.92	1.50	2	1	3.2	2.0	474	6.6	7.3		
NG9	2.45	0.92	1.51	2	1	3.2	2.0	470	6.4	7.2		
NG11	2.42	0.92	1.50	2	1	3.4	2.0	481	6.9	7.5		
N-WG280	2.51	0.92	1.52	1	0	1.0	2.0	558	7.1	8.4	0.06	
N-WG295	2.51	0.92	1.52	1	0	1.0	2.0	565	7.2	8.4	0.06	
N-WG305	2.51	0.92	1.52	1	0	1.0	2.0	562	7.1	8.4	0.06	
N-WG320	2.51	0.92	1.52	1	0	1.0	2.0	563	7.1	8.4	0.06	
KG1	2.53	0.92	1.52	3	0	2.0	3.0	599	5.3	6.1		V, [!]
KG2	2.52	0.92	1.51	3	0	2.0	3.0	605	5.4	6.3		V, [!]
KG3	2.52	0.92	1.51	3	0	2.0	4.0	581	5.3	6.1		V, [!]
KG5	2.53	0.92	1.51	3	0	3.0	4.0	565	5.4	6.2		V, [!]

Table 13: Filter glass product range: reference values (continued)

14. Internal transmittance graphs (spectral range from 200 to 1200 nm)

The internal transmittance curves are to be understood to be typical curves for first information only. Additional information is contained in the data sheets. The information relating to filter color, which is more or less subjective, is based on the reference thickness listed for the filter glasses and should only serve as a point of reference. The determination was made in natural daylight. The data sheets contain additional information regarding colorimetric evaluations.

UV band pass filters

UG1, UG5, UG11

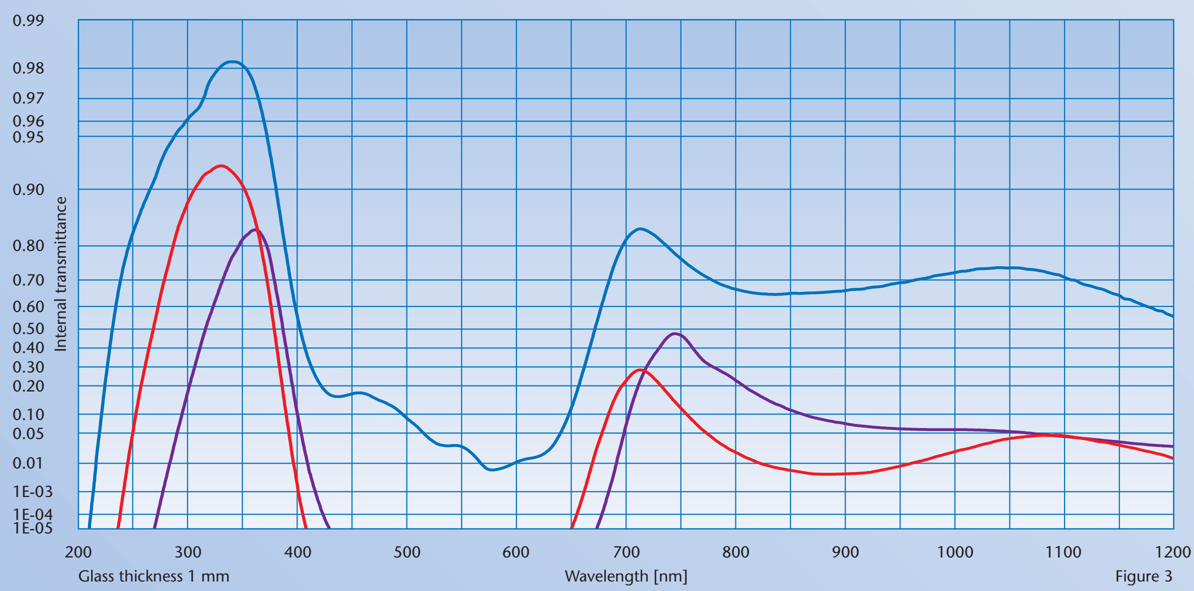


Figure 3

Color: dark violet-black (UG1)
dark violet (UG5)
dark red-black (UG11)

UG5 UG11
UG1

Band pass filter

BG3

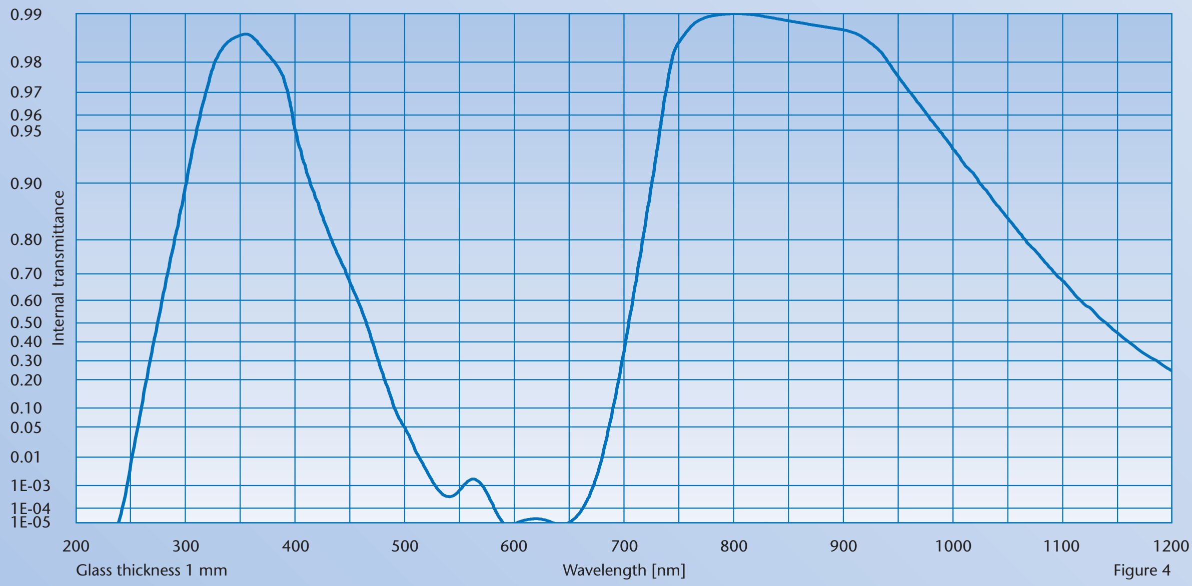


Figure 4

Color: blue

BG3

Band pass filter

BG25

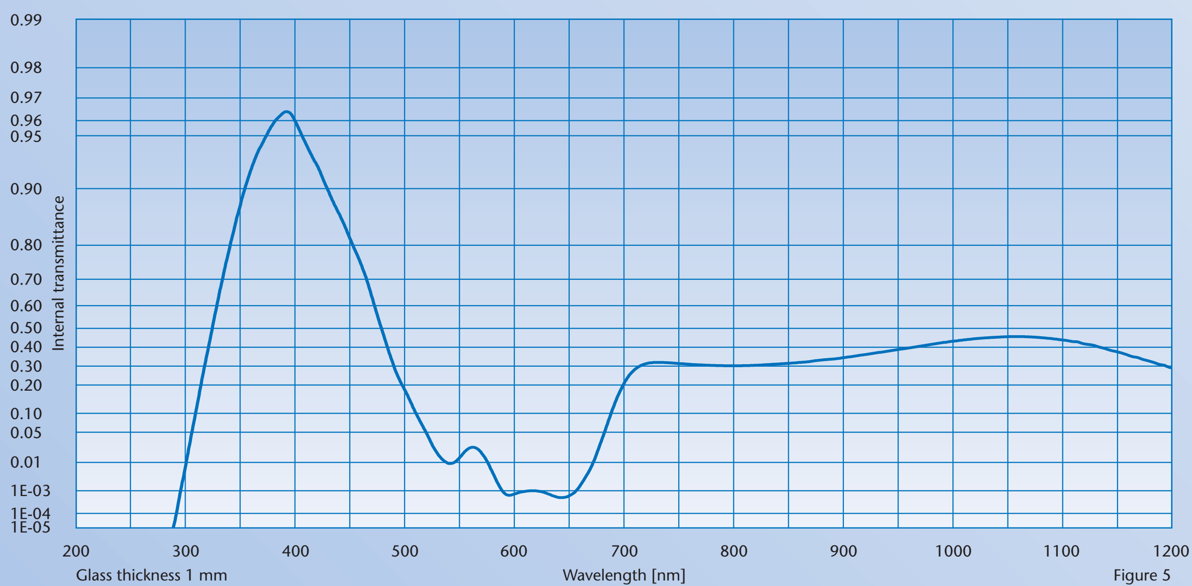


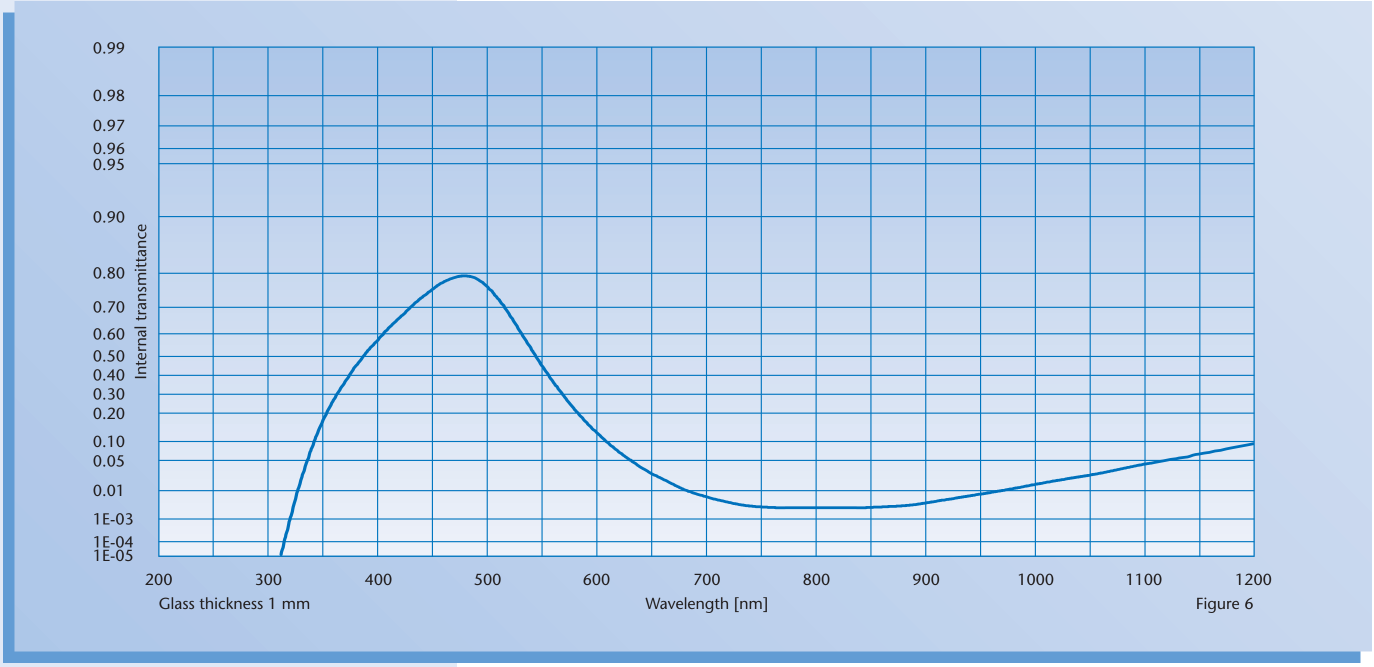
Figure 5

Color: blue

BG25

Band pass filter

BG7

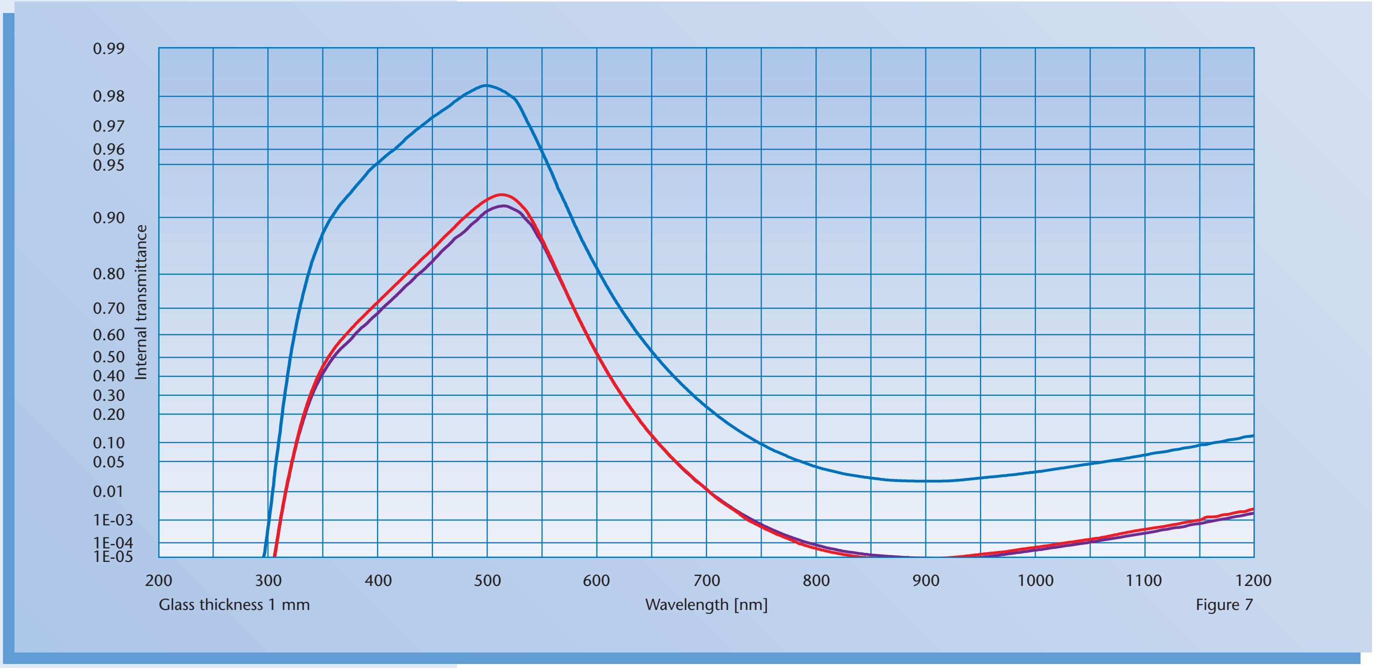


Color: blue

BG7

Band pass filter

BG18, BG38, BG42



Color: bright blue-green

BG38
BG42
BG18

Band pass filter

BG39, BG40

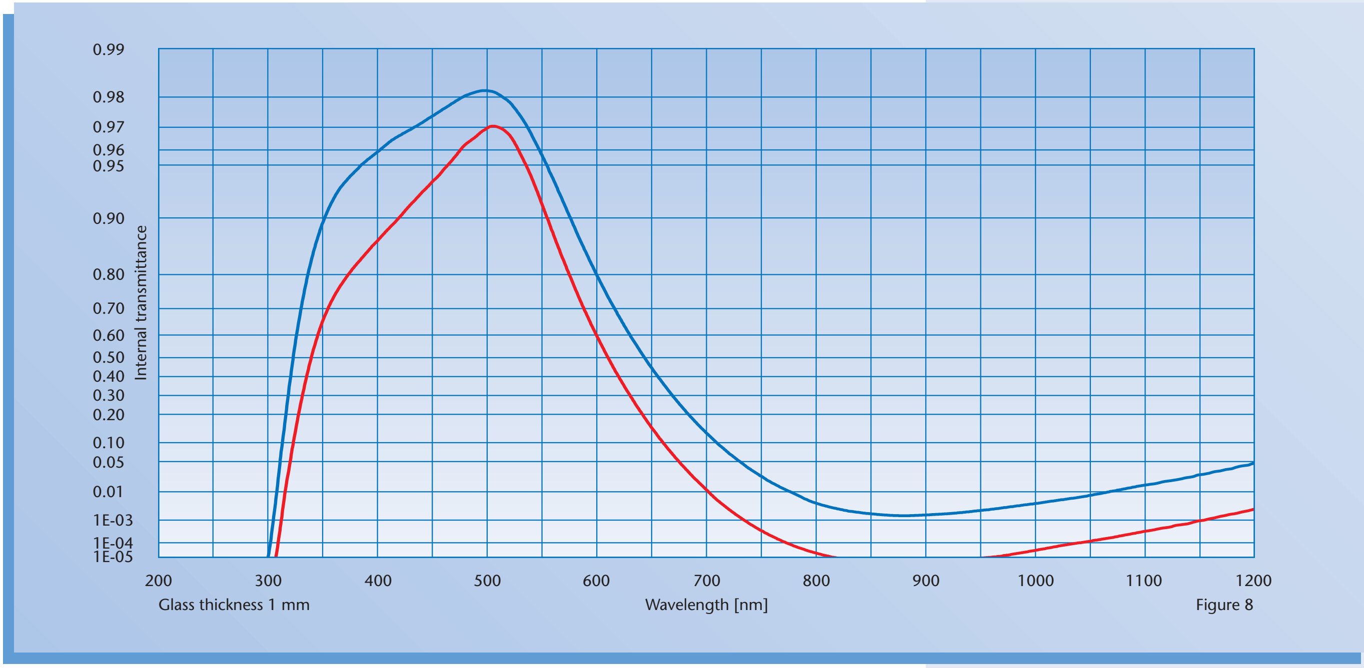


Figure 8

Color: bright blue

BG40 BG39

Band pass filter

VG9

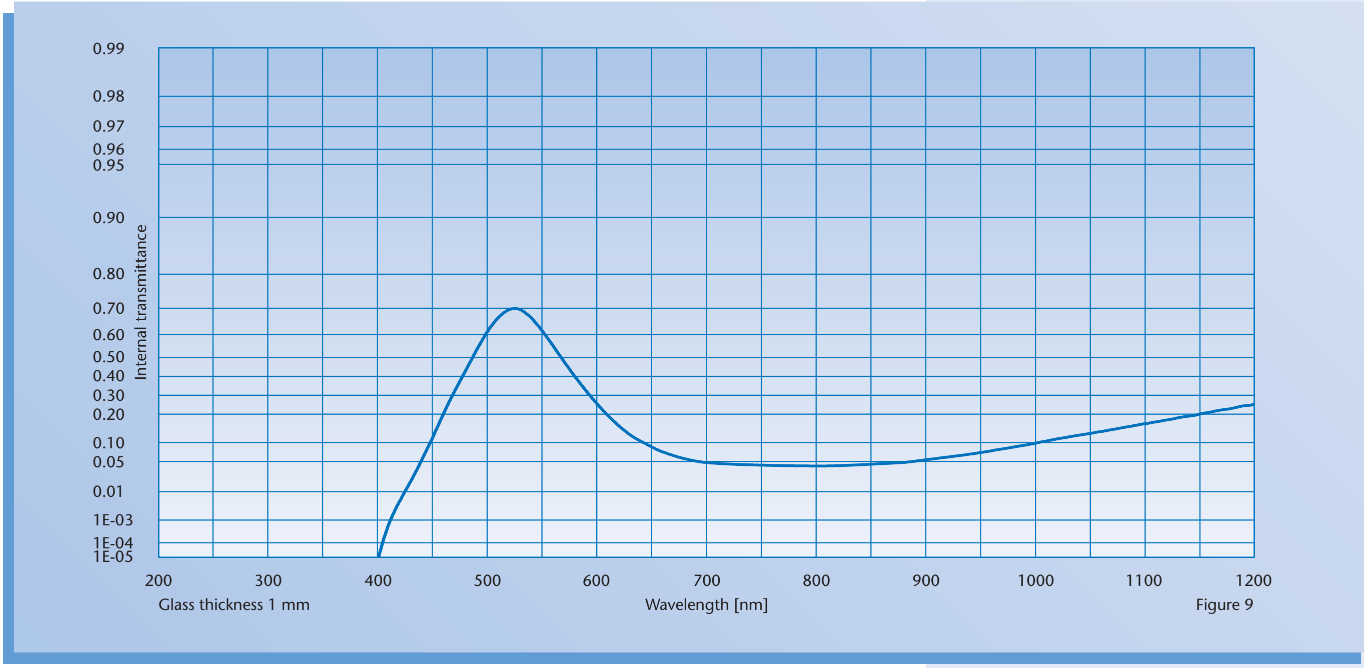


Figure 9

Color: green

VG9

Long pass filters

N-WG280, N-WG295, N-WG305, N-WG320
GG395, GG400, GG420, GG435, GG455, GG475, GG495
OG515, OG530, OG550, OG570, OG590
RG610, RG630, RG645, RG665, RG695, RG715, RG780,
RG830, RG850, RG1000

Long pass / band pass filter

RG9

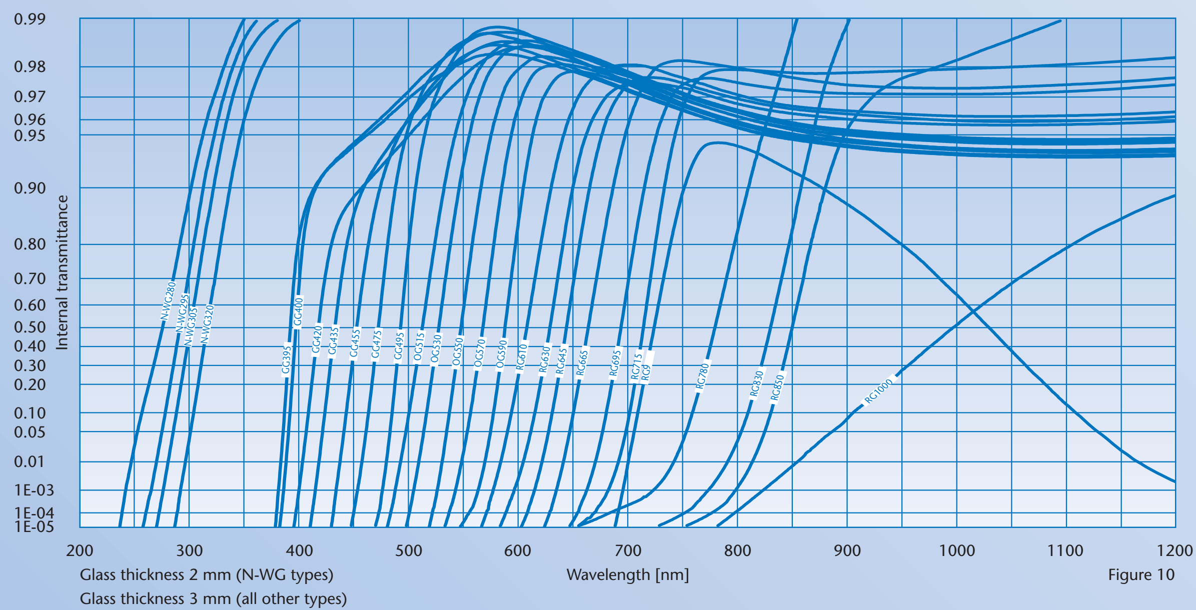
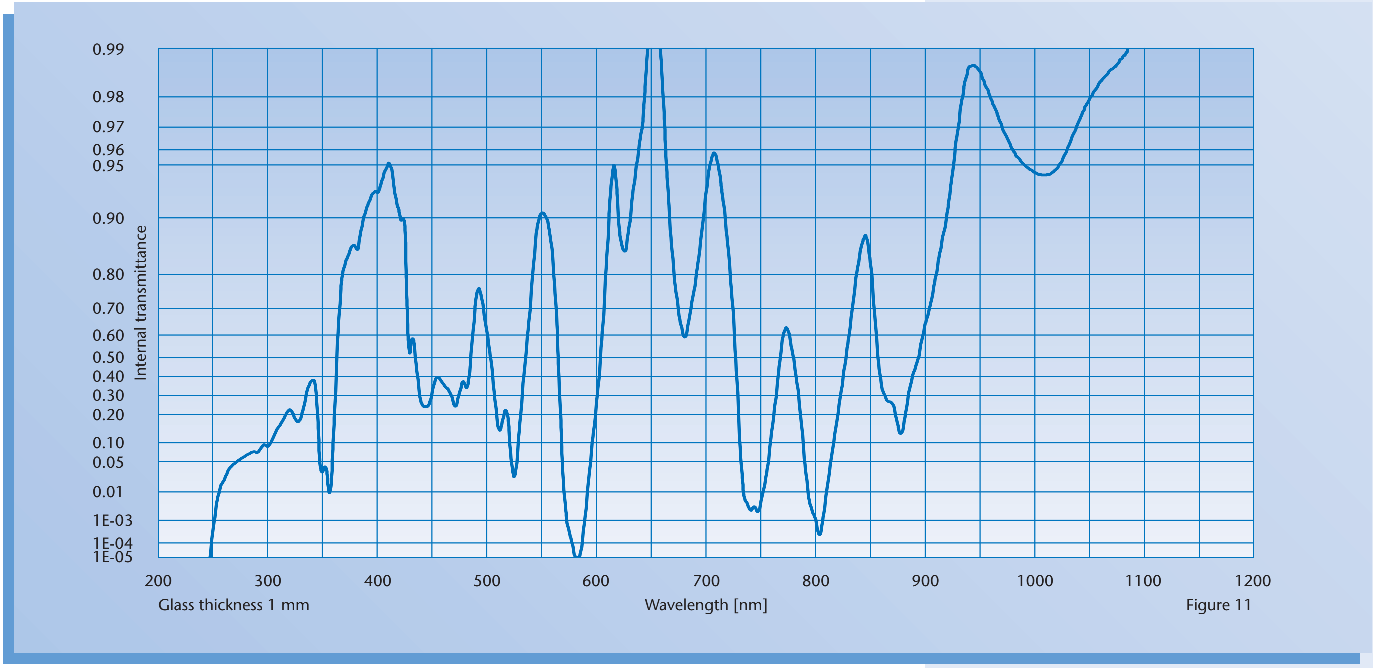


Figure 10

Color: range from clear (N-WG280) to pale green, yellow, orange, and red to black (RG1000)

Multiband filter

BG36



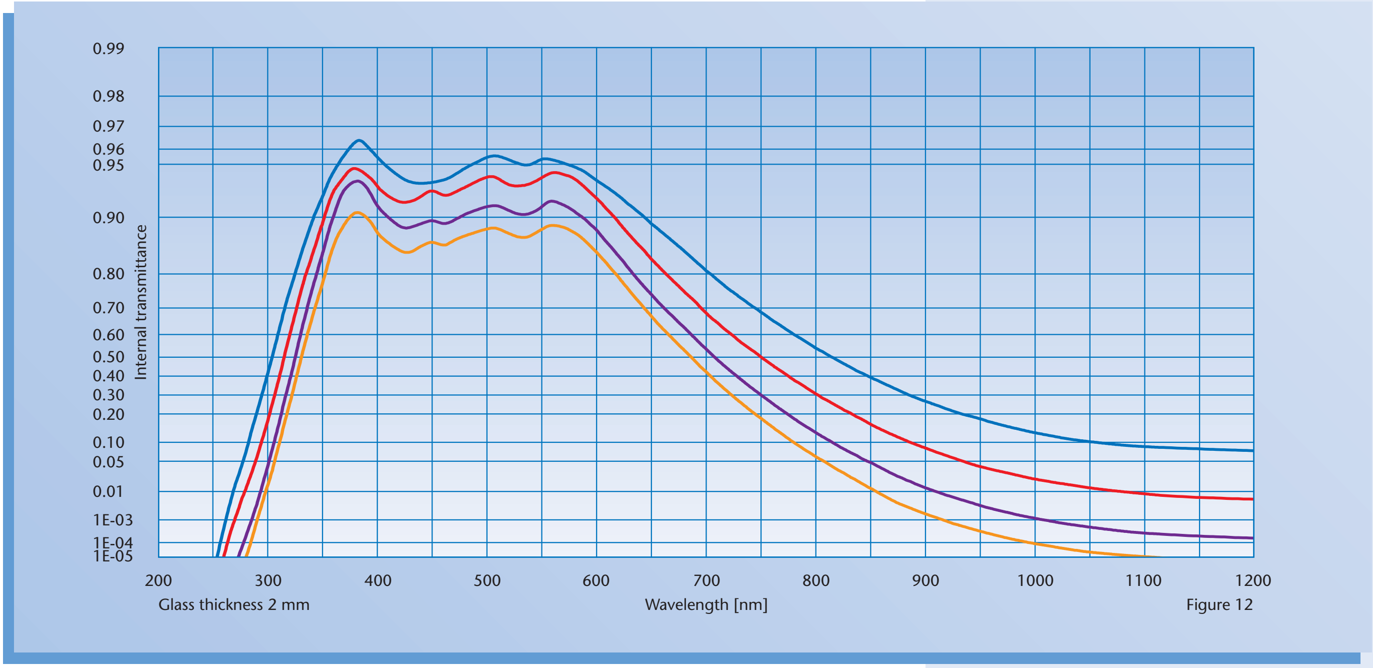
Color: pale brown-violet

BG36

Short pass filters

Application as heat protection / cold light filters

KG1, KG2, KG3, KG5



Color: nearly clear
(light greenish tint)

KG2 KG1
KG3 KG5

Neutral density filters

NG1, NG3, NG4, NG5, NG9, NG11

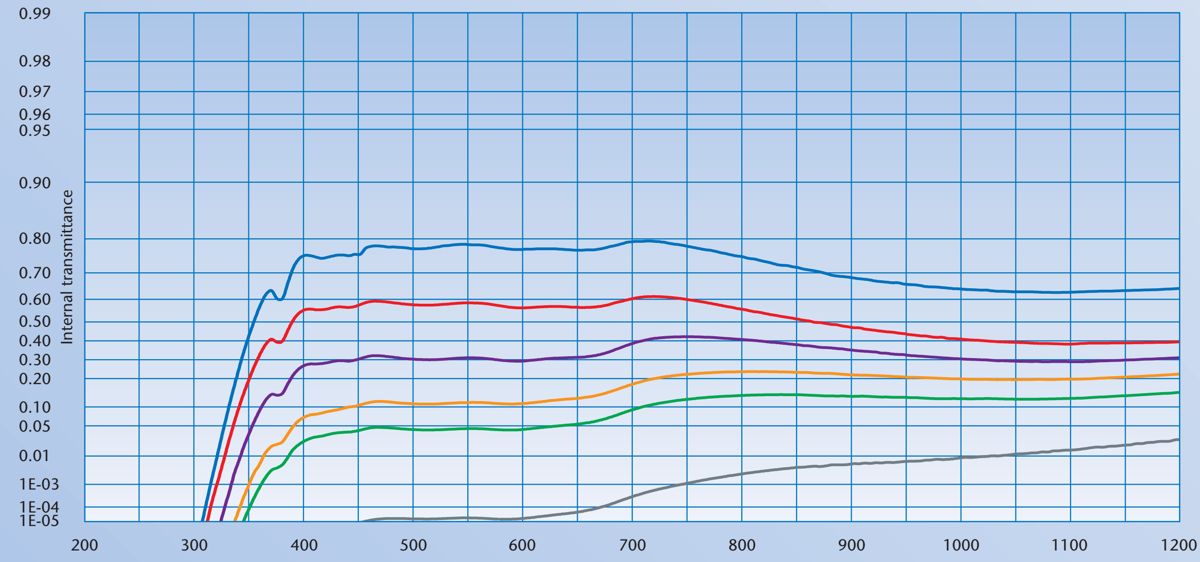


Figure 13

Color: bright gray to dark gray

NG11 NG5
NG4 NG3
NG9 NG1

For your notes

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