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SCHOTT Optical Filter Glass

Filter Technology: Which Type is Right for Your Application?

Introduction

SCHOTT Academy of Optics is a free, online seminar series designed to take your industry knowledge and expertise to new levels.

Throughout the series, you will learn from leading glass and material experts as they cover various topics pertaining to the optics industry.

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When selecting filters for your application it is critical to understand how interference filters and glass filters differ. These two types of filters not only work differently but also vary in their transmittance properties and responses to environmental factors such as temperature. For some applications, combining the two filter types can produce exactly the right optical properties needed.

Optical filters, also known as color glass or volume filters, absorb some of the light energy so that only the desired radiation passes through the glass. Because the absorption is a function of glass thickness, this type of filter tends to be between 0.1 millimeter to several millimeters thick. Interference filters, also known as optical coatings or thin films, use interference effects to reflect unwanted light and transmit the desired wavelengths. Interference is created by alternating very thin layers with different reflective indexes. Because the reflection happens on the surface of this component, these filters can be extremely thin.

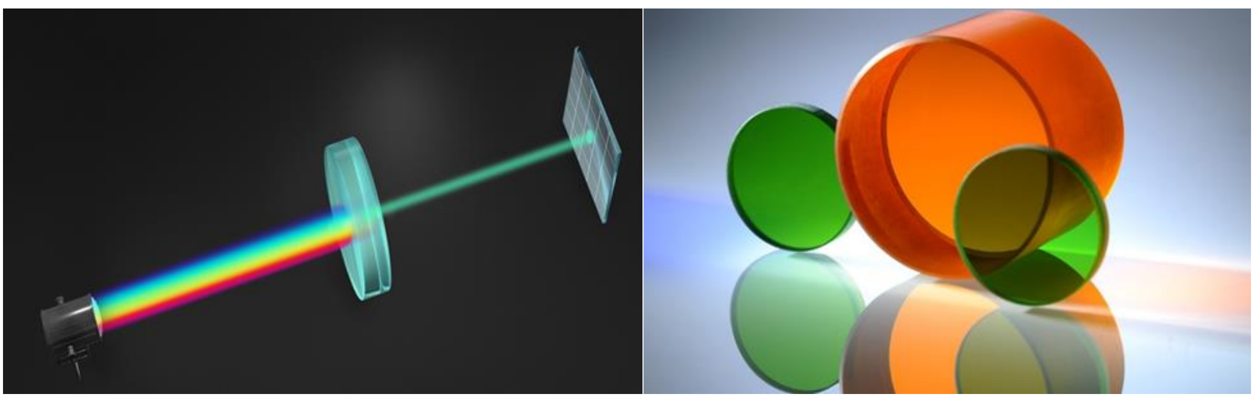

Figure 1: Absorption filters absorb the unwanted light within their volume. Also known as, color glass, volume filters or bulk absorption filters.

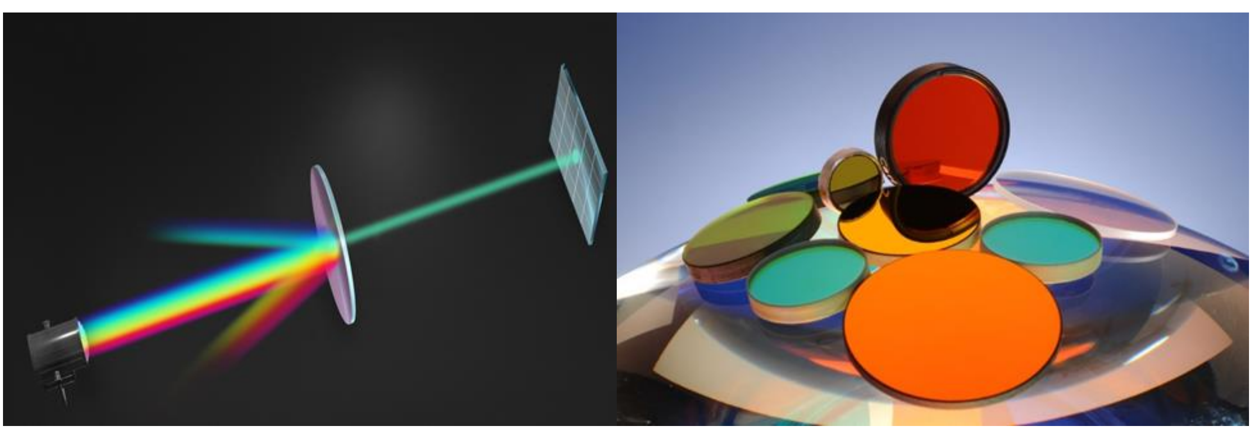

Figure 2: Interference filters are made of alternating thin films that reflect the unwanted light. Also known as optical thin film filters.

1. Transmittance properties

The transmission characteristics of a filter are one of the most important considerations. The transmission of optical glass filters is a result of the chemical elements they are made from, which means there are a limited number of options available. Glass filters tend to exhibit a steep cut-off in transmission on the short wavelength side and a shallow cut-off on the long wavelength side. Although the transmission of these optical components does not depend on the light's angle of incidence, it does exhibit a reversible dependence on temperature. In the case of colloidally colored longpass filters, the cut-on wavelength shifts linearly with temperature. Higher temperatures move the cut-on wavelength to a longer wavelength. Because of the linear nature of this shift, you can use a temperature coefficient that is listed on the data sheet to calculate the variation of the spectrum with temperature. All other filter glasses have a non-linear temperature dependence.

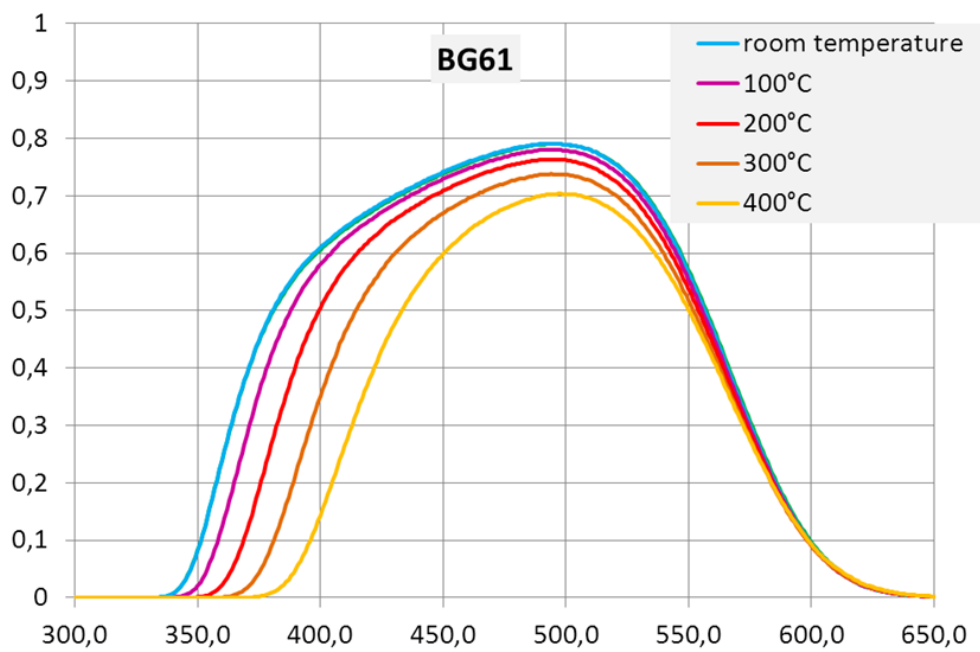

Figure 3: Non-linear variation of the spectrum of a bandpass filter as a function of temperature.

Because of the way they are made, interference filters can be designed to meet almost any spectral requirement. They typically have a steep cut-off in transmission on both the short and long wavelength sides. When using these filters, it is important to keep in mind that their spectra will slightly shift with increasing ambient temperature due to thermal expansion of the layers. However, this effect is reversible and depends on the coating technology used. Unlike optical filter glasses, the overall transmission spectra of interference filters will shift toward shorter wavelengths with an increasing angle of incidence. As the angle of incidence gets more oblique, this effect gets stronger, leading to a discrete range of incidence angles between which these filters remain optically functional.

2. Graphical representation of the transmittance spectrum

The linear scaling of the transmittance spectrum of a filter has limitations because the blocking properties cannot be displayed. Therefore, we recommend to use a coordinate transformation to the spectral diabatic transmittance. Such a scaling of the abscissa enlarges the region of high transmittance and it enlarges the blocking regime as well. So, blocking and transmittance properties are depicted in the same chart.

The spectral diabatic transmittance is calculated by the formula:

$$\Theta(\lambda) = 1 - \log\left(\log\frac{1}{\tau_i(\lambda)}\right)$$

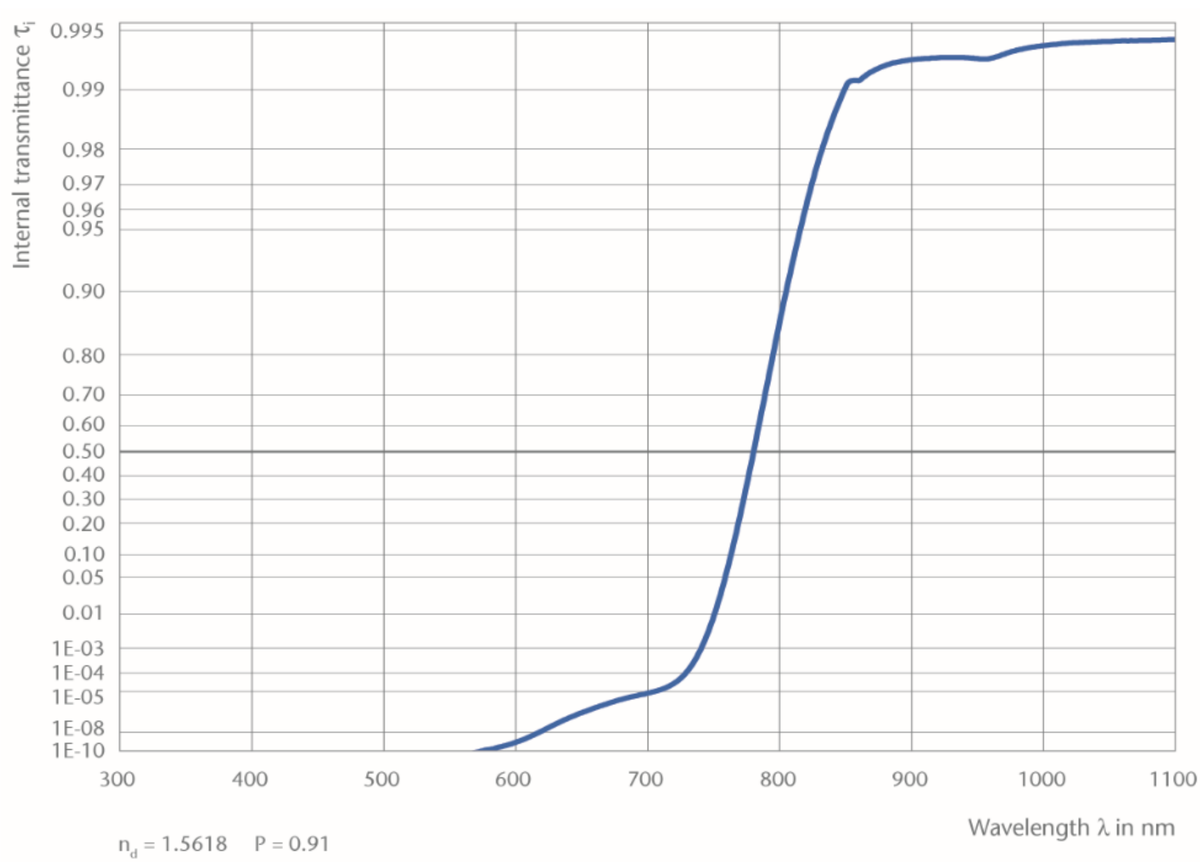

Figure 4: Spectrum of internal transmittance of a longpass filter glass using a diabatic scaling of the abscissa. The region of blocking and the region of high transmittance are easily examinable.

3. Choosing the right filter

Optical glass filters are ideal for applications such as digital color cameras, where NIR cut filters are used to block NIR radiation. An absorptive filter is better for color recognition because the cut-off wavelength does not shift as a function of the angle of incidence. Using an absorption filter also reduces ghosting and stray light problems in a camera lens system because all unwanted radiation is absorbed. An interference filter could reflect radiation back into the lens system, creating stray light and ghosting.

Glass filters are not dependent on polarization and are useful for applications where there is not a need to change the light's polarization. Depending on the glass used, costs can vary a great deal for this type of filter. Filters made from standard stock glasses are typically inexpensive but using a new type of glass can be more costly due to the fabrication effort involved. You will find guaranteed tolerances and spectral values for standard glass filters in our catalog and datasheets. You can also use our filter glass calculation tool to calculate combinations of up to five different glasses, calculate color for any combination of filter and light source, or to obtain numerical filter data.

If your application requires a narrow bandpass filter with steep edges, then interference filters are the only option. Although glass filters are often preferred in color imaging, certain applications require extra-slim designs. For example, interference filters are used in smartphone camera modules because absorptive filters would be too large.

Interference filters are highly customizable, and because they are made using a batch process, costs decrease with greater volumes. When using interference filters, it is important to know that the interference does create some changes in polarization, depending on the angle of incidence. This property can be harnessed to manipulate polarization by using oblique angles of incidence. Although tolerances of below 0.5% of the design wavelength are possible with these filters, tighter specifications will increase the costs because it makes fabrication more complex. Thus, be sure the spectral ranges and tolerance values specified reflect the actual application requirements.

4. Combining filter types

Glass and interference filters can be combined to get the performance needed. This is useful for astronomy applications that require out-of-band blocking over a broad range. Because a rather complex interference filter design is required to block visible light, it is much easier to use a long pass filter glass of RG type as a substrate for an interference bandpass filter design.

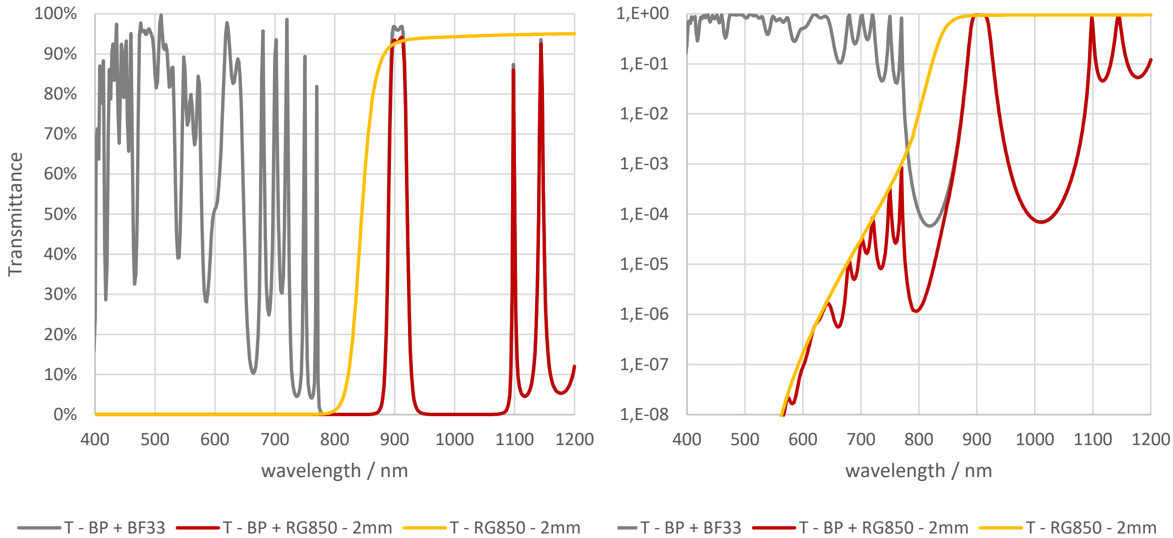

Figure 5: The graphs show the transmittance of different filter elements that can be combined. On the left is a linear scaling and the right shows logarithmic scaling of the ordinate. The grey graph depicts the interference filter design while the orange curve is the filter glass RG850. The red graph shows the result: very low transmittance from 400 nm to 900 nm, a high transmittance area from 900 to 920 nm, and nice blocking from 920 to 1050 nm.

For NIR blocking, combining BG55 glass with a short pass interference filter design can expand the blocking range to give an OD of above 8 for the application wavelength. This can be useful for digital color cameras used in automotive applications. Although a 1- millimeter thick NIR cut filter BG55 glass will produce nice color images, new LIDAR systems being incorporated into cars have a strong laser illumination at 905 nm. This laser emission isn't visible to the human eye but can affect imaging because it is detectable by camera sensors. Applying additional interference filter blocking to the BG55 will help block the laser light.

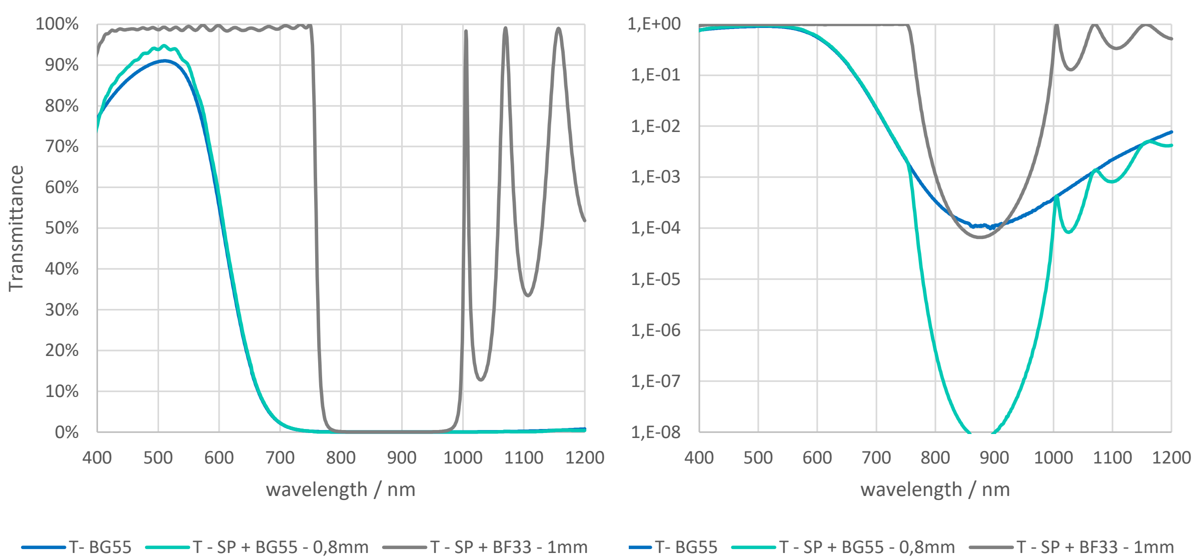

Figure 6: The blue graph shows the filter glass, and the grey graph depicts the interference filter design. The cyan curve displays the combination of the two. As seen in the right graphs, at 900 nm, the transmittance is reduced by four orders of magnitude.

SCHOTT has more than 30 years of experience in manufacturing glass filters and optical coatings that benefit a vast range of applications. This experience enables us to produce a wide range of challenging and complex filters. No matter what kind of filters you are interested in, you can be sure that all SCHOTT's filters, materials, and production processes follow all relevant regulations, including the Restriction of Hazardous Substances Directive and the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations.

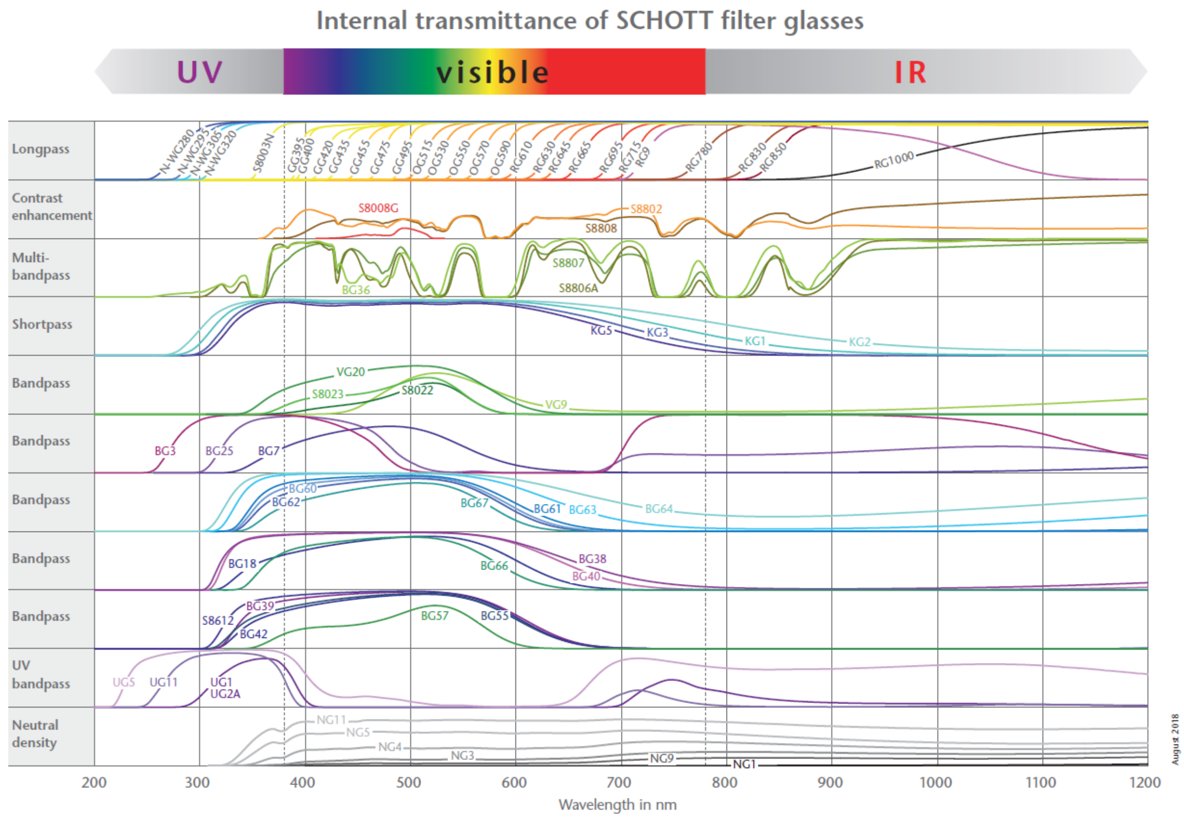

Figure 7: Overview of the filter glass spectra of our portfolio. The picture visualizes the internal transmittance of our standard filter glasses over wavelength.

Want to learn more about optical filter glass?

Check out these related resources:

- H. A. Macleod: Thin-Film Optical Filters, 5th edition, CRC Press, 2017
- E. Hecht: Optics, Global Edition, 5th edition, Pearson Education Limited, 2016
- R. R. Willey: Field Guide to Optical Thin Films, SPIE Press, 2006
- H.G. Pfaender: Schott Guide to Glass, Chapman & Hall, London, 1996

You can also find additional information and resources on optical filter glass by visiting our website: schott.com/products/optical-filter-glass.