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Optics and Photonics — Bulk absorption optical filters

Optique et photonique — Filtres optiques à absorption de masse

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Foreword

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The optical properties of a bulk absorption filter are characterized by spectrophotometric values. These values relate to the energy transported by electromagnetic waves (radiant or luminous) and they vary as a function of wavelength. Additional influences can be caused by scattering.

NOTE 1 The functional spectral dependency is generally indicated by including the wavelength, λ, in parentheses as part of the symbol.

NOTE 2 The wavelength, λ, can be replaced by the wavenumber, σ, or the photon energy, $h\nu$, h = Planck constant; ν = frequency. The units recommended are the nanometre (nm) or the micrometre (μm) for the wavelength, the reciprocal centimetre (cm^{-1}) for the wavenumber and the electron volt (eV) for the photon energy. Bulk absorption filters are defined according to their function, i.e. according to the nature of the principal modification of the spectral transmission (see Table 1).

Optics and Photonics — Bulk absorption optical filters

1 Scope

This document specifies filter functions of uncoated bulk absorption filters for optical applications excluding ophthalmic optics (spectacles) and gives a standard form for their specification. Additionally, basic definitions and a description of the specification concerning optical bulk absorption filters are given.

This document specifies the optical properties of the filters and the test and measurement methods whenever necessary.

This document does not specify any material properties (internal quality, homogeneity, etc.) and it does not apply to any production method.

This document applies to both the raw material (filter glass, filter plastics, etc.) and the polished component.

NOTE 1 Colorimetric parameters for the description of the filter function are specified in e.g. ISO 11664-1 and ISO 11664-2.

NOTE 2 For filters where the spectral transmission characteristics are achieved by the application of optical coatings, see ISO 9211 series.

NOTE 3 In the case of high power applications, further optical effects may occur.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9211-1, *Optics and photonics — Optical coatings — Part 1: Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9211-1 and the following terms and definitions apply.

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

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

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

3.1 Boundary conditions

3.1.1
optical surface
optically effective surface, into which the radiation enters the bulk absorption filter or from which it leaves

Note 1 to entry: In general, bulk absorption filters are made as plane parallel plates and have two optical surfaces which are opposite to each other.

3.1.2
angle of incidence
Θ
angle between the normal to the optical surface and the incident ray

Note 1 to entry: Unless otherwise specified, the angle of incidence is equal to 0°; this means the incident rays are normal to the optical surface.

[SOURCE: ISO 9211-1:2018, 3.1.2.6, modified — Note 1 to entry was added.]

3.1.3
thickness
d
geometrical length that the radiation passes through the bulk absorption filter at normal incidence to the optical surfaces

Note 1 to entry: At normal incidence onto a plane parallel bulk absorption filter the path length of the radiation is equal to the thickness, *d*, of the bulk absorption filter. All parameters and characteristic numbers of this document are referenced to the case of normal incidence, when the path length and the thickness of the bulk absorption filter are the same.

Note 2 to entry: For the case of non-normal incidence, the thickness is not equal to the path length of the light.

3.1.4
witness sample
sample, which represents the bulk absorption filter component and which is used for spectral measurements and environmental testing

Note 1 to entry: The details about the witness sample and the measurement (i.e. material, surface condition, geometry, number per batch) may be subject to the negotiation between manufacturer and customer.

[SOURCE: ISO 9211-1:2018, 3.1.1.6, modified — In the note "sampling procedures" has been replaced by "measurement".]

3.2 Optical properties

3.2.1
spectral transmittance
$\tau(\lambda)$
ratio of the spectral radiant flux transmitted to that of the incident radiant flux

Note 1 to entry: The spectral transmittance is dependent on the internal absorption properties, especially on the travel path of the light, as well as on the optical properties of the surface.

$$\tau(\lambda) = \frac{\Phi_{e\lambda,2}}{\Phi_{e\lambda,1}} \tag{1}$$

where

$\Phi_{e\lambda,1}$ is the incident spectral radiant flux;

$\Phi_{e\lambda,2}$ is the transmitted spectral radiant flux.

Note 2 to entry: See Figure 1.

Note 3 to entry: Wherever the Greek letter τ is mistakable T may be used.

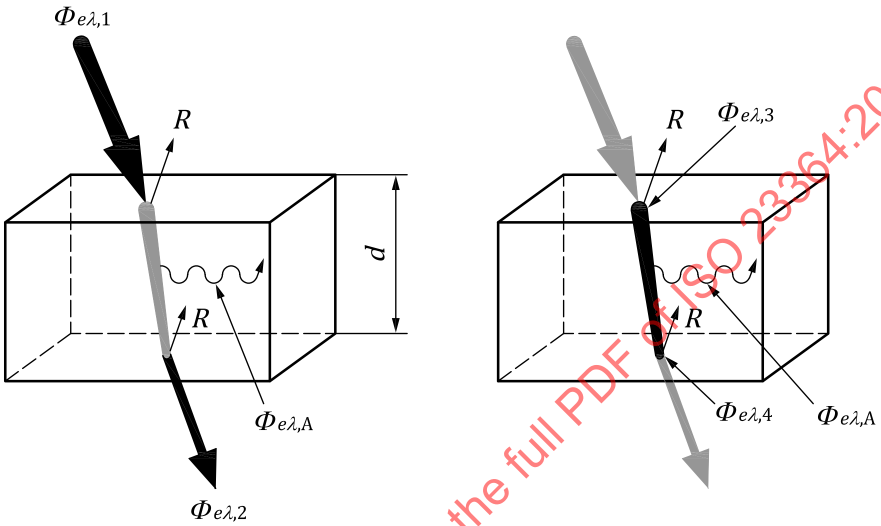
Note 4 to entry: If necessary, the transmittance can be represented as an average over a wavelength range from λ_1 to λ_2 as follows:

$$\tau_{\text{ave}}(\lambda_1 \text{ to } \lambda_2) = \frac{\int_{\lambda_1}^{\lambda_2}\tau(\lambda)\mathrm{d}\lambda}{\lambda_2 - \lambda_1} \approx \frac{\sum_{i=1}^{\mathrm{m}}\tau(\lambda_i)\Delta\lambda}{\lambda_2 - \lambda_1} = \frac{\sum_{i=1}^{\mathrm{m}}\tau(\lambda_i)}{\mathrm{m}} \quad (2)$$

where

$\Delta\lambda = (\lambda_2 - \lambda_1)/\mathrm{m}$

Note 5 to entry: The subscript "ave" stands for "average". As an alternative the subscript "avg" may be used.



NOTE The light falls onto the optical surface at normal incidence, however, it is sketched at an angle in order to visualize the surface reflection R. As such, path length of the light and geometrical thickness d are the same.

Figure 1 — Sketch for depicting the differences between transmittance and internal transmittance

3.2.2
spectral internal transmittance

$\tau_{\mathrm{i}}(\lambda)$

ratio of the spectral radiant flux arriving without reflection at the exit surface of the bulk absorption filter to that of the entered radiation

Note 1 to entry: The internal transmittance describes the properties inside the material, thus surface effects do not have an influence.

Note 2 to entry: The subscript "i" stands for "internal".

$$\tau_{\mathrm{i}}(\lambda) = \frac{\Phi_{e\lambda,4}}{\Phi_{e\lambda,3}} \quad (3)$$

where

$\Phi_{e\lambda,3}$ is the spectral radiant flux, which has entered the volume;

$\Phi_{e\lambda,4}$ is the spectral radiant flux, which is going to leave the volume.

Note 3 to entry: For bulk absorption filters with a homogeneous distribution of absorption within the material the following applies:

$$\tau_{\mathrm{i}} = e^{-\alpha_{\mathrm{i}}d} \quad (4)$$

where

α_l is the absorption coefficient;

d is the thickness of the bulk absorption filter.

From this context, the internal transmittance can be calculated for different thicknesses of the bulk absorption filter (at normal incidence) by:

$$\tau_{i,d_1} = \left(\tau_{i,d_2}\right)^{\left(\frac{d_1}{d_2}\right)} \tag{5}$$

where

τ_{i,d_1} is the internal transmittance that corresponds to the thickness d_1 ;

τ_{i,d_2} is the internal transmittance that corresponds to the thickness d_2 .

Note 4 to entry: See Figure 1.

3.2.3
cut-off wavelength of the internal transmittance
$\lambda_{i0,5}$
wavelength in the transition between a region of high and a region of low transmittance, where the transmittance has a value of $\tau_i = 0{,}5$

Note 1 to entry: The subscript “i” stands for “internal”.

3.2.4
cut-off wavelength of the transmittance
$\lambda_{0,5}$
wavelength in the transition between a region of high and a region of low transmittance, where the transmittance has a value of $\tau = 0{,}5$

Note 1 to entry: The Annex A of ISO 9211-2 defines $\lambda'_{0,5}$ and $\lambda''_{0,5}$ as the wavelength where the transmittance is half of τ_A or τ_M, respectively.

3.2.5
spectral absorptance
$a(\lambda)$
ratio of the spectral concentration of radiant flux absorbed to that of the incident radiation

3.2.6
refractive index
$n(\lambda)$
ratio of the velocity of propagation of electromagnetic radiation in vacuum to the velocity of propagation in a medium

[SOURCE: ISO 9211-1]

3.2.7
reflection factor
$P(\lambda)$
ratio of *spectral transmittance* (3.2.1) to *spectral internal transmittance* (3.2.2)

$$P(\lambda) = \frac{\tau(\lambda)}{\tau_i(\lambda)} \tag{6}$$

Note 1 to entry: When neglecting diffuse scattering the following formula applies at normal incidence onto the bulk absorption filter:

$$P(\lambda) = \frac{2n(\lambda)}{n^2(\lambda) + 1} \tag{7}$$

Note 2 to entry: Because the spectral dependency of $P(\lambda)$ is weak, a constant reflection factor is used in most cases. Unless otherwise specified, a constant reflection factor is used, which is derived at the d-line (587,6 nm).

$$P = P_d = P(\lambda = 587{,}6\ \text{nm}) = \frac{2n_d}{n_d^2 + 1} \tag{8}$$

Note 3 to entry: *P* is the Greek upper case letter Rho.

3.3 Calculated parameters

3.3.1
spectral optical density
$D(\lambda)$
logarithm to the base 10 of the reciprocal of the *spectral transmittance* (3.2.1)

$$D(\lambda) = \lg \frac{1}{\tau(\lambda)} \tag{9}$$

3.3.2
spectral extinction
$E(\lambda)$
logarithm to the base 10 of the reciprocal of the *spectral internal transmittance* (3.2.2)

$$E(\lambda) = \lg \frac{1}{\tau_i(\lambda)} = \frac{\alpha_l d}{\ln(10)} \tag{10}$$

Note 1 to entry: Extinction = Absorbance. Sometimes letter *A* is used.

3.3.3
spectral diabatic transmittance
$\theta(\lambda)$
a characterization of the *spectral internal transmittance* (3.2.2) represented by the following formula:

$$\theta(\lambda) = 1 - \lg\left(\lg \frac{1}{\tau_i(\lambda)}\right) \tag{11}$$

Note 1 to entry: For transformation of spectral internal transmittance and spectral diabatic transmittance see Annex A.

3.3.4
luminous transmittance
τ_V
ratio of the luminous flux transmitted by an ocular or filter to the incident luminous flux for a specified illuminant and photopic vision

Note 1 to entry: This is usually expressed as a percentage and is calculated from the following formula:

$$\tau_V = 100 \times \frac{\int_{380\ \text{nm}}^{780\ \text{nm}} \tau(\lambda) \cdot S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda}{\int_{380\ \text{nm}}^{780\ \text{nm}} S_{D65}(\lambda) \cdot V(\lambda) \cdot d\lambda} \tag{12}$$

where

λ is the wavelength of the light in nanometres;

$\tau(\lambda)$ is the spectral transmittance of the ocular or filter;

$V(\lambda)$ is the spectral luminous efficiency function for photopic vision;

$S_{D65}(\lambda)$ is the spectral distribution of incident radiation of CIE standard illuminant D65 (see ISO 11664-2).

Note 2 to entry: Although τ_V is defined as above using the spectral distribution of standard illuminant D65, for other purposes, $S_{D65}(\lambda)$ can be replaced by the spectral distribution of standard illuminant A or the relevant light source.

Note 3 to entry: The values of the spectral radiation distribution of CIE standard illuminant D65, $S_{D65}(\lambda)$ are given in ISO/CIE 11664-2.

Note 4 to entry: The values of the spectral luminous efficiency function $V(\lambda)$ are given in ISO/CIE 11664-1.

Note 5 to entry: The values for the spectral weighting function, $S_{D65}(\lambda) \cdot V(\lambda)$, are given in Annex C.

[SOURCE: ISO 4007:2012-05]

3.4 Definition of bulk absorption filters by their function

3.4.1 Attenuating function

3.4.1.1
ND
code for a bulk absorption filter which reduces the transmittance independent of wavelength at the same ratio

3.4.2 Bandpass function

3.4.2.1
BP
code for a bulk absorption filter which has high transmittance in a defined wavelength region and low transmittance in the neighbouring regions

3.4.3 Bandrejecting function

3.4.3.1
BR
code for a bulk absorption filter which has low transmittance in a defined wavelength region and high transmittance in the neighbouring regions

3.4.4 Longpass function

3.4.4.1
LP
code for a bulk absorption filter which has high transmittance in the region of long wavelengths and low transmittance in the region of short wavelengths

3.4.5 Shortpass function

3.4.5.1
SP
code for a bulk absorption filter which has high transmittance in the region of short wavelengths and low transmittance in the region of long wavelengths

4 Measurement

4.1 General

The optical properties of a bulk absorption filter are defined by spectral radiometric values, see Table 1. These values relate to energy which is transported by electromagnetic waves and they vary as a function of the wavelength and the path length of the light. The polarization of the radiation is not considered in this document. Additional effects may be caused by surface scattering or internal scattering. Scattering effects are not considered in this document.

NOTE 1 A change of the polarization can be caused in the case of non-normal incidence, in special materials or via internal stresses of the material. All these effects are not considered here.

NOTE 2 In order to check their optical properties, bulk absorption filters are usually polished or immersed in oil to eliminate the effect of the surface roughness.

Table 1 — Definition of bulk absorption filters by function

Principal function	Code designation	Definition	Example of application
Attenuation	ND	Bulk absorption filter which reduces the transmittance independent of wavelength at the same ratio.	Neutral density filter
Bandpass	BP	Bulk absorption filter which has high transmittance in a defined wavelength region and low transmittance in the neighbouring regions.	Green filter
Band rejection	BR	Bulk absorption filter which has low transmittance in a defined wavelength region and high transmittance in the neighbouring regions.	Rare earth doped notch filter
Longpass	LP	Bulk absorption filter which has high transmittance in the region of long wavelengths and low transmittance in the region of short wavelengths.	UV-cut filter
Shortpass	SP	Bulk absorption filter which has high transmittance in the region of short wavelengths and low transmittance in the region of long wavelengths.	NIR-cut filter

4.2 Measurement conditions

The measurement conditions for the spectrophotometric characterization shall be subject to an agreement between supplier and user. These conditions depend on the principle of the measurement method and the instruments used, including the angle of incidence, the thickness of the witness sample, the spectral range and bandwidth of the measurement beam, etc. and shall be recorded in sufficient detail to enable verification of the measurement.

Annex B gives a recommendation about the choice of thickness for a witness sample in the case of strong absorption.

5 Numerical specification and graphical representation of spectral characteristics

5.1 General

This document defines the rules for the spectrophotometric characterization of optical bulk absorption filters. Because the spectral properties depend on the thickness *d* of the bulk absorption filter, a specification for the thickness is required at least once. For different spectral properties different thicknesses may be specified.

When the specification is written for a raw material, then there is no tolerance to the thickness and the thickness is a reference value for the spectral characteristic, or vice versa.

When the specification is written for a finished polished filter component, then a tolerance for the thickness must be given as well.

NOTE For high optical densities, the specification of thin witness sample is common, which enables a stable measurement of optical density.

5.2 Rules for the numerical specification of spectral characteristics

5.2.1 Rules for the spectral characteristics, τ_i, τ, τ_V, a, E, D or θ

The general structure of a numerical specification, as distinguished from a graphical specification, of a spectral optical property shall follow the structure of an inequality with the following:

(lower limit term) < or ≤ (spectral optical property term, thickness) < or ≤ (upper limit term)

EXAMPLE 1 (lower limit term) < (spectral optical property term, thickness) ≤ (upper limit term).

The inequality may contain only two terms if the spectral optical property needs to be bounded only on one side.

EXAMPLE 2 (spectral optical property term, thickness) ≤ (upper limit term) or (spectral optical property term, thickness) > (lower limit term)

Table 2 gives a schematic representation of elements necessary for the numerical specification of spectral characteristics.

Table 2 — Scheme of elements for the numerical specification of spectral characteristics

Lower limit (subscript L)	**Comparator sign**	**Spectral optical property**	**Wavelength range, thickness** (or wavenumber range) or single wavelength (or wavenumber)[a]	**Compar-ator sign**	**Upper limit** (subscript U)	***Z* represents any of**
$n = 1, 2, \ldots$			$n = 1, 2, \ldots$		$n = 1, 2, \ldots$	
Z_{Ln}	< or ≤	Z	$(\lambda_n \text{ to } \lambda_{n+1}, d)$ or (λ_n, d)	< or ≤	Z_{Un}	τ_i, τ, τ_V, α, E, D or θ
$Z_{Ln} \rightarrow Z_{Ln+1}$[b]	< or ≤	Z	$(\lambda_n \text{ to } \lambda_{n+1}, d)$	< or ≤	$Z_{Un} \rightarrow Z_{Un+1}$[b]	τ_i, τ, τ_V, α, E, D or θ
$Z_{ave,Ln}$	< or ≤	Z_{ave}	$(\lambda_n \text{ to } \lambda_{n+1}, d)$	< or ≤	$Z_{ave,Un}$	τ_i, τ, τ_V, α, E, D or θ

[a] Each optical property can be specified for different wavelength (or wavenumber) ranges and/or different single wavelengths (or wavenumbers), if necessary.

[b] The arrow → indicates a linear change of the tolerance limit from value Z_{Ln} at λ_n to value Z_{Ln+1} at λ_{n+1} (from value Z_{Un} at λ_n to value Z_{Un+1} at λ_{n+1} respectively).

5.2.2 Rules for the cut-off wavelength and peak transmittance

The cut-off wavelength $\lambda_{i0,5}$ or the peak transmittance shall be given in conjunction with the acceptable tolerances $\Delta\lambda_1$ and $\Delta\lambda_2$.

$$\lambda_{i0,5}(d) = \lambda_{-\Delta\lambda_2}^{+\Delta\lambda_1} \qquad (13)$$

$$\lambda_{\tau_{\mathrm{imax}}}(d) = \lambda_{-\Delta\lambda_2}^{+\Delta\lambda_1} \tag{14}$$

When $\Delta\lambda_1 = \Delta\lambda_2 = \Delta\lambda$ then the formula is simplified to

$$\lambda_{\mathrm{i}0,5}(d) = \lambda \pm \Delta\lambda \tag{15}$$

$$\lambda_{\tau_{\mathrm{imax}}}(d) = \lambda \pm \Delta\lambda \tag{16}$$

Numerical example $\lambda_{\mathrm{i}0,5}(3\ \mathrm{mm}) = 570\ \mathrm{nm}_{-9\ \mathrm{nm}}^{+6\ \mathrm{nm}}$

When more than one cut-off wavelength is specified, the cut-off wavelengths may be distinguished by prime symbols. Where the cut-off wavelength with the shortest wavelength has a prime symbol, the cut-off wavelength with the following longer wavelength has a double prime symbol, and so forth.

$\lambda'_{\mathrm{i}0,5} = 570\ \mathrm{nm} \pm 6\ \mathrm{nm}$

$\lambda''_{\mathrm{i}0,5} = 1\ 200\ \mathrm{nm} \pm 8\ \mathrm{nm}$

$\lambda'''_{\mathrm{i}0,5} = 2\ 800\ \mathrm{nm} \pm 26\ \mathrm{nm}$

Table 3 lists some numerical examples.

Table 3 — Numerical examples

Code Designation	Spectral characteristics/numerical specification
ND	0,3 < τ_i (400 nm to 700 nm, 1 mm) < 0,4
ND	0,2 < τ_{iave} (400 nm to 700 nm, 1 mm) < 0,35
BP	τ_i (200 nm to 350 nm, d = 0,8 mm) < 0,2; τ_i (405 nm to 550 nm) > 0,85; $\lambda_{\mathrm{i}0,5}$ = 650 nm ± 8 nm; τ_i (700 nm to 1 100 nm) < 0,05
LP	τ_i (405 nm to 550 nm) < 1 × 10^{-5}; $\lambda_{\mathrm{i}0,5}$ (3 mm) = 590 nm ± 6 nm; τ_i (660 nm to 1 100 nm) > 0,92
SP	τ_i (405 nm to 550 nm) > 0,92; $\lambda_{\mathrm{i}0,5}$ (2 mm) = 585 nm ± 8 nm; τ_i (700 nm to 1 100 nm) < 0,01

5.3 Rules for the graphical representation of spectral characteristics

Spectrophotometric characterization consists of indicating the following parameters in a graph:

a) on the abscissa, the spectral region in which the characteristics are specified as a function of wavelength λ or the wavenumber σ;

b) on the ordinate, the values of the individual optical properties (τ_i, τ, A, D or Θ) are displayed;

c) the thickness, d, shall be given, for which the optical property refers to.

The upper and/or lower tolerance limits (indicated by subscripts U and L respectively) within which the spectral characteristics are located shall be indicated on the graph with hatched areas outside of the tolerance band. An alternative is the marking with triangles (▲ for the lower tolerance limit and ▼ for the upper tolerance limit) at both edges of the corresponding tolerance band. This way of marking is especially suited for tolerance limits at defined single wavelengths. If average values are specified, this shall be indicated as text on the graph, e.g. $\tau_{ave,L} < \tau_{ave}(\lambda_1 \text{ to } \lambda_2) < \tau_{ave,U}$.

The tolerance limits for the cut-off wavelengths are marked with triangles (symbol ▶ for the lower tolerance limit and ◀ for the upper tolerance limit) at the height of "0,5"-line of the transmittance τ, and of the internal transmittance τ_i, respectively.

If the bulk absorption filter is employed in several spectral regions, the characterization of the function in those different regions may appear on the same representation. Using different scales is permitted if necessary.

5.4 Graphical representation of optical functions

5.4.1 General

The following graphical representations of optical functions are used for specification and actual measurement. If appropriate, specified and measured upper, lower and/or average values can be combined in one graphical representation.

NOTE The curves, the limits and the numerical values shown in the following figures are only examples used for illustration. They are not to be taken as typical or standard values and limits.

5.4.2 Attenuating function (ND)

The attenuating function shall be defined by its upper and lower tolerance limits ($\tau_{i,U}$ and $\tau_{i,L}$, respectively τ_U and τ_L) of the spectral internal transmittance or the spectral transmittance, respectively (D_U, D_L). See Figure 2 for the graphical representation.

General designation:

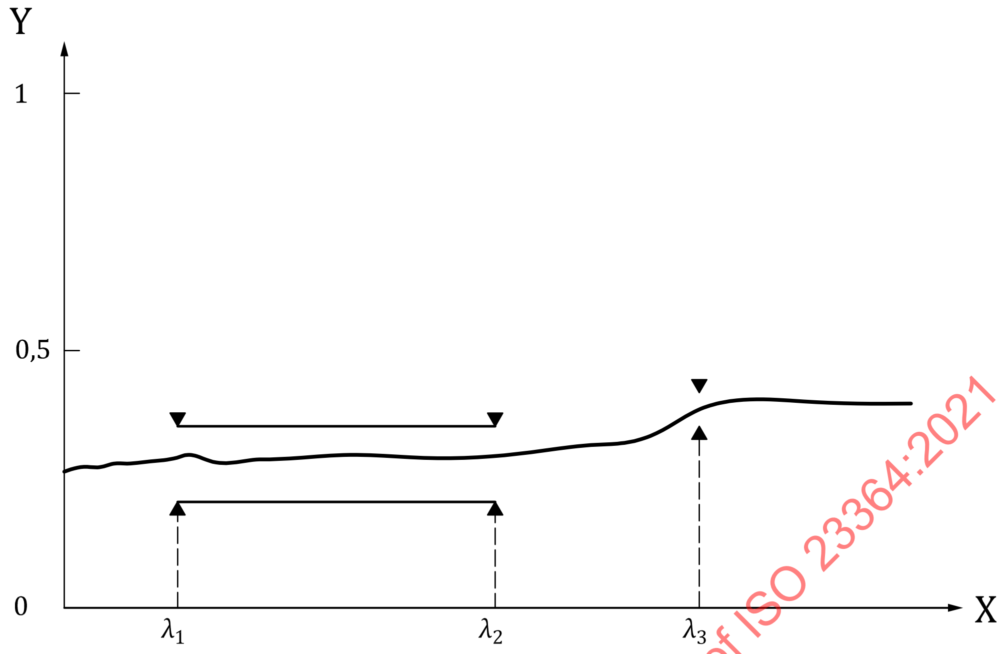
ND $D_{Ln} < D\ (\lambda_n \text{ to } \lambda_{n+1}, d) < D_{Un}$; $n = 1, 3, 5, \ldots$

or

ND $\tau_{i,Ln} < \tau_i\ (\lambda_n \text{ to } \lambda_{n+1}, d) < \tau_{i,Un}$; $n = 1, 3, 5, \ldots$

Numerical example:

ND 0,2 < τ_i (450 nm to 600 nm, 1 mm) < 0,35; 0,35 < τ_i (700 nm) < 0,45



Key

X wavelength λ in nm

Y internal transmittance τ_i

Figure 2 — Sketch of the graphical representation of a neutral density filter at thickness d = 1 mm (attenuating function ND)

5.4.3 Function bandpass (BP) or bandrejection (BR)

The bandpass filtering function or the band rejection filtering function shall be characterized by their upper tolerance limits ($\tau_{i,U}$) of spectral internal transmittance in the blocking ranges and by its lower tolerance limits ($\tau_{i,L}$) of spectral internal transmittance in the pass bands. As an option, the cut-off wavelengths with their tolerances may be specified. See Figure 3 for the graphical representation.

General designation:

BP τ_i (λ_n to λ_{n+1}, d) < $\tau_{i,Un}$;

τ_i (λ_m to λ_{m+1}, d) > $\tau_{i,Lm}$; n = 1, 3, 5, ..., m – 2, m, m + 2,... ;

$\lambda_{i0,5} = \lambda_k \pm \Delta\lambda_k$; k = 1, 2, ...

Numerical example 1:

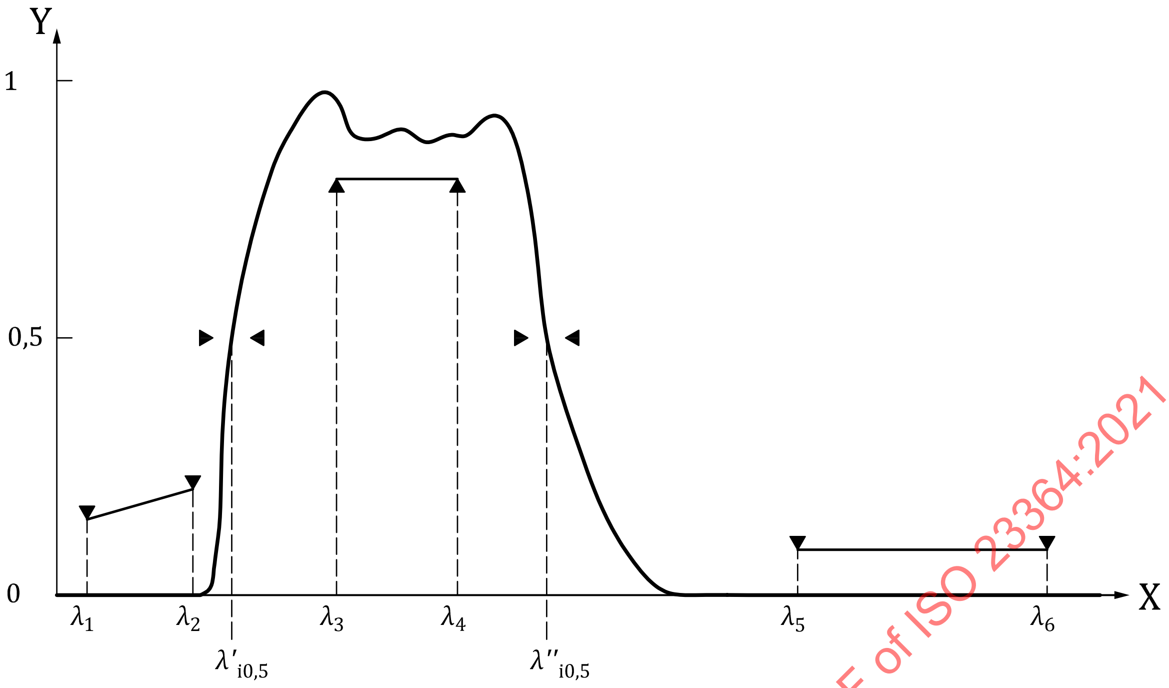
BP τ_i (200 nm to 340 nm, 1 mm) < 0,15 → 0,2;

τ_i (415 nm to 560 nm) > 0,8;

τ_i (710 nm to 1 100 nm) > 0,1;

$\lambda'_{i0,5} = 375\ \text{nm}^{+10\ \text{nm}}_{-8\ \text{nm}}$;

$\lambda''_{i0,5}$ = 650 nm ± 6 nm



Key

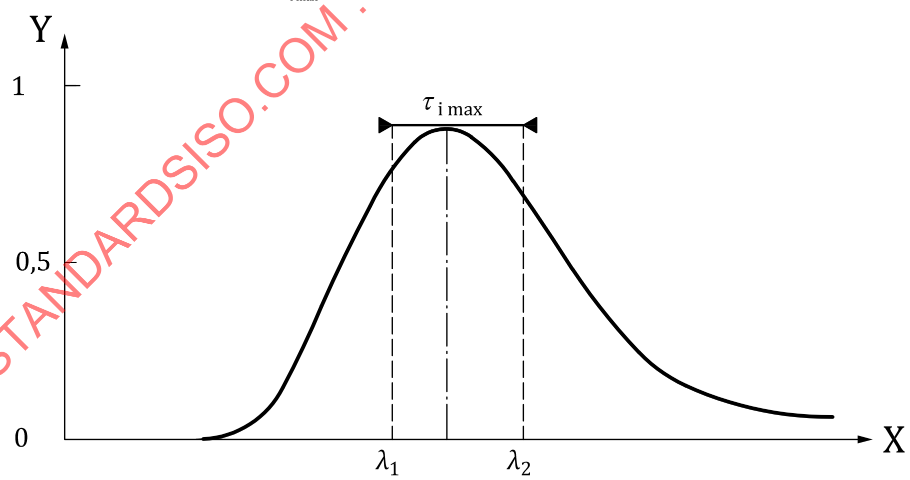
X wavelength λ

Y internal transmittance τ_i

Figure 3 — Sketch for the graphical representation of the specification of a bandpass filter BP at thickness d = 1 mm

Numerical example 2:

BP $0{,}7 \leq \tau_{i\ max}$ (d = 1 mm) $\leq 0{,}8$; $\lambda_{\tau_{i\ max}}$ = 550 nm ± 10 nm ; $0{,}6 \leq \tau_i$ (500 nm to 550 nm) $\leq 0{,}8$

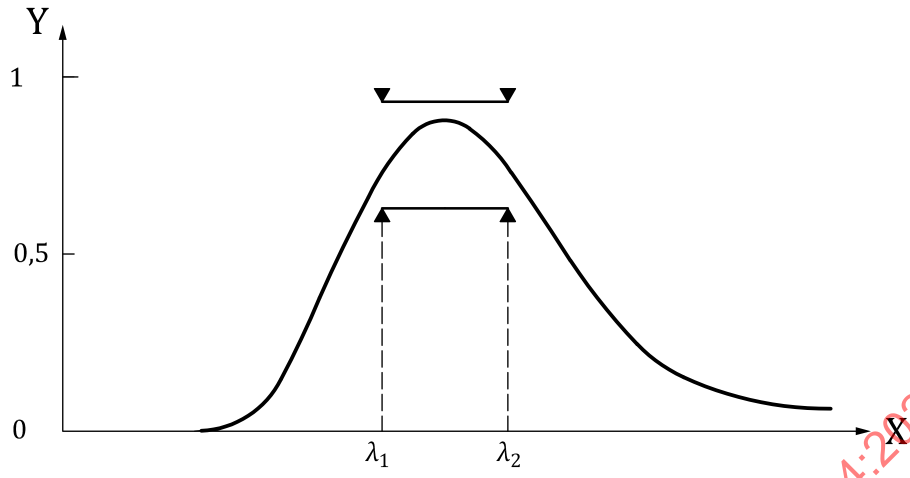


Key

X wavelength, λ

Y internal transmittance, τ_i

Figure 4 — Sketch for the graphical representation of the specification of wavelength range for peak transmittance of a bandpass filter BP at thickness d = 1 mm



Key

X wavelength, λ

Y internal transmittance, τ_i

Figure 5 — Sketch for the graphical representation of the specification of upper and lower limits of transmittance of a bandpass filter BP at thickness d = 1 mm

5.4.4 Function shortpass (SP) or longpass (LP)

The functions shortpass or longpass filtering are characterized by their upper tolerance limits ($\tau_{i,U}$) of spectral internal transmittance in the blocking range and by their lower tolerance limits ($\tau_{i,L}$) of spectral internal transmittance in the pass band. Additionally, the cut-off wavelength $\lambda_{i0.5}$ with its upper and lower limit (λ_L, λ_U) shall be specified. See Figure 4 for the graphical representation of a shortpass filter.

General designation:

LP $\lambda_{i0,5}$ $(d) = \lambda \pm \Delta\lambda$;

τ_i $(\lambda_n$ to $\lambda_{n+1}) < \tau_{i,Un}$;

τ_i $(\lambda_m$ to $\lambda_{m+1}) > \tau_{i,Lm}$; n = 1, 3, 5, .., m – 2, m, m + 2,...

SP $\lambda_{i0,5}$ $(d) = \lambda \pm \Delta\lambda$;

τ_i $(\lambda_n$ to $\lambda_{n+1}) > \tau_{i,Ln}$;

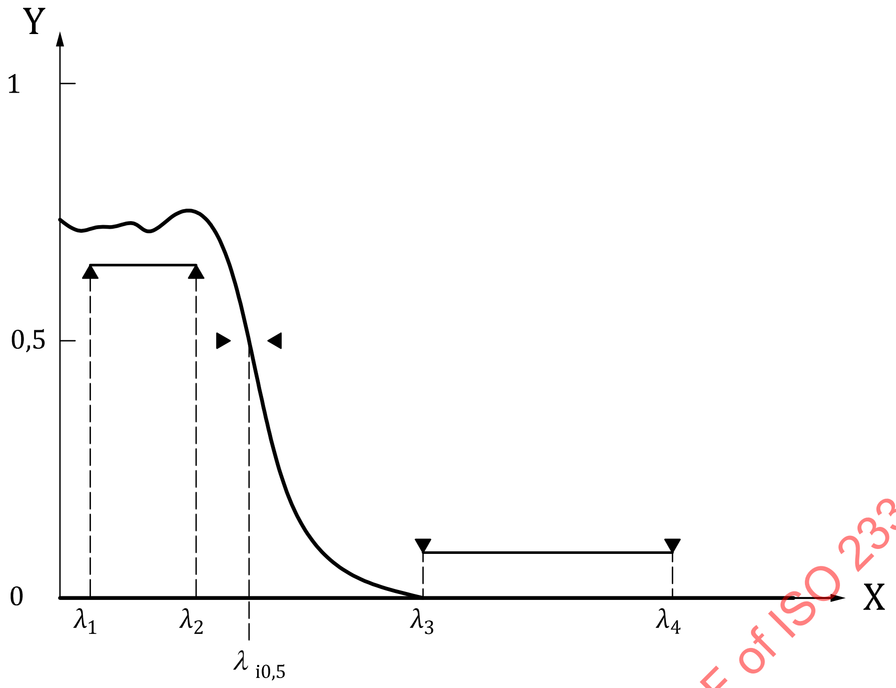
τ_i $(\lambda_m$ to $\lambda_{m+1}) < \tau_{i,Um}$; n = 1, 3, 5, .., m – 2, m, m + 2,...

Numerical example for a shortpass filter:

SP $\lambda_{i0,5}$ (2 mm) = 700 nm ± 6 nm;

τ_i (400 nm to 565 nm) > 0,88;

τ_i (940 nm to 2 200 nm) < 0,01



Key

X wavelength, λ

Y internal transmittance, τ_i

Figure 6 — Sketch for the graphical representation of the specification of a shortpass SP of thickness $d = 2$ mm

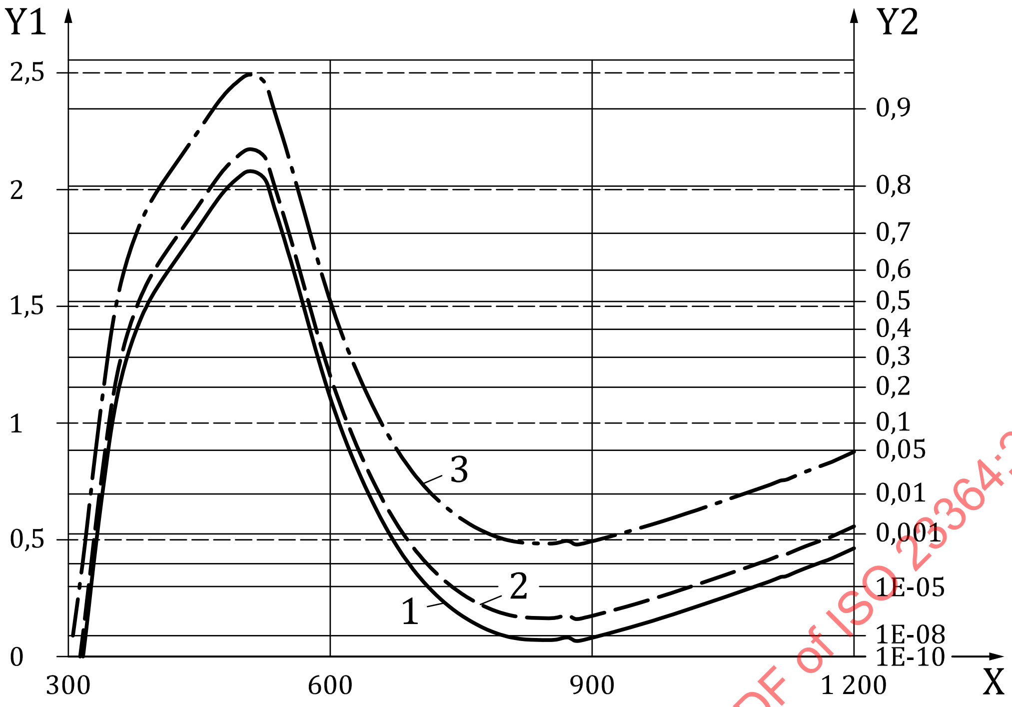
Annex A
(informative)

Graphical representation of transmission using a diabatic scale as an ordinate

The transformation of internal transmittance values into spectral diabatic transmittance-values has big advantages in the graphical representation of the internal transmittance. When the diabatic transmittance is linearly scaled on the ordinate (see leftmost scale from 0 to 2,5 in Figure A.1), the values of the corresponding internal transmittance (second scale in Figure A.1 ranging from 1e–10 to 0,9) are rearranged. This is called a diabatic scale for internal transmittance. The transformation is given by Formula 11, see 3.3.4

By using this coordinate transformation, the region of high transmittance as well as the region of high absorption is enlarged. This gives a clear representation of both regions. (A linear representation would visualize the regime of high transmittance only. Using a logarithmic representation would visualize the regime of absorption only.)

When the transmittance of the same bulk absorption filter material is depicted in this representation for different thicknesses, the graphs will have the same shape but they are just shifted by a value in the y-direction, see Figure A.1.



Key

1 thickness d = 1 mm

2 thickness d = 0,8 mm

3 thickness d = 0,4 mm

X wavelength, λ, in nm

Y1 diabatic of the internal transmittance

Y2 internal transmittance

Figure A.1 — Graphical representation of the diabatic internal transmittance (scale on the left Y1; dashed horizontal lines) and of the internal transmittance (scale on the right Y2; solid horizontal lines) of a bandpass filter glass at different thicknesses

