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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.

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

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.

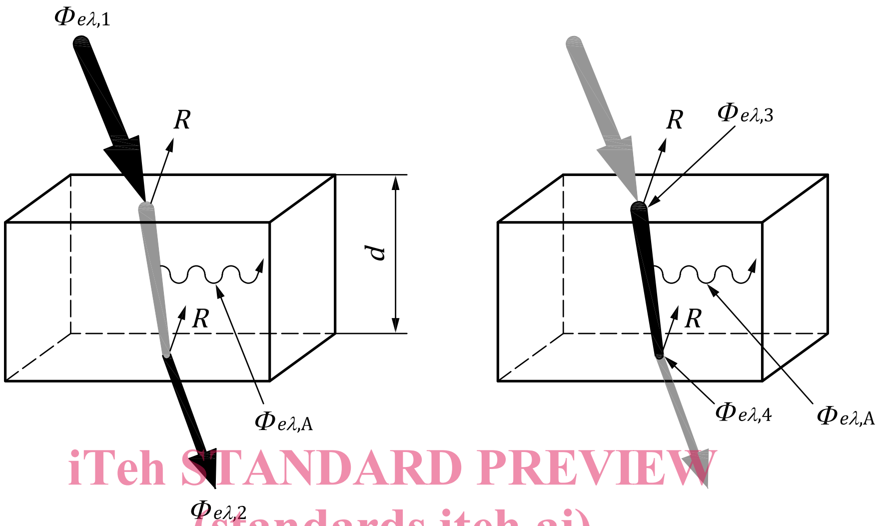
Note 4 to entry: If necessary, the transmittance can be represented as an average over a wavelength range from λ_1 to λ_2 as follows:

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

where

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

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
$\tau_i(\lambda)$
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”.

$$\tau_i(\lambda) = \frac{\Phi_{e\lambda,4}}{\Phi_{e\lambda,3}} \quad (3)$$

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:

$$\tau_i = e^{-\alpha_i d} \quad (4)$$

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:

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

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).

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

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)

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

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

$$E(\lambda) = \lg\frac{1}{\tau_i(\lambda)} = \frac{\alpha_1 d}{\ln(10)} \quad (10)$$

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:

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

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:

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

where