Optical Filter Glass calculation tool

A tutorial for the use of our EXCEL calculation tool

Intention of the calculation tool

Overview on the functions of the Excel Spreadsheet

- The calculation tool is intended to use for visualizing the optical reference values of our glasses.
  Internal Transmittance, Transmittance, Optical Density and Extinction data can be displayed as a function of wavelength and a desired thickness.
- The internal transmittance data is listed from 200 nm to 5200 nm.
- Some values for the color analysis can be calculated as well.
- The spread sheet offers the possibility to combine and compare several filters in respect to their optical properties.
- The user may add spectral data of filter functions as a target.
- The user may add spectral data for a user defined light source for color analysis.

Functions that are not present

- This tool is not designed for optimizing the design process of an optical system.
- The data base contains only typical transmittance data. There are no tolerances given in this tool.
- This tool was composed with utmost care, however, there is no guarantee on the correctness of algorithms and data.

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Mainz, June 2024

Agenda

01

Introduction and Formulas

- Sources of information
- Absorbance, extinction, diabatic transmittance
- Transmittance at different thicknesses

Sources of information on Optical Filters

Selected Literature

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

Internet www.schott.com/en-gb/products/optical-filter-glass

- Download “Optical Glass Filters Calculation Program”
- Download catalogs on Optical Glass Filters and Interference Filters as well as data sheets
- “SCHOTT Technical Information” series (TIE)

Other sources
SCHOTT Application Team

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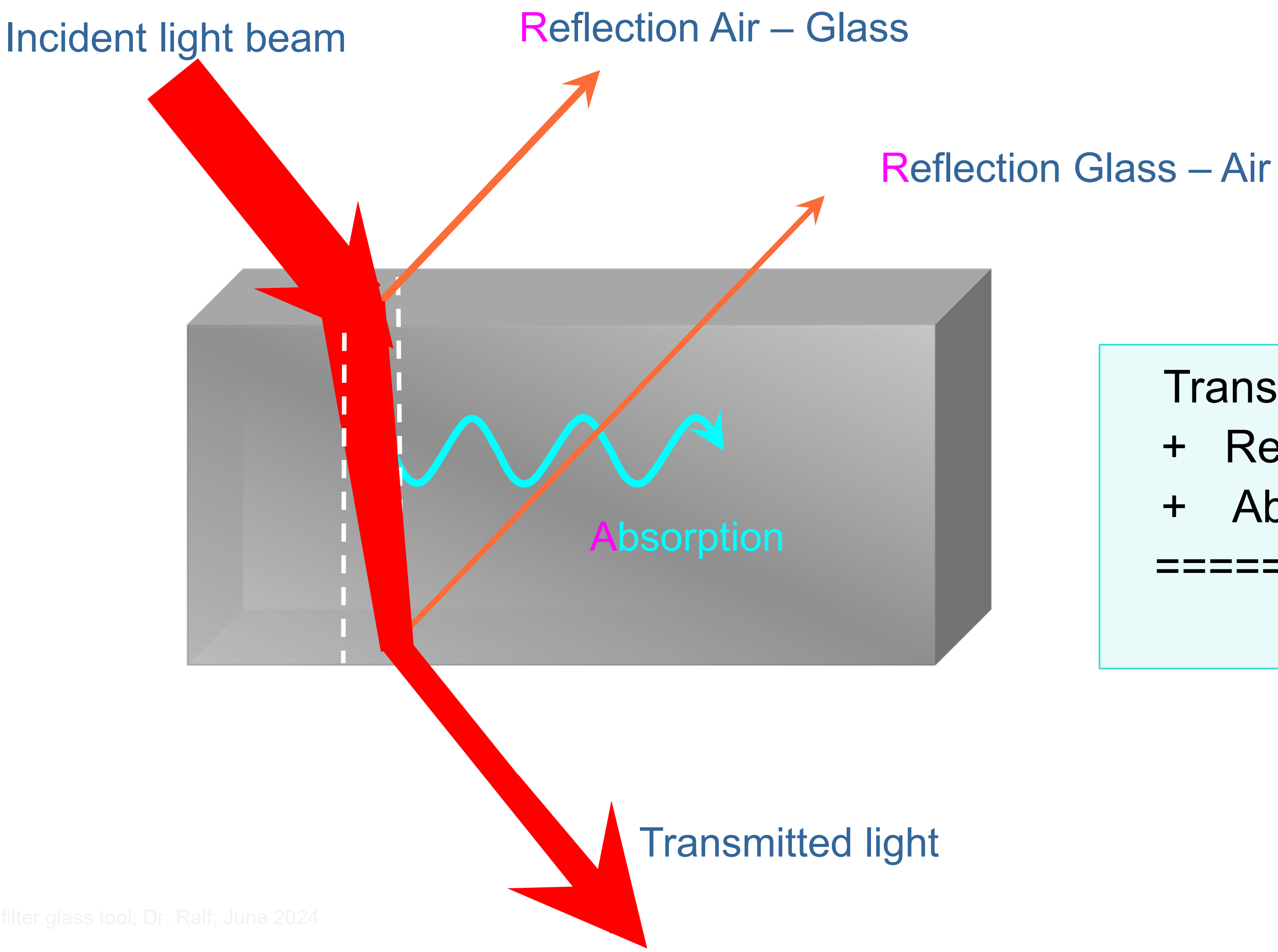
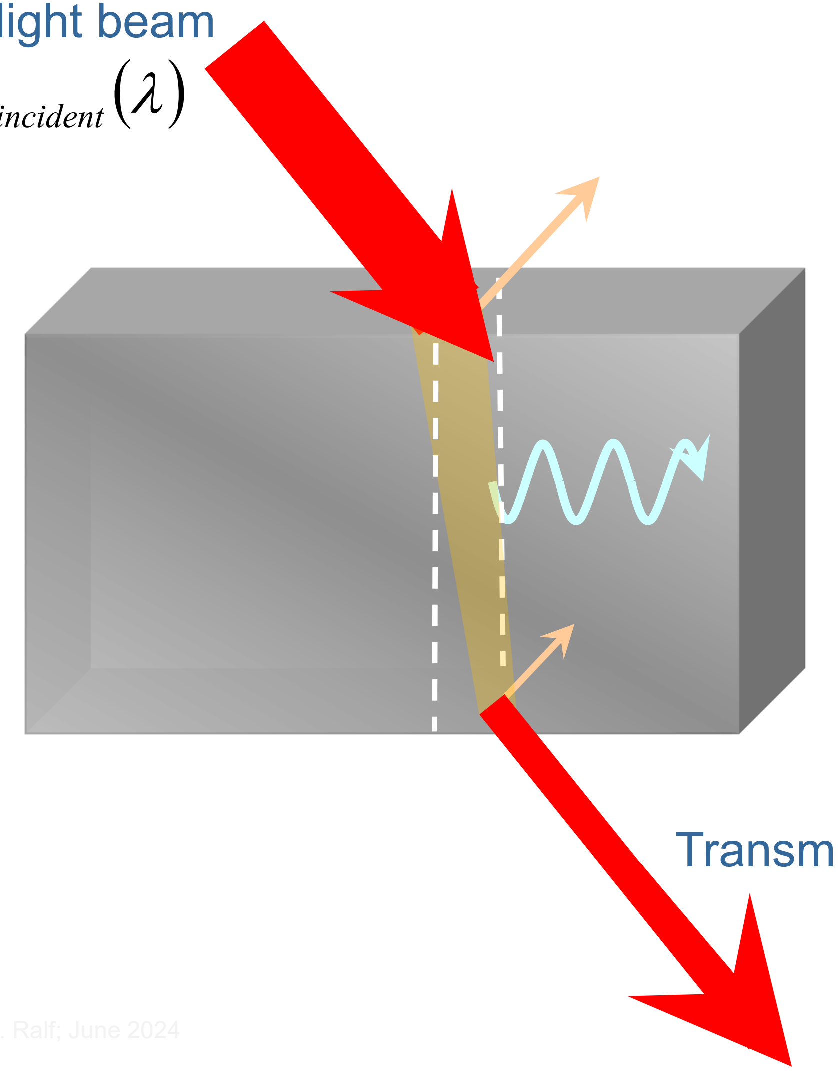
Definition of transmittance and internal transmittance



Transmittance
\+ Reflections
\+ Absorption
============
1

Definition regulärer spektraler Transmissionsgrad
spectral transmittance = regular transmittance

Incident light beam $\Theta_{e,\,incident}(\lambda)$

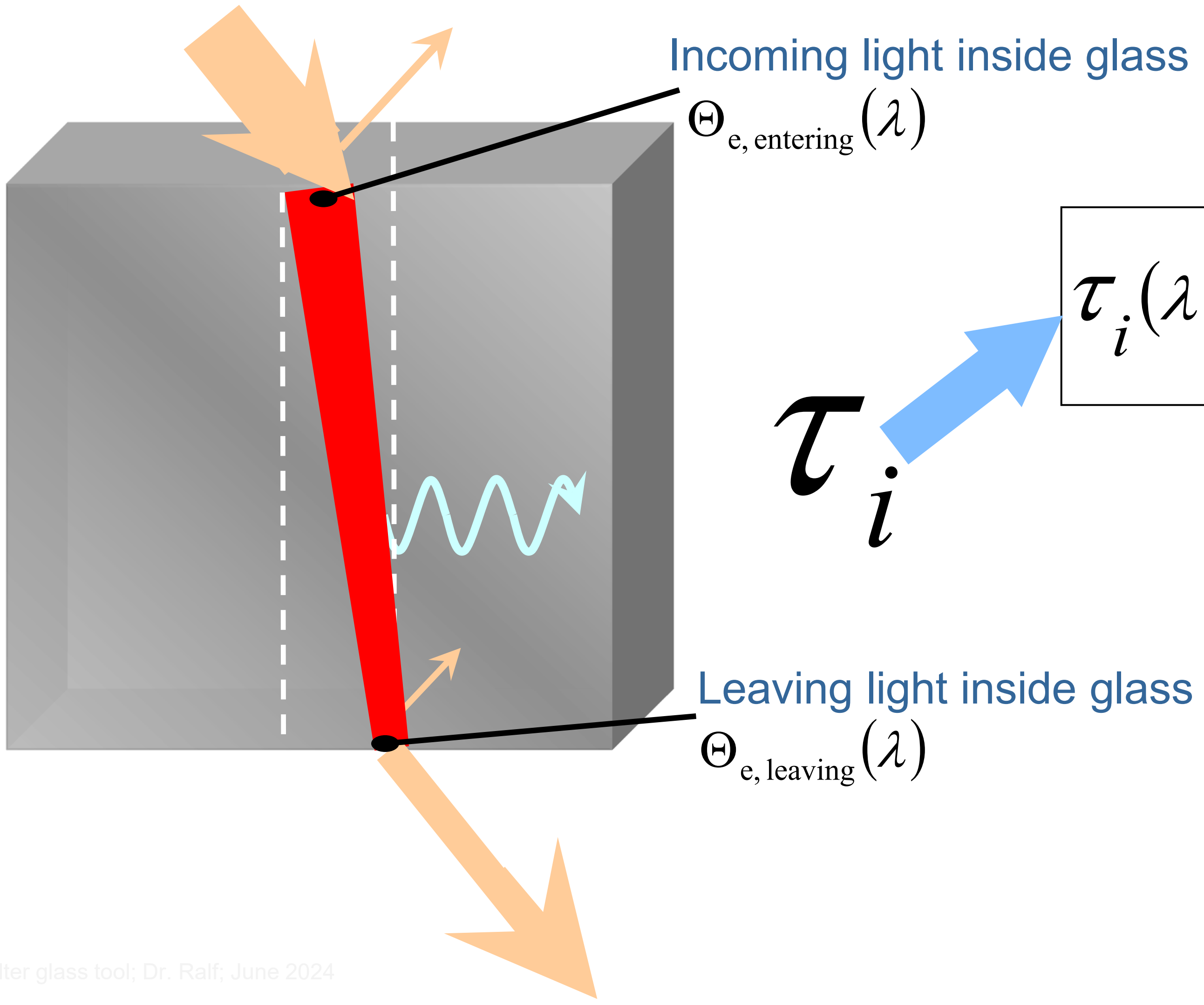


$$\tau(\lambda) = \frac{\Theta_{e,\,transmitted}(\lambda)}{\Theta_{e,\,incident}(\lambda)}$$

easy to measure!

Transmitted light $\Theta_{e,\,transmitted}(\lambda)$

Definition spektraler Reintransmissionsgrad
spectral internal transmittance



τ_i

$$\tau_i(\lambda) = \frac{\Theta_{e,\,leaving}(\lambda)}{\Theta_{e,\,entering}(\lambda)}$$

Our bulk absorption filter glasses are homogeneous

- In a homogeneous bulk material the internal transmittance $\boldsymbol{\tau_i}$ can be expressed by an exponential function of thickness ***d*** of the filter and the linear absorption coefficient $\boldsymbol{\alpha_l}$:

$$\tau_i = e^{-\alpha_l \, d}$$

Relation between internal and regular transmittance

Reflection of an uncoated plano-plano glass plate in air (a window or a filter glass)

- The **reflection factor** P (upper case greek letter „Rho“) between **regular** transmittance and **internal** transmittance for a window is:

$$\tau(\lambda) = \boldsymbol{P(\lambda)} \cdot \tau_i(\lambda)$$

- The reflection factor P is calculated from the Fresnel formulae using the refractive index $\boldsymbol{n}$ of the glass. An easy approximation is

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

- In our data sheets and calculation program we use a constant reflection factor $\boldsymbol{P_d}$ at the d-line (587,6 nm)

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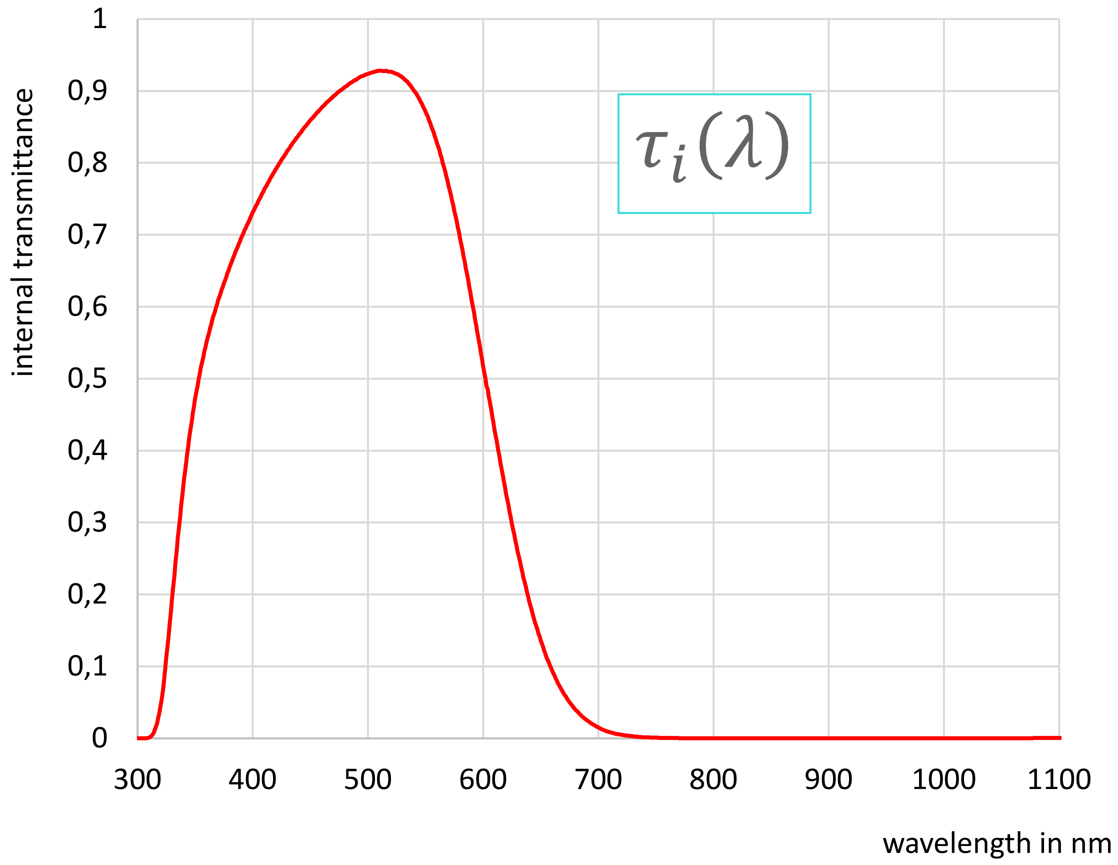
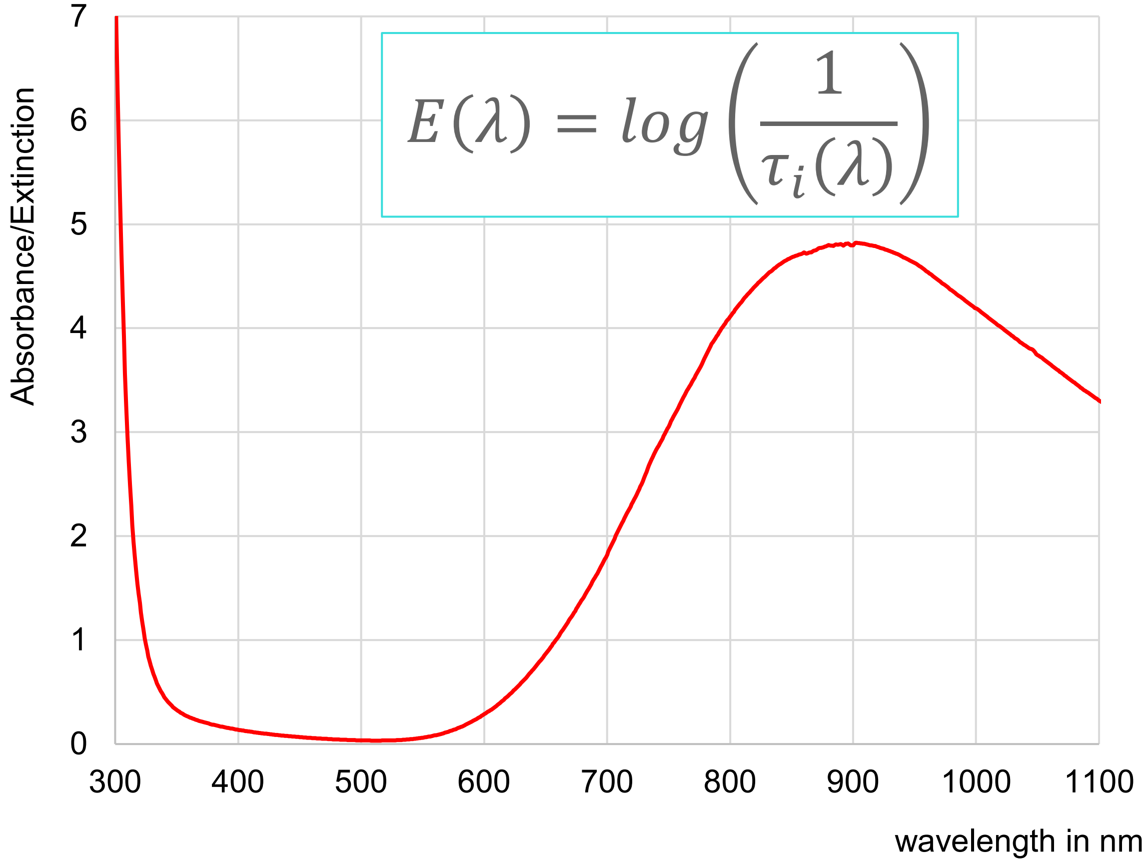
Transmittance τ_i – Absorbance/Extinction E are characterizing filters

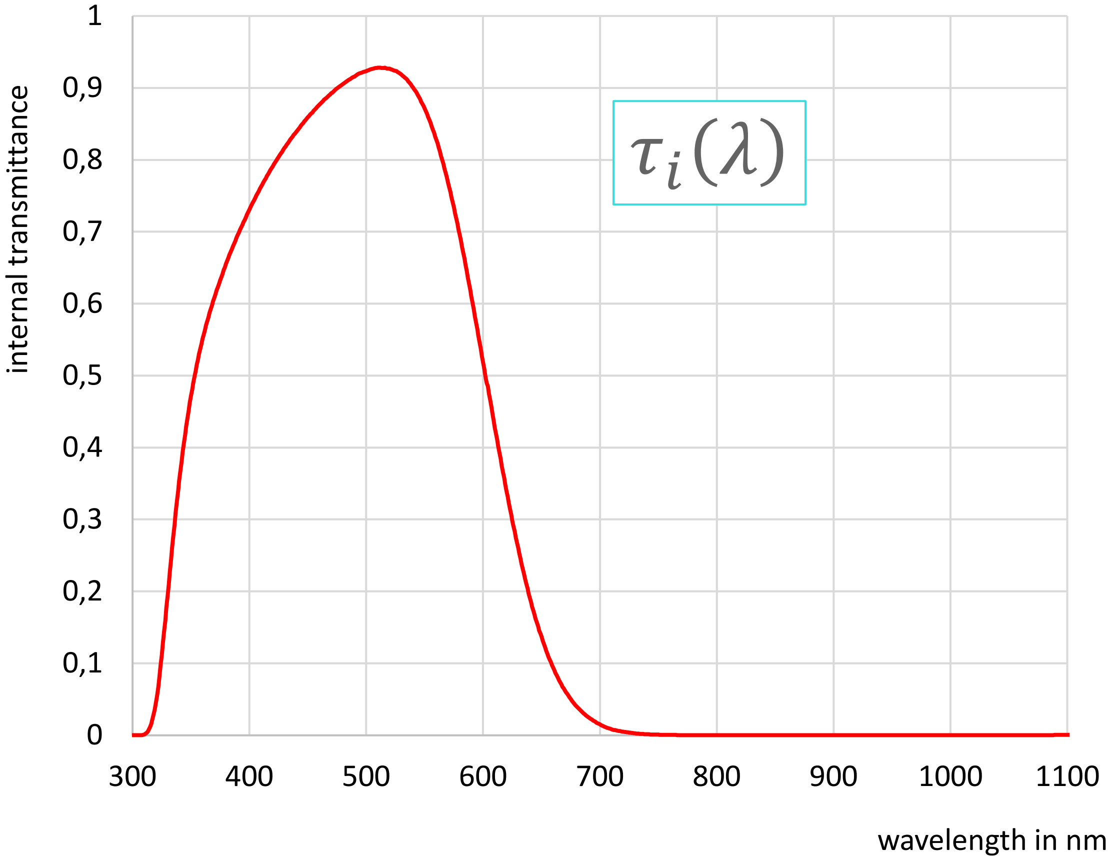
Spectrophotometers are measuring the transmittance of a sample and the extinction E is calculated from transmittance τ.

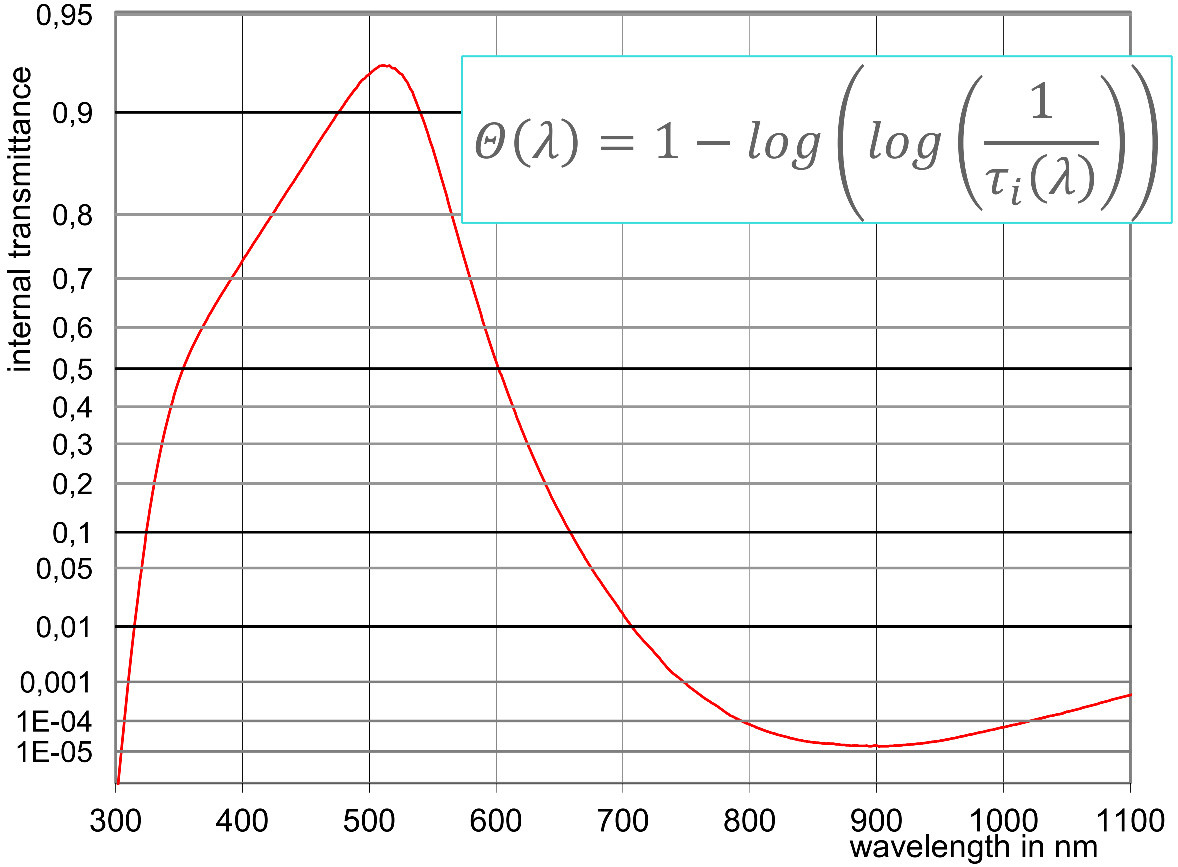




Diabatic transmittance scaling provides better overview about blocking and high transmission regions

Transformation of the ordinate with diabatic scaling is an elongation of the high and the low transmittance regions





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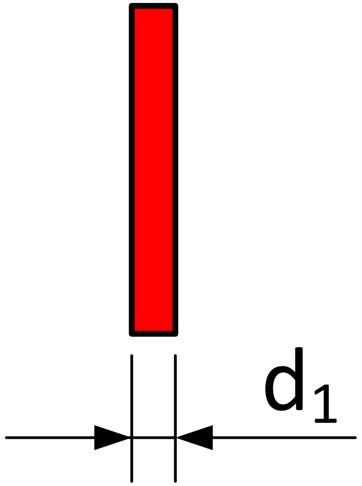
Internal transmittance calculated at a different thickness

The calculation is a simple 3 step process:

(1) Use internal transmittance data at a reference thickness d_{ref}.

(2) Define new thickness d_1.



(3) Calculate internal transmittance at new thickness using the formula:

Data sheet
with internal transmittance data at a reference thickness

Rei…				d [mm] =	3				
Di…				…hisch, sind als Richtwerte zu verstehen					
λ					τ_i	λ [nm]	τ_i	λ [nm]	τ_i
2…					9,7E-01	1100	9,6E-01	2200	9,5E-01
2…					9,7E-01	1110	9,6E-01	2250	9,5E-01
2…					9,7E-01	1120	9,6E-01	2300	9,6E-01
2…					9,7E-01	1130	9,6E-01	2350	9,6E-01
240	< 1,…	…40	< 1,0E-05	840	9,7E-01	1140	9,6E-01	2400	9,5E-01
250	< 1,0E-…	…50	< 1,0E-05	850	9,7E-01	1150	9,6E-01	2450	9,5E-01
260	< 1,0E-05	…60	< 1,0E-05	860	9,7E-01	1160	9,6E-01	2500	9,5E-01
270	< 1,0E-05	…70	2,1E-05	870	9,7E-01	1170	9,6E-01	2550	9,4E-01
280	< 1,0E-05	580	1,5E-03	880	9,7E-01	1180	9,6E-01	2600	9,3E-01
290	< 1,0E-05	590	3,1E-02	890	9,7E-01	1190	9,6E-01	2650	9,2E-01
300	< 1,0E-05	600	2,0E-01	900	9,7E-01	1200	9,7E-01	2700	8,7E-01
310	< 1,0E-05	610	5,2E-01	910	9,7E-01	1250	9,7E-01	2750	5,2E-01
320	< 1,0E-05	620	7,7E-01	920	9,6E-01	1300	9,7E-01	2800	3,7E-01

$$\tau_{i,d1} = \left(\tau_{i,d_{ref}}\right)^{\left(\frac{d_1}{d_{ref}}\right)}$$

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02

Single filter analysis

How to analyze spectral data of a single filter in polished condition

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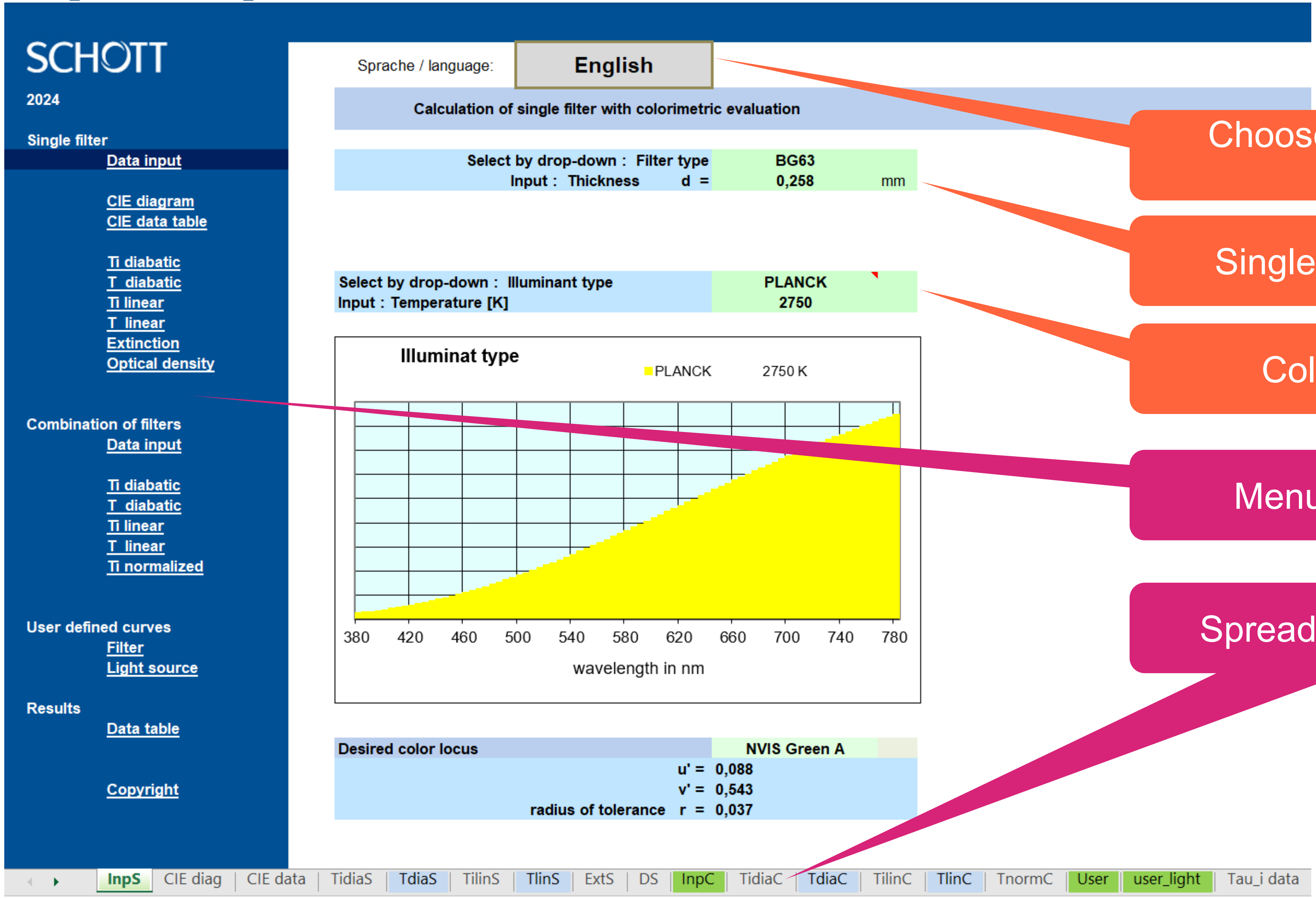
Input spread sheet



Choose your preferred language

Single filter data input

Color data input

Menu bar with links

Spread sheet menu bar

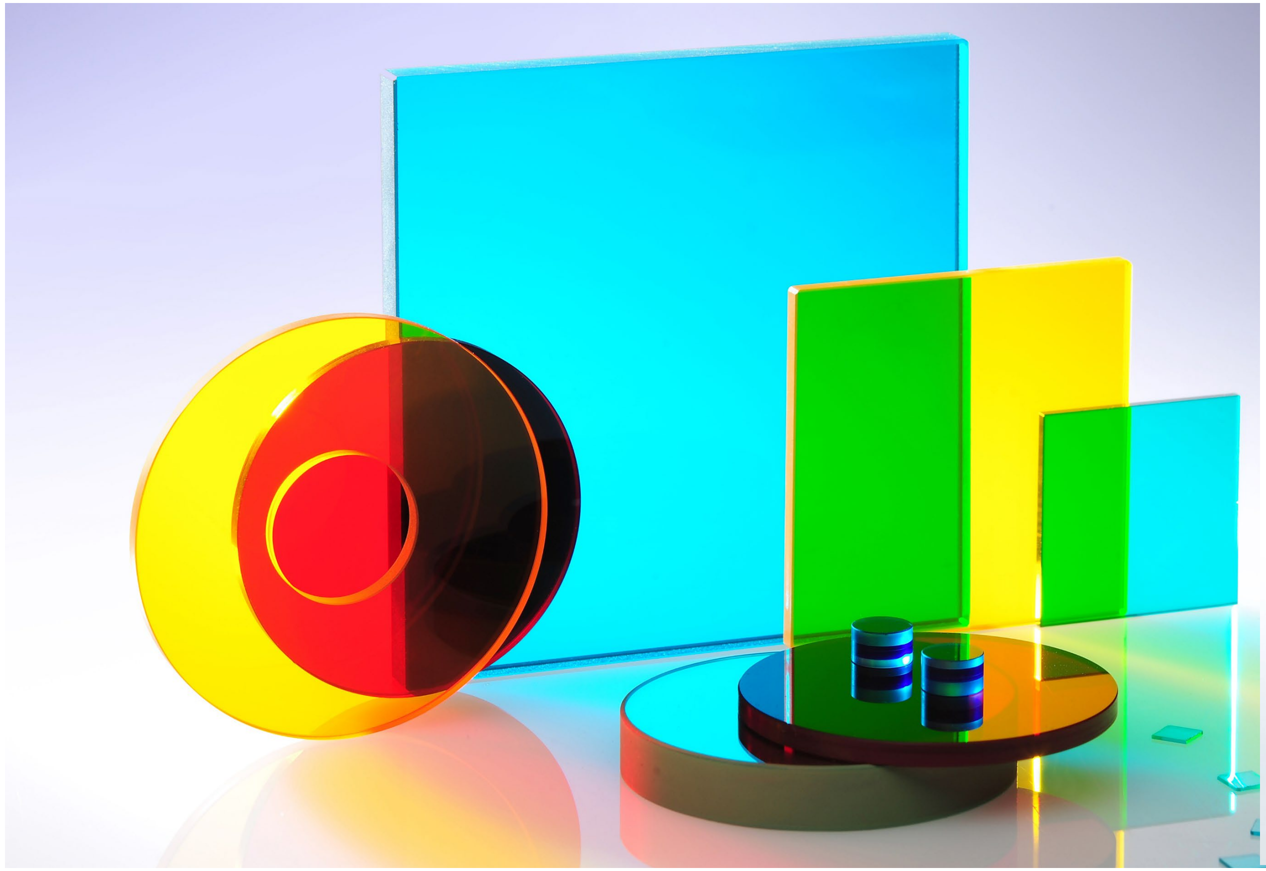
03

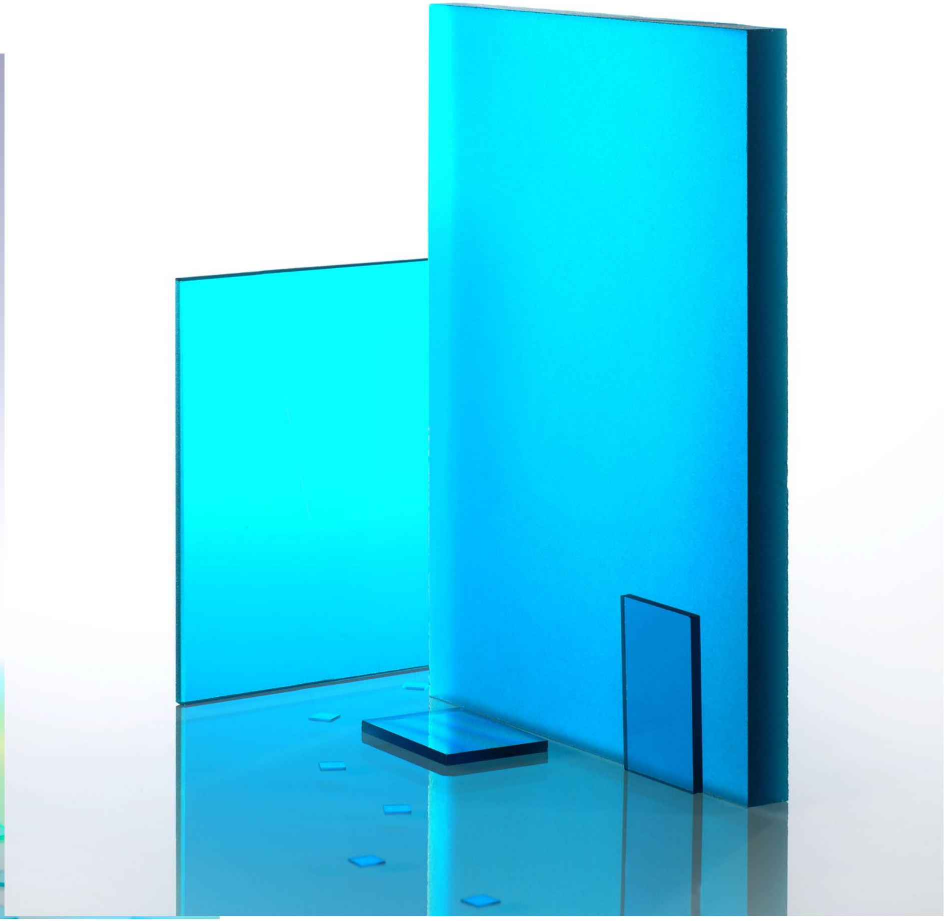
Comparing filters

How to analyze spectral data of a multiple filters
How to combine filters (virtual cementing)

Comparing and combining of polished filters

Analyzing multiple filters





04

Color of a filter

Light sources
Color coordinates of light source and filter

Calculation of the color of an illuminated filter

Optisches Filterglas – optische Eigenschaften

Tristimulus values according to ISO 11664-3

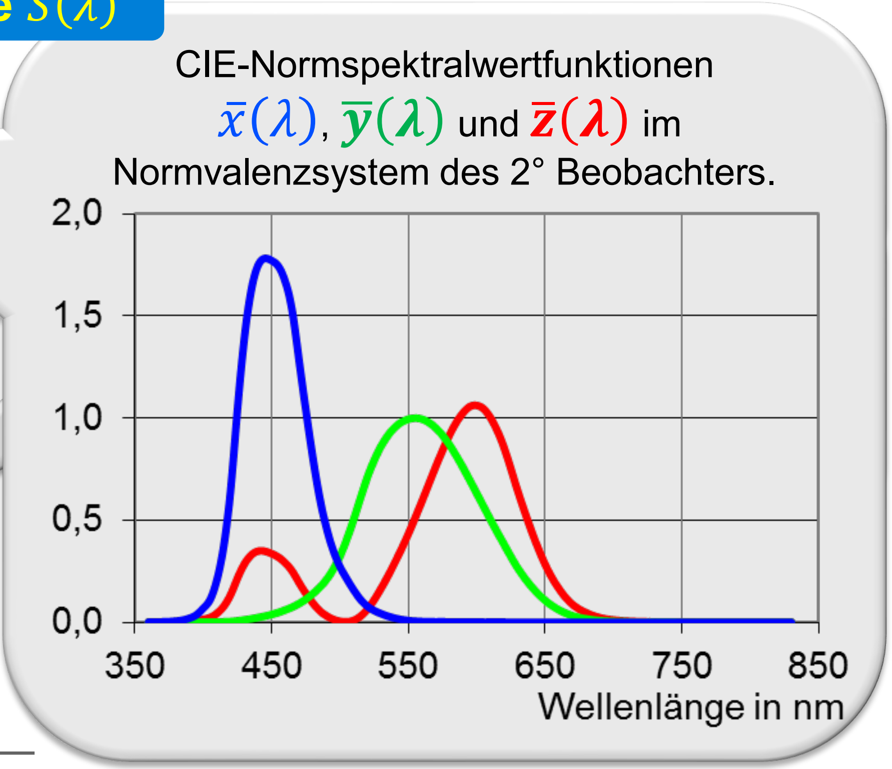
Filter $\tau(\lambda)$ **Light source $S(\lambda)$**

$$X = k \int_{\lambda=360\,nm}^{830\,nm} \tau(\lambda)\ S(\lambda)\ \bar{x}(\lambda)\, d\lambda$$

$$Y = k \int_{\lambda=360\,nm}^{830\,nm} \tau(\lambda)\ S(\lambda)\ \bar{y}(\lambda)\, d\lambda$$

$$Z = k \int_{\lambda=360\,nm}^{830\,nm} \tau(\lambda)\ S(\lambda)\ \bar{z}(\lambda)\, d\lambda$$

using factor $k = \frac{100\%}{\int_{\lambda=360\,nm}^{830\,nm} S(\lambda)\ \bar{y}(\lambda)\, d\lambda}$



Color coodinates *x, y, z*

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

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Move to Excel

05

Tabulated data

Light sources
Color coordinates of light source and filter

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Move to Excel

06

User defined data

Your own light sources
Your own filters

Move to Excel