INTERNATIONAL STANDARD

ISO 9211-2

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Optics and optical instruments — Optical coatings —

Part 2:
Optical properties

Optique et instruments d'optique — Traitements optiques —

Partie 2: Propriétés optiques

Reference number
ISO 9211-2:1994(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9211-2 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 3, *Optical materials and components*.

ISO 9211 consists of the following parts, under the general title *Optics and optical instruments — Optical coatings*:

— *Part 1: Definitions*

— *Part 2: Optical properties*

— *Part 3: Environmental durability*

— *Part 4: Specific test methods*

Annexes A and B of this part of ISO 9211 are for information only.

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Optics and optical instruments — Optical coatings —

Part 2:
Optical properties

1 Scope

ISO 9211 identifies surface treatments of components and substrates excluding ophthalmic optics (spectacles) by the application of optical coatings and gives a standard form for their specification. It defines the general characteristics and the test and measurement methods whenever necessary, but is not intended to define the process method.

This part of ISO 9211 indicates how to specify optical properties of coatings and to represent their spectral characterisation. It also gives recommendations for specifications in drawings.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 9211. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9211 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 9211-1:1994, *Optics and optical instruments — Optical coatings — Part 1: Definitions.*

3 Definitions

For the purposes of this part of ISO 9211, the definitions given in ISO 9211-1 apply.

4 Optical properties to be specified

The optical properties of a coating and its optical operating conditions shall be specified in a standard format by using table 1 in order to provide a comprehensive description of a coating with regard to its minimum optical properties, and to the optical conditions in which the coating is intended to be used. Entries into the spaces provided in the columns "Region 1", "Region 2", etc., shall be completed with a numerical value with tolerances or a comparator sign (<; >; =) if appropriate, and the unit. Spaces left blank intentionally shall be marked with a hyphen (-) or a slash (/).

5 Measurement conditions

The measurement conditions for the spectrophotometric characterization shall be subject to 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 cone angle aperture, the state of polarization, the spectral range and bandwidth of the measurement beam, etc. and shall be recorded in sufficient detail to enable duplication of the measurement.

Table 1 — Conditions and optical properties to be specified

		Spectral range		
		Region 1	Region 2	Region n
Conditions	Wavelength range			
	Incident medium[1] Refractive index			
	Emergent medium[1] Refractive index			
	Angle of incidence			
	Cone angle of aperture			
	Useful area or clear aperture			
	Rim			
	Polarization of incident radiation			
Optical properties	Transmittance[2]			
	Reflectance[3]			
	Absorptance[4]			
	Scatter[4]			
	Colorimetric parameters[5]			
	Polarization of emergent radiation			
	Phase difference between S and P vectors of emergent radiation			
Supplementary properties				

1) Either one of these can be the substrate.

2) Measured through the coated optical component or a specified witness sample.

3) Per coated surface.

4) Measurement procedures to be specified.

5) For visual applications colorimetric parameters may be used instead of reflectance and transmittance.

6 Graphical representation of spectral characteristics

This part of ISO 9211 defines the rules for the spectrophotometric characterization of optical coatings.

NOTE 1 Drawings are in accordance with the specifications given in the series of standards ISO 10110:—[1], *Optics and optical instruments — Preparation of drawings for optical elements and systems.*

6.1 Rules for the graphical representation

6.1.1 The optical properties of the coating to be specified are given in table 1.

6.1.2 The spectrophotometric characterization consists of indicating the following in a graph:

a) On the abscissa, the spectral region in which the characteristics are specified as a function of wavelength (λ) in nanometres or micrometres, or wavenumber (σ) in reciprocal centimetres;

b) on the ordinate, the value of transmittance and/or reflectance and/or absorptance and/or optical density and/or phase and/or scatter within the spectral region.

1) To be published.

6.1.3 The upper and/or lower tolerance limits (indicated by subscripts U and L respectively) within which the spectral curve must be located shall be indicated on the graph with hatched areas outside of the tolerance band if necessary. The average value, if specified, can be represented by a distinct line or chain of symbols indicated by the subscript "ave". The average values can also be represented with an upper and lower limit indicated by subscripts "ave_U" and "ave_L" respectively.

6.1.4 If the coating 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.

6.1.5 The spectrophotometric values shall correspond to the specified conditions of use. If the measurement requires different conditions, these shall be noted on the graph.

NOTES

2 The limits shown in the graphs are only examples used for illustration. They should not be taken as typical or standard limits.

3 It is recommended that an illustration of the measurement geometry be included on the spectral graph. Examples are shown in annex A.

6.2 Format of graphical representation

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

NOTE 4 In the characterization of various optical functions, the tolerance limits of reflectance (ρ), transmittance (τ), wavelength (λ), etc. can be replaced by those of average values (ρ_{ave}, τ_{ave}, λ_{ave}, etc.).

6.2.1 Reflecting function

The reflecting function shall be characterized by its lower tolerance limit (ρ_L) of spectral reflectance, as shown in figure 1. The upper tolerance (ρ_U) should also be indicated if necessary.

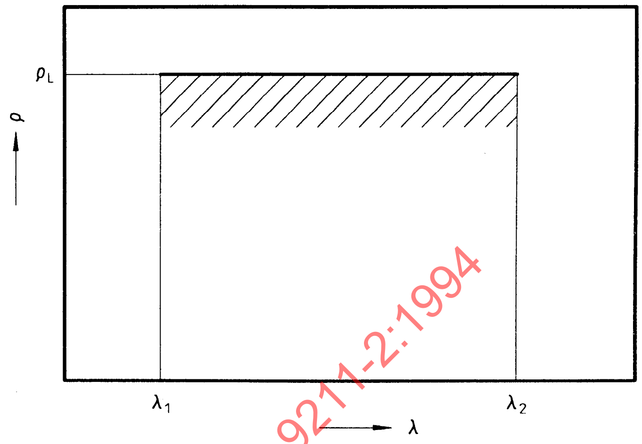


Figure 1 — Reflecting function

6.2.2 Antireflecting function

The antireflecting function shall be characterized by its upper tolerance limit (ρ_U) of spectral reflectance, as shown in figure 2. If necessary, the transmittance with its lower tolerance limits (τ_L) should be indicated on the same drawing.

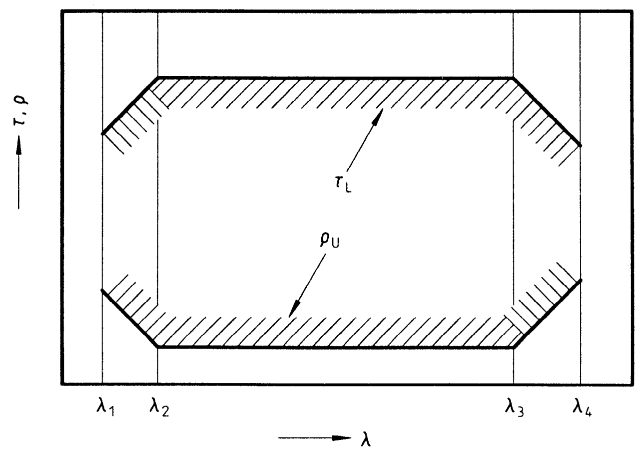


Figure 2 — Antireflecting function

6.2.3 Beam splitting function

The beam splitting function shall be characterized by its upper and lower tolerance limits (τ_U, τ_L, ρ_U, ρ_L) of spectral transmittance and reflectance, as shown in figure 3. These two representations can be shown in separate graphs.

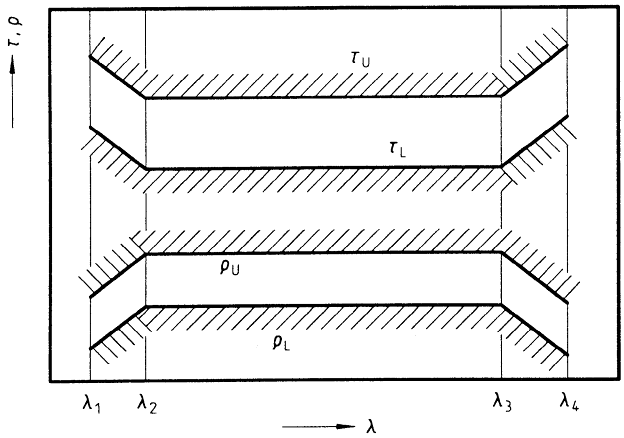
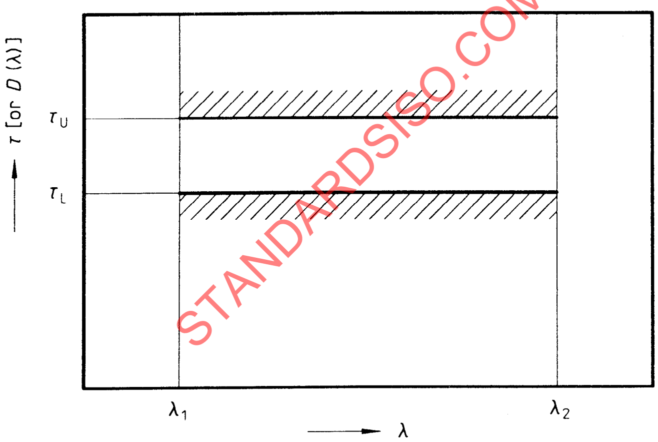


Figure 3 — Beam splitting function

6.2.4 Attenuating function

The attenuating function shall be characterized by its upper and lower tolerance limits (τ_U, τ_L) of spectral transmittance (or optical density), as shown in figure 4.



NOTE — Optical density is related to the transmittance by the formula

$$D(\lambda) = - \log \tau(\lambda)$$

Figure 4 — Attenuating function

6.2.5 Filtering function

The filtering function shall be characterized by τ_A or τ_M, λ_{max}, λ_C, $\Delta\lambda_{0,5}$ and $\Delta\lambda_{0,2}$ with tolerance limits, and τ_b, $\lambda_{0,8}$, S' and S'' (see figure 5), as follows:

1) $\tau_A = \dfrac{\tau_U + \tau_L}{2}$

where

τ_U is the upper tolerance limit for maximum transmittance;

τ_L is the lower tolerance limit for maximum transmittance.

2) τ_M is the measured maximum value of transmittance.

NOTE 5 Whether τ_A or τ_M will be used must be specified.

3) λ_{max} is the wavelength at which spectral transmittance equals τ_M.

4) $\lambda'_{0,5}$ and $\lambda''_{0,5}$ are the wavelengths at which the spectral transmittance equals $0,5\tau_A$ or $0,5\tau_M$, whichever is specified.

5) $\Delta\lambda_{0,5}$ is the bandwidth (or half bandwidth) defined by $\Delta\lambda_{0,5} = \lambda''_{0,5} - \lambda'_{0,5}$.

6) λ_C is the arithmetic average of a pair of wavelengths, $\lambda'_{0,5}$ and $\lambda''_{0,5}$.

7) $\lambda_{0,8}$, $\lambda_{0,2}$ and $\lambda_{0,1}$ are the wavelengths at which transmittance equals $0,8\tau_A$ or $0,8\tau_M$, $0,2\tau_A$ or $0,2\tau_M$ and $0,1\tau_A$ or $0,1\tau_M$, respectively.

8) $\Delta\lambda_{0,1}$ is the bandwidth defined by $\Delta\lambda_{0,1} = \lambda''_{0,1} - \lambda'_{0,1}$.

9) S' and S'' are the edge slopes defined by

$$S' = \frac{0,8\tau_{A \text{ or } M} - 0,2\tau_{A \text{ or } M}}{\lambda'_{0,8\tau_{A \text{ or } M}} - \lambda'_{0,2\tau_{A \text{ or } M}}}$$

and

$$S'' = \frac{0,8\tau_{A \text{ or } M} - 0,2\tau_{A \text{ or } M}}{\lambda''_{0,2\tau_{A \text{ or } M}} - \lambda''_{0,8\tau_{A \text{ or } M}}}$$

10) τ_b is the upper limit of the spectral transmittance of the blocking range, λ_1 to λ_2 and λ_7 to λ_8.

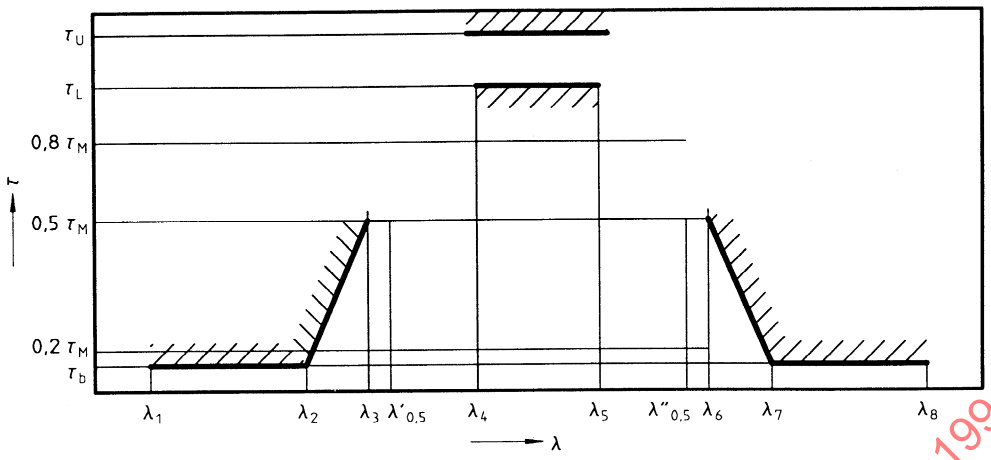


Figure 5 — Filtering function

6.2.6 Selecting function

The selecting function shall be characterized by τ_A or τ_M, and $\lambda_{0,5}$ with tolerance limits and $\lambda_{0,8}$, $\lambda_{0,2}$, τ_b and S (see figure 6), as follows:

1) $\tau_A = \frac{\tau_U + \tau_L}{2}$

where

τ_U is the upper tolerance limit for maximum transmittance of the first peak adjacent to the edge;

τ_L is the lower tolerance limit for maximum transmittance of the first peak adjacent to the edge.

2) τ_M is the measured maximum value of transmittance of the first peak adjacent to the edge.

NOTE 6 Whether τ_A or τ_M will be used must be specified.

3) $\lambda_{0,5}$ is the edge wavelength at which the spectral transmittance is equal to $0,5\tau_A$ or $0,5\tau_M$, whichever is specified.

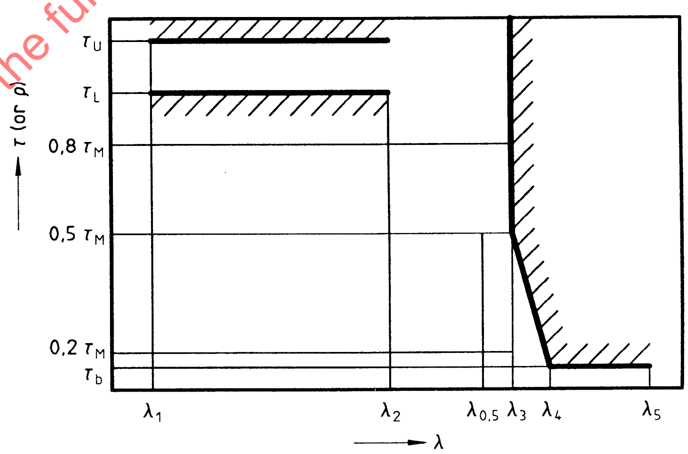
4) $\lambda_{0,8}$ is the edge wavelength at which the spectral transmittance is equal to $0,8\tau_A$ or $0,8\tau_M$, whichever is specified.

5) $\lambda_{0,2}$ is the edge wavelength at which the spectral transmittance is equal to $0,2\tau_A$ or $0,2\tau_M$, whichever is specified.

6) τ_b is the upper limit of the spectral transmittance of the blocking range, λ_4 to λ_5.

7) $S_{\text{A or M}}$ is the edge slope defined as

$$S_{\text{A or M}} = \frac{0,8\tau_{\text{A or M}} - 0,2\tau_{\text{A or M}}}{\left| \lambda_{0,8\tau_{\text{A or M}}} - \lambda_{0,2\tau_{\text{A or M}}} \right|}$$



NOTE — The reflectance ρ can be specified (substituted for τ) to characterize the selecting function in all or in specific wavelength regions.

Figure 6 — Selecting function

6.2.7 Polarizing function

The polarizing function shall be characterized by its upper and lower tolerance limits (τ_{PU}, ρ_{PU}, etc.) of spectral transmittance and/or reflectance for both polarization components, S and P, as shown in figure 7.

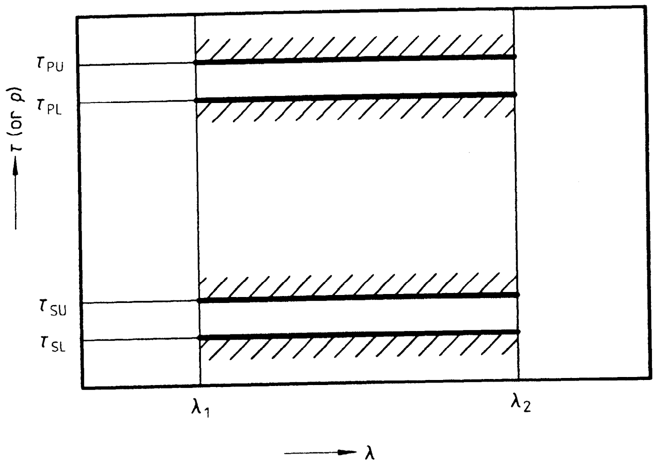


Figure 7 — Polarizing function

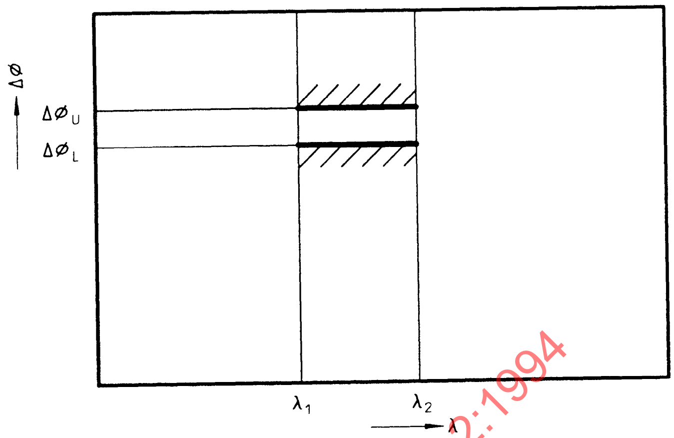


Figure 8 — Phase-changing function

6.2.8 Phase-changing function

The phase-changing function shall be characterized by its upper and lower tolerance limits of phase difference between P and S components ($\Delta\Phi_U$, $\Delta\Phi_L$; $\Delta\Phi$ is defined by $\Delta\Phi = \Phi_P - \Phi_S$), as shown in figure 8.

6.2.9 Absorbing function

The absorbing function shall be characterized by its upper and lower tolerance limits (α_U, α_L) of spectral absorptance, as shown in figure 9.

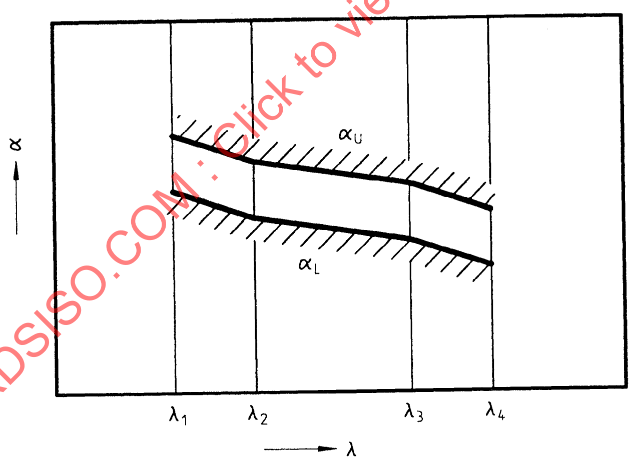


Figure 9 — Absorbing function

Annex A
(informative)

Examples of recommended spectral geometry

Figures A.1 to A.6 give examples of recommended spectral geometry, illustrated on spectral graph or separate drawing (unless otherwise specified, unpolarized radiation is implied).

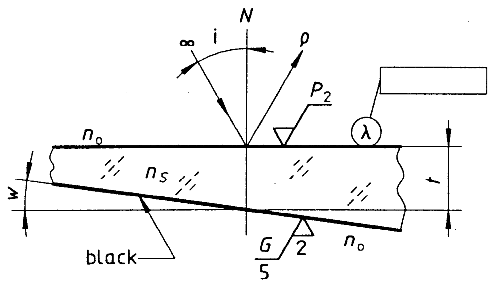


Figure A.1 — Reflectance, collimated beam

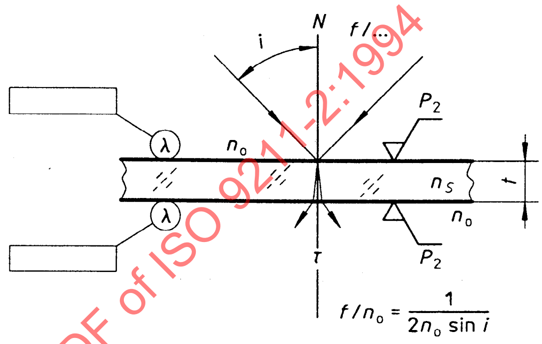


Figure A.3 — Transmittance, conical, normal incidence

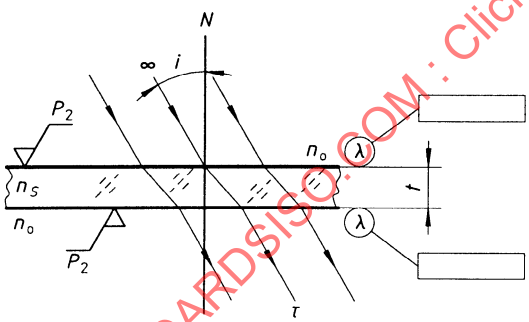


Figure A.2 — Transmittance, collimated beam

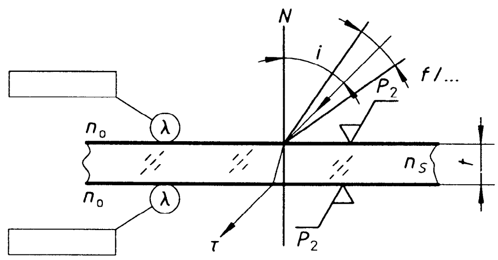


Figure A.4 — Transmittance, conical, oblique incidence

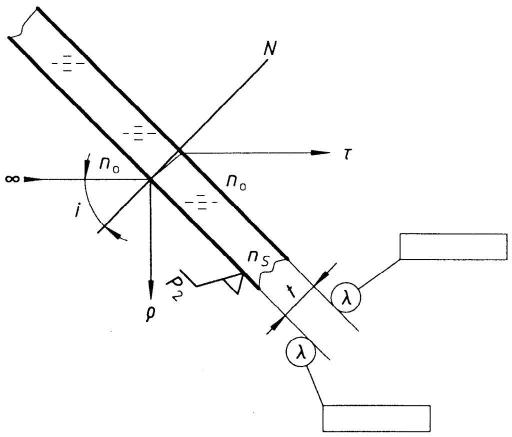


Figure A.5 — Beamsplitter, plate

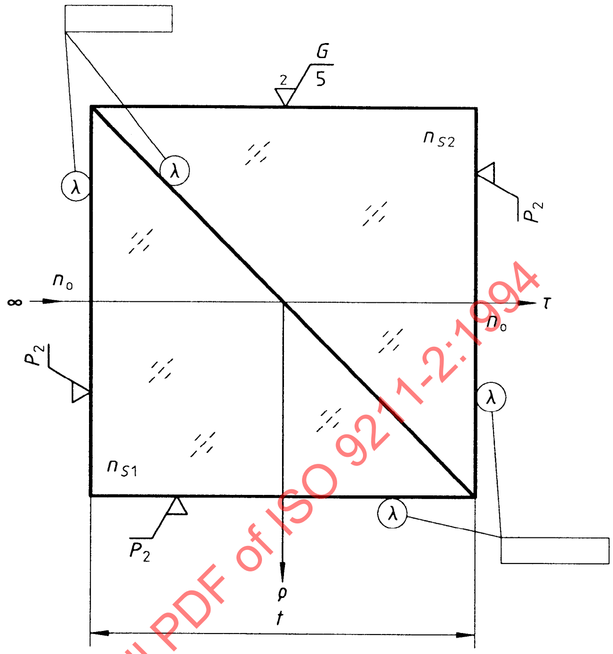
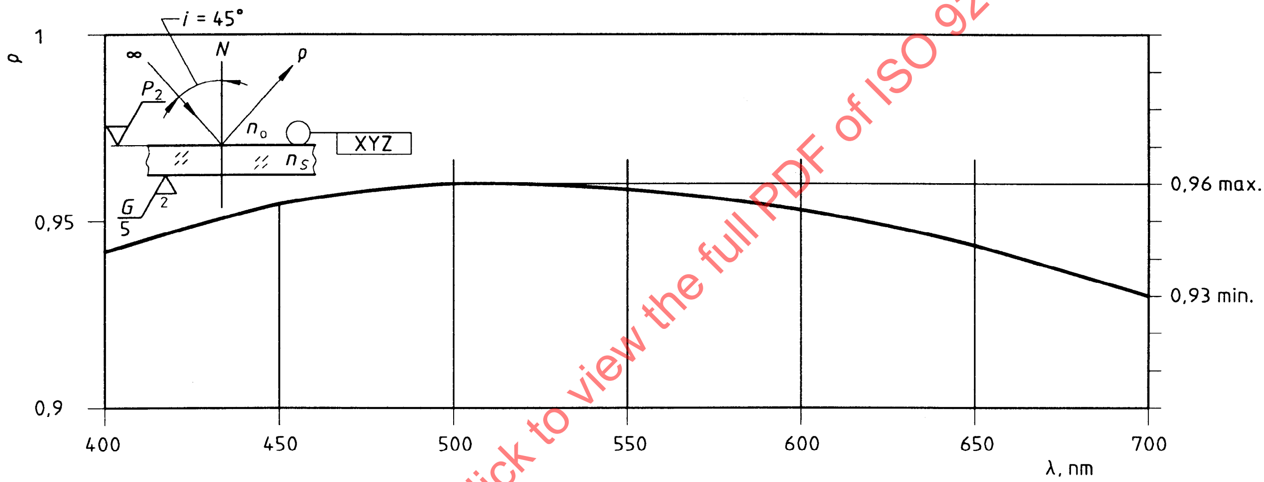


Figure A.6 — Beamsplitter, cube

Annex B
(informative)

Numerical examples of spectral graphs (recommended formats)

Figures B.1 to B.4 give numerical examples of spectral graphs.



NOTE — Reflectance values are measured values.

Figure B.1 — Reflecting function

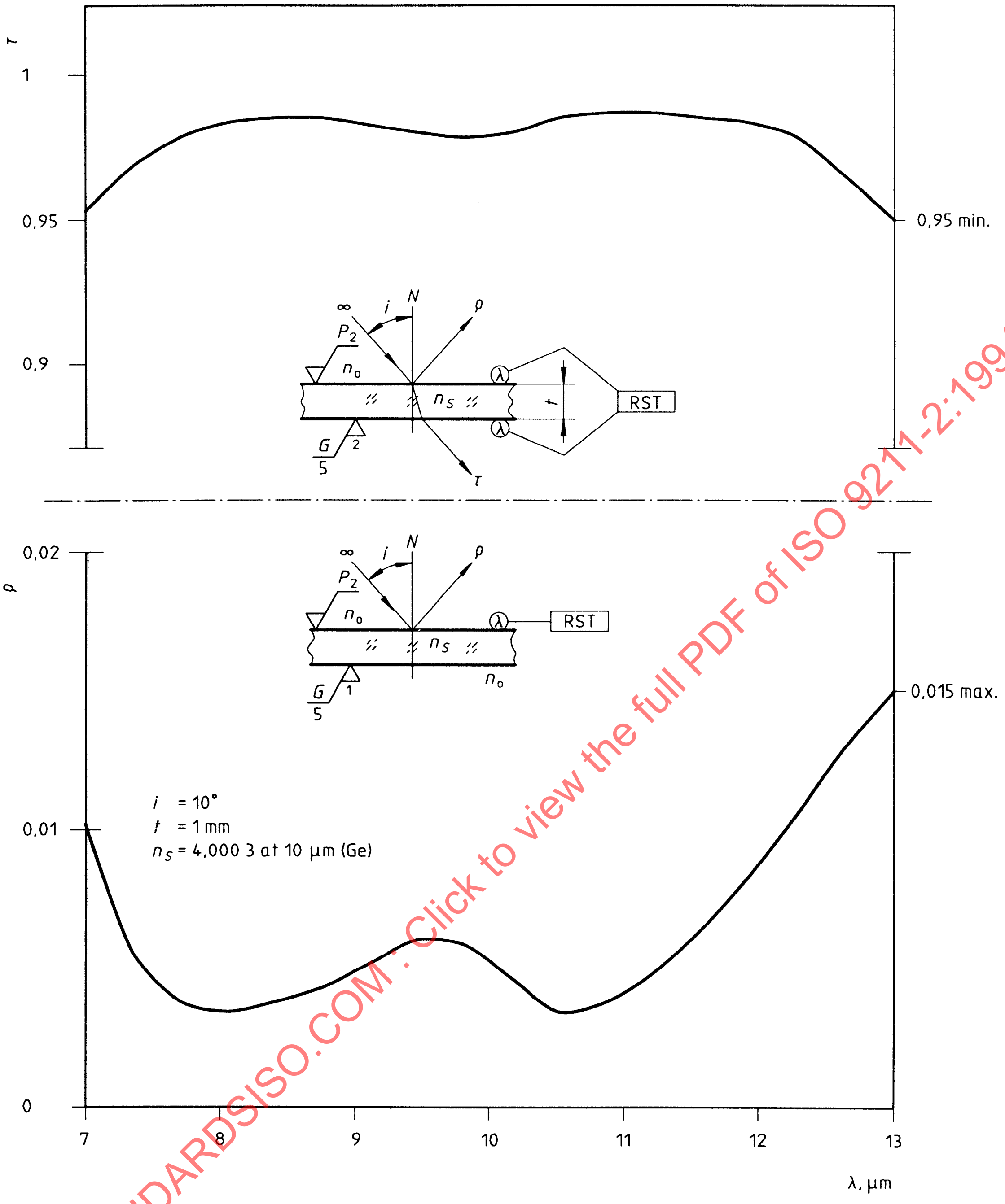


Figure B.2 — Antireflecting function