International Standard

ISO 6760-1

Optics and photonics — Test method for temperature coefficient of refractive index of optical glasses —

Part 1: Minimum deviation method

Optique et photonique — Méthode d'essai pour déterminer le coefficient de température de l'indice de réfraction des verres optiques —

Partie 1: Méthode de la déviation minimale

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Contents

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

A list of all parts in the ISO 6760 series can be found on the ISO website.

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Introduction

Optical glass is widely used in optical devices such as cameras, telescopes, and microscopes, and its refractive index is measured by the minimum deviation method (see ISO 21395-1) and the V-block refractometer method (see ISO 21395-2[4]). Here, when designing an optical apparatus that requires high resolution, it is necessary to consider the temperature change of the refractive index of the optical glass in the usage environment, however up until now, there is no International Standard. In view of the above situation, this document proposes a method for measuring the temperature coefficient of refractive index of optical glass with high accuracy, aiming to help mutual understanding of measured value users and contribute to efficiency and fairness.

Optics and photonics — Test method for temperature coefficient of refractive index of optical glasses —

Part 1:
Minimum deviation method

1 Scope

This document specifies the measurement method used for calculating the temperature coefficient of the refractive index by measuring the refractive index, which changes with the temperature of the optical glass using the minimum deviation method.

The intended temperature range for the specified measurement method is −40 °C to +80 °C.

The intended wavelength range for the specified measurement method is 365 nm to 1 014 nm.

The intended accuracy for the specified measurement method is 1×10^{-6} K^{-1}.

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 21395-1:2020, *Optics and photonics — Test method for refractive index of optical glasses — Part 1: Minimum deviation method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
temperature coefficient of refractive index
ratio of refractive index change to temperature change at a selected wavelength

Note 1 to entry: Similar to ISO 9802[2].

3.2
temperature coefficient of absolute refractive index
$\Delta n_{abs}/\Delta T$
ratio of refractive index change in vacuum to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[2], 3.4.2.3]

3.3
temperature coefficient of relative refractive index

$\Delta n_{rel}/\Delta T$

ratio of refractive index change at an air pressure of 1,013 3 × 10^5 Pa and a relative humidity of 0 % to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[2], 3.4.2.4, modified — 1,013 3 × 10^5 Pa and a relative humidity of 0 %.]

Note 1 to entry: This definition of $\Delta n_{rel}/\Delta T$ is for a specific pressure and humidity. $\Delta n_{rel}/\Delta T$ can be calculated for any other pressure and humidity by understanding the index of air in those conditions.

3.4
thermal chamber

chamber where the temperature of the specimen can be changed and maintained to a preset temperature

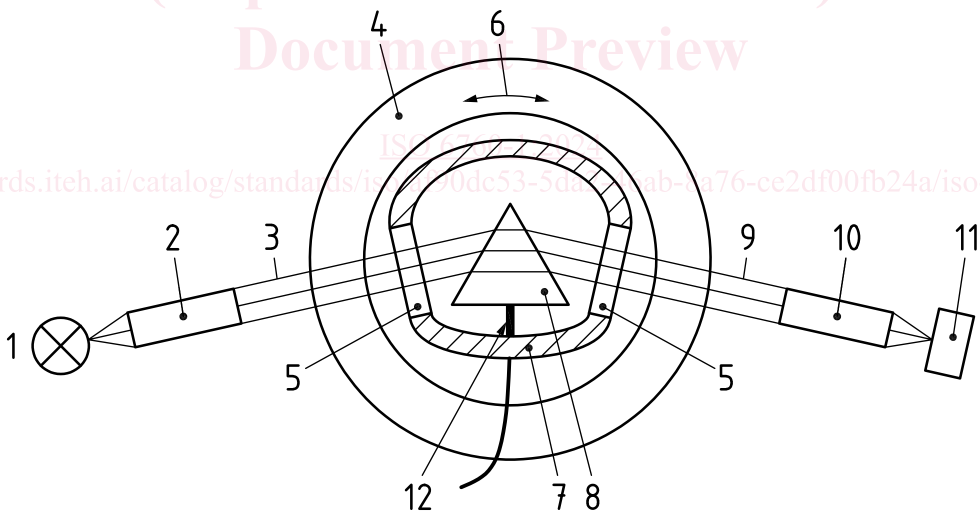
4 Principle

As shown in Figure 1, a specimen prism is placed in a thermal chamber. The temperature of the specimen prism is changed from T_1 to T_2 or from T_2 to T_1, and the refractive index of the specimen prism is measured at the temperatures of T_1 and T_2 respectively, in accordance with the method described in ISO 21395-1 to find the temperature coefficient of refractive index. Figure 2 shows the concept of calculating this temperature coefficient of refractive index.

NOTE 1 In this document the term “light” is used to describe not only optical radiation visible to the human eye but also radiation in the infrared and ultraviolet spectrum.

NOTE 2 In this document, all temperature symbols are represented by "T". The original symbol for temperature in ISO 80000-5 is "t" or "ϑ " for temperature in Celsius degrees, and "T" for absolute temperature.

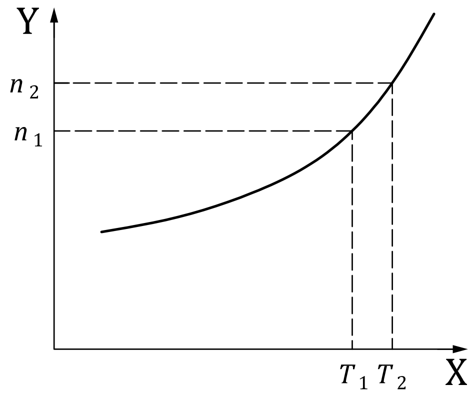
NOTE 3 Alternatively the measurement principle according to Annex C can be applied.



Key

1	light source	7	thermal chamber containing the specimen prism
2	collimator	8	specimen prism
3	incident light	9	transmitted light
4	goniometer containing the telescope and detector	10	telescope
5	window	11	detector
6	rotating stage containing the thermal chamber	12	thermometer

Figure 1 — Measurement set-up with thermal chamber



$$\frac{\Delta n}{\Delta T} = \frac{n_2 - n_1}{T_2 - T_1}$$

Key

X temperature

Y refractive index

T_1, T_2 temperature of specimen prism

n_1 refractive index of specimen prism at temperature T_1

n_2 refractive index of specimen prism at temperature T_2

Figure 2 — Conceptual diagram for calculation of temperature coefficient of refractive index

5 Measuring apparatus

5.1 Goniometer

The goniometer shall be in accordance with ISO 21395-1:2020, 5.2.

5.2 Light source

The light source shall be in accordance with ISO 21395-1:2020, 5.3.

5.3 Detector

The detector shall be in accordance with ISO 21395-1:2020, 5.4.

5.4 Thermal chamber

The thermal chamber shall follow the requirements below. An example of a thermal chamber is shown in Figure 3. The thermal chamber shall

a) have the ability to change the temperature of the specimen prism between the temperatures to be measured,

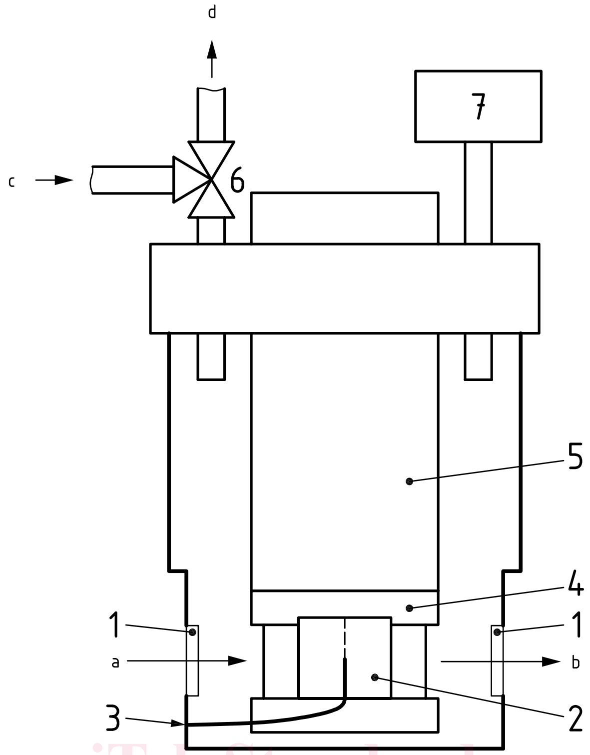
b) have a structure that can maintain the temperature distribution in the specimen within the range of 1,0 K during raising and lowering of the temperature,

c) have a thermometer to measure the temperature of the specimen prism with an accuracy of ±0,2 K or better,

d) have the ability to provide a vacuum with a residual pressure of less than 10 Pa for the purpose of having a negligible influence of the refractive index of air and of preventing condensation, and

e) have windows made of a parallel plate of quartz glass polished on both sides. The wedge angle between the parallel polished faces shall not exceed 5 arc sec, the flatness of the parallel polished faces shall be $\lambda/10$ or better.

NOTE Quartz glass is used because it has a high transmittance over a wide wavelength range, a high durability against temperature changes, and is resistant to breakage.



Key

1 window
2 specimen prism
3 thermometer
4 thermal conductor specimen holder
5 heating and cooling unit
6 three-way valve
7 vacuum gauge
[a] Incident light.
[b] Outgoing light.
[c] Leak inlet.
[d] To vacuum pump.

Figure 3 — Example of thermal chamber

6 Specimen prism

The specimen prism shall be in accordance with ISO 21395-1:2020, Clause 6.

7 Measurement

7.1 Measurement of apex angle

The apex angle of the specimen prism shall be measured in accordance with ISO 21395-1:2020, 8.2.

7.2 Measurement of the angle of minimum deviation

The angle of minimum deviation of the specimen prism shall be measured at two or more temperatures in accordance with ISO 21395-1:2020, 8.3.

The bisector of the apex angle, α, is parallel to the bisector of the angle, β, formed by the opposite two-surface window of the thermal chamber. (See Figure 4)

The degree of vacuum around the specimen prism shall be less than 10 Pa. The minimum deviation angle should be measured at a temperature within ±0,5 °C with respect to the target temperature.

NOTE 1 Allowable measurement error is an error in the measurement of the refractive index. When the allowable measurement error is smaller than $0{,}5 \times 10^{-6}$, the allowable angle difference between the bisectors of α and β is within 2°; when the allowable measurement error is smaller than $0{,}5 \times 10^{-5}$, the allowable angle difference between the bisectors of α and β is within 6°.

NOTE 2 The temperature to be measured is arbitrary. Allow sufficient time for the specimen prism to reach a uniform temperature throughout. In most cases, the temperatures measured are -40 °C, -20 °C, 0 °C, 20 °C, 40 °C, 60 °C and 80 °C.

8 Calculation

8.1 Absolute refractive index

The absolute refractive index at each temperature of the specimen prism shall be calculated by Formula (1) (adaptation of ISO 21395-1:2020, Clause 4).

$$n_{\mathrm{abs}}(T) = \frac{\sin\left[\dfrac{\alpha + \delta_{\mathrm{min,vac}}(T)}{2}\right]}{\sin\left(\dfrac{\alpha}{2}\right)} \tag{1}$$

where

$n_{\mathrm{abs}}(T)$	is the absolute refractive index of specimen prism at temperature T;
α	is the apex angle of the specimen prism;
$\delta_{\mathrm{min,vac}}(T)$	is the minimum deviation angle at temperature T;
T	is the temperature (°C) of the specimen prism during the measurement (°C).

NOTE In ISO 21395-1 the measurements are performed in air, therefore the refractive index n obtained is the relative refractive index. In this document, the measurements are performed in vacuum, and therefore the result obtained by Formula (1) is the absolute refractive index.

Figure 4 shows a schematic drawing of the light path through the thermal chamber windows and the specimen prism. The internal and external environments are air and vacuum respectively. As a consequence, light transmitted through a parallel window at non-normal incidence will be deflected.

Consequently the minimum angle of deflection in vacuum $\delta_{\mathrm{min,vac}}$ must be calculated using the correction Formula (2) to the observed angle of minimum deflection in air $\delta_{\mathrm{min,air}}$.