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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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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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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.

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

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 (ISO 21395-1) and the V-block refractometer method (ISO 21395-2[6]). 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 of the specified measurement method is an arbitrary range.

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 $1{\times}10^{-6}$ 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, *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 9802:2022[1], 3.4.2.3, 3.4.2.4.

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[1], 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[1], 3.4.2.4, modified: 1,013 3 × 10^5 Pa and a relative humidity of 0 %.]

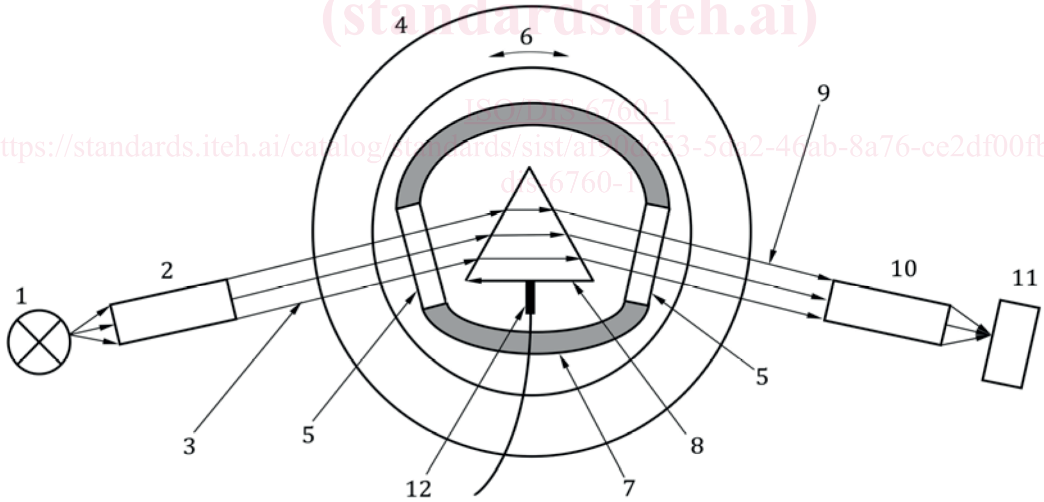
Note 1 to entry: This definition of $\Delta n_{rel}/\Delta T$ is for a specific pressure and humidity. $\Delta n_{rel}/\Delta T$ can be calculated for any other pressure and humidity by understanding the index of air in those conditions.

3.4
thermal chamber
chamber where the temperature of the specimen can be changed and/or maintained to the 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.

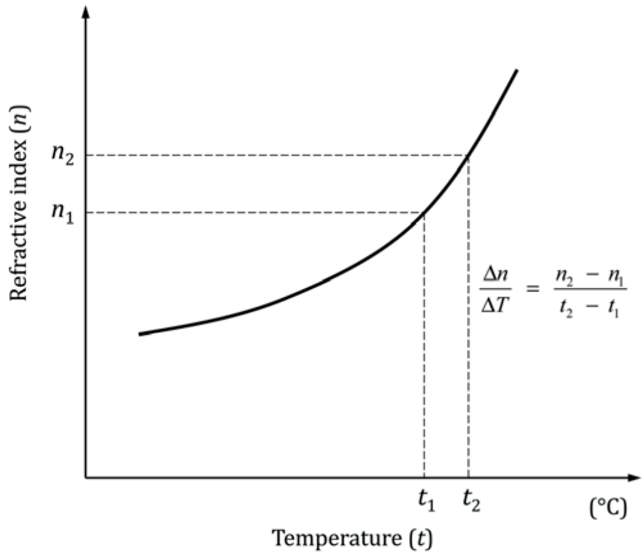
NOTE In this document the term “light” is used to describe not only optical radiation visible to the human eye but also radiation in the infrared and ultraviolet spectrum.



Key

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

Figure 1 — Measurement set-up with thermal chamber



Key

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.

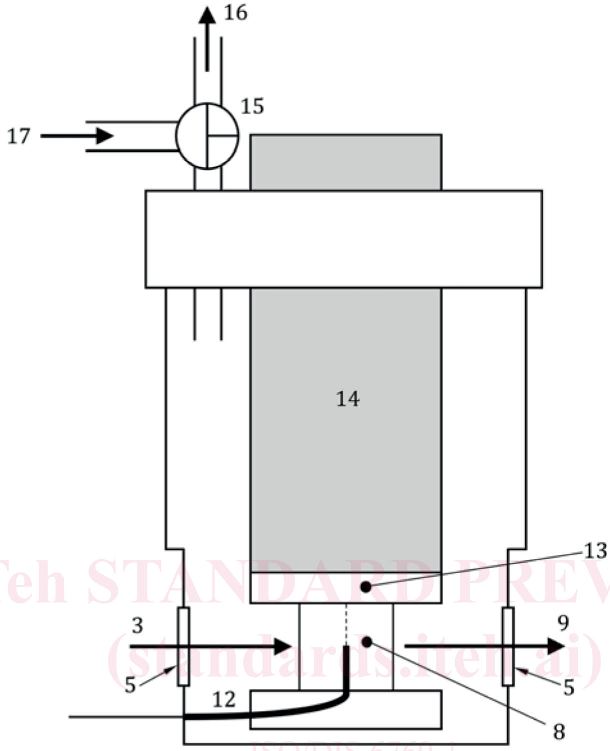
b) have a structure that can maintain the temperature distribution in the specimen within the range of 1,0 K during raising and lowering of the temperature and a capability to realize the temperature change rate..

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.

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 λ/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

3 incident light
9 outgoing light
5 window
8 specimen prism
12 thermometer
13 thermal conductor specimen holder
14 heating and cooling unit
15 three-way valve
16 to vacuum pump
17 leak inlet

Figure 3 — Example of thermal chamber

6 Specimen prism

The specimen prism shall be in accordance with ISO 21395-1:2020, 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 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 (1) (adaptation of ISO 21395-1:2020, 4).

$$n_{abs}(t) = \frac{\sin\left(\frac{\alpha + \delta_{min,vac}(t)}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)} \quad (1)$$

where

$n_{abs}(t)$ is the absolute refractive index of specimen prism at temperature t;

α is the apex angle of the specimen prism;

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