ENSURING METROLOGICAL TRACEABILITY FOR MEASUREMENTS OF REFRACTIVE INDEX

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Abstract: In this article are presented the traceability chain, standards and reference materials for Refractive Index in Bulgarian Institute of Metrology.

Keywords: metrological traceability; standards; reference materials; refractive index

1. Introduction

The Refractive Index is a ratio of the velocity of the electromagnetic waves in vacuum to the phase velocity of the waves of the monochromatic radiation in the medium [1]. Unit: 1.

$$n = \frac{Vo}{V} \qquad (1)$$

Where:

n - Refractive Index;

V_0 - velocity of the electromagnetic waves in vacuum;

V - phase velocity of the waves of the monochromatic radiation in the medium.

In practice, the relative Refractive Index "n_{21}" is the most commonly used and it is determined by the ratio of the optical radiation velocities when passing from one medium to the other.

$$n_{21} = \frac{n_2}{n_1} = \frac{V_1}{V_2} \qquad (2)$$

Law of Snellius, Fig. 1

$$\frac{\sin i}{\sin \theta} = \frac{n_2}{n_1} = n_{21} \qquad (3)$$

The Refractive Index depends on the wavelength of the radiation λ, the temperature t, the atmospheric pressure, and so on. The dependence of λ and t is denoted as follows: n_{λ}^{t}. For example n_{D}^{20} - a Refractive Iindex for the D line (589.3nm) of a sodium lamp at 20 °C.

The Refractive Index is an optical quantity that is related to the construction of the substances and their intrinsic properties. This makes it possible to use this measurable optical quantity in various fields of science and practice as a qualitative indicator as well as to quantify the composition of the substances.

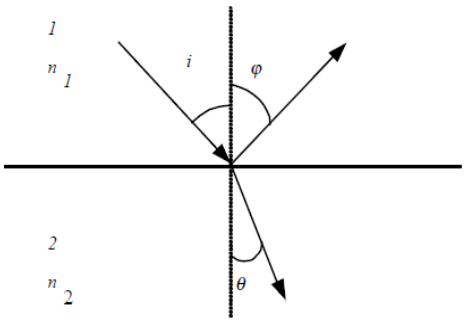

Fig.1. Law of Snellius

2.Description and metrological characteristics of the Standard of the Refractive Index Unit

The standards in the field of refractometry are:

• Measuring instruments – goniometers, refractometers.

• Certified reference materials (CPM) and reference materials (RM) [2], which may be liquid and solid (prisms and flat parallels plates, made from various brands of optical glass).

The Standard of the Refractive Index Unit of the Republic of Bulgaria is a set of measuring instruments designed, together with supporting devices, to store, reproduce and transmit the unit of lower standards. The range is from 1.4 to 1.7 and includes:

• Goniometer G-5, made in Russia with angle measuring range from 0° to 360°, resolution 1 ", basic error of the device 5" [3] – Fig. 2;

• 60° Disperrsion-Prism, made in the Faculty of Physics of Sofia University "St. Kliment Ohridsky" from optical glass K8 with angle of refraction φ = 60°±5°, deviation from planarity 0.14 μm, dimensions - basic edge 50 mm and surrounding edge 42 mm, refractive index with nominal value 1.51 - Fig. 3;

Fig.2. Goniometer G-5

Fig.3. 60° Dispersion-Prism

• Sodium spectral lamp with wavelength λ = 589.3 nm;

• Mercury spectral lamp with wavelength λ = 546.1 nm;

• A set of five Disperrsion-Prisms, made in VZORMAT, Poland with dimensions 20 x 25 x 25 mm and angles of refraction of 90° ± 5′ and 60°. The Disperrsion-Prisms have nominal Refractive Index values: № 1/87, Fluor Crown n_D^{20} = 1.46449; № 3/87, Crown n_D^{20} = 1.51759; № 4/87, Dense Barium Crown n_D^{20} = 1.62034; № 5/87, Dense Barium Flint n_D^{20} = 1.65398; Dense Flint n_D^{20} = 1.73968 - Fig. 4;

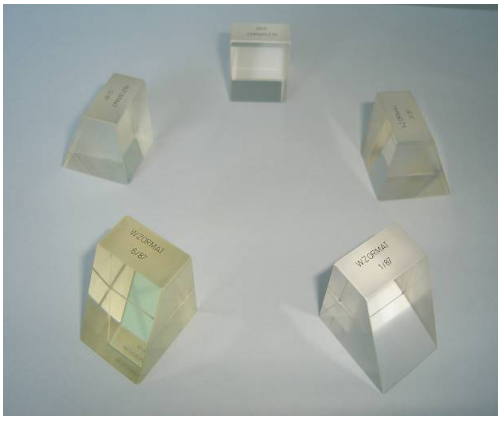

Fig.4. Set of five Dispersion-Prisms

• Refractometer type Pulfrih PR 2 with Vo prism for solid and liquid samples manufactured by Carl Zeiss Jena, Germany with a measuring range from 15° to 100°, resolution a 0.05', basic error of the instrument when measuring the Refractive Index ± 0.00002 [4] - Fig. 5.

Fig.5. Refractometer type Pulfrich PR 2

3. Traceability

A traceability chain is an unbroken chain of comparisons, all having stated uncertainties. This ensures that a measurement result or the value of a standard is related to references at the higher levels, ending at the primary standard [5].

The traceability chain for the transmission of the Refractive Index Unit is presented in Fig. 6.

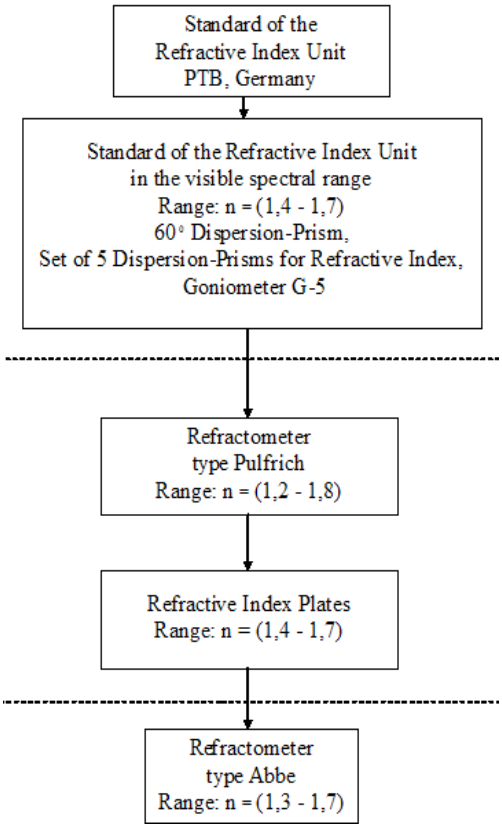

Fig.6. Traceability chain for the transmission of the Refractive Index Unit

The set consisting of five Disperrsion-Prisms was calibrated in June 2003, August 2007, June 2012, and September 2017 in the PTB, Germany. The last Certificate of calibration is shown in Fig. 7. The values of Refractive Indices from calibration are presented in Table 1. The expanded uncertainty of measurement of the Refractive Index in PTB is $U = \pm 0.000008$ for the wavelength of the yellow Sodium double line in air $\lambda = 589.3$ nm and $U = \pm 0.000005$ for the Mercury line in air $\lambda = 546.1$ nm.

The Refractive Index Unit is transmitted from the Disperrsion-Prisms set of a refractometer type Pulfrih PR 2. From the Pulfrih PR 2 refractometer, it is transmitted at the lower levels of the traceability chain of the reference refractometric plates - Fig. 8 with the expanded uncertainty of measurement $U = \pm 0.00002$, and through them on refractometers type Abbe - Fig. 9 with the expanded uncertainty of measurement $U = \pm 0.0001$.

Fig.7. Calibration Certificate of a set of five Dispersion-Prisms in September 2017 in PTB, Germany

Fig.8. Set of four Refractive Index Plates

Fig.9. Refractometer type Abbe

Table 1. Results of calibration in PTB, Germany

Refractive Index for λ=589,3 nm and temperature (20,0 ± 0,1) ºC						
Dispersion-Prism №		№ 1/87, Fluor Crown	№3 /87, Crown	№ 4/87, Dense Barium Crown	№ 5/87, Dense Barium Flint	№ 6/87, Dense Flint
PTB, Germany - 06.2003	n	1,464479	1,517575	1,620335	1,653990	1,739678
PTB, Germany - 08.2007	n	1,464482	1,517576	1,620338	1,653992	1,739682
PTB, Germany - 06.2012	n	1,464479	1,517577	1,620336	1,653987	1,739682
PTB, Germany - 09.2017	n	1,464477	1,517579	1,620345	1,653988	1,739683
Refractive Index for λ=546,1 nm and temperature (20,0 ± 0,1) ºC						
Dispersion-Prism №		№ 1/87, Fluor Crown	№3 /87, Crown	№ 4/87, Dense Barium Crown	№ 5/87, Dense Barium Flint	№ 6/87, Dense Flint
PTB, Germany - 06.2003	n	1,466228	1,519660	1,624540	1,658730	1,746098
PTB, Germany - 08.2007	n	1,466230	1,519660	1,624544	1,658731	1,746101
PTB, Germany - 06.2012	n	1,466228	1,519661	1,624544	1,658726	1,746102
PTB, Germany - 09.2017	n	1,466225	1,519663	1,624550	1,658727	1,746102

5. Conclusions

With the presented Standards of the Refractive Index Unit that are metrologically traceable to the Standard of PTB, Germany and the integrated management system implemented under ISO / IEC 17025 General requirements for the competence of testing and calibration laboratories and ISO / IEC 17043 Conformity assessment - General requirements for proficiency testing , BIM can transmit these units by calibrating measurement instruments and reference materials at different laboratories in the country, as well as organizing interlaboratory comparisons and proficiency testing.

6. References

[1] CIE S 017/E:2011 ILV: International Lighting Vocabulary.

[2] ISO/IEC.Guide 99:2007 International vocabulary of metrology — Basic and general concepts and associated terms (VIM)

[3] Goniometer G-5, Technical description

[4] Pulfrich PR 2 Gebrauchsanleitung,“Carl Zeiss JENA”

[5] Metrology in short. 3-td edition, EURAMET, 2006.

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