Optica Applicata, Vol. XII, No. 1, 1982

Letters to the Editor

Interferometric measurement of optical glass fibre refractive profiles $n(r)$ employing the zonal approximation method

MIROSŁAWA BOŻYK

Department of Physics, Technical University of Białystok, ul. Wiejska 45a, 15-351 Białystok, Poland.

1. Introduction

Of many calculation methods of the optical fibre refractive profile $n(r)$, the interferometric ones [1] are worth to notice. They offer many various measuring possibilities, and moreover, in the investigations with the use of the light perpendicularly transmitted to the fibre axis the fibres are not destroyed.

The basic assumption in the nondestructive interferometric method of testing the refractive profile $n(r)$, described in this paper is the radial symmetry of the objects to be investigated. The optic fibres, which meet this condition, are characterized by the core symmetric to the axis. The measurement method used for determining the $n(r)$ relationship, is based on the division of the fibre tested into the zones within which the constant refractive index is assumed (Fig. 1a), [2]. By calculating the index value in the successive zones of the fibre under test, the so-called zonal approximation (Fig. 1b) and thus the desired refractive profile $n(r)$ are determined.

The interferometer-polarization microscope Biolar PI, used to test the $n(r)$ relationship, belongs to microinterferometers in which the intereference of two identical waves, separated from each other, takes place. These waves produce an interference pattern of rectilinear fringes deformed in opposite directions at the point at which there appear the ordinary and extraordinary images of the object tested.

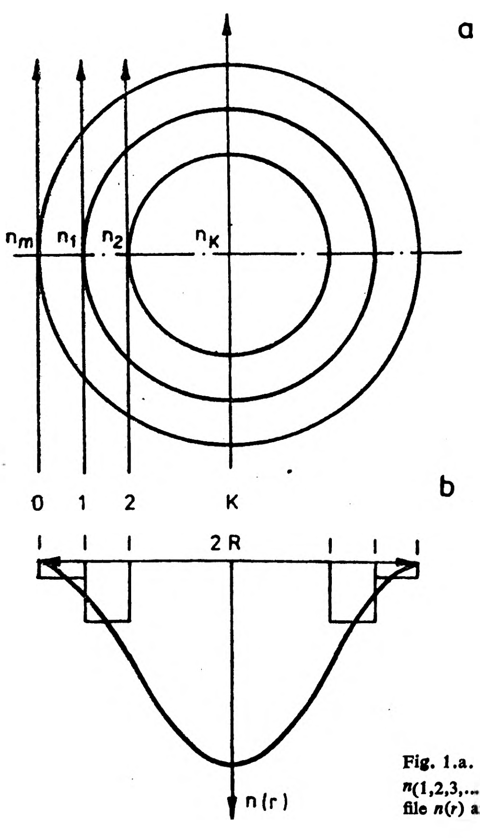

Fig. 1.a. Cross-section of the optical fibre where constant refractive index $n(1,2,3,...,i)$ = const of the annular zones is assumed. b. Refraction profile $n(r)$ and zonal approximation for the fibre of radial symmetry

2. Measurement of the refraction profile $n(r)$ by using the zonal approximation method

Two-layer optical fibres to be tested, made of multicomponent glasses, were obtained by double crucible method. This method is not always ensured to keep the correct concentricity of the core towards the fibre clading. To avoid this kind of deviation, the clading image has been eliminated from the interference image by selection of the matching oil having refractive index n_m equal to the clading refractive index n_p (Fig. 2), and therefore, $n_m - n_p = 0$. Moreover, the elimination of the clading image enables to obtain the real

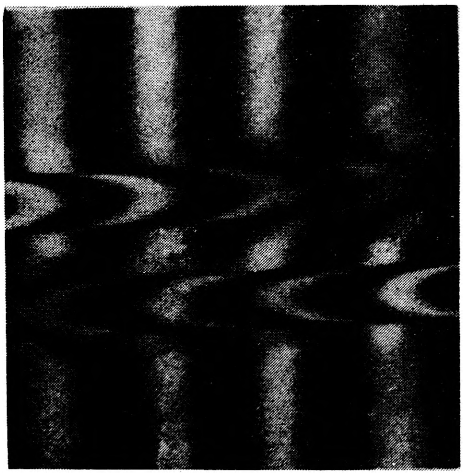

Fig. 2. Intereference image of two-layer optic fibre ($n_m = n_p$). Magnification 600 ×. (The photo was made with white light. Because of different dispersion between the matching oil fibre material, the interference fringes of order higher than zero are slightly shifted. The measurements were taken with the use of the filter for which the fringe shift in fibre clading is imperceptible.)

refraction profile, i.e., not distorted by the clading, that has been determined for the core of the fibre under test. The identity of n_p and n_m indices was visually checked with the interferometer-polarization microscope Biolar PI. Using the micrometric eyepiece coupled with the microscope, the whole area of the core under test has been divided into 10 zones equal to and symmetrical with the fibre axis. Afterwards, basing on the interference fringes position on the fibre image, the optical path difference between the beam transmitted nearby the fibre and the beam transmitted through the successive core zones was determined. By using the formula

$$\delta_k = \frac{p-p_0}{h}\lambda, \tag{1}$$

where δ_k — optical path difference in the given core zone, p_0 — position of the interference fringe of given order outside the fibre area, p — position of the same fringe in the fibre, λ — wavelength of the light used, h — fringe spacing.

Measurement of the δ value can be performed in another way. It is based on making a photo of the interference pattern appearing in the microscope and then determining the desired optical path difference by analysing the negative obtained. The analysis can be carried out with the use of any measuring microscope. A suitable transformation of the expression included in the paper [2] gives the formula describing the refractive index of any core zone of the fibre tested

$$n_i = \frac{\sum\limits_{k=1}^{i} A_{ik}\delta_k}{2R} + n_m. \tag{2}$$

The coefficients (A_{ik})*, included in the equation (2), describe a purely geometrical relationship and can be applied to the fibres of different outside diameter, provided that the number of zones into which the fibre was divided is the same (e.g., $k = 10$).

* In Table I [2] the coefficients, published by H. Hannes, for the fibre divided into 10 annular symmetric zones are included.

By measuring the p, p_0, h and R values directly on the interferogram, and selecting the suitable coefficients A_{ik}, the refraction profile in the core of the optic fibre tested (Fig. 3) has been determined from the equation (2). To avoid not complicated but time-consuming calculations a computer was used.

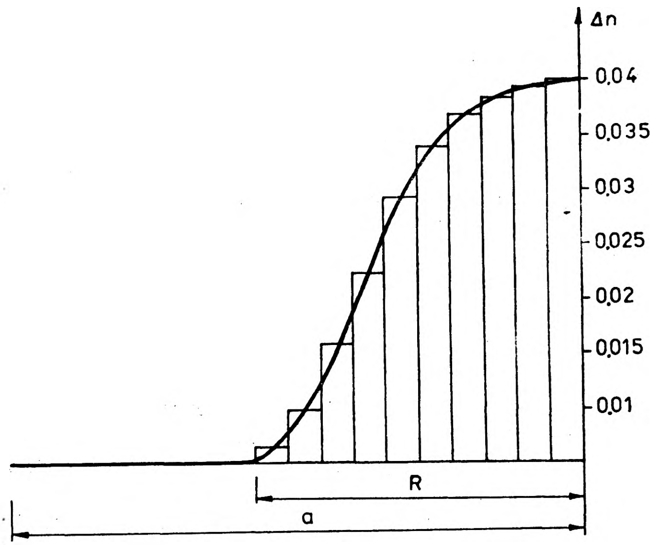

Fig. 3. Sample of refraction profile $n(r)$ of optical fibre, $\Delta n = n_i - n_m$, a — fibre radius

3. Concluding remarks

A very important question in all interferometric measuring methods is the accuracy of the optical path difference determining. The δ value should be determined for the central point of the interference fringe measured. The measuring method used in the work permitted to determine δ with the accuracy of 0.02. A higher measuring accuracy of this value can be obtained by means of the photometric method [3].

The other errors in the $n(r)$ relation estimation result due to deviations from the assumptions of the measuring method to be used. The obtained refractive-index profile $n(r)$ is as accurate as the cylindrical symmetry of the optical waveguides during the production process can be assured. Moreover, because of the fact that the refractive-index profile changes steplessly in the core, the error, related to the beam refraction in the optical fibre [4], is generated while determining the profile.

It should be emphasized that the refractive-index profile $n(r)$, obtained by the described method and determined for the tested optical glass fibres offers a suitable confirmation of the fibre production technology to be used.

The zonal approximation method described here, applied so far only in the measurements of the refractive-index profile $n(r)$ of synthetic textile fibre, can be successfully used in the glass optical waveguides as well.

References

[1] Pluta M., II Krajowe Sympozjum: *Światłowody i ich zastosowanie*, Jabłonna 1979, Vol. 2, p. 148 (in Polish).
[2] Hannes H., Kolloid-Z. u. Z. Polymere **250** (1972), 765.
[3] Pluta M., Biuletyn CLO Optyka **2** (1976), 62 (in Polish).
[4] Kokubun Y., Iga K., Trans. IECE of Japan **60** (1977), 702.

Received March 9, 1981