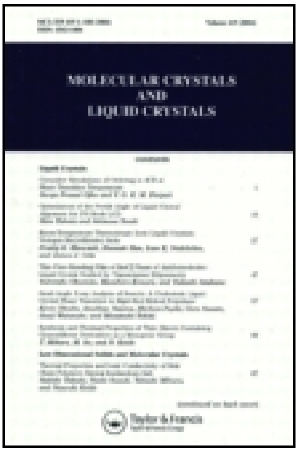


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# Interference Method for Determining Dispersion of Refractive Indices of Liquid Crystals

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*An efficient, quick and pretty accurate interference method for determining dispersions of ordinary* $n_o$ *and extraordinary* $n_e$ *refractive indices and optical anisotropy of nematic liquid crystals, i.e.,* $n_e(\lambda)$, $n_o(\lambda)$ *and* $\Delta n(\lambda) \equiv n_e(\lambda) - n_o(\lambda)$, *as functions of wavelength* $\lambda$ *(in visible and near infrared region), is presented. The method relies on measurements of positions of interference fringes in spectrogram produced by a flat-parallel nematic liquid crystal cell in only one run.*

**Keywords** Dispersion of refractive index; nematic liquid crystals; refractive indices of nematic liquid crystals



## 1. Introduction

Determination of refractive indices of homogeneously aligned nematic liquid crystals (NLC) is based on observation of light transmitted normally through a flat-parallel cell. A basic phenomena is then multi-beam interference in a homogeneous dielectric plane-parallel plate. Consider such plate or film, parallel to *Oxy* plane, being a NLC layer bounded at the distance of $d$ in *Oz* direction, and normal light incidence in *Oz* direction of three-dimensional Cartesian co-ordinate system (Fig. 1). When a beam of monochromatic, polarised and coherent light falls on a transparent film (like a

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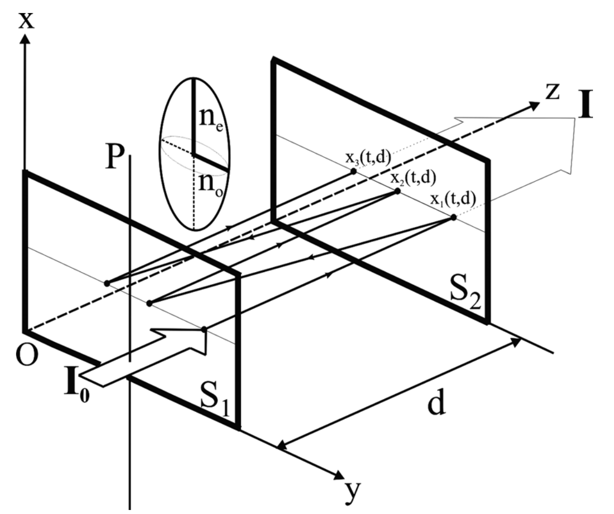


**Figure 1.** Multi-beam interference in a plane-parallel NLC cell (or a homogeneous transparent birefringent plate). The NLC layer of thickness $d$ is confined between two partially transparent and aligning surfaces $S_1$ and $S_2$. The cell is placed between two polarisers. The director of NLC is homogeneous and parallel to $Ox$ axis. The extraordinary $n_e$ and ordinary $n_o$ refractive indices, are long and short semi-axes of NLC layer optical indicatrix (in inset). Incident light travels in $Oz$ direction. Suitable combination of transmission axes of polarisers enables measurements of both refractive indices or optical anisotropy: when $\alpha=\beta=0$ or $\alpha=-\beta=1/2\pi$ or $\alpha=-\beta=1/4\pi$ (polariser axis angles measured with respect to $Ox$ axis), $n_e$ or $n_o$ or $\Delta n$ is measured, correspondingly.

NLC layer), a reflected or transmitted beam can be imagined as a series of beams of diminishing amplitudes that are produced in the consequence of multiple reflections at the film surfaces $S_1$ and $S_2$. Such plate of fixed refractive index can be surrounded by a medium of distinct refractive index or confined by partially transparent thin conductive or dielectric films. The fractions of the transmitted, reflected and absorbed light intensities satisfy equation:

$$T + R + A = 1 \tag{1}$$

where $T$, $R$ and $A$ are the coefficients of transmission, reflection and absorption. The intensity $I$ of transmitted light relates the intensity $I_0$ of the incident light by Airy's formula [1–5]

$$I = I_0\left[1 - \frac{A}{(1-R)}\right]^2 \frac{1}{1 + F\sin^2\{\frac{1}{2}\delta(\lambda)\}} \tag{2}$$

that involves Fabry's coefficient of finesse $F$

$$F = \frac{4R}{(1-R)^2}, \tag{3}$$

and the phase difference $\delta(\lambda)$ takes the form:

$$\delta(\lambda) = \frac{2\pi}{\lambda} \cdot 2dn(\lambda) + 2\psi(\lambda) \tag{4}$$

where $n$ is the refractive index of NLC layer influencing incident light polarised by a polariser OP (as explained in Fig. 1), $\lambda$ is the wavelength in vacuum and $\psi(\lambda)$ is the change of phase on reflection.

An interference methods for measuring extraordinary and ordinary refractive indices and their anisotropy for NLCs, $n_e(\lambda)$, $n_o(\lambda)$ and $\Delta n(\lambda) \equiv n_e(\lambda)–n_o(\lambda)$, as functions of wavelength (i.e., optical dispersion) can be based on exploiting experimental configuration as in Figure 1 and formulae (1)–(4) within the limit of spectral characteristics of confining surfaces $S_1$ and $S_2$ and interferometer light wavelength range [6–8].



## 2. Determination of Extraordinary and Ordinary Refractive Indices and Optical Anisotropy of Nematic Liquid Crystals in Dependence on Light Wavelength

### 2.1. *Principle of Measurements*

The interference fringes can be observed in dependence on light wavelength (by using spectrophotometer) in the focal plane of a lens collecting light transmitted normally through the plane-parallel NLC layer. According to Equation (2) maxima of intensity occur when $\sin^2(1/2\delta) = 0$ and the phase difference $1/2\delta$ is entire multiple of $\pi$:

$$\frac{1}{2}\delta = \frac{2\pi dn(\lambda)}{\lambda} + \psi(\lambda) = m\pi, \quad m = 1, 2, 3, \ldots, \tag{5}$$

and minima when $\sin^2(1/2\delta) = 1$ and the phase difference $1/2\delta$ is half-entire multiple of $\pi$:

$$\frac{1}{2}\delta = \frac{2\pi dn(\lambda)}{\lambda} + \psi(\lambda) = m\pi - \frac{1}{2}\pi, \quad m = 1, 2, 3, \ldots \tag{6}$$

Given interference order $m$, cell thickness $d$ and wavelength $\lambda$, one can calculate $n(\lambda)$ (being $n_e(\lambda)$ or $n_o(\lambda)$ in accordance with corresponding experimental configuration as in Fig. 1). To this end one of interference orders corresponding to fringes of spectrogram must be determined with using data e.g., from Abbe spectrometer.

Another way for observing the interference fringes is the use of a wedge cell with confining planes $S_1$ and $S_2$ inclined at a small angle $\alpha$ to one another ($\alpha < 0.01$ rad), that can be interpreted as a system of plane-parallel plates of different thicknesses [5].

### 2.2. *Cells for Measurements*

In order to measure unknown dispersion of refractive indices and their anisotropies and to test the method, special measuring cells of eight types (WATGl, WAT10, WAT50, WAT100, WAT500, WATIn, WATMo and WATDi) were constructed and manufactured in our laboratory under WAT1 standard. The scheme of

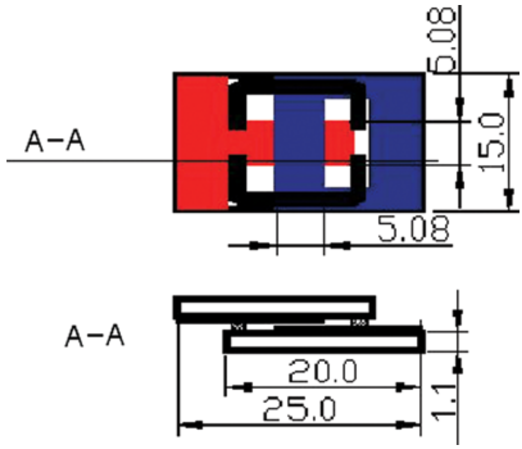


**Figure 2.** Scheme of WAT1 measuring cell. (Figure appears in color online.)



WAT1 cell is shown in Figure 2. The bottom and top substrates were prepared on the base of commercial high quality float glass mechanically polished (from Praezisions Glas&Optik GmbH) of thickness of 1.1 mm and refractive index of 1.52. The patterns of active areas (5.08 mm × 5.08 mm) in the WAT10, WAT70, WAT100 and WAT500 cells were etched in the indium-tin oxide (ITO) transparent layers deposited on glass substrates with sheet resistances of 10, 70, 100 and 500 Ω/□ (ohm per square) respectively. The patterns of active areas in the WATIn and WATMo cells were made of partially transparent layers (with thicknesses about 20 nm) of heat-resisting alloy inconel (~50 Ω/□) or molybdenum (~50 Ω/□), respectively, by deposition from vapour. The active areas of the WATDi cells were formed by deposition of multilayer dielectric mirrors (with 21 layers). The active areas of the WATGl cells were confined by glass plates. To obtained planar orientation of NLCs in all-type cells the covers were coated with Nissan SE-130 polyimide and rubbed. After rubbing treatment, two substrate glasses were joint parallel with using 3, 5, 6, 7, 8 or 10 μm thick spacers added to the sealing adhesive material printed around the edges of the cell (Fig. 2). In a properly adjusted cell, the fingers of equal inclination vanish and the whole surface has got identical colour, when observed in perpendicular incident beam of white light. Transmission $T(\lambda)$ and reflection $R(\lambda)$ spectral characteristics (obtained by spectrometer JASCO V670) of most reflecting films deposited on glass substrates are shown in Figures 3–8.

## 3. Results of Experiments and Discussion

### 3.1. *Determination of Refractive Indices of Nematic Liquid Crystals in Dependence on Light Wavelength*

Firstly transmission spectra $T(\lambda)$ of polarised light were measured for empty cells placed in the thermostatic stage of the spectrometer (JASCO V670 or BRC111A); examples are shown in Figures 9 (3.0WAT500), 10 (3.0WAT10) and 11 (3.5WATDi).

All obtained interference characteristics of empty cells are described well by Equations (2), (3) and (4) for $n = 1$ and reflection coefficients shown in

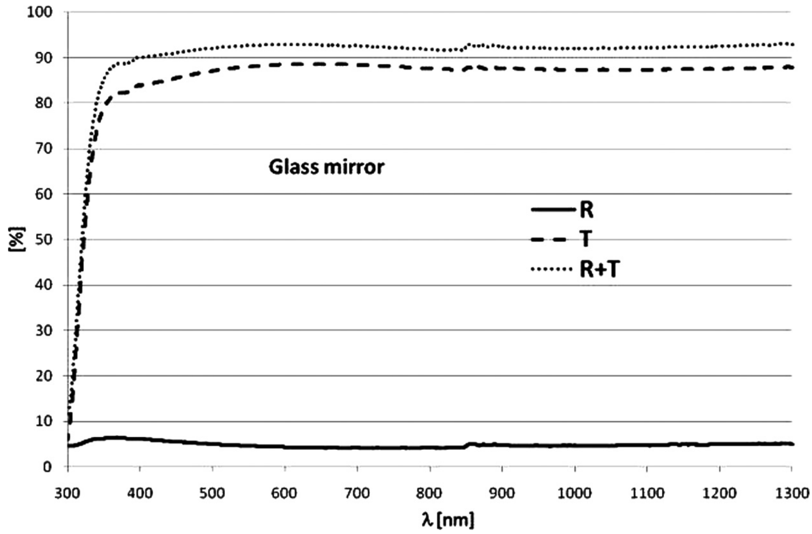


**Figure 3.** Transmission (T) and reflection (R) spectra of glass substrate.

Figures 3–8. Generally, the larger $R$, the larger coefficient of finesse $F$ and the sharper and better visible fringes, as seen in Figures 9–11. In this place it is worth to point out that in a WATGl cell (with non-coated glass plates only) filled with a NLC, with the corresponding refractive indices $n_G = 1.54$ and $n_{LC} = 1.70$,

$$R = \frac{(n_{LC} - n_G)^2}{(n_{LC} + n_G)^2} \approx 0.0024 \quad \text{and } F \approx 0.01, \tag{7}$$

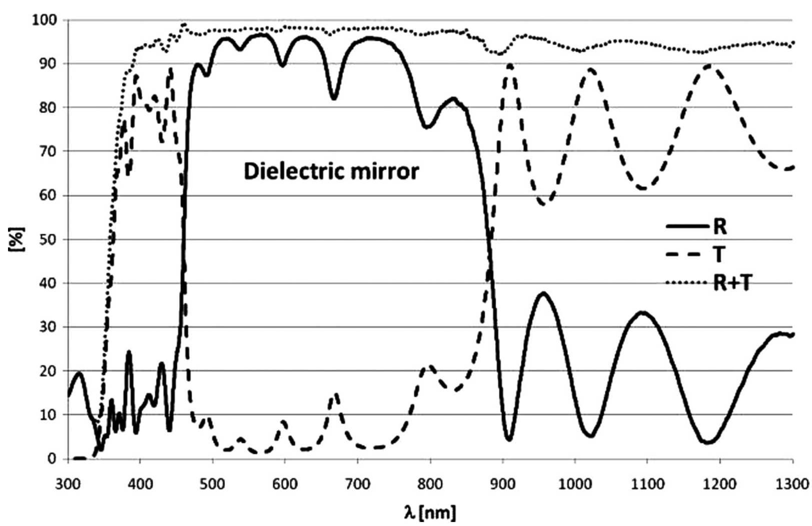


**Figure 4.** Transmission (T) and reflection (R) spectra of dielectric mirror on glass substrate.

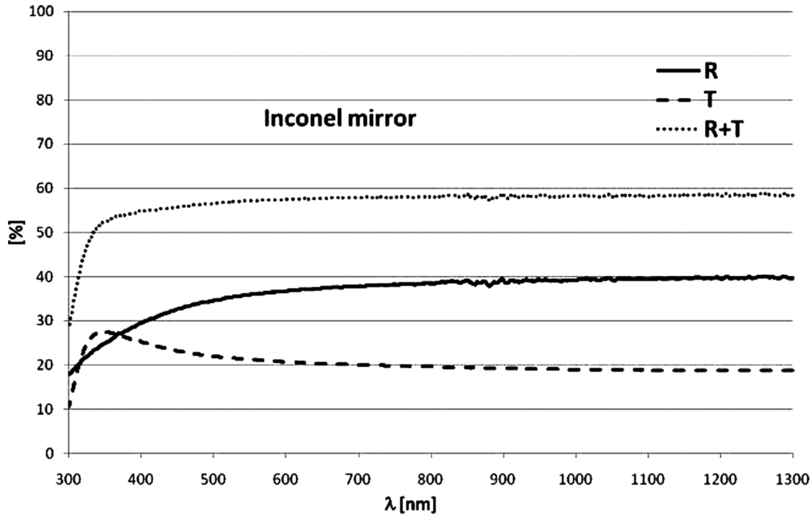


**Figure 5.** Transmission (T) and reflection (R) spectra of inconel mirror on glass substrate.

thus the interference fringes are not observed in practice. When the glass plates are covered with a thin metal film (inconel or molybdenum), for which $R \approx 0.3$ and $F \approx 3$, the fringes are sharp enough to be distinguished. The sharpest and narrowest interference fringes were observed in WATDi cells with $R \approx 0.9$ in nearly whole visible range. Moreover, for these cells (with dielectric mirrors) the change of phase $\psi(\lambda)$ on reflection in (5) equals exactly $\pi$ [4], thus (5) takes the form:

$$\frac{1}{2}\delta = \frac{2\pi d \cdot n(\lambda)}{\lambda} + \pi = m\pi, \quad m = 1, 2, 3, \ldots \tag{8}$$

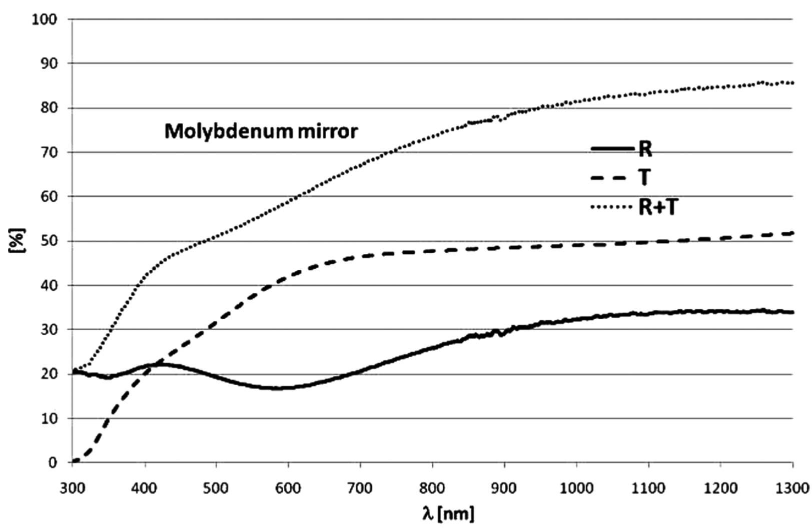


**Figure 6.** Transmission (T) and reflection (R) spectra of molybdenum mirror on glass substrate.

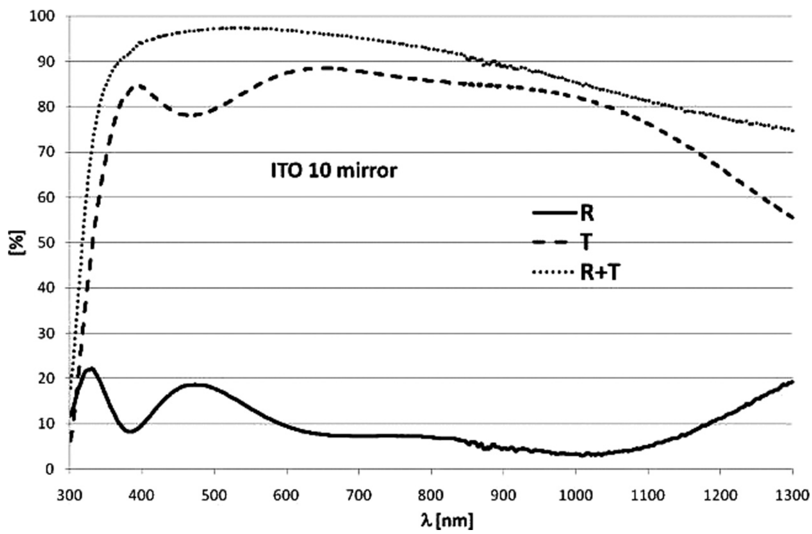


**Figure 7.** Transmission (T) and reflection (R) spectra of ITO10 mirror on glass substrate.

what can be written as

$$\frac{1}{2}\delta = \frac{2\pi dn(\lambda_m)}{\lambda_m} = m\pi, \quad m = 1, 2, 3, \ldots \tag{9}$$

for wavelength $\lambda_m$ corresponding to subsequent interference fringes. This case is illustrated in Figure 11.

When reflecting mirrors in cells are conductive (made of ITO, inconel or molybdenum) the change of phase on reflection $\psi(\lambda)$ in (5) differ from $\pi$ [4] and (5) can be

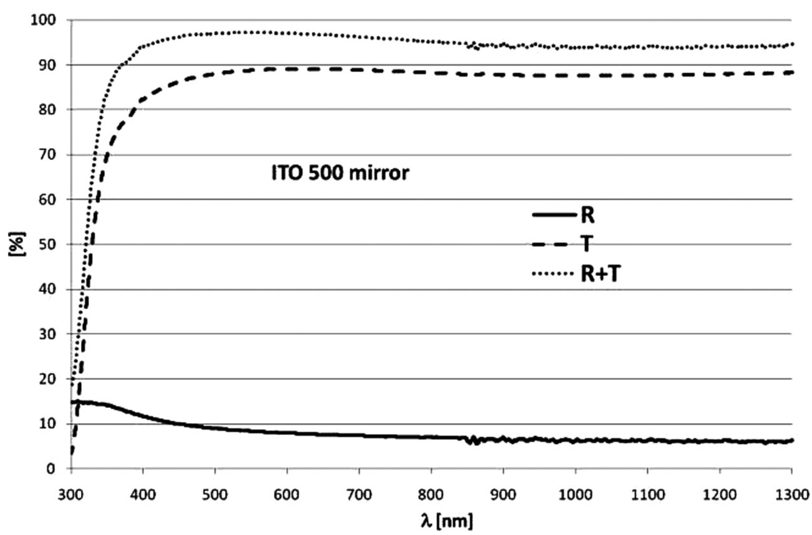


**Figure 8.** Transmission (T) and reflection (R) spectra of ITO500 mirror on glass substrate.

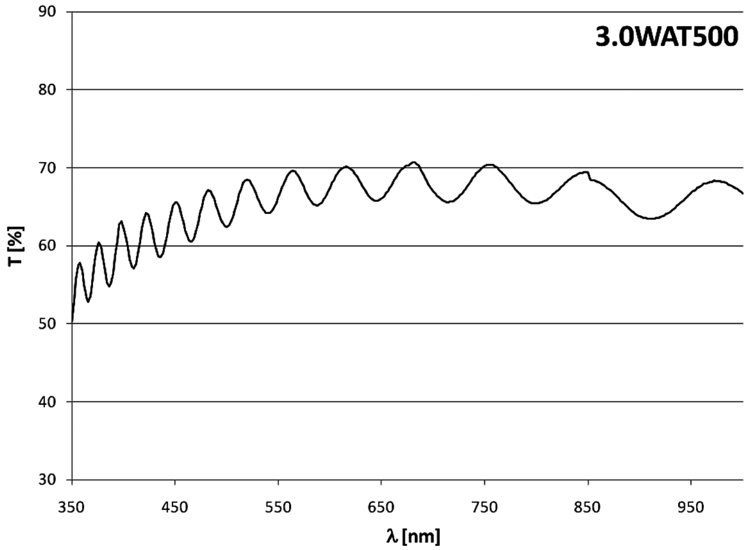


**Figure 9.** Interference fringes from empty 3.0WAT500 cell (with $d = 3.00\,\mu m$) recorded by the JASCO V670 spectrometer.

written as:

$$\frac{1}{2}\delta = \frac{2\pi d n(\lambda_m)}{\lambda_m} + \varphi_m \pi = m\pi, \quad m = 1, 2, 3, \ldots \tag{10}$$

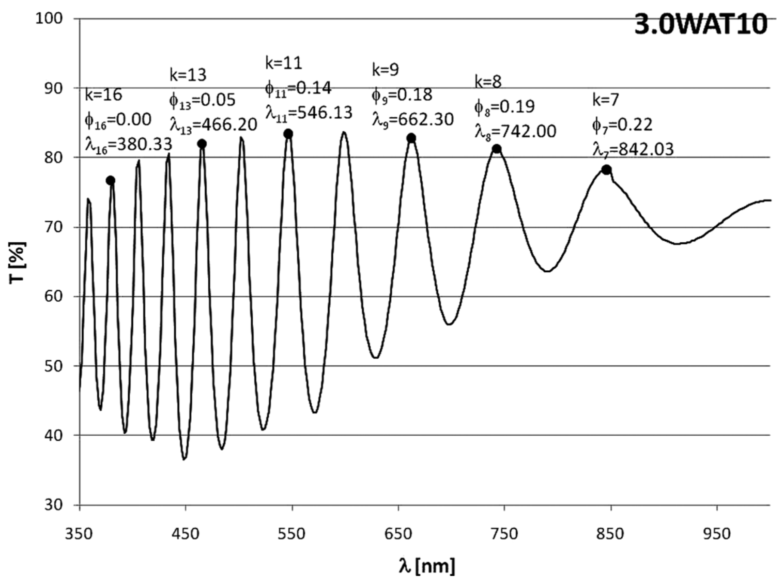


**Figure 10.** Interference fringes from empty 3.0WAT10 cell (with $d = 3.04\,\mu m$) recorded by the JASCO V670 spectrometer.

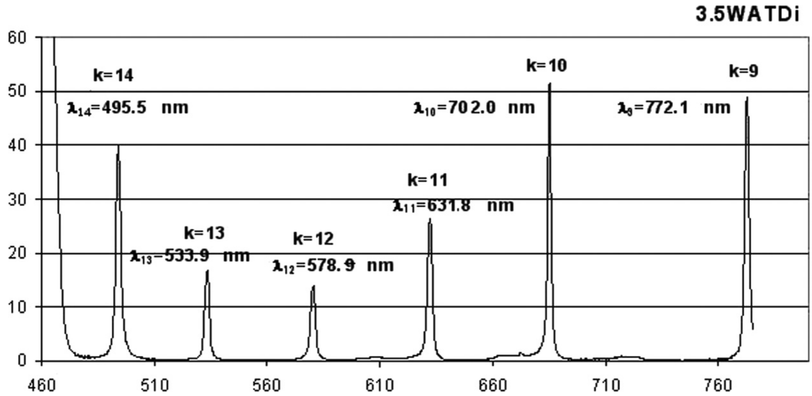


**Figure 11.** Interference fringes from empty 3.5WATDi cell (with $d = 3.47\,\mu$m) recorded by the BRC111A spectrometer.

where $\varphi_m$ is a positive real number (this case is illustrated in Fig. 10). It is very difficult to determine experimentally or predict theoretically the character of changes of $\psi(\lambda_m)$ [4]. Omitting $\psi(\lambda_m)$ from equation (10) by taking $\varphi_m = 0$ results in error of determining refraction index that depends on the numbers involved.

After registering transmission spectra for empty cells, cells of all types were filled with 5CB (4-n-pentyl-4′-cyanobiphenyl), for which the dispersions of refractive indices $n_e(\lambda)$ or $n_o(\lambda)$ are well known [9,10]. Hence these cells were applied to verify suitability of the method. Figure 12 shows interference fringes in transmission spectrum recorded (by the BRC111A spectrometer) for 5CB in 3.5WATDi cell (with thickness $d = 3.47\,\mu$m) when only one polariser with $\alpha = 1/2\pi$ (before the cell) was applied. Positions $\lambda_m$ of peak maxima satisfy precisely Equation (9) with $n(\lambda_m) = n_o(\lambda_m)$:

$$\frac{2dn_o(\lambda_m)}{\lambda_m} = m\pi, \quad m = 1, 2, 3, \ldots \tag{11}$$

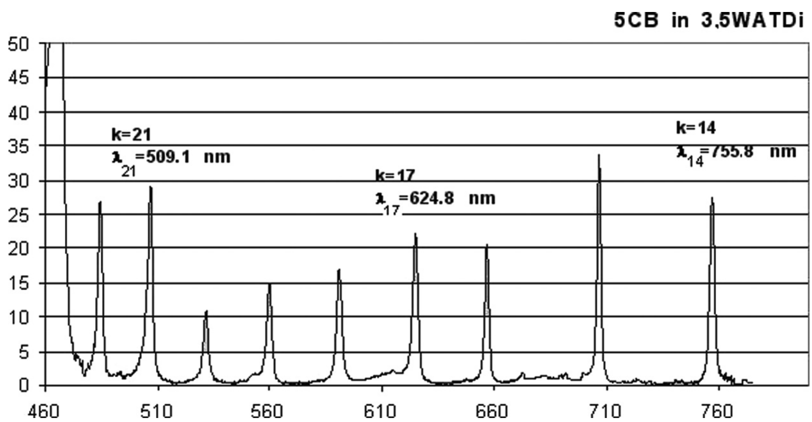


**Figure 12.** Interference fringes for 5CB in 3.5WATDi cell (with $d = 3.47\,\mu$m) when $\alpha = 1/2\pi$ (only one polariser before the cell was applied). Transmission spectrum $T(\lambda)$ related to $n_o(\lambda)$ was recorded by the BRC111A spectrometer.

**Table 1.** 5CB in 3.5WATDi cell with $d = 3.47\,\mu m$ when $\alpha = 1/2\pi$ (only one polariser before the cell was applied). The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_o(\lambda_m)$ and $d$ by Equation (9)

| $m$ | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda_m$[nm] | 467.0 | 487.4 | 509.1 | 534.0 | 561.0 | 590.9 | 624.8 | 659.1 | 706.4 | 755.8 |
| $n_o(\lambda_m)$ | 1.5478 | 1.5452 | 1.5406 | 1.5396 | 1.5360 | 1.5327 | 1.5305 | 1.5194 | 1.5268 | 1.5246 |
| $n_o$ [10] | 1.5495 | 1.5453 | 1.5420 | 1.5383 | 1.5354 | 1.5326 | 1.5307 | 1.5285 | 1.5267 | 1.5248 |

and can be unequivocally attributed to proper interference orders $m$ provided one of them is identified. The measurement were repeated with $\alpha = 0$ for $n_e(\lambda_m)$. The values $n_o = 1.5330$ and $n_e = 1.7170$ determined with using an Abbe refractometer for yellow sodium line $\lambda = 589.3$ nm served for scaling both spectrograms. The results are gathered in Tables 1 and 2 together with data from work [10] for comparison. Except two outliers the absolute differences between corresponding entries of both result series are not larger than 0.003.

When conductive mirrors are used (in WAT10, WAT70, WAT100, WAT500, WATIn and WATMo cells), the difficulties with unknown changes of phase on reflections, $\psi(\lambda_m)$, appear. In this cases the identification of proper numbers $m$ for $\lambda_m$ is not so clear, as it was before, and can result in imprecise values of $n_o(\lambda)$ and $n_e(\lambda)$ for studied NLCs. This ambiguity is illustrated in Tables 3–5. Figure 13 shows interference fringes produced for $n_e(\lambda)$ by 5CB in 7.7WAT70 cell with thickness of $7.62\,\mu m$ when $\alpha = 0$ (only one polariser before the cell was applied). The coefficients $\varphi_m$ were calculated from formula (10) by treating the characteristic $n_e(\lambda)$ for 5CB from [10] as the reference (Table 3). A clear tendency of variation $\varphi_m = \varphi_m(\lambda_m)$ is

**Table 2.** 5CB in 3.5WATDi cell with $d = 3.47\,\mu m$ when $\alpha = 0$ (only one polariser before the cell was applied). The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_e(\lambda_m)$ and $d$ by Equation (9)

| $m$ | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda_m$[nm] | 468.9 | 484.9 | 503.9 | 523.0 | 544.6 | 568.7 | 594.9 | 626.0 | 656.7 | 694.9 |
| $n_e(\lambda_m)$ | 1.7568 | 1.7468 | 1.7426 | 1.7338 | 1.7265 | 1.7209 | 1.7144 | 1.7139 | 1.7032 | 1.7023 |
| $n_e$ [10] | 1.7573 | 1.7443 | 1.7417 | 1.7340 | 1.7260 | 1.7214 | 1.7150 | 1.7102 | 1.7056 | 1.7010 |

**Table 3.** 5CB in 7.6WAT70 cell with $d = 7.62\,\mu m$ when $\alpha = 0$ (only one polariser before the cell was applied). The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_e(\lambda_m)$ and $\varphi_m$ by Equation (10)

| $m$ | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda_m$[nm] | 461.4 | 469.6 | 478.1 | 486.7 | 496.0 | 505.6 | 515.7 | 526.3 | 537.6 | 547.9 |
| $\varphi_m$ | −1.23 | −1.01 | −0.84 | −0.77 | −0.56 | −0.43 | −0.33 | −0.17 | −0.04 | 0.00 |
| $n_e$ [10] | 1.7627 | 1.7569 | 1.7519 | 1.7490 | 1.7442 | 1.7397 | 1.7367 | 1.7326 | 1.7298 | 1.7259 |

**Table 4.** 5CB in 7.6WAT70 cell with $d = 7.62\,\mu\mathrm{m}$ when $\alpha = 0$ (only one polariser before the cell was applied). The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_e(\lambda_m)$ by Equation (9) ($\varphi_m = 0$ is assumed). Spectrum is scaled to $n_e = 1.7170$ at $\lambda_m = 589.3$ nm and $m = 44$ assigned

| $m$ | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda_m$[nm] | 461.4 | 469.6 | 478.1 | 486.7 | 496.0 | 505.6 | 515.7 | 526.3 | 537.6 | 547.9 |
| $\varphi_m$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $n_e(\lambda_m)$ | 1.7256 | 1.7257 | 1.7254 | 1.7245 | 1.7248 | 1.7253 | 1.7257 | 1.7267 | 1.7284 | 1.7258 |
| $n_e$ [10] | 1.7627 | 1.7569 | 1.7519 | 1.7490 | 1.7442 | 1.7397 | 1.7367 | 1.7326 | 1.7298 | 1.7259 |

**Table 5.** 5CB in 7.6WAT70 cell with $d = 7.62\,\mu\mathrm{m}$ when $\alpha = 0$ (only one polariser before the cell was applied). The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_e(\lambda_m)$ by Equation (9) ($\varphi_m = 0$ is assumed). Spectrum is scaled to $n_e = 1.7490$ at $\lambda_m = 486.1$ nm and $m = 55$ assigned

| $m$ | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\lambda_m$[nm] | 461.4 | 469.6 | 478.1 | 486.7 | 496.0 | 505.6 | 515.7 | 526.3 | 537.6 | 547.9 |
| $\varphi_m$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $n_e(\lambda_m)$ | 1.7559 | 1.7565 | 1.7567 | 1.7565 | 1.7574 | 1.7584 | 1.7595 | 1.7611 | 1.7636 | 1.7617 |
| $n_e$ [10] | 1.7627 | 1.7569 | 1.7519 | 1.7490 | 1.7442 | 1.7397 | 1.7367 | 1.7326 | 1.7298 | 1.7259 |

noticeable. If the light phase shift on reflection is neglected by taking $\varphi_m = 0$, then the results of measurement interpreted with using formula (9) may depend on the choice of scaling reference values obtained from an Abbe spectrometer: by taking $n_e = 1.7170$ at $\lambda_m = 589.3$ nm (yellow sodium line) and $m = 44$ (instead of resulting $m \approx 44.40$) one obtains entries collected in Table 4 (where $m = 54$ is assigned to

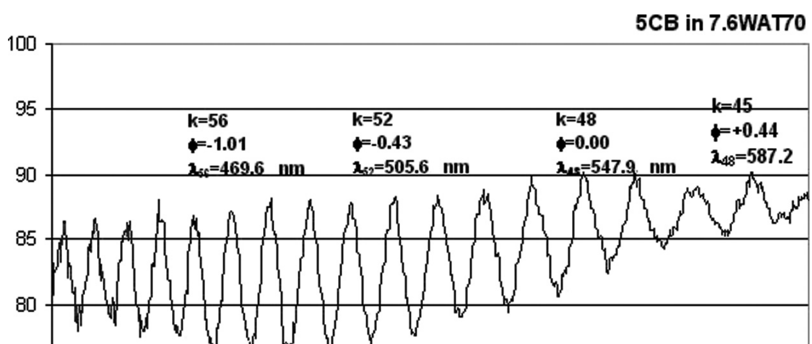


**Figure 13.** Interference fringes for 5CB in 7.6WAT70 cell (with $d = 7.62\,\mu\mathrm{m}$) when $\alpha = 0$ (only one polariser before the cell was applied). Transmission spectrum $T(\lambda)$ related to $n_e(\lambda)$ was recorded by the BRC111A spectrometer.

the fringe of $\lambda_m = 486.7\,\text{nm}$), while by taking $n_e = 1.7490$ at $\lambda_m = 486.1\,\text{nm}$ (blue mercury line) and $m = 55$ (instead of resulting $m \approx 54.83$) one obtains entries collected in Table 5 (where $m = 55$ is assigned to the fringe of $\lambda_m = 486.7\,\text{nm}$). The absolute error of determining $n_o(\lambda)$ and $n_e(\lambda)$ in this way is smaller than 0.04. It was observed smaller when measurements were realised with using thicker cell equipped with reflectors of larger resistivity (e.g., for 5CB in the 10WAT500 cell the absolute error was smaller than 0.01 in visible and near-infrared range). Determination of anisotropy of refractive index as $\Delta n(\lambda) \equiv n_e(\lambda) - n_o(\lambda)$ from such data would be rather imprecise (with relative error up to 40%).

As it follows from these results, the cells with dielectric cover mirrors provide good accuracy of determining refractive indices and optical anisotropy, but on expense of manufacturing rather complicated, laborious and costly cells. Rather cheap and quick measurements of $n_o(\lambda)$ and $n_e(\lambda)$ with accuracy sufficient for brief overview of new materials can be performed by applying cells with conductive mirrors of larger resistivity, like WAT500, WATIn and WATMo.



### 3.2. *Determination of Optical Anisotropy of Nematic Liquid Crystals in Dependence on Light Wavelength*

The optical anisotropy of NLC as a function of light wavelength can be determined (using experimental configuration as described above) in two ways: by computing $\Delta n(\lambda) \equiv n_e(\lambda) - n_o(\lambda)$ from $n_o(\lambda)$ and $n_e(\lambda)$ previously measured or by immediate measurements exploiting birefringent configuration. Both method were applied to determining optical properties of a new NLC.

Based on mixtures of isothiocyanato tolane and isothiocyanato terphenyl developed in our university [11,12], a new NLC with phase sequence: Cr 12.0°C N 136.7°C Iso, featured with large optical anisotropy, was produced. The optical properties of this NLC, labelled W1825 K, were studied in a 5.2WAT500 cell with using the JASCO V670 interferometer and method described above. The results were verified by means of wedge cell (where glass plates were covered with inconel reflectors) and more accurate measurement method [5]. Dispersion characteristics $n_o(\lambda)$ and $n_e(\lambda)$ measured at 25°C with using one polariser ($\alpha = 1/2\pi$ or $\alpha = 0$, respectively, as in Fig. 1) are presented in Table 6. Similar characteristics determined by means of wedge cell are shown in Table 7. The optical anisotropy as a function of wavelength was determined from cell placed between crossed polarisers ($\alpha = 1/4\pi$, $\beta = -1/4\pi$, Fig. 1); the birefringent interference spectrum is shown in Figure 14. According to [13] an order $b$ of a birefringent line is related with $\Delta n$ and cell thickness $d$ by:

$$\frac{d\Delta n}{\lambda_b} = \frac{2b - 1}{2} \tag{12}$$

where $\lambda_b$ is the wavelength at the maximum of the birefringent fringe. The birefringent interference spectrogram for W1825K is shown in Figure 14, and the dispersion characteristic calculated from maxima of this curve (by formula (12)) is presented in Table 8. All values of $\Delta n(\lambda)$ obtained for W1825 K NLC from data of Tables 8 (squares), 7 (circles) and 6 (triangles) are displayed in diagram in Figure 15. The agreement of these three characteristics is good, partially due to large values of $\Delta n(\lambda)$. The point marked by diamond, $\Delta n = 0.31$ at $\lambda = 1064\,\text{nm}$, seems to belong

**Table 6.** W1825 K in 5.2WAT500 cell with $d = 5.21\,\mu m$. Transmission spectra were recorded (only one polariser before the cell was applied): related to $n_o(\lambda_m)$ when $\alpha = 0$ and related to $n_e(\lambda_m)$ when $\alpha = 1/2\pi$. The interference order $m$ for maximum light intensity in the fringe at position $\lambda_m$ is related to $n_\bullet(\lambda_m)$ by Equation (9) ($\varphi_m = 0$ is assumed). Spectra were scaled to $n_e = 1.830$ and $n_o = 1.453$ at $\lambda = 673.1$ nm (determined from the wedge cell method)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $m_o$ | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 |
| $\lambda_m$[nm] | 612.5 | 634.5 | 659.0 | 686.5 | 715.0 | 749.0 | 787.0 | 829.0 | 877.0 |
| $n_o$ | 1.470 | 1.462 | 1.455 | 1.450 | 1.441 | 1.438 | 1.435 | 1.432 | 1.431 |
| $m_e$ | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 |
| $\lambda_m$[nm] | 641.0 | 657.5 | 679.0 | 703.0 | 746.0 | 765.0 | 787.0 | 811.5 | 842.5 |
| $n_e$ | 1.845 | 1.830 | 1.825 | 1.822 | 1.820 | 1.815 | 1.813 | 1.791 | 1.779 |



**Table 7.** Refraction indices $n_o(\lambda)$, $n_e(\lambda)$ and $\Delta n(\lambda) \equiv n_e(\lambda)–n_o(\lambda)$ of W1825 K NLC measured by means of wedge cell with inconel reflectors

| $\lambda$[nm] | 486.1 | 500.7 | 589.3 | 656.2 | 673.1 |
|---|---|---|---|---|---|
| $n_o(\lambda)$ | 1.525 | 1.515 | 1.475 | 1.460 | 1.453 |
| $n_e(\lambda)$ | 2.011 | 1.995 | 1.901 | 1.855 | 1.830 |
| $\Delta n(\lambda)$ | 0.486 | 0.480 | 0.426 | 0.395 | 0.377 |

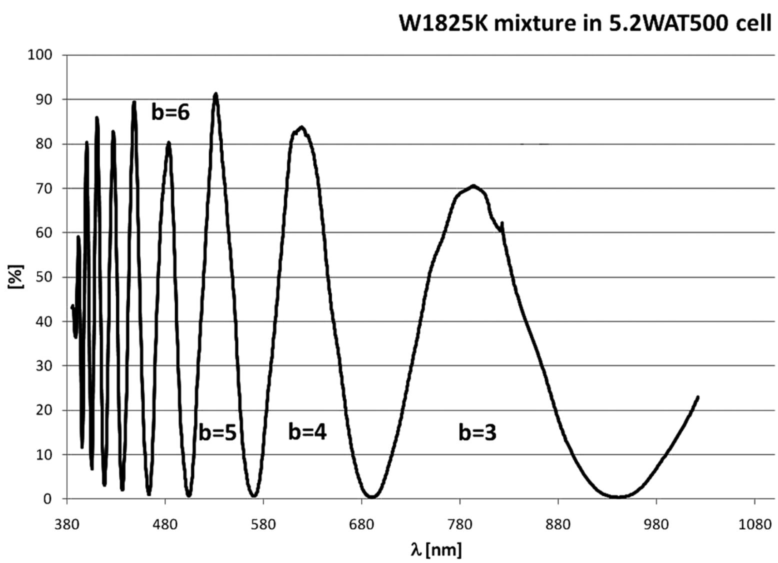


**Figure 14.** The birefringent interference fringes for W1825 K NLC in 5.2WAT500 cell (with $d = 5.21\mu m$) placed between crossed polarisers ($\alpha = 1/4\pi$, $\beta = -1/4\pi$). Transmission spectrum $T(\lambda)$ was recorded by the JASCO V670 interferometer.

**Table 8.** Dispersion of optical anisotropy $\Delta n(\lambda)$ for W1825 K NLC measured independently (computed from Eq. (12))

| $b$ | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 |
|---|---|---|---|---|---|---|---|---|---|
| $\lambda_b$[nm] | 391.5 | 400 | 410.5 | 427 | 448.5 | 483.5 | 531 | 611.5 | 782 |
| $\Delta n(\lambda)$ | 0.866 | 0.846 | 0.671 | 0.616 | 0.561 | 0.484 | 0.460 | 0.412 | 0.376 |

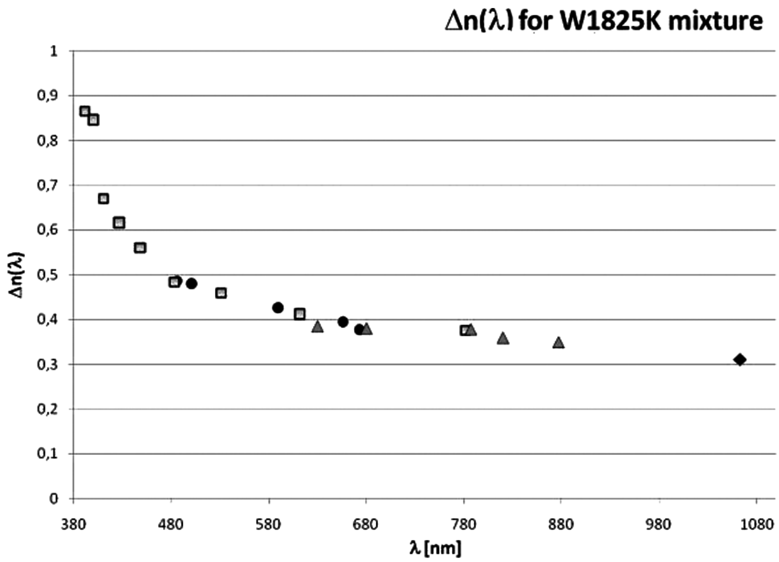


**Figure 15.** Dispersion of optical anisotropy $\Delta n(\lambda)$ for W1825K NLC. Data points are taken from tables 8 (squares), 7 (full circles) and 6 (triangles), diamond denotes $\Delta n = 0.31$ at $\lambda = 1064$ nm.

to this characteristic and in this way the W1825 K NLC may satisfy the requirements of International Space Mission "Fobos-Grunt" program for optical properties of LC to be applied.

## Conclusion

The method for determining the dispersion of refractive indices of nematic liquid crystals was proposed and verified experimentally. It relies on constructing a special flat-parallel NLC cell with covers coated with semi-transparent reflecting films and measuring interference spectra in only one run of a spectrometer. It enables quick measurements with accuracy quite sufficient for qualification of NLC newly produced, especially when only a small amount of substance is disposable. The limitation for accuracy of the method are accuracy of determining the cell thickness and omitting the light phase change on reflection from cell cover mirrors. The accuracy can be significantly improved by taking thicker cells and exploiting non-conducting mirrors, but it requires producing expensive multi-layer dielectric films.

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