Optica Applicata, Vol. XX, No. 1, 1990

Matrix analysis of the polarization transformer

L. Jaroszewicz

Institute of Technical Physics, ul. S. Kaliskiego 25, 01–489 Warszawa, Poland.

M. Szustakowski

Institute of Plasma Physics and Laser Microfusion, P.O. Box 49, 00–908 Warszawa, Poland.

A mathematical analysis of operation of the passive fiber optic polarization transformer (PT) is presented. Using the Jones matrix formalism, the equivalent lumped element representation (ELER) of the system is given and the physical meaning for each of its elements is described. It is shown that any state of polarization in optical fiber may be formed by polarization transformer.

1. Introduction

The development of the basis of fundamental optical elements introduced by the fiber optic technology made it possible to produce a new generation of optical sensors. The fiber optic gyroscope is one of such sensors the parameters of which are considerably better than those of mechanical gyroscopes. In a technical sense, this sensor is composed of five optical elements, such as: sensing loop, optical couplers, polarizer, phase modulator, and polarization transformer.

The analysis of the gyroscope operation requires the description of individual elements by means of analytical functions and the application of a proper method to the description of the whole system. The effective mehod is the Jones matrix formalism which allows the description of the interference phenomena in terms of the known input polarization and matrix characteristics of individual system elements [1], [2].

Below, the representation of the Jones matrix and its analysis for the polarization transformers, the construction of which was presented in paper [3], are given. The polarization transformer system is based on a Lefevre fiber optic quarter-wave elements conception [4], and consists of two single mode fiber loops of radii (R) chosen in such a way that the birefringence forced in those loops causes the phase delay equal to a wavelength. This is possible for the loop radii given by the formula

$$R = \frac{2\pi}{\lambda} a\, d^2 \tag{1}$$

wnere: λ – light wavelength, d – diameter of single-mode fiber, and $a = 0.133$ is a constant for silica fiber. The mounting of each loop enables its rotation by an arbitrary angle (Fig. 1). Such a rotation through the twisting of the fiber within the segments beyond the loop causes the change of the direction of the main axis of input

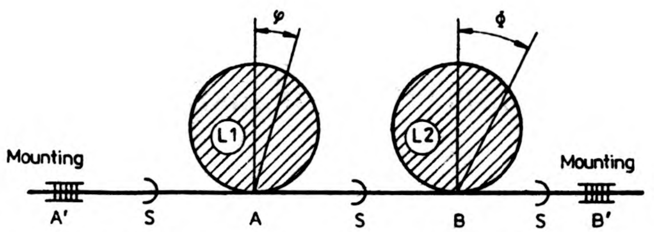

Fig. 1. Polarization transformer scheme: A', B' – places the fiber was fixed, $L1$, $L2$ – quarter-wave loops, S – fiber segments subject to twist

polarization ellipse for the light entering the second loop, which, in turn, brings about the change in the state of polarization leaving the system. Thus, by a suitable arrangement of both the loops the polarizations state (SOP) can be changed arbitrarily.

2. Jones matrix formalism

Because of the matrix description requirements the concept of the Jones vector was introduced. This vector describes completely the polarization state of a light beam in terms of two orthogonal components of the electric field vector. If we assume the Cartesian co-ordinate system (ξ, η, z), the Jones vector for a beam propagating along the z-direction takes the form

$$\boldsymbol{E}(z) = \begin{bmatrix} E_\xi \exp(j\delta_\xi) \\ E_\eta \exp(j\delta_\eta) \end{bmatrix} \tag{2}$$

where E_i, δ_i ($i = \xi$, η) are the amplitude and phase of electric field components along i-axis, respectively.

Let us assume that the Jones vector $\boldsymbol{E}(0)$ describes the SOP of the beam entering the optical system and that the $\boldsymbol{E}(z)$ describes SOP of the wave leaving this system. Then, in conformity with the Jones matrix formalism [2], these two vectors are connected by the following matrix relation:

$$\boldsymbol{E}(z) = \boldsymbol{M}\boldsymbol{E}(0) \tag{3}$$

where $\boldsymbol{M}$ is 2×2 the Jones matrix of the system.

The above matrix describing the optical system has different form depending on the choice of basic vectors. In order to unify the description as basic vectors the eigenvectors of the given matrix are taken. In such a case the Jones vector is a linear combination of the above vectors and the Jones matrix takes a diagonal form with its elements equal to its eigen values [5]. The Jones matrices obtained in this way may be divided into three groups, describing the operation of optical elements [2]:

i) Matrix of linear phasedelayer (retarder)

$$\boldsymbol{G}(\delta) \equiv \begin{bmatrix} e^{j\delta} & 0 \\ 0 & e^{-j\delta} \end{bmatrix} \tag{4a}$$

where 2δ is birefringence introduced by this element or a matrix of constant-phase delay element which describes the light passes through the isotropic element

$$D(\Delta) \equiv e^{-j\Delta}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix} \tag{4b}$$

where Δ is the phase delay of light wave introduced by this element.

ii) Matrix of polarizer

$$P(p_1, p_2) \equiv \begin{bmatrix}p_1 & 0\\ 0 & p_2\end{bmatrix}, \quad p_1, p_2 \leqslant 1, \tag{5a}$$

a particular case of which is the matrix of absorber element

$$A(p) \equiv \begin{bmatrix}p & 0\\ 0 & p\end{bmatrix}, \quad p < 1 \tag{5b}$$

where p_1, p_2, p, are the amplitude losses of a given field component.

iii) Matrix of an element twisting the polarization state (rotator)

$$R(\theta) \equiv \begin{bmatrix}\cos\theta & -\sin\theta\\ \sin\theta & \cos\theta\end{bmatrix} \tag{6}$$

where θ denotes the angle about which the polarization is twisted during light propagating through this element.

The essence of the given classification is the fact that an arbitrary optical system may be represented as a combination of the above basic elements [2].

3. Jones matrix of a disturbed single-mode fiber

The ideal single-mode optical fiber is the isotropic waveguide medium having two degenerated polarization eigenmodes e_1, e_2 [6], [7]. These modes have equal spatial field distributions and propagation constants $\beta_1 = \beta_2 = \beta$ and linear, mutually orthogonal polarization states. The assumption of two eigenmodes as basic vectors for determining the Jones vector

$$E(z) = E_x e_1 + E_y e_2 = \begin{bmatrix}E_x\\ E_y\end{bmatrix} \tag{7}$$

leads in the Jones matrix formalism to the representation of beam propagating across the fiber in z direction as

$$E(z) = e^{-j\beta z}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}E(0). \tag{8}$$

The product of the exponential function and the unit matrix appearing in Eq. (8)

$$M \equiv e^{-j\beta z}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix} = D(\beta z) \tag{9}$$

is the Jones matrix for an ideal single-mode optical fiber.

In this case, an optical fiber is physically equivalent to a constant-phase βz delayer, which is characterized by a matrix of $\boldsymbol{D}$ type.

An elastic deformation may cause a change of both the polarization eigenstates and the propagation constants ($\beta_1 \neq \beta_2$). In this case, optical fiber becomes an anisotropic medium of the definite value of birefringences $\Delta\beta = (\beta_1 - \beta_2)$ [8]. The changes introduced by deformation may be determined by the modified theory of the coupling modes given by SAKAI [9]. This theory is based on the assumption that the introduced deformations cause a small distortion of the permittivity tensor

$$[\varepsilon] = [\varepsilon_i] + [\delta\varepsilon] \tag{10}$$

where: $[\varepsilon_i]$ – permittivity tensor for non-disturbed system, $[\delta\varepsilon]$ – disturbance tensor. The search for the solution of Maxwell equations as a combination of eigenmodes of non-disturbed system

$$\boldsymbol{E}(z) = A(z)\boldsymbol{e}_1 + B(z)\boldsymbol{e}_2 \tag{11}$$

leads in that case to the following equation for the coupled modes of disturbed structure

$$d/dz\begin{bmatrix} A \\ B \end{bmatrix} = -j\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix}\begin{bmatrix} A \\ B \end{bmatrix} \tag{12}$$

where

$$\begin{aligned} N_{ll} &= \beta + \omega\varepsilon_0 \int \boldsymbol{e}_l^* [\delta\varepsilon] \boldsymbol{e}_l ds, \quad (l = 1, 2), \\ N_{lm} &= N_{ml}^* = \omega\varepsilon_0 \int \boldsymbol{e}_l^* [\delta\varepsilon] \boldsymbol{e}_m ds, \quad (l \neq m). \end{aligned} \tag{13}$$

The suitable choice of z coordinate allows us to obtain the coefficients of the intermode coupling N_{lm} independent of this coordinate. In this case, Eq. (12) may be solved by letting $A(z) = E_{xi}\exp(-i\beta_i z)$ and $B(z) = E_{yi}\exp(-i\beta_i z)$. The results obtained for β_i and E_{yi}/E_{xi} determine the eigenvalues and eigenfunctions of Eq. (12), which allows us to determine the birefringence of the fiber

$$\Delta\beta = [(N_{11} - N_{22})^2 + |N_{12}|^2]^{1/2}. \tag{14}$$

By taking advantage of the Jones matrix formalism and of the relation between differential form of the Jones matrix (Eq. (12)) and global matrix $\boldsymbol{M}$ [10], we are able to determine the matrix characteristic of the disturbed optical fiber. Assuming that the introduced light is in elliptical state of polarization determined by $E_{xi}(0) = E_x(0)$ and $E_{yi}(0) = E_y(0)$ the output polarization is determined by the relation

$$\boldsymbol{E}(z) = \exp\left[-j\frac{N_{11} + N_{22}}{2}z\right]\begin{bmatrix} m_1 & -m_2^* \\ m_2 & m_1^* \end{bmatrix}\boldsymbol{E}(0) \tag{15}$$

where

$$m_1 = \cos\left(\frac{\Delta\beta z}{2}\right) - j\left[\frac{N_{11}-N_{22}}{\Delta\beta}\right]\sin\left(\frac{\Delta\beta z}{2}\right),$$

$$m_2 = -j\left[\frac{2N_{21}}{\Delta\beta}\right]\sin\left(\frac{\Delta\beta z}{2}\right).$$

The above relation allows us to determine the Jones matrix characteristic of the given type of fiber determination when only the deformation tensor is known.

If the optical fiber is twisted by ζ rad/m, then the application of the coefficients N_{lm}, calculated in [9] on the base of Eq. (13), leads through Eqs. (14), (15) to the following form of the Jones matrix of the fiber

$$M = e^{-j\beta z}\begin{bmatrix}\cos\alpha' & -\sin\alpha' \\ \sin\alpha' & \cos\alpha'\end{bmatrix} \equiv D(\beta z)R(\alpha') \tag{16}$$

where

$$\alpha' = |N_{12}|z = \frac{GC}{n_1}\zeta z = \frac{GC}{n_1}\alpha = g\alpha.$$

Assuming the numerical value: $G = 3.27\times10^{10}$ N/m^2 (the modulus of rigidity), $C = 3.51\times10^{-12}$ m^2/N (the elastoopic constant), $n_1 = 1.45$ (the refractive index of the fiber core), we get the value of parameter $g = 0.08$. As one can see from the form of the Eq. (16), the optical fiber is equivalent to the complex of the constant phase delayer – matrix $\boldsymbol{D}$, and the rotator – matrix $\boldsymbol{R}$ [1]. In other words, the twisting of the fiber by the angle $\alpha = \zeta z$ will cause the rotation of polarization by the angle α' without changing the fiber ellipticity.

In the case of the pure bend of an optical fiber, of the diameter d and the curvature radius R (Fig. 2), the application of Eqs. (12)–(15), on the basis of [10], leads to the following Jones matrix:

$$M = e^{-j\bar{\beta} z}\begin{bmatrix}e^{j\delta} & 0 \\ 0 & e^{-j\delta}\end{bmatrix} \equiv D(\bar{\beta} z)G(\delta), \tag{17}$$

$\bar{\beta} = \beta + \frac{1}{2}(d/R)^2 EkC_1, \quad \delta = -\Delta\beta z/2, \quad \Delta\beta = -\frac{1}{2}(d/R)^2 EkC$

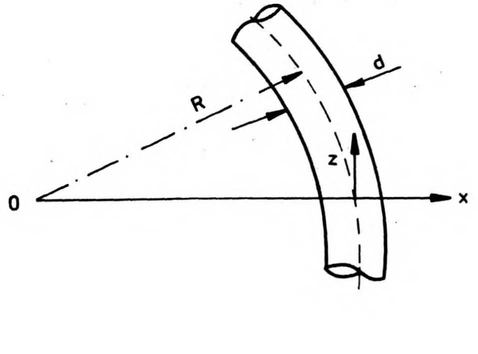

Fig. 2. Bend of the optical fiber with the curvature radius *R*

where: $E = 7.60\times10^{10}$ N/m^2 (the Young's modulus), $k = 2\pi/\lambda$ (the wave number), $C_1 = -0.26\times10^{-12}$ m^2/N (the elastooptic constant) [9]. Equation (17) shows that the bending fiber has the changed polarization characteristics and is equivalent to a complex consisting of the constant-phase delayer (***D***) and the linear phase delayer (***G***). Physically is means the change in ellipticity of the light beam passing through this element. It may be noticed that in this case the delay introduced by the light transmission in optical fiber is also changed (see Eqs. (9) and (17)).

4. Jones matrix of the polarization transformer system

To describe the polarization transformer we shall apply Cartesian coordinates shown in Fig. 3. Using the Jones matrix formalism we can notice that the matrix of the whole system PT is the product of the Jones matrix of the system elements, hence

$$\boldsymbol{T} = \boldsymbol{R}(\xi)\boldsymbol{L2}\,\boldsymbol{L1}\,\boldsymbol{R}(-\xi) \tag{18}$$

where $\boldsymbol{L1}$, $\boldsymbol{L2}$ are the Jones matrices of individual fiber-optic loops and $\boldsymbol{R}$ includes the

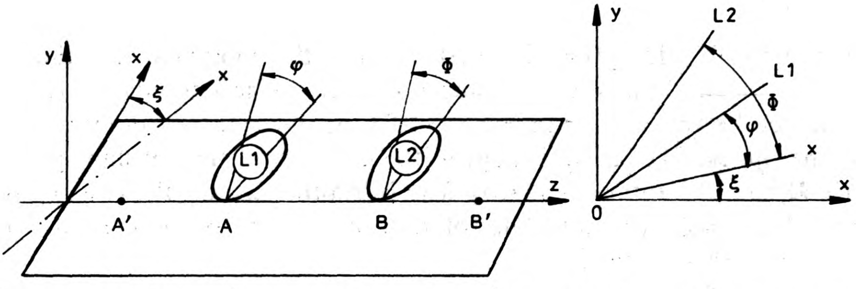

Fig. 3. Polarization transformer and the accepted system of coordinates, ξ – angle between the laboratory system (x, y) and plane of the loop rolling and mounting, φ – angle of the turn of the loop $L1$, ϕ – angle of the turn of the loop $L2$

angular mismatch of the laboratory (x, y) and local (x_T, y_T) systems of coordinates [1]. While considering the separate loops, it can be easily shown that in the local coordinate system (Fig. 4) they form a complex of waveguides three times independently deformed. These deformations are: the twice twist of fiber by the angle $\pm\varphi(\pm\Phi)$ – the segments A'A, AB, AB, BB' and the rolling of the fiber into the loop of the radius R – the segments AA, BB. Using Eq. (16) we get

$$\boldsymbol{M}_1 = e^{-j\beta z_1}\begin{bmatrix}\cos\varphi' & -\sin\varphi' \\ \sin\varphi' & \cos\varphi'\end{bmatrix} \equiv \boldsymbol{D}(\beta z_1)\boldsymbol{R}(\varphi'), \qquad \varphi' = g\varphi, \tag{19a}$$

$$\boldsymbol{M}_3 = e^{-j\beta z_3}\begin{bmatrix}\cos(\Phi'-\varphi') & -\sin(\Phi-\varphi') \\ \sin(\Phi'-\varphi') & \cos(\Phi'-\varphi')\end{bmatrix} \equiv \boldsymbol{D}(\beta z_3)\boldsymbol{R}(-\varphi')\boldsymbol{R}(\Phi'), \tag{19b}$$

$$\boldsymbol{M}_5 = e^{-j\beta z_5}\begin{bmatrix}\cos\Phi' & -\sin\Phi' \\ \sin\Phi' & \cos\Phi\end{bmatrix} \equiv \boldsymbol{D}(\beta z_5)\boldsymbol{R}(\Phi'), \qquad \Phi' = g\Phi. \tag{19c}$$

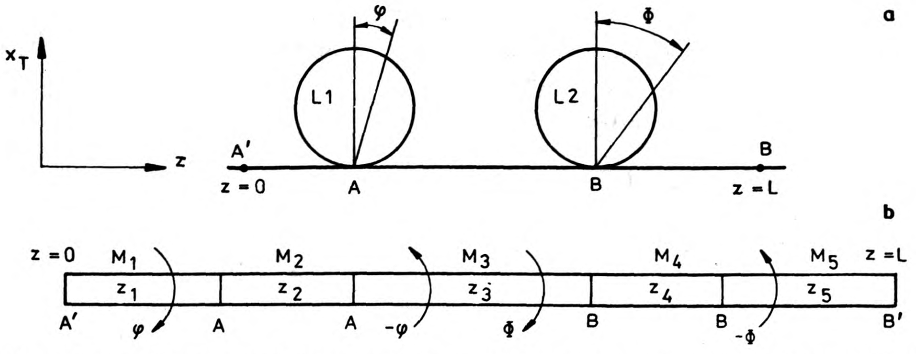

Fig. 4. Matrix description of the loops $L1$ and $L2$: the accepted system of coordinates (**a**) and the matrix representation of PT (**b**)

The same fiber loops, however, when fixed at the angle $\varphi(\Phi)$ correspond to the linear retarders (Eq. (17)), which according to [1] are in laboratory coordinates described by:

$$\boldsymbol{M}_2 = e^{-j\bar{\beta}z_2}\begin{bmatrix}\cos\varphi & -\sin\varphi\\ \sin\varphi & \cos\varphi\end{bmatrix}\begin{bmatrix}\exp(j\delta_1) & 0\\ 0 & \exp(j\delta_1)\end{bmatrix}\begin{bmatrix}\cos\varphi & \sin\varphi\\ \sin\varphi & \cos\varphi\end{bmatrix}$$

$$\equiv \boldsymbol{D}(\bar{\beta}z_2)\boldsymbol{R}(\varphi)\boldsymbol{G}(\delta_1)\boldsymbol{R}(-\varphi), \tag{20a}$$

$$\boldsymbol{M}_4 = e^{-j\bar{\beta}z_4}\begin{bmatrix}\cos\Phi & -\sin\Phi\\ \sin\Phi & \cos\Phi\end{bmatrix}\begin{bmatrix}\exp(j\delta_2) & 0\\ 0 & \exp(-j\delta_2)\end{bmatrix}\begin{bmatrix}\cos\Phi & \sin\Phi\\ -\sin\Phi & \cos\Phi\end{bmatrix} \quad (20)$$

$$\equiv \boldsymbol{D}(\bar{\beta}z_4)\boldsymbol{R}(\Phi)\boldsymbol{G}(\delta_2)\boldsymbol{R}(-\Phi), \tag{20b}$$

$$z_2 = z_4 = 2\pi R, \quad \delta_1 = \delta_2\frac{\pi d^2}{4R}ECk = \frac{\pi}{4}, \quad \bar{\beta} = \beta+\beta', \quad \beta' = \tfrac{1}{2}(d/R)^2 EC_1 k,$$

here, for the parameter R, relation (1) is used.

Substitution of Equations (19), (20) to Eq. (18) leads to the Jones matrix of PT system of the form

$$\begin{aligned}\boldsymbol{T} &\equiv \boldsymbol{R}(\xi)\boldsymbol{L2L1}\boldsymbol{R}(-\xi) = \boldsymbol{R}(\xi)\boldsymbol{M}_5\boldsymbol{M}_4\boldsymbol{M}_3\boldsymbol{M}_2\boldsymbol{M}_1\boldsymbol{R}(-\xi)\\ &= \boldsymbol{D}(\beta L)\boldsymbol{D}(4\pi R\beta')\boldsymbol{R}(\xi)\boldsymbol{R}(a\Phi)\boldsymbol{G}(\delta_2)\boldsymbol{R}(-a\Phi)\boldsymbol{R}(a\varphi)\boldsymbol{G}(\delta_1)\boldsymbol{R}(-\varphi)\boldsymbol{R}(-\xi)\\ &= \boldsymbol{D}(\Delta)\boldsymbol{R}(\gamma_2)\boldsymbol{G}(\delta_2)\boldsymbol{R}(-\gamma_2)\boldsymbol{R}(\gamma_1)\boldsymbol{G}(\delta_1)\boldsymbol{R}(-\gamma_1)\\ &= \boldsymbol{D}(\Delta)\boldsymbol{M}(\gamma_2, \delta_2)\boldsymbol{M}(\gamma_1, \delta_1)\end{aligned} \tag{21}$$

where:

$$\Delta = \beta L + 2\pi\frac{d^2}{R}EC_1 k, \quad \mathrm{a} = 1-g = 0.92, \quad \gamma_2 = a\Phi+\xi, \quad \gamma_1 = a\varphi+\xi.$$

As one can see from Eq. (21), the polarization transformer system is equivalent to the complex of two quarter-wave planes ($\delta_1 = \delta_2 = \pi/4$), the axes of which are set at the angles γ_1, γ_2 with respect to the axes of the assumed laboratory coordinate system.

Based on the first theorem about the equivalence of optical systems [1] the PT system described by the Eq. (21) is functionally equivalent to the system consisting of one rotator and one linear retarder

$$\boldsymbol{D}(\Delta)\boldsymbol{M}(\gamma_2, \delta_2)\boldsymbol{M}(\gamma_1, \delta_1) \equiv \boldsymbol{D}(\Delta)\boldsymbol{M}(\gamma, \delta)\boldsymbol{R}(-\gamma'). \tag{22}$$

Such a representation is univocal and, as it was presented in [11], it may be determined from the relations

$$\begin{aligned}
\tan\gamma' &= \frac{x_2 x_1 \sin(2\gamma_2 - 2\gamma_1)}{1 - x_2 x_1 \cos(2\gamma_2 - 2\gamma_1)},\\
\tan(2\gamma+\gamma') &= \frac{x_1 \sin 2\gamma_1 + x_2 \sin 2\gamma_2}{x_1 \cos 2\gamma_1 + x_2 \cos 2\gamma_2},\\
x^2 = \tan^2\delta &= \frac{x_1^2 + 2x_1 x_2 \cos(2\gamma_2 - 2\gamma_1) + x_2^2}{1 - 2x_1 x_2 \cos(2\gamma_2 - 2\gamma_1) + x_1^2 x_2^2},\\
x_i &= \tan\delta_i, \quad i = 1, 2.
\end{aligned} \tag{23}$$

After the values of δ_i, γ_i determined by Eq. (21) are put into Eq. (23), the simple mathematical operations allow us to determine:

$$\begin{aligned}
\gamma' &= \pi/2 + \gamma_1 - \gamma_2 = \pi/2 + a(\varphi - \Phi),\\
\gamma &= \gamma_2 - \pi/4 = a\Phi + \xi - \pi/4,\\
\delta &= \pi/2 + \gamma_1 - \gamma_2 = \pi/2 + a(\varphi - \Phi).
\end{aligned} \tag{24}$$

Hence, the equivalent form of the polarization transformer is described by the matrix

$$\begin{aligned}
\boldsymbol{T}_{\mathrm{E}} &= \boldsymbol{D}(\Delta)\boldsymbol{R}(\gamma)\boldsymbol{G}(\delta)\boldsymbol{R}(-\gamma-\gamma') =\\
&= \boldsymbol{D}(\Delta)\boldsymbol{R}(a\Phi + \xi - \pi/4)\boldsymbol{G}[\pi/2 + a(\varphi - \Phi)]\boldsymbol{R}(-\pi/4 - a\varphi - \xi).
\end{aligned} \tag{25}$$

The above formula describes the scheme of equivalent lumped element representation (ELER) of the PT which is shown in Fig. 5. As one can see, the turn of fiber loops in the analysed system causes the changes of the twist angle (in the rotator matrix $\boldsymbol{R}$), and the linear delay (in the retarder matrix $\boldsymbol{G}$). These changes bring about the change of both the direction of the principal axis of polarization ellipse and of its

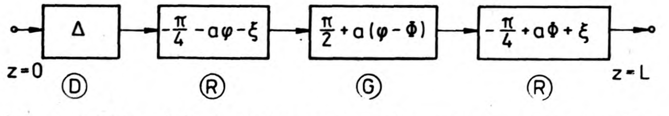

Fig. 5. ELER of the polarization transformer: D – constant phase delay element, R – optical rotator, G – linear retarder

ellipticity. The latter is univocal with the change of the state of polarization of the output beam. Numerical simulation of PT operating is presented in Fig. 6.

The second loop angle changed from $-90°$ to $90°$ for three different angles of first loop was used as the parameter. It can be seen that this change causes the changes of the ellipticity ε, and the azimuth θ of SOP. Since the change of the azimuth can occur within the interval $-90°$–$90°$ and the ellipticity ranges from $\pm 45°$, thus the above sytem can transform the input SOP to an arbitrary different one.

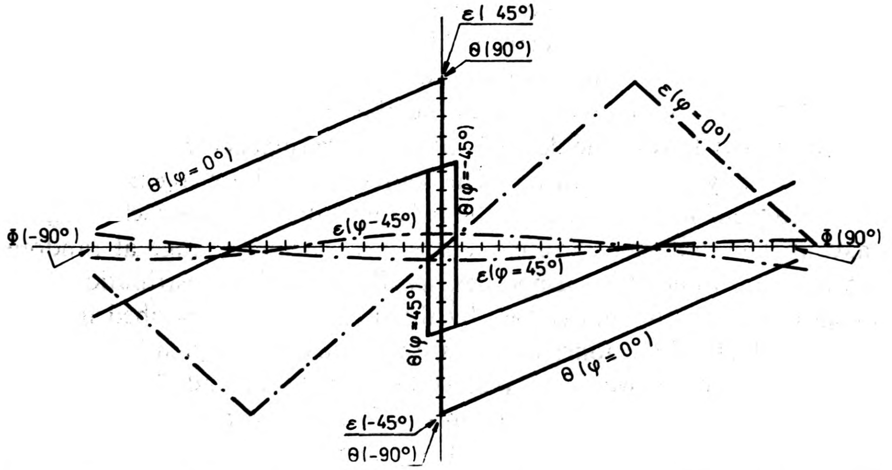

Fig. 6. Changes of ellipticity ε (———) and azimuth θ (— · —) as a function of angle position of second loop Φ. As a parameter the angle position of first loop φ was used

As an example we will consider the transformation of the linear input polarization into the linear polarization of changed direction. In this case, as follows from Eq. (25), the element of retarder $\boldsymbol{G}$ must be the half-wave plate $\delta \equiv \pi/2$, hence $\varphi = \Phi$, and hence the matrix of the system takes the form

$$T_E = \boldsymbol{D}(\Delta)\boldsymbol{R}(a\Phi - \pi/4)\boldsymbol{G}(\pi/2)\boldsymbol{R}(-a\Phi - \pi/4) = \boldsymbol{D}(\Delta)\boldsymbol{R}(a\Phi)\boldsymbol{G}(\pi/2)\boldsymbol{R}(-a\Phi) = $$
$$= \boldsymbol{D}(\Delta)\boldsymbol{M}(a\Phi, \pi/2). \tag{26}$$

As it follows from the above relation, it is the system of the constant phase delay element (matrix $\boldsymbol{D}$), and the half-wave plate twisted by the angle $a\Phi$ (matrix $\boldsymbol{M}$), which means the twist of the direction of polarization by the angle $2a\Phi = 1.84\ \Phi$. This result is in agreement with the demanded operation of a similar system described in a general way in [4].

5. Summary

In the former chapter we have shown that the assumed description of the sytem leads to simple analytical formulae determining its operation mode. The application of the Jones matrix formalism gave the following results:

i) The possibility of determining the output beam SOP as a function of input SOP, and the turn angles of fiber loops of which the system is made.

ii) The form of the characteristic matrix of the system describing completely its operation.

iii) The possibility of the decomposition of the total system matrix into the product of the finite number of the elementary matrices.

The description obtained in this way (Eq. 25) constitutes the equivalent lumped element representation of the PT system operation. Since the matrices in this representation have definite physical meanings (rotators, linear retarders, constant phase delay elements), therefore the scheme enables us to watch the physical changes in the operation mode of the system connected with the changes of its parameters.

In this description it has been assumed that the fiber is ideally isotropic. The real single-mode optical fibers have some defined value of birefringence which may play a significant role in the system's operation. The source of this birefringence are: the ellipticity and nonconcentricity of the core, the twist introduced in the technological process, the asymmetric inner tensions, etc. Since these factors change at random along the fiber, then the value of birefringences has also a random distribution. The above birefringence is added to that caused by the deformations described in Sect. 4 and can change the form of the Jones matrix of the system, consequently, it can be the source of disagreement between the real system operation and the presented theoretical model. However, the experimental model PT, the operation of which was described by the authors in [3], has shown that this element can produce any linear polarization state from any other input SOP. In this way, the work [3] is the experimental verification of the theory presented in this paper.

References

[1] JONES R. C., J. Opt. Soc. Am. **31** (1941), 488.
[2] JONES R. C., HURWITZ H., J. Opt. Soc. Am. **31** (1941), 493.
[3] SZUSTAKOWSKI M., JAROSZEWICZ L., Elektronika **8** (1987), 3 (in Polish).
[4] LEFEVRE H. C., Electron. Lett. **16** (1980), 778.
[5] JONES R. C., J. Opt. Soc. Am. **32** (1942), 464.
[6] SNITZER E., J. Opt. Soc. Am. **51** (1961), 491.
[7] SNYDER A. W., YOUNG W. R., J. Opt. Soc. Am. **68** (1978), 297.
[8] KAMINOW I. P., IEEE J. Quant. Electron. **17** (1981), 15.
[9] SAKAI J., KIMURA T., IEEE J. Quant. Electron. **17** (1981), 1041.
[10] JONES R. C., J. Opt. Soc. Am. **38** (1948), 671.
[11] RICHARTZ H., HSU H. Y., J. Opt. Soc. Am. **39** (1949), 136.

Received July 27, 1989
in revised form October 9, 1989

Матричный анализ трансформатора поляризации

В работе представлен математический анализ действования пассивного световодного трансформатора поляризации (STP). Используя матричный формализм Джонса дана функциональная схема действования такой системы и определен физический смысл очередных ее элементов. Показано, что с помощью трансформатора поляризации можно получить любое состояние поляризации светового пучка в световоде.