Effect of Strong Linear Polarization Anisotropy on Geometrical Modes Characteristics of Optical Fiber

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Abstract **:-**The geometric polarization in single mode optical fibers is investigated theoretically and experimentally and the measurement results are reported. This paper consider the geometrical measurement method of weights the own modes of poorly directing optical fiber with strong linear anisotropy. This given method is based on definition the geometrical parameters lines with equal intensity in a vicinity of zero radiation image from fiber output. The modes weights have been received as a result of computer processing of experimental images of intensity distribution at displacement of laser spot concerning the center of fiber input. It is found that neglecting the geometrical birefringence, even under the weakly guiding approximation, can lead to significant errors in the calculation of PMD and the zero PMD wavelengths. It is also found that one can obtain zero PMD in the single-mode region even by applying a suitable differential stress along the major axis. This is very attractive since then the geometrical and stress birefringence adds up to give increased total birefringence.

Key-Words:-Anisotropy, double-refraction, polarization, mode weigh, displacement, intensity distribution.

1 Introduction

Optical fibers are making ever increasing demand into areas traditionally satisfied by older, more established technologies. Interest in the utilization of polarization effects in fibers is continuing to grow. In ordinary single-mode fibers, widely used in present optical communication systems, the polarization states of the input and the output light beams do not match, since the polarization of the output light beam is unstable. By contrast, PM fibers maintain the state of polarization of a light beam passing through them. PM fibers are imperative for obtaining a stable output in interferometric fiber optical sensors. In optical communication devices the use of PM fiber becomes mandatory when performing any polarized waves operations; e.g., for polarization combining. There are many applications where the polarization of the light is required to be stable and well defined; such as coupling to the integrated optical circuits, interferometric sensors, coherent optical communication systems, and certain in-line fiber optic components. Nowadays, one of the issues of concern is the kind of fiber to use in all optical networks and the advantages they can offer regarding polarization-mode dispersion, chromatic dispersion, and optical fiber nonlinearities[1].Recently, the single modes optical fibers were strongly used in many fields of science and techniques. The debugged technology of such fibers assumes their application exclusively in optical systems were there parameters strictly correspond to characteristics of fiber. One of the most rigid requirements is concern the lengths of light wave, which transmitted through the wave guide. and any deviations from the value of bearing wave length are entail not only a sharp increasing of light losses, but also essential infringements of system functional abilities and this is due to the change of modal structure of transmitted radiation. As example, the optical fiber with wave guide parameter $V = 2.1$ and wave length $\lambda = 1.33\mu m$ is capable to support only.

In ordinary circularly cylindrical fibers, there are two types of hybrid modes, $\boldsymbol{HE}_{\nu\mu}$ and $\boldsymbol{EH}_{\nu\mu}$ modes. The label ν refers to the azimuthal variation of the field while the label μ accounts for modes of different radial variation. The dominant mode of an ordinary optical fiber is designated as the $\boldsymbol{HE}_{11}$ mode. However, under weakly guiding condition, an approximate modal field description can be obtained by solving the scalar wave equation instead of the full set of Maxwell's equations. This dominant mode solution is designated as LP_{01} mode for which the electric field is linearly polarized . In the framework of Cartesian coordinates, the electric field of the dominant mode has three components, *Ex*, *Ey* and *Ez*. One of the two transverse components, *Ex* or *Ey* predominates, while the *Ez* component, considered in the direction of the fiber axis, is much smaller than the transverse. If *Ex* is the dominant field component in an isotropic circularly symmetric fiber, the LP_{01} mode is said to be polarized in the x-direction, while for if *Ey* is the dominant component, the mode is y-polarized. Thus, single-mode fibers can, in fact, simultaneously support two identical modes which are mutually orthogonally polarized. In an ideal dielectric waveguide of circular cross section, these two modes are degenerate; that is, there is no difference between their propagation constants, and thus propagate with same phase-velocity. In practical situations, an actual optical fiber is not absolutely perfect. It is neither completely axially-symmetric nor perfectly straight. In addition, the fiber material is often assumed to be nominally isotropic, in which the refractive index is the same regardless of the direction of the polarization of the electric field. This is also not strictly true in practical fibers. Small departures from perfect circularity and fluctuations of the anisotropy of the fiber material, couple the x-polarized mode to the y-polarized mode since both modes are very nearly degenerate. These conditions lead to a complete mixing of the two polarization states so that the initially linearly polarized light field quickly reaches a state of arbitrary polarization . Furthermore, environmental factors such as twists, bends, anisotropic stress and ambient conditions also cause unstable fluctuations in the polarization state of the propagating light. In multimode fibers, such instability usually causes little trouble except for its possible effect on modal noise. The following problems arise in a single-mode fiber due to the factors mentioned previously:

1- The two polarization states travel at different phase velocities, which causes the state of polarization of the output light to change randomly with time. Fluctuations in the received signal level are not desirable when the receiver is sensitive to polarization. In many applications, the output state of polarization should be strictly maintained, such as interferometric sensors, coherent transmission systems and for coupling to integrated optical circuits, i.e., when the heterodyne-type or homodyne-type optical polarization state is required between the received signal and the local oscillator.

2- The polarization instability deteriorates measurements accuracy in magneto optic current sensors and in laser gyroscope. In coherent systems, polarization instability adversely affects the bit-error rate.

3- A slight geometrical deformation exists in single-mode circular fibers. This residual deformation breaks the degeneracy of the two orthogonal dominant modes. These modes propagate with different group velocities, causing polarization-mode dispersion which can limit the ultimate bandwidth of a single-mode optical communication system[1,2,12].

One basic HE_{11} mode(for simplicity we neglect the double-refraction fiber).however on the wave length $\lambda = 0.63\mu m$ the wave guide parameter becomes $V = 4.4$,and the fiber then is capable to support $N = 12$ own modes [3].the situation becomes more complicated for double-refraction fibers, and at the same time in the real case on the fiber input, the energy of initial bunch is non-uniformly distributed on their own modes and the weights of modes are rigidly connected with conditions of optical fiber system excitation. and here again we collide with the problem of weighing of own modes.

Forty years ago the scientists try to measure the weight size of directed own modes, which radiated from fiber output. These methods of measurement were based on the using of complex holographic masks established after the fiber [4]. The masks disseminate a part of a bunch in a certain direction which corresponds to own modes. Certainly, accuracy of measurements and resolution of used method was extremely small, therefore till now they limited to the qualitative analysis of field modal structure comparing the form bunch intensity distribution which radiated from both classical optical fibers [4,5]and from fibers which made from photon crystal[6]. Recently it was suggested a method of geometrical analysis of optical core[7,8]that allows to put in pawn the bases of new geometrical measurement the weights of own modes of optical fiber.

2 Related works.

Linear polarized light propagating through a monomode optical fiber of negligible intrinsic linear and circular birefringence and stress-induced effects will also produce the rotation of polarization as the geometric path is changed.

This effect was first studied in[13,14]Their theories are based on geometry and the axiom of parallel transport of light. When the input and output ends of fibers are parallel, the rotation is

$$\int_{inputend}^{outputend} \tau \, \mathrm{ds}.$$

where τ is the torsion of the curve. In a uniform helix, this leads to $\phi = 2\pi(1 - P / S)$, where P is the pitch and S is the total length of fiber[13].in [14]they pointed out another method which was derived from Berry's phase factor in the adiabatic limit of quantum mechanics. When a system takes an adiabatic transport around a closed path in parameter space, a nonintegral phase factor will result which must multiply the wave function of the system. As linear polarized light travels along a helically wound optical fiber, a closed path ***C*** will form in momentum or ***K*** space and Berry's phase $\nu(c) = -\sigma\Omega(c)$. here $\sigma = \pm 1$ is the helicity quantum number of the photon and $\Omega(c)$ is the solid angle subtended by curve ***C*** with respect to the origin ***K = 0***. The phase factor is just the rotation angle of polarization. For a single-turn uniform helix, we have $\nu(c) = -2\pi\sigma(1 - p / s)$.

Then, how about the nonparallel case? It is obvious that, when the two ends of fiber are not parallel, a closed curve will not exist in ***K*** space, as shown in Fig. 1.

In [15] the treatment using differential geometry is purely classical. On the unit ***K*** sphere, the initial and final wave vectors ***Ko, K1*** are separated because of the nonparallel input and output ends. We found a great circle connecting the two vectors, as shown in Fig. 1. Then a closed curve appears in K space and it spans a solid angle which is equal to the rotation angle of polarization. This fact is natural because a path lying along the great circle is a plane curve which will not raise polarization rotation according to the parallel transport of light. So the rotation angle is just the shaded area shown in Fig. 1. The calculation of this area could be done as follows (see Fig. 1):

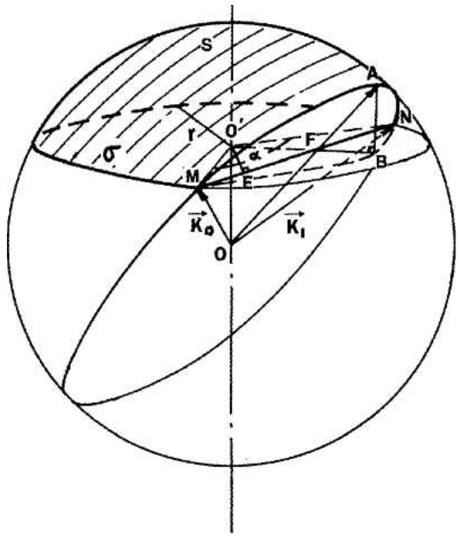

Fig.1:Spherical surface in ***K*** space: ***Ko***,the ***K*** vector on the input end and ***K1***, the ***K*** vector on the output end.

In [16,17] it was shown that the polarization characteristics of an elliptical, core fiber can be obtained to a very good approximation by considering a suitably chosen rectangular core waveguide that can be analyzed by a perturbation technique . The perturbation technique was shown to be applicable for analyzing anisotropic rectangular waveguides as well in [17]. Since the effect of an applied stress is, effectively, to modify the refractive index "seen" by the two polarizations, it was intuitive to apply the method of [17] to obtain the polarization characteristics of stress-birefringent fibers, particularly, those having an elliptical core. In this paper we have shown that the simple rectangular core model can be effectively used to study birefringent fibers having both geometrical and stress anisotropy. Fibers having differential material anisotropy in the core and cladding have also been studied, and the results are in agreement with those of [18] for circular core fibers. However, in the case of elliptical core fibers with weak or moderate guidance, we show that neglecting the contribution due to geometrical anisotropy can lead to significant errors in predicting the region of zero- or low-PMD. Further, we have found that a suitable differential stress anisotropy along the major axis of an elliptical core fiber can result in a large birefringence as well as zero PMD within the single-mode region.

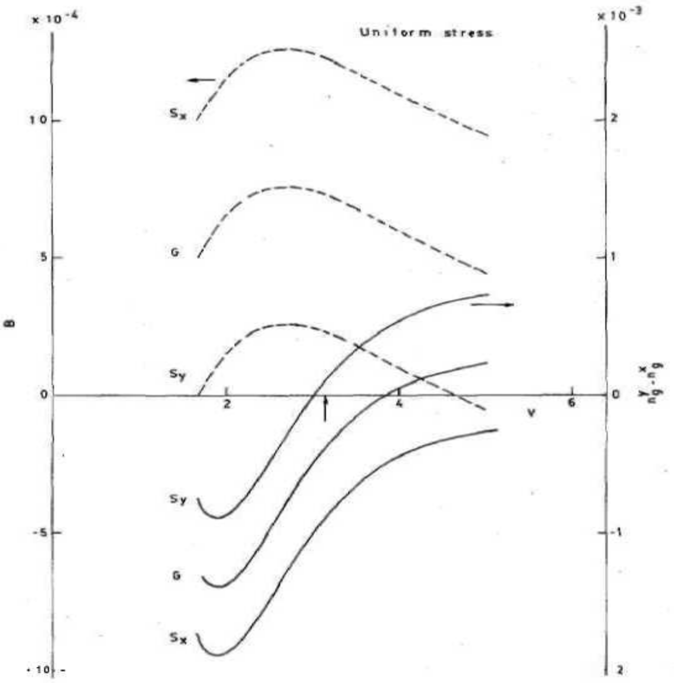

Fig.2: variation of birefringence (dashed curves) and group index (solid curves) fiber.a/b=2.

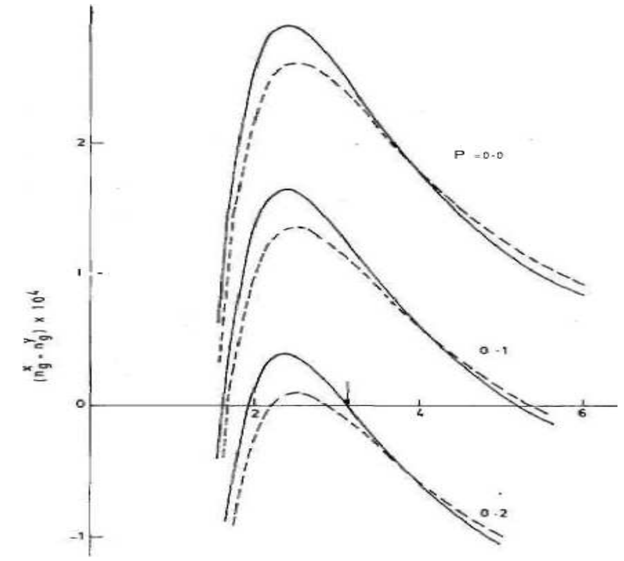

Fig.3(b)

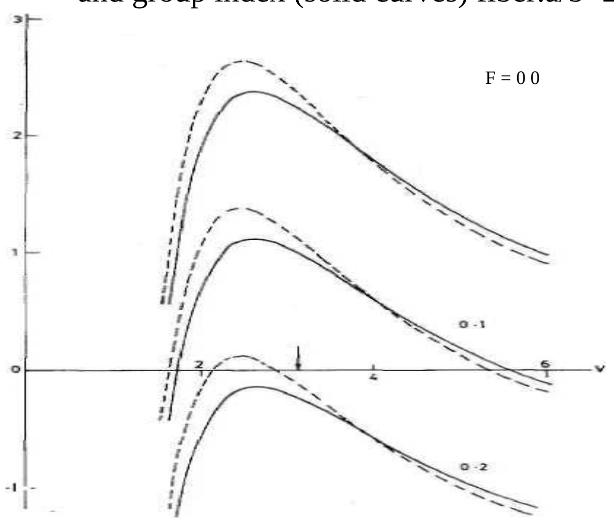

Fig.3(a)

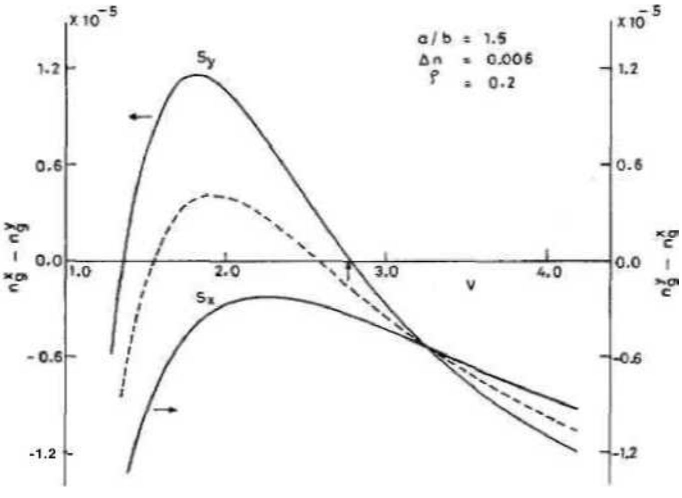

Fig.3(c)

Fig.3: variation of group index difference with **V.**(a) and (b) correspond to the same elliptic core fiber as in fig.2 when the differential anisotropy is along the x and y directons,(c) corresponds to a fiber with a/b=1.5.Dashed curves correspond to calculations neglecting geometrical anisotropy and solid curves give the combined effect of stress and geometrical anisotropy.

3 Polarization in single-Mode Fibers.

The polarization of wave describes the time-varying direction of the electric field vector at a fixed point in space. Polarization is observed along the direction of propagation by tracing out the tip of the instantaneous electric field. There are three types of wave polarization: linear, circular, and elliptical. In general, the tip of the electric field vector traces out an ellipse and the wave is said to be elliptically polarized. The other two types of polarization, linear and circular, are special cases of elliptical polarization. The linearly polarized wave is characterized by the property that the orientation of the electric field vector is the same everywhere in space and is independent of time. In linear polarization, the field vector is directed along a line. The circularly polarized wave is characterized by a constant amplitude field vector, and the field vector orientation in space changes continuously with time so that the tip of the field vector traces out a circular locus in a plane transverse to the direction of propagation.

The polarization of light propagating in a single-mode fiber is initially determined by the polarization of the output light from the laser source. Often the polarization of light generated by a laser diode is linear and so is the polarization of light in the excited mode. However, at some distance away from the light source, the polarization of light in regular non-polarization-preserving fibers becomes random due to various perturbing effects. Using appropriate techniques, it is possible to generate and maintain any of the three types of polarization in a fiber.

3.1 Circular Polarization Fibers.

It is possible to introduce circular-birefringence in a fiber so that the two orthogonally polarized modes of the fiber are clockwise and counter-clockwise circularly polarized. The most common way to achieve circular birefringence in a round (axially symmetrical) fiber is to twist it to produce a difference between the propagation constants of the clockwise and counter clockwise circularly polarized fundamental modes. Thus, these two circular polarization modes, i.e., $\boldsymbol{HE}_{11}^{+}$ and $\boldsymbol{HE}_{11}^{-}$ are decoupled. Also, it is possible to conceive externally applied stress whose direction varies azimuthally along the fiber length causing circular birefringence in the fiber. If a fiber is twisted, a torsional stress is introduced and leads to optical-activity in proportion to the twist. It is shown theoretically that if ϕ represents the twist rate per unit length then the plane of polarization of a linearly polarized light is rotated in the same direction with a rate of $g\phi$ where g = 0.07 for silica. The birefringence of such a fiber is very small (as g is small) and it is difficult to obtain beat lengths less than 10 cm, because fiber breaks at high twist rates and such fiber is difficult to handle. It is shown that the twist rate required to provide immunity from external effects such as pressure and bends is excessively large. Circular birefringence can also be obtained by making the core of a fiber follows a helical path inside the cladding as shown in Fig.4. This makes the propagating light, constrained to move along a helical path, experience an optical rotation. The birefringence achieved is only due to geometrical effects and a large birefringence value B = 2x10~^{4}. Such fibers can operate as a single mode up to a very large value of the normalized frequency (V ~ 25), and suffer high losses at high order modes.

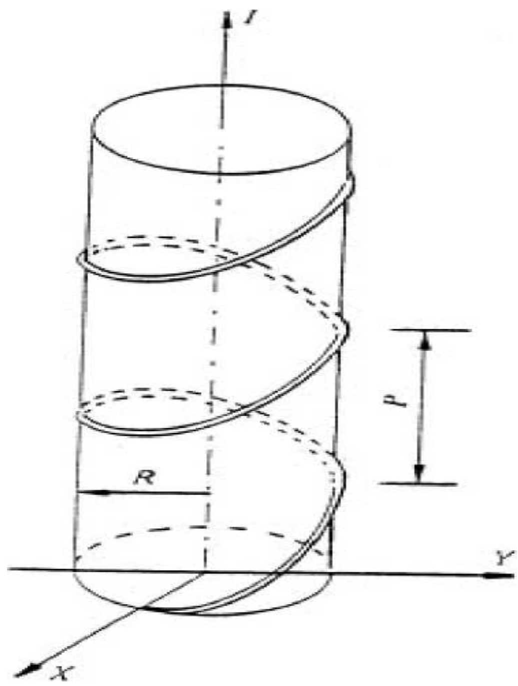

Fig.4: the structure of helical or spiral fiber.

the linear polarization fibers are of two types. The linear single polarization type is characterized by a large transmission loss difference between the two polarizations of the fundamental mode. The linearly birefringent fiber type is such that the propagation constants between the two polarizations of the fundamental mode are significantly different.

3.2 Polarization Fibers with geometrical asymmetry.

various kinds of linear polarization-maintaining fibers, such as elliptical core fibers, dumbbell core fibers, stress-induced (elliptical cladding) fibers were proposed and investigated. The early research on elliptical-core fibers dealt with the computation of the polarization birefringence. In the first stage, propagation characteristics of rectangular dielectric waveguides were used to estimate birefringence of elliptical-core fibers. Computations based upon a rigorous analysis showed a better accuracy than various approximate analysis performed previously .

3.3 Polarization Mode Dispersion PMD in Optical Fiber.

The polarization-mode dispersion in optical fibers has attracted considerable attention over the past few years. Different techniques for polarized – mode dispersion (PMD) measurements and characterization have been reported in many references. Two main factors contribute to PMD in circular fibers: the deformation of the circular

Geometry of the fiber and the internal stresses which leads to stress anisotropy, both of which could happen during manufacturing. Other factors that could contribute to PMD in fibers are bends, twists, and cabling process. A circular fiber with small core elliptical deformation causes a difference between the group velocities in the two orthogonal polarizations of the fundamental mode.This difference contributes to the overall dispersion and the effect is referred to as polarization-mode dispersion. The magnitude of PMD in fibers depends on this difference in propagation constants. In ordinary step-index single-mode fibers, PMD vanishes outside the single-mode wavelength region. To improve fiber performance in long-haul high bit rate systems, a zero PMD must be within the single-mode wavelength region[1,3,19,20,21].

4 Problem and Solution.

Highly birefringent fibers that can maintain a stable state of polarization are of considerable interest in the field of optical fiber sensors and coherent detection systems. Birefringence can be induced in fibers by introducing geometrical anisotropy in the core [16] and/or by incorporating stress producing regions in the cladding.

When a linearly birefringent fiber is used for coherent transmission, only one of the two orthogonal modes is excited in the hope that no coupling occurs to the other mode. However, there can be power coupling between the two orthogonally polarized modes due to perturbations like bends, twists, imperfectjoints, etc. This would result in an unstable state of polarization at the output, and can severely affect the bandwidth of a coherent optical communication system, if the group delay difference between the two modes is significant. Therefore it is important to have high birefringence and low PMD fibers for these applications. It has been shown that zero PMD with high birefringence fibers can be achieved in the single mode region by a suitable combination of geometrical and stress induced anisotropy in the fiber cross section. However, this would require a large relative index difference between the core and the cladding which makes it difficult in practice to keep the fiber loss low. It has also been shown that the stress distribution over the fiber cross section has a strong influence on the polarization characteristics of the fiber. However, no simple analytical method exists which can take into account simultaneously both geometrical and stress induced birefringence[14].

The purpose of the given paper is to measure the weights of own modes of poorly directional optical fiber with strong linear anisotropy on the basis of geometrical analysis of intensity distribution.

As in the investigated sample, we shall choose a fiber with strong double-refraction that allows reducing the quantity of extending modes with excitation by linearly polarized light which focused along one of the anisotropy axes [5].

The field type of own modes of such fiber are possible to present as[5,12]:

$$e_{tl}^{1,x} = \hat{x}\cos(l\varphi)F_l(R)\exp\left\{i\beta_l^{1,x}z\right\},$$
$$e_{tl}^{2,x} = \hat{x}\sin(l\varphi)F_l(R)\exp\left\{i\beta_l^{2,x}z\right\}$$
$$e_{tl}^{1,y} = \hat{y}\cos(l\varphi)F_l(R)\exp\left\{i\beta_l^{1,y}z\right\},$$
$$e_{tl}^{2,x} = \hat{y}\sin(l\varphi)F_l(R)\exp\left\{i\beta_l^{2,x}z\right\}, \quad (1)$$

Where $\hat{x},\hat{y}$ -linear polarization along the fiber of anisotropy axes.

l- mode orbital index, $F_l(R)$ - radial function of field distribution, $R = r/\rho, r, \varphi, z$ -cylindrical coordinates, ρ - fiber core radius, β -mode distribution constant; the top indexes in designations of field (1) and (2) corresponds to an even and odd mode accordingly.

Let’s consider the poorly directional fiber with wave guide parameter $V <$ 3.8,in which modes with $l = 0.1$ can extend only. we shall consider that the structure of refraction index has a parabolic form, then $F_l(R) = R^l\exp\left\{-VR^2/2\right\}$.and let the fiber is raised by linearly polarized light along the axis x,in this case the fiber wave guide field will be in the form:

$$e_t = (a_0 \exp\{i\beta_0 z\} + a_1 X \exp\{i\beta_1 z\} + a_2 Y \exp\{i\beta_2 z\}) \exp\{-VR^2/2\},$$

(2)

Where a_i - modes weights factor, $X = r\cos(\varphi)/\rho$, $Y = r\sin(\varphi)/\rho$.

In the intensity distribution image, there is a zero field which surrounded by lines of equal intensity of the elliptic form (fig.5, a).the zero intensity can be determined by equated the expression (2) to zero. so from the given condition it is possible to define the coordinates X_0, Y_0 of zero field:

$$X_0 = \frac{a_0 \sin((\beta_0 - \beta_2)z)}{a_1 \sin((\beta_2 - \beta_1)z)} \;,$$

$$Y_0 = \frac{a_0 \sin((\beta_0 - \beta_1)z)}{a_2 \sin((\beta_2 - \beta_1)z)} \qquad (3)$$

It is easy to show that the intensity of light bunch which is near to the zero fields can be described by expression:

$$I = \begin{bmatrix} a_1^2 X^2 + a_2^2 Y^2 + 2a_1 a_2 XY \cos((\beta_2 - \beta_1)z) \\ + a_0^2 + 2a_0\{a_1 X \cos((\beta_0 - \beta_1)z) + a_2 Y \cos((\beta_0 - \beta_2)z)\} \end{bmatrix} \exp(-VR_0^2) = cons$$

(4)

Where $R_0^2 = X_0^2 + Y_0^2$. We can notice that the equation $I(X,Y) = const.$ where lines of equal intensity in a vicinity of zero characterize an ellipse which axes are focused under the angle φ to the coordinates axes of laboratory system. Therefore it is ellipse $Q = b/a$, where a and b - the half axis ellipse.(fig.5,b).

Now we shall pass to the system of coordinates (X', Y'),which connected with zero intensity and the axes are focused along the ellipse axes, then the ellipse equation could be written as:

$$A^2 X'^2 + B^2 Y'^2 = C^2 = const. \qquad (5)$$

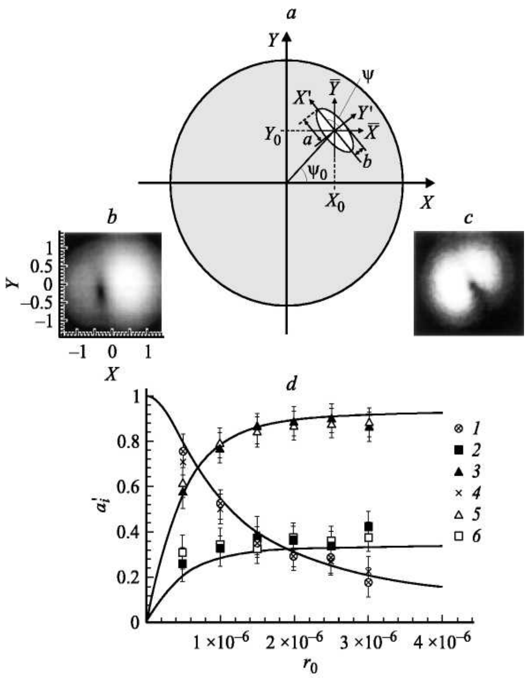

Fig.5: Scheme of intensity distribution of the fiber (a):calculated (b):experimental (c):image of fiber propagation with displacement of $r_0 = 2\mu m$ along the horizontal axes (d):dependence of coefficient excitation the own modes of anisotropic fiber on radial displacement: $\alpha = 110^0$,1- a_0' ,2- a_1' ,3- a_2' and for $\alpha = 20^0$,4- a_0' ,5- a_1' ,6- a_2' .

and therefore :

$$A^2 = a_1^2 \cos^2\psi + a_2^2 \sin^2\psi + a_1 a_2 \cos((\beta_2 - \beta_1)z)\sin(2\psi),$$

$$B^2 = a_1^2 \sin^2\psi + a_2^2 \cos^2\psi - a_1 a_2 \cos((\beta_2 - \beta_1)z)\sin(2\psi), \qquad (6)$$

$$tg(2\psi) = \frac{2a_1 a_2}{a_1^2 - a_2^2}\cos((\beta_2 - \beta_1)z) \qquad (7)$$

and $a = C/A$, $b = C/B$ .after some transformation from (5)-(7) we can find the expression for modes amplitudes

$$a_1 = (\sin^2\psi + Q^2\cos^2\psi)^{1/2},$$

$$a_2 = (Q^2\sin^2\psi + \cos^2\psi)^{1/2} \qquad (8)$$

for cosine differences of these modes phases

$$\cos((\beta_2 - \beta_1)z) = \frac{\sin(2\psi)(Q^2 - 1)}{\left[(1+Q^2)\sin^2(2\psi) + 4Q^2(\cos^4\psi + \sin^4\psi)\right]^{1/2}} \qquad (9)$$

from figure (5.a)we can find also the expression for amplitude a_0 and ctg phase difference in the basic mode:

$$a_0 = \frac{R_0 a_2 \sin((\beta_2 - \beta_1)z)}{\sin((\beta_0 - \beta_1)z)} \sin\psi_0 \,, \qquad (10)$$

$$ctg((\beta_0-\beta_1)z)=\frac{a_1}{a_2}\frac{ctg\psi_0}{\sin((\beta_2-\beta_1)z)}+ctg((\beta_2-\beta_1)z). \qquad (11)$$

Parameters a_0, ψ_0, Q, ψ can be measured directly on experiment. and now we shall find expressions for excitation factors of own modes, so lets the optical fiber is raised by Gaussian-bunch, which displaced concerning the center on distance $r_0 = (x_0, y_0)$ .then the excitation coefficients according to [3,12],can be defined as:

$$a_i^{x,y} = \int_{S_\infty} E_l^{x,y} .(e_l^{i,x(y)})^* dS \Big/ \int_{S_\infty} \left| e_l^{i,x(y)} \right|^2 dS . \qquad (12)$$

We can choose the field of falling bunch in the form: $E_t^x = \hat{x}\exp\left\{-r'^2/(2\rho_g^2)\right\}$,

Where $r'^2 = (x-x_0)^2 + (y-y_0)^2$ .and if there is a diffraction of light on the fiber output then we can neglect the small light losses in the fiber and the partial redistribution of modes energy, so the weights of own modes could be written as:

$$a_0 = \frac{2\rho_g^2}{(\rho^2/V+\rho_g^2)}\exp\left\{-\frac{x_0^2+y_0^2}{2}\frac{1}{\rho^2/V+\rho_g^2}\right\}$$

$$a_1 = \frac{4x_0\rho\rho_g^2}{(\rho^2/V+\rho_g^2)^2}\exp\left\{-\frac{x_0^2+y_0^2}{2}\frac{1}{\rho^2/V+\rho_g^2}\right\}$$

$$a_2 = \frac{4y_0\rho\rho_g^2}{(\rho^2/V+\rho_g^2)^2}\exp\left\{-\frac{x_0^2+y_0^2}{2}\frac{1}{\rho^2/V+\rho_g^2}\right\} \quad , \qquad (13)$$

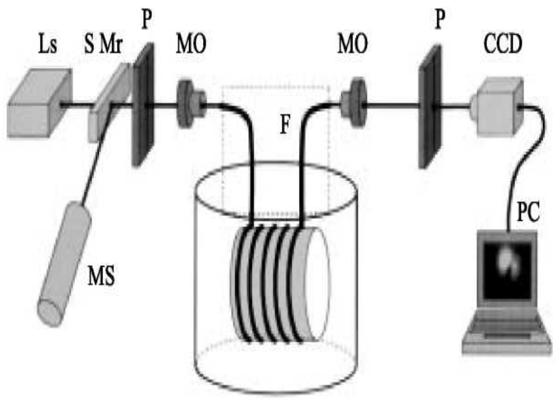

Fig.6: Experimental scheme

Where: S-laser; S Mr-semitransparant mirror; P-polarizator , MO-micro-object's;-fiber optic; MS-microscope;CCD-camera;PC-computer.

According to formal (13) and (2), the intensity distribution in the case of displacement Gaussian bunch at the distance $r_0 = 2\mu m$ is shown on figure (5. b).

The experimental researches were spent as shown on figure.6.where the *He-Ne* laser (with wave length 0.63 μm) passes through polarizer, and then it is entered into optical fiber with waveguide parameter $V = 2.8$ and core radius $3.5\mu m$,and cable length of 1m with strong linear double refraction indices $n_x - n_y \sim 10^{-4}$.

The entrance polarizer was established to reach the maximum polarization degree on the waveguide output, this specified concurrence the direction of light polarization to an axis of anisotropy of fiber. in our case this condition was carried out for angle $20^0 \, and 110^0$ which counted from the vertical axis. the polarizer output was established on the maximum intensity [5].

The own modes weights redistribution was measured at displacement of laser spot on the fiber input and along vertical and horizontal axes. the bunch axes and fiber were exposed coaxially with accuracy up to 2^0 .to control the bunch displacement, it was used a microscope with side view.

Measurements were spent for turn angle of first polarizer $20^0 \, and 110^0$,the characteristic radiation of the fiber is shown on figure(5.c)theoretical calculations of fiber and radiation were used corresponding to the experimental and as we see the theoretical calculations will be coordinated with experimental results. the intensity distribution images of bunch were processed by a program written in programming language *Delphi* at which the parameters of elliptic curve equal intensity and modes weight were defined according to formulas (8),(10).

Figure(5.d) show the curve dependence of modes weights with displacement r_0 of laser spot on the fiber input and the continuous line show the curve that calculated by formula(13).

5 Conclusions and Results

From figures it is visible that by increasing the displacement parameter r_0, the weight of basic mode decreases while the modes weight with upper order $(l=1)$ increased. It is also noticed a small deviation of experimental curves concerning theoretical and this is due to non-agreement of bunch and fiber axes. also it was noticed an intensity losses in waveguide channel and a partial redistribution of energy caused by anisotropic diffraction of own modes at the fiber output, the axes change of displacement from vertical to horizontal leads to symmetric change of curve branches for factors a_1', a_2' .

We can conclude that the given method of measurement allows translating the field radiation to essentially new level. Also this method enables to pass from qualitative comparison of intensity distribution to quantities measurement of modes weight, moreover when we need to define the geometrical parameters of intensity constant, it is not necessary to consider the non linear sensitivity of photo- detectors to the light intensity and this is leads to decrease the measurement tolerance. So this method could be used to produce a transmitter on the basis of anisotropic fiber.

Limiting the propagation to one polarization state can be achieved by either breaking the degeneracy between the mutually orthogonal polarization states through deforming the circular geometry of a fiber and/or introducing shape, stress regions, certain refractive index profiles, or by incorporating metal boundaries into the structure of waveguides.

It is shown that neglecting the geometrical birefringence, even under the weakly guiding approximation, can lead to significant errors in the calculations of PMD and zero PMD wavelength. It is also shown that it is possible to obtain zero PMD in the single-mode region by applying a suitable differential stress along the major axis. This is a very attractive feature since then the geometrical and stress birefringences add to give increased total birefringence. This method should find use in the design of single polarization single-mode fibers for applications in coherent optical communication and fiber-optic sensors.

In elliptical fibers, the birefringence is not as high , and the required core size becomes impractical (extremely small) for the fiber to operate as a single mode waveguide. This problem can be solved by introducing stress regions in the fiber or azimuthal variations of the refractive index.

Finally, the causes of PMD in optical fibers and its effects have been addressed. PMD is considered as a residual dispersion due to stress anisotropies, geometrical noncircularities, and external effects. Polarization-mode dispersion affects the bandwidth of digital and the linearity of analog optical communication systems.

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