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STUDY OF TIME FLUCTUATION OF POLARIZATION OF POLARIZATION PRESERVING FIBERS

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Abstract - This paper deals with the measurement of SOP (State of Polarization) of polarization preserving fiber and its time stability. Linear or circular polarized light was launched into the input of "bow-tie" and "Panda" fibers respectively and the resultant output intensity for different positions of output polarizer was measured. The resultant values have been interpreted on the Poincaré sphere by means of the MATLAB® environment. Typical curves of time fluctuation of ellipticity and ellipse azimuth of the output SOP are presented, too.

Keywords: fiber, polarization effects**,** time stability.

1. BASIC INFORMATION

In the frame of solution research plan [1] the polarization properties of different polarization preserving fibers dependent on torsion have been studied. The state of polarization in the output of short part of fiber has been measured and significant time dependence has been found for excitation of both polarization axes during the long time experiments. These fluctuations of SOP make it more difficult to correctly interpret the results.

Along the excitation of fiber only in one polarization axis, optical power continues to be coupled to this axis, if there is not some extreme mechanical stress. This case of power launching is typical for communication applications, mainly coherent systems or interferometric fiber sensors where preserving of polarization is important along the whole length of fiber.

However for a series of sensor applications where the fiber is a polarization sensitive element we require excitation of both polarization axes. These facts were deduced by detailed measurement of the time dependence of power distribution between axes and a detailed analysis of the results.

2. MEASURING WORK PLACE, FIBER SPACEMENTS AND MEASUREMENT CONDITIONS

During the former stages a lot of measurement has been made [1], [2] especially with fiber "bow-tie" F-SPV (Newport) and "PANDA" PM-630 HP (Thorlabs). The wavelength of 633nm that was used was determined by the He-Ne laser. This has a very good linear polarization and is also suitable for making a change to the circular polarization and back to the linear with different orientation. Also coherent length is substantial which enables observation of interference of polarization modes.

Both fibers have the beat length of less than 2mm. This means that the circular polarization in the input of fiber will change to the elliptical, linear, elliptical and back to the circular and all this on a length of less than 2mm. The reason for this is due to the difference of phase velocities of both polarization modes propagation. The length of the fiber used in this experiment was 2m. Arrangement of work place is evident from Fig. 1. The fiber is placed into the ceramic capillary for elimination of random mechanical affects on the fiber position. The retarder λ/4 changes the linear polarization of the laser to the circular which is used for launching the fiber. The polarizer enables setting of linear polarization in the required direction. Deviation from circular polarization is less than ±5% of mean value which is sufficient regarding the fluctuations of output power in the end of fiber.

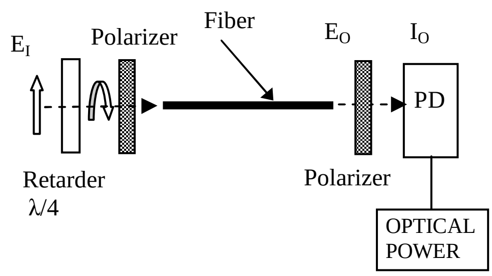

Fig. 1. Arrangement of the work place

The program AMEX [3] has been used for measurement and data processing in the Excel environment. Measurement was made at first for circular polarization of input radiation, because of the same excitation of both polarization axes and after that for linear polarization to the determination of polarization axes system and observing the time dependence in the comparison with the circular polarization.

The units for long time measurement were 10 or 5 minutes. Power launched into the fiber was 100µW for circular polarization and 75µW for linear polarization. We obtained a lot of results in the form graphical dependence of parameters of polarized radiation, ellipticity and angle of main axis position [1], [2]. For selected input polarization the intensity after output polarizer has been measured. The orientation of the polarizer was changed with 10° steps. For measurement of output intensity a power meter with a combination of digital multimeter controlled by the PC has been used.

3. EXPERIMENTAL RESULTS

The results were processed in a graphical form of functional dependences and approximated by means of the continuous curves (Fig. 2). They have also been transformed on the Poincaré sphere.

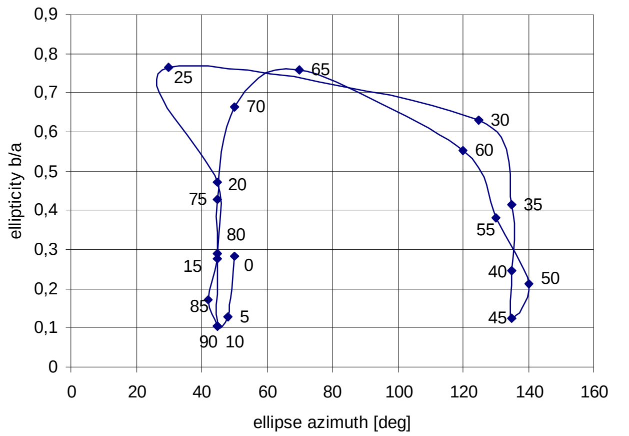

Fig. 2. Time dependence of ellipticity and ellipse azimuth for fiber PANDA with input circular polarization, measured from 0 to 90 minutes

The Poincaré sphere provides a convenient way of representing polarized light and predicting how any given retarder will change the polarization state. The method is essentially one of mapping with each point on the sphere representing a different polarization state. The mapping for our application has been carried out with the aid of a 3D model. The method is applicable only for a completely polarized beam.

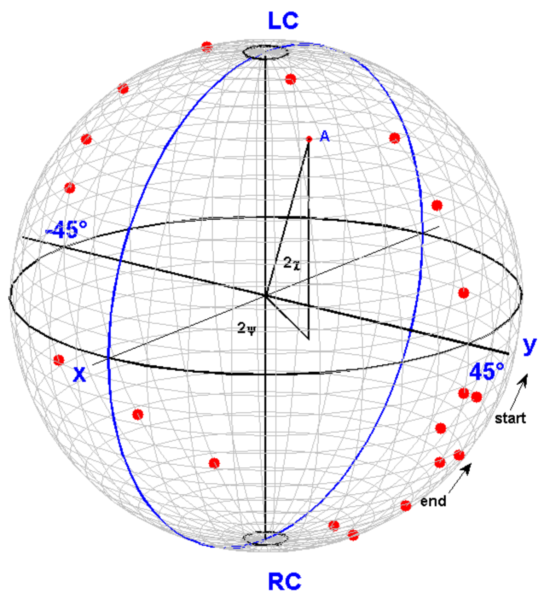

Fig. 3. The Poincaré sphere in MATLAB environment

The mapping allows us to see at glance the solution to a problem that would be difficult to solve by conventional methods. Fig. 3 indicates the significance of the various parts of the sphere. The upper and lower poles represent left and right circularly polarized light respectively. The equator represents the linear polarization and the differences among points on the equator represent the plain angle of the propagating beam. Other points represent elliptical polarization.

The MATLAB environment was chosen for interpretation of polarization states. The MATLAB allows support in math area, graphical interface, transmission of data among different applications, simulation and simulation. The Poincaré sphere self-made application is based on the method of *Switched board programming*.

Fig. 3 represents three dimensional projection of the Poincaré sphere. The application allows interpretation of Stokes parameters or inserts the ellipticity and the ellipse azimuth. In our case we insert the obtained data (ellipticity, ellipse azimuth). The application has two slide potentiometers, which allow the rotation of sphere and we can attain two dimensional projections or other arbitrary projection. This property allows reading of deviations more comfortable in comparison with conventional graphical method.

Fig. 4 represents two dimensional projection of Fig. 3, in MATLAB environment. To obtain this projection we easily used two slide potentiometers as mentioned above. The projection from Fig. 4 allows us to see at a glance the polarization eigen axes of the PANDA fiber. The first step is to approximate the state of polarization that is represented by the dashed double arrow. In the next step we impose an orthogonal straight line that is represented by the full line double arrow. The ends of the full line double arrow represent the sought polarization eigen axes. The length between two nearby meridians represents 5° and we can obtain information that sought polarization eigen axes laid on 1° and 91° approximately. Information about the extinction ratio between the polarization eigen modes cannot be obtained from the projection in MATLAB. To determine the extinction ratio we have to conduct other measurements with input linear polarization oriented in obtained eigen polarization axes.

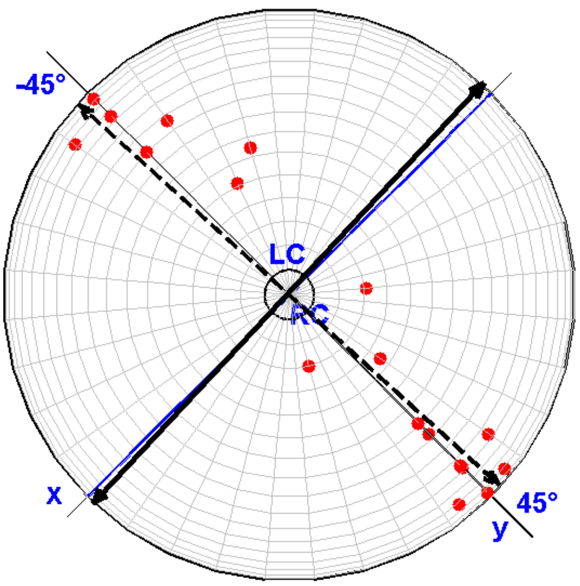

Fig. 4. The Poincaré sphere in XY plane

The linear polarized light was also launched into the input of the Panda fiber as shown in Figs. 5, 6, 7 and 8. Figs. 5 and 6 represent the input linear polarization with a light input orientated at 5°.

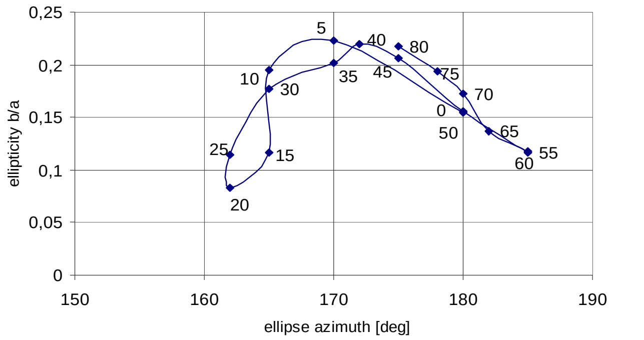

Fig. 5 Time dependence of ellipticity and ellipse azimuth for the PANDA fiber with input a linear polarization input of (90°), measured from 0 to 80 minutes

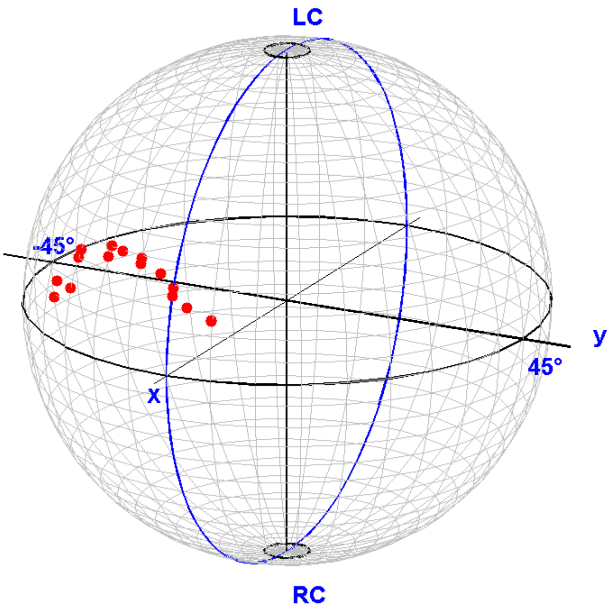

Fig. 6. Time dependence of ellipticity and ellipse azimuth for the PANDA fiber with input linear polarization (90 deg), on the Poincaré sphere

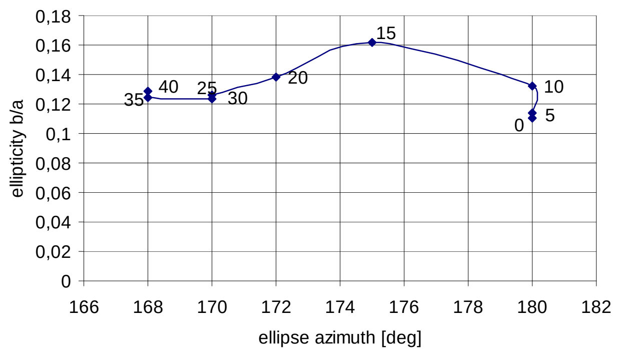

Fig. 7. Time dependence of ellipticity and ellipse azimuth for the PANDA fiber with input linear polarization (75°) measured from 0 to 40 minutes

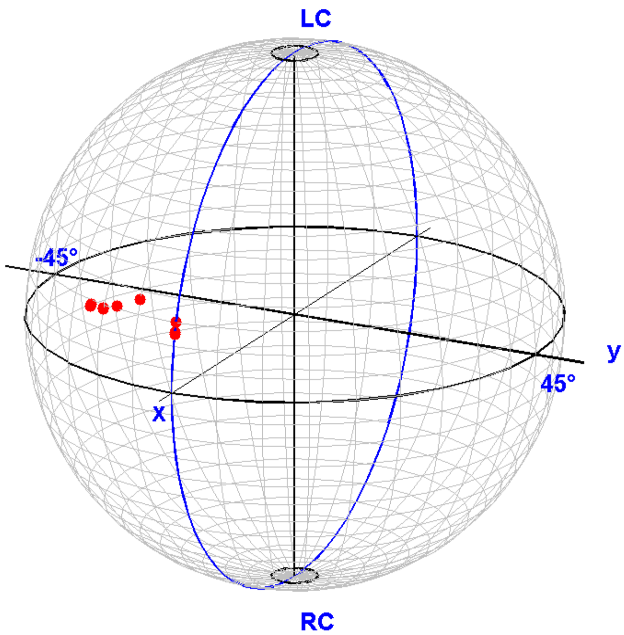

Fig. 8. Time dependence of ellipticity and ellipse azimuth for the PANDA fiber with input linear polarization (75 deg), on the Poincaré sphere

From these figures we can see that the dependence of ellipticity and ellipse azimuth is relatively large. The ellipse azimuth fluctuates from 162° to 185° and ellipticity fluctuates from 0,08 to 0,22.

Figs. 7 and Fig. 8 represent input linear polarization with input light oriented to 75°. From these figures it is evident that in comparison with input linear polarization of 90° that the dependence of ellipticity and ellipse azimuth is smaller. This conclusion means that with input linear polarization of 75° we are drawing nearer to the polarization eigen axes than for input linear polarization of 90°.

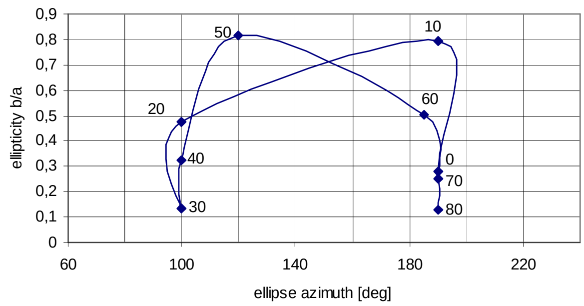

Fig. 9 Time dependence of ellipticity and ellipse azimuth for the F - SPV fiber with input circular polarization, measured from 0 to 80 minutes

With regards to the considerable fluctuations as is shown in the Fig. 6 we can't at a glance find polarization eigen axes with the sufficient accuracy. To find the polarization axes with sufficient accuracy we must conduct other measuring with a different orientation of input linear polarized light. From the projection in the MATLAB environment (Fig. 8) we can determine the position of engine polarization axes at -6° and 84° with more accuracy.

The circular polarized light was been launched into the input of fiber F-SPV that is shown in the Figs. 9 and 10.

From Fig. 10 it is evident that time fluctuation of polarization state for the input circular polarized light is developing on the Poincaré sphere by a circle which lies in the plane which is orthogonal to the eigen polarization axes. That is the definition for method that allows finding the polarization axes, as mentioned above. The development of polarization state runs once past this circle on the beat length. It means the state of polarization will change from linear to elliptical to circular and back to elliptical and linear during the one beat length.

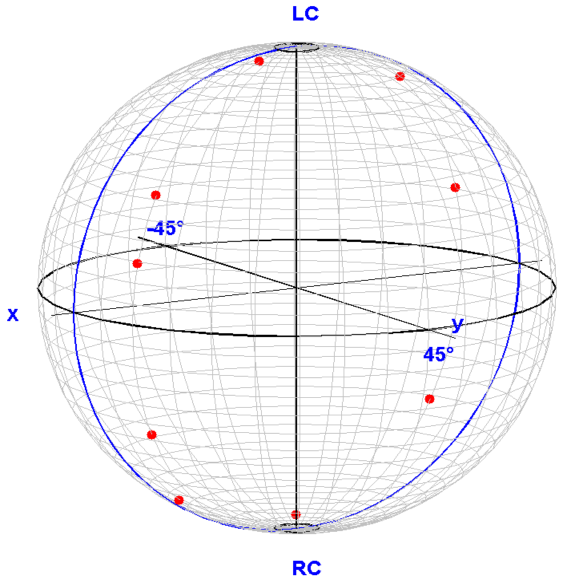

Fig. 10 Time dependence of ellipticity and ellipse azimuth for the F-SPV fiber with input circular polarization, on the Poincaré sphere

The development of the polarization state for the input linear polarized light will past this circle on the beat length, too, but polarization will develop from linear to elliptical and back from elliptical to linear as is shown in the Fig. 10. In the situation where the input linear polarized light will be oriented exactly into the polarization eigen axes, the development of the state of polarization will be represented by one point and input polarization will be preserved.

4. UNCERTAINTY

Fluctuations of measured output power are the main problem of measurement. These fluctuations are caused by coupling between the polarization modes with values in the interval of about 5% around the mean value and changes with frequency of order about 10^{-1} to 10^{0} Hz. Owing to the integration time of the output voltmeter (only 0,2 ms), the fluctuations exert in the measured value of output optical power. On the other side, only ellipticity and ellipse azimuth have been determined, so that incorrect values could be eliminated by the approximation. In addition, the direction of the major axes stated as the angle of maximum intensity can be confronted with the angle of minimum intensity corresponding with the direction of the minor axes. If we consider possible mistakes in determination of maximum with respect to the flat shape of curve in the point of maximum, we can estimate uncertainty in the determination of the ellipticity of about 5% and about 5° for the determination of the angle of major axes. The results that have been obtained could be improved by the measurement of output intensity with the polarizer step rotation equalled to 5° or 1°.

Maximum output fluctuations occur with output polarization close to the circular. With regard to the fact that power relations are relatively stable for the states close to the linear, we can approximate the transition over circular polarization based on the linear polarization states.

We can consider our measuring process as sufficiently accurate with regard to uncertainty in determining ellipticity at about 5% and the major axes angle of about 5°.

5. CONCLUSION

Some selected results from investigation of polarization preserving fiber and its time fluctuation have been presented in this paper. We found variations of ellipticity and ellipse azimuth (angle of the main axis) at the output of short part of fiber "bow-tie" and "PANDA". These variations are caused by the fluctuations of polarization modes and with regard to the fiber structure also some significant space modes should affect. The results obtained for both types of fibers are similar and they will be also used for laboratory practice by PhD students.

ACKNOWLEDGMENTS

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