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The effect of light waves on polarization mode disperts

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ABSTRACT

Optical fiber is a medium that spreads information in the form of light waves. The quality of the optical fiber can be determined by knowing the dispersion value of the polarization mode which is one of the characteristics of the optical fiber by using a single-mode optical fiber design simulation method using the OptiFiber software. The single-mode optical fibers used in the simulation are SMF-28, SMF-28e, SMF-28e+, SMF-28e+ LL, SMF-28 ULL. A good quality SMF for long-distance communication is an SMF that has a small PMD value.

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1. INTRODUCTION

Optical fiber is a medium that can transmit information in the form of light waves [1-3]. Optical fiber has many advantages, by having insulating properties and can be used as future products for communication systems. Optical fiber can convey accurate information in a fast time [4, 5].

Optical fiber can be used as a transmission because it is linear. Linear properties can have two main effects on optical light propagation, namely dispersion, and absorption. Dispersion is the widening of optical pulses that propagate along with the fiber [6-8]. Absorption is the absorption of optical light that occurs due to impurities from the optical fiber material used [9, 10]. The optical fiber used for long-distance communication is a single-mode optical fiber. This optical fiber has a high data transfer capability so that there is no modal noise in the fiber [11-13].

Single-mode optical fiber design simulation is necessary because the use of single-mode optical fiber is required for long-distance communication because it has less attenuation to the fiber and single-mode optical fiber can be used as a sensor. In this simulation, we can see the quality of single-mode optical fiber from how much value the polarization dispersion mode is in single-mode optical fiber. Damage and losses that occur in single-mode optical fiber can be seen from the simulation of polarization mode dispersion.

2. THEORY

2.1. Single-Mode Fiber (SMF)

SMF has a small core diameter of 4 – 10 μm and a diameter of 125 μm. This optical fiber can only transmit signals in one mode because SMF only transmits signals in the main mode and can prevent chromatic dispersion of the fiber [14-16]. The performance of multimode optical fiber depends on the numerical values of the aperture and core diameter, while the stump mode optical fiber is affected by the radial distribution of optical power contained in the basic propagation mode. MFD is known as modal point size in single-mode optical fiber [11].

2.2. Birefringence

Birefringence occurs because optical fiber has a fiber core that is not perfectly cylindrical so variations in diameter cause stress unevenness along the length of the fiber so that it experiences different propagation constants for the fiber [11]. Modal birefringence is defined by:

$$\delta n = |n_x - n_y| \tag{1}$$

In a single-mode optical fiber, there are two groups of intrinsic and extrinsic disturbances, intrinsic interference is a permanent feature of the fiber due to errors during the manufacturing process. Meanwhile, extrinsic disturbances are disturbances that occur due to external stresses that occur in the fiber during cable installation. The imperfection of the fiber causes the fiber to experience birefringence [17, 18].

2.3. Group Speed Dispersion

Group speed dispersion is when an optical fiber has different spectral components propagating at slightly different speeds resulting in pulse widening over the optical fiber. The group velocity dispersion is called intramodal dispersion, in which the intramodal dispersion is divided into two, namely material dispersion and wave coupling [11]. The group speed can be expressed by the equation:

$$V_g = \frac{1}{d\beta/d\omega} \tag{2}$$

2.4. Material Dispersion

Material dispersion is caused by frequency and wavelength which depend on the response of atoms and electromagnetic waves of the material [19-21]. Pulse widening in material dispersion occurs due to differences in velocity variations of the spectrum components propagating to the fiber [11].

2.5. Wave Integer Dispersion

The coupling dispersion depends on the wavelength and the dimensions of the waves, the speed of the combiner depends on the frequency [22-24].

2.6. Polarization Mode Dispersion (PMD)

PMD is pulse widening that occurs due to differences in propagation time [11]. PMD is a case of modal dispersion, modal dispersion is a distortion mechanism that occurs in multimode optical fiber and other wave combiners. The signal spreads over time because the optical signal propagation speed is not the same for all modes. PMD is generated when the two velocity moving modes have fiber core geometry and stress symmetry moving at different speeds due to random imperfections that break the symmetry.

PMD on optical fiber is an input signal into the fiber which is linearly polarized into circular polarization, elliptical polarization and when the output signal comes out it will return in a linear form with a different position. When the input signal enters the output, there will be a time delay (TD). TD causes the incoming signal to have first and second-order because the fiber will experience a slow delay and short delay on the fiber.

The PMD-induced pulse dilation can be calculated by the equation:

$$\Delta T = D_{PMD}\sqrt{L} \tag{3}$$

where ΔT measured in units of ps/√km, D_{PMD} is the average PMD parameter and L is the length of the fiber. Values usually vary from 0.01 to 10 ps/√km [11].

For single mode fiber optic length, the PMD value is given in the form of the mean DGD value by equation [25, 26]:

$$\langle \Delta\tau \rangle = \sqrt{\frac{8}{3\pi}} \Delta\beta' \sqrt{l_c} \sqrt{z} \tag{4}$$

PMD is also given in the form of root mean square (RMS):

$$\sqrt{\langle \Delta\tau^2 \rangle} = \Delta\beta' \sqrt{l_c} \sqrt{z} \tag{5}$$

3. RESEARCH METHODS

This research is a simulation using OptiFiber application version 2. 1.0.133 to design single-mode optical fiber. The SMFs to be simulated are SMF-28, SMF-28e, SMF-28e +, SMF-28e + LL and SMF-28 ULL. The process carried out in the single-mode optical fiber design simulation is to determine the profile of the SMF fiber by entering the type of profile used and entering the radius and refractive index values contained in the SMF. When simulating the fiber mode, first determine the dispersion model contained in the optical fiber, this dispersion model is determined by selecting the material contained in the material properties. Next, simulate the cutoff wavelength using LP Modes (matrix method) which shows the mode parameters LP01 and LP11. If there is LP01 then reduce the wavelength.

To simulate the polarization of the dispersion model, first, simulate the birefringence caused by disturbances in the parameters contained in the fiber. This simulation has constant values such as photoelastic value, Young's modulus, and Poisson's ratio. Birefringence is influenced by extrinsic factors (bending and stress). When simulating PMD, the length and fiber length values can be varied to determine fiber quality. And PMD simulation is also influenced by the spectrum length and iteration contained in single-mode optical fiber.

4. RESULTS AND DISCUSSION

Discussion of the simulation results of the influence of the wave spectrum on the polarization of the dispersion mode of several types of single-mode optical fiber which have different waves and different PMD values for each SMF when signal propagation occurs.

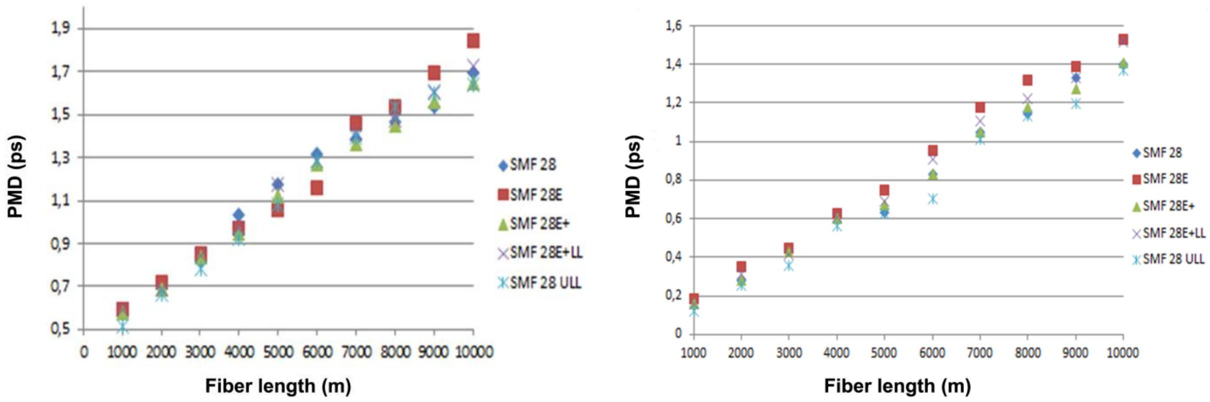

Figure 1. Changes in the first-order (left) and second-order (right) PMD values at a wavelength of 1310 nm.

In Figure 1 the first-order section, it can be seen that the PMD value has a small fluctuation because the 1310 wavelength has large energy for the fiber. When the fiber length was 600 m SMF 28e increased higher because the refractive index value in SMF 28e was greater than other SMFs. Meanwhile, the PMD value at SMF 28e+ slightly increased because the normalization frequency value for SMF 28e+ was larger, and at SMF 28 ULL the PMD value was smaller because the refractive index value for SMF 28 ULL was very small compared to other SMFs. On the other hand, the second-order PMD value is smaller than the first-order PMD. This second-order PMD value as a comparison value for the first and second-order is the second wave that occurs due to the relatively slow delay in the optical fiber. In Figure 2 it can be seen that the SMF which has the smallest value is SMF 28 ULL because the refractive index of SMF 28 ULL is smaller than the refractive index of other SMFs.

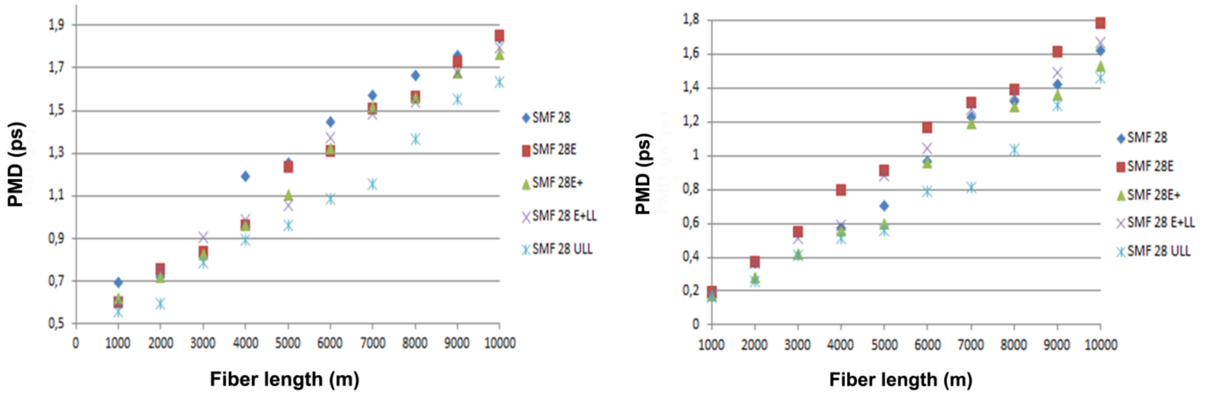

Figure 2. Changes in the first-order (left) and second-order (right) PMD values at a wavelength of 1550 nm.

In Figure 2 the first-order section, it can be seen that the PMD value at a wavelength of 1550 nm is greater than the PMD value at a wavelength of 1310 nm, but PMD is not good for optical fiber. In the picture above, there are high fluctuations due to the large wavelength, because the larger the wavelength, the smaller the energy contained in the optical fiber. PMD is directly proportional to the fiber length so the PMD value varies along with the optical fiber. On the other hand, the second-order PMD value at a wavelength of 1550 nm linear to the fiber length. It can be seen in Figure 4 that the second-order PMD value fluctuates greatly with large wavelengths and there are significant differences for all SMFs. At a wavelength of 1550 nm, there is a large dispersion so that the PMD value of each SMF becomes large, but at SMF 28 ULL the PMD value has a small increase compared to SMF 28. This is because the value of the refractive index at SMF 28 ULL is smaller than the value of the SMF refractive index. 28. The PMD value is also influenced by the frequency of normalization of the optical fiber, the value of the normalized frequency of SMF 28 is greater than that of ULL SMF 28. So that the greater the normalization frequency, the more light will be transmitted to SMF, and SMF which has a large normalized frequency value will experience more fiber dispersion.

5. CONCLUSION

PMD in SMF is directly proportional to the wavelength. The 1550 nm wavelength has a greater dispersion value than the 1310 nm wavelength because the energy at the 1550 nm wavelength is smaller than the 1310 nm wavelength. Fiber length and wavelength are directly proportional to PMD. The longer the optical fiber, the greater the PMD value in the fiber and causes the PMD value to vary along with the optical fiber during propagation.

REFERENCES

[1] Parida, B. P. B. M. A. (2014). Fiber Bragg grating as a dispersion compensator in an optical transmission system using optisystem software. *International Research Journal of Engineering and Technology (IRJET)*, **2**(06).

[2] Saktioto, Zairmi, Y., Veriyanti, V., Candra, W., Syahputra, R. F., Soerbakti, Y., Asyana, V., Asyana, V., Irawan, D., Okfalisa, Hairi, H., Hussein, N. A., Syamsudhuha, & Anita, S. (2020). Birefringence and polarization mode dispersion phenomena of commercial optical fiber in telecommunication networks. *Journal of Physics: Conference Series*, **1655**(1), 012160.

[3] Saktioto, T., Ramadhan, K., Soerbakti, Y., Syahputra, R. F., Irawan, D., & Okfalisa, O. (2021). Apodization sensor performance for TOPAS fiber Bragg grating. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, **19**(6), 1982–1991.

[4] Horvath, T., Munster, P., Vojtech, J., Velc, R., & Oujezsky, V. (2018). Simultaneous transmission of accurate time, stable frequency, data, and sensor system over one fiber with ITU 100 GHz grid. *Optical Fiber Technology*, **40**, 139–143.

[5] Roslan, M. S., Chaudhary, K. T., & Mazalam, E. (2020). Overview of temporal soliton transmission on photonic crystal fiber and nanowires. *Science, Technology and Communication Journal*, **1**(1), 15–18.

[6] Sharma, P., Pardeshi, S., Arora, R. K., & Singh, M. (2013). A review of the development in the field of fiber optic communication systems. *International Journal of Emerging Technology and Advanced Engineering*, **3**(5), 113–119.

[7] Saktioto, T., Ramadhan, K., Soerbakti, Y., & Irawan, D. (2021). Integration of chirping and apodization of Topas materials for improving the performance of fiber Bragg grating sensors. *Journal of Physics: Conference Series*, **2049**(1), 012001.

[8] Saktioto, T., Fadilla, F. D., Soerbakti, Y., & Irawan, D. (2021). Application of fiber Bragg grating sensor system for simulation detection of the heart rate. *Journal of Physics: Conference Series*, **2049**(1), 012002.

[9] Wang, Z., Wu, H., Hu, X., Zhao, N., Mo, Q., & Li, G. (2016). Rayleigh scattering in few-mode optical fibers. *Scientific Reports*, **6**(1), 35844.

[10] Roslan, M. S., Zin, A. F. M., Rosley, R., Abdullah, F. B., Amran, N. S., Rosslan, N. J. A., Jameel, M. H., & Haider, S. Z. (2021). Reflective and structural characteristics of natural pearl. *Science, Technology and Communication Journal*, **2**(1), 14–18.

[11] Jamaludin, M. Z. & Abdullah, F. (2014). OptiSystem: an alternative to optoelectronics and fiber optics teaching e-laboratory. *International Journal of Asian Social Science*, **4**(2), 307–313.

[12] Ramadhan, K., Saktioto, Syahputra, R. F., Soerbakti, Y., & Fauzan, M. (2020). Dispersi multi-layer pada inti serat optik moda tunggal. *Seminar Nasional Fisika Universitas Riau V (SNFUR-5)*, **5**(1), 1–5.

[13] Fitri, A., Candra, W., & Meyzia, B. (2021). Determination of optical parameters on knee bending of the feet using fiber optic. *Science, Technology and Communication Journal*, **2**(1), 9–13.

[14] Addanki, S., Amiri, I. S., & Yupapin, P. (2018). Review of optical fibers-introduction and applications in fiber lasers. *Results in Physics*, **10**, 743–750.

[15] Portnov, E. L. & Rabenandrasana, J. (2020, March). The Choice of Optical Fiber with the Best Transmission Characteristics. *2020 Systems of Signals Generating and Processing in the Field of on Board Communications*, 1 – 5.

[16] Puttnam, B. J., Rademacher, G., & Luís, R. S. (2021). Space-division multiplexing for optical fiber communications. *Optica*, **8**(9), 1186–1203.

[17] Poole, C. D. & Nagel, J. (1997). Polarization effects in lightwave systems. *Optical Fiber Telecommunications IIIA*, 114–161.

[18] Prisutova, J., Krynkin, A., Tait, S., & Horoshenkov, K. (2022). Use of fibre-optic sensors for pipe condition and hydraulics measurements: A review. *CivilEng*, **3**(1), 85–113.

[19] Miah, M. S. & Rahman, M. M. (2012). The Performance Analysis Fiber Optic Dispersion on OFDN-QAM System. *International Journal of Advanced Computing, Engineering and Application (IJACEA)*, **1**(1), 29.

[20] Soerbakti, Y., Syahputra, R. F., Saktioto, S., & Gamal, M. D. H. (2020). Investigasi kinerja antena berdasarkan dispersi anomali metamaterial struktur heksagonal split ring resonator. *Komunikasi Fisika Indonesia*, **17**(2), 74–79.

[21] Gamal, M. D. H. (2020). Investigasi karakteristik anomali indeks bias negatif metamaterial array struktur split ring resonator. *Seminar Nasional Fisika Universitas Riau V (SNFUR-5)*, **5**(1), 1–4.

[22] Pirich, R. & Mazurowski, J. (2012). Engineering of fiber optics infrastructure. *2012 IEEE Long Island Systems, Applications and Technology Conference (LISAT)*, 1–4.

[23] Collins, C. O., Rogers, W. E., & Lund, B. (2017). An investigation into the dispersion of ocean surface waves in sea ice. *Ocean Dynamics*, **67**, 263–280.

[24] Moores, B. A., Sletten, L. R., Viennot, J. J., & Lehnert, K. W. (2018). Cavity quantum acoustic device in the multimode strong coupling regime. *Physical review letters*, **120**(22), 227701.

[25] Foschini, G. J. & Poole, C. D. (1991). Statistical theory of polarization dispersion in single mode fibers. *Journal of Lightwave Technology*, **9**(11), 1439–1456.

[26] Saktioto, T., Zairmi, Y., Erlinda, S., & Veriyanti, V. (2021). Simulation of Birefringence and Polarization Mode Dispersion Characteristics in Various Commercial Single Mode Fibers. *Application of Optical Fiber in Engineering*, 94127.