Comparison The Propagation Loss of The Electromagnetic Waves Through Different Materials of Fiber

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المستخلص

في الاتصالات البصرية، ان الخسارة التي تحدث في انتقال الاشعة الكهرومغناطيسية تعتمد على نوع الوسط الذي تنتقل فية الموجة. نسبة خطأ الارقام الثنائية (BER) والتي تمثل السرعة التي تنقل عندها هذه الارقام الثنائيةاو البيانات هي عامل مهم في سلوك الليف. في هذا البحث تم المقارنة بين الخسارة التي تعتمد على الطول الموجي للفضاء والفايبر الموصل الجيد. وتمت المقارنة بين نسبة خطأ الارقام الثنائية والتي تعتمد على التشتت، طول الليف والطول الموجي لانواع مختلفة من الالياف البلورية الفوتونية. ان المواد الليف المختارة في هذا البحث هي الزجاج ال SCOTT وزجاج OHARA وزجاج quartz. كذلك سيتم حساب التشتت اللوني ($D(\lambda)$) باستخدام برنامج MATLAB ويكون مقارناً لثلاث اطوال مختلفة من الالياف البلورية الفوتونية المستخدمة. كنتيجة لهذا العمل وطبقاً للمواد المختلفة fused silica (SiO_2), OHARE Barium (BAH)، SCOTT Phosphate crown (PK) ان زجاج (PK) افضل من الياف SiO_2 وBAH في الارسال لاقل تشتت لوني.

Abstract

In optical communication, the propagation loss of the electromagnetic wave depends on the type of fibers that will propagate in. The Bit Error Rate (BER) which is the speed at which data or bits were transmitted is an important parameter in fiber behavior. In this paper the comparison between propagation loss which depends on the wavelength for free space & good conductor fiber. The comparison for bit error rate (BER) which depends on dispersion, fiber length and wavelength were found for different types of photonic crystal fibers. The fiber materials selected in this paper were SCOTTE optical glass, OHARA optical glass, & Fused Silica (Fused quartz) fibers glass. The chromatic dispersion (D (λ)) will also be calculated by using (MATLAB R2013a) software and be compared for three different photonic crystal fiber lengths used. As a result of this work and according to the different materials the phosphate crown (PK), Barium, high index (BAH) and the pure silica (SiO2) glass that used. The SCOTT Phosphate crown (PK) fiber is better than other (BAH, SiO2) fibers in transmission with less chromatic dispersion.

Keywords: the Phosphate crown (PK) crystal fiber, the Barium (BAH) glass fiber, the pure silica SiO2 glass fiber, (MATLAB R2013a) software

1-Theoretical Basics

Maxwell's equations predict the propagation of electromagnetic energy away from time-varying sources (current and charge) in the form of waves. The real part of the propagation constant (α) is defined as the attenuation constant while the imaginary part (γ) is defined as the phase constant. The equations of α & γ is:[1,2]

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}-1\right]} \quad \text{.......(1)}$$

$$\gamma = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}+1\right]} \quad \text{........(2)}$$

The relation between waveguide dispersion $D_w(\lambda)$ and the effective refractive index n_{eff} of a guided mode in Photonic Crystal Fiber PCF is as Eq. (3) [3,4]:

$$D = -\frac{\lambda}{c}\times\frac{d^2(n_{eff})}{d\lambda^2} \quad \text{...(3)}$$

$$n_{eff}(\lambda) = \frac{\beta(\lambda, n_m)}{k_0} \quad \text{.....(4)}$$

Where β is the propagation constant, n_m is the refractive index of any material is chosen, k_0 is the wave number. In order to utilize the scaling transformation of PCF, the chromatic dispersion $D(\lambda)$ of a PCF can be approximated by a sum of waveguide dispersion and material dispersion[5]:

$$D(\lambda) = D_w(\lambda) + \Gamma(\lambda)D_m(\lambda) \quad \text{.....(5)}$$

Where $\Gamma(\lambda)$ is the confinemental factor in PCF, which is close to unity for most particular PCFs. The material dispersion D_m is decided by the material that used in the PCF. For the case of SCHOTT –PK (Phosphate crown), the material dispersion can by directly derived from the Sellmeier formula:[5,6]

$$n(\lambda,T)=\sqrt{1+\frac{1.156107\lambda^2}{\lambda^2-0.00585}+\frac{0.15322\lambda^2}{\lambda^2-0.0194}+\frac{0.78561\lambda^2}{\lambda^2-140.537}} \quad \text{........(6)}$$

For the Barium, high index (BAH) material the Sellmeier formula is:

$$n_{(\lambda)}=\sqrt{1+\frac{1.59034\lambda^2}{\lambda^2-0.009327}+\frac{0.1384645\lambda^2}{\lambda^2-0.042749}+\frac{1.21988\lambda^2}{\lambda^2-119.25177}} \quad \text{........(7)}$$

And for the Pure silica (SiO2) material the Sellmeier formula is:

$$n(\lambda)=\sqrt{1+\frac{0.696166300\lambda^2}{\lambda^2-0.00467914826}+\frac{0.407942600\lambda^2}{\lambda^2-0.135120631}+\frac{0.897479400\lambda^2}{\lambda^2-97.9340025}} \quad \text{.......(8)}$$

$$BER=\frac{1}{4*D(\lambda)*L*\Delta\lambda} \quad \text{..... (9)}$$

Where BER is the bite error rate, L is the fiber length, $\Delta\lambda$ is the spectral width of the light source. An especially (MATLAB R2013a) package is designed to evaluate these parameters through the simulation of equations (1,2,3,4,5,6,7,8,9).[7,8,9]

2- Results and discussion

In this paper the propagation of electromagnetic wave through different fibers is examined. The relation between the different wavelength range (1-2) µm and chromatic dispersion of (PK), (BAH) & (SiO2) fibers is shown in figures (1, 4 & 7), that explain the behavior of chromatic dispersion for these three fibers. The chromatic dispersion in The PK have very low dispersion than (BAH &SiO2) fibers. The Bit Error Rate(BER) is calculated as the number of bits that were in error, as a proportion of the total number of bits transmitted, or received, or

processed over a given period of time. The numerical results are shown in tables (1, 2 & 3). Bit error rate with chromatic dispersion for different crystal fiber lengths shown in figure (2,5 8) so that the error at the 300km length will be less than that of 100km length, because the relation between them is inversely proportional. When compare the BER in PK, BAH & SiO2 fibers, the BER of SiO2 is less than that of PK, BAH fibers. The behavior of the BER and chromatic dispersion and fiber length is shown in figures (3, 6 & 9) for PK, BAH and SiO2 fibers.

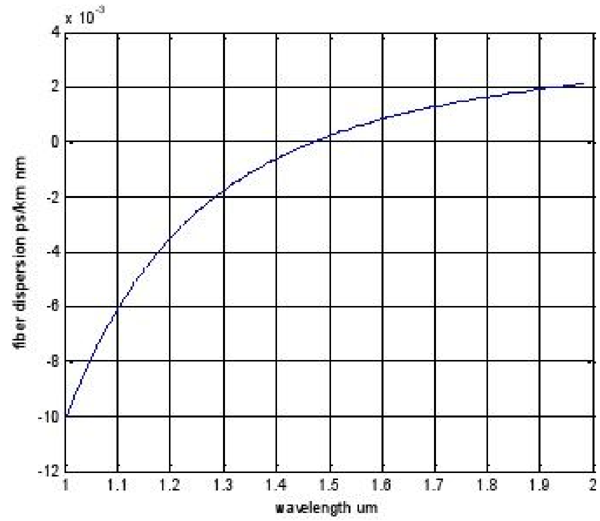

Figure (1) The relation between phosphate crown (PK) fiber dispersion and wavelength

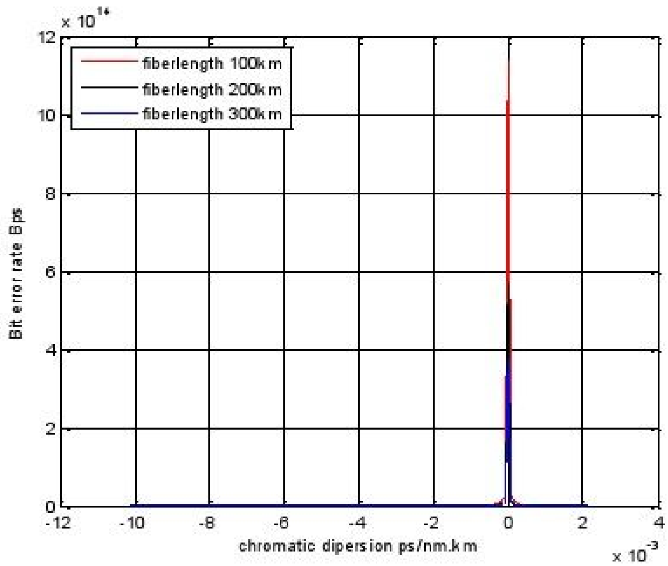

Figure (2) The relation between dispersion and Bit error rate of phosphate crown (PK) fiber

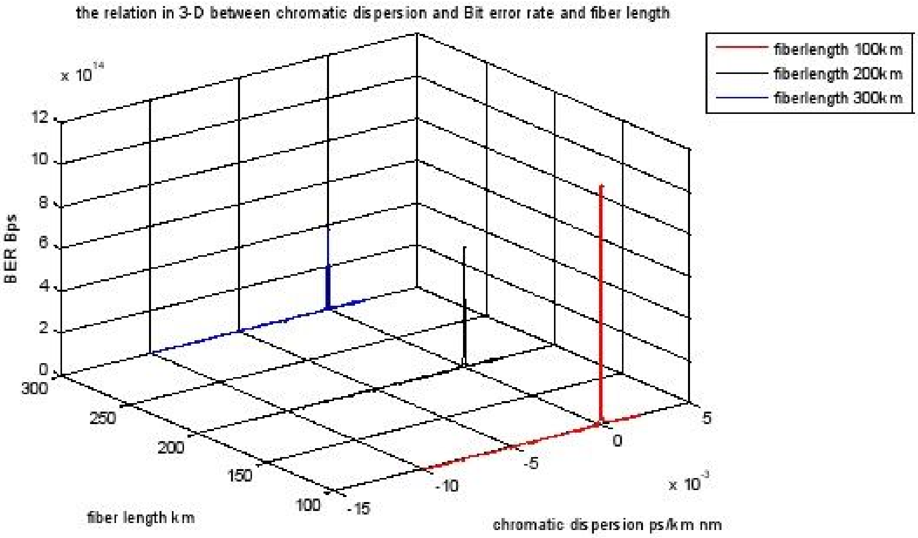

Figure (3) The relation in 3-D between chromatic dispersion and Bit error rate and fiber length of phosphate crown (PK) fiber

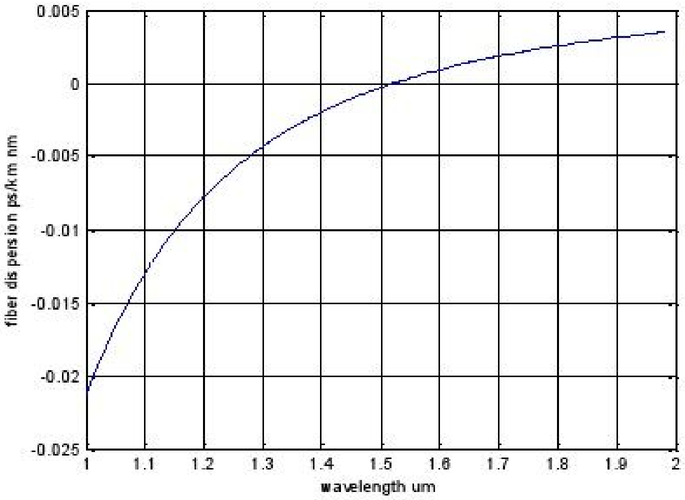

Figure (4) The relation between Barium high index (BAH) fiber dispersion and wavelength

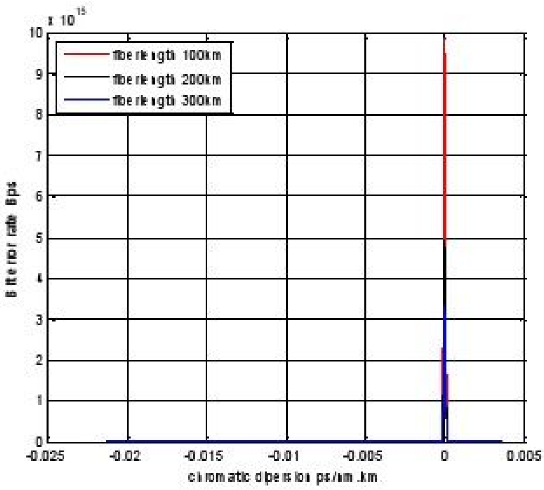

Figure (5) The relation between dispersion and Bit error rate of Barium high index (BAH) fiber

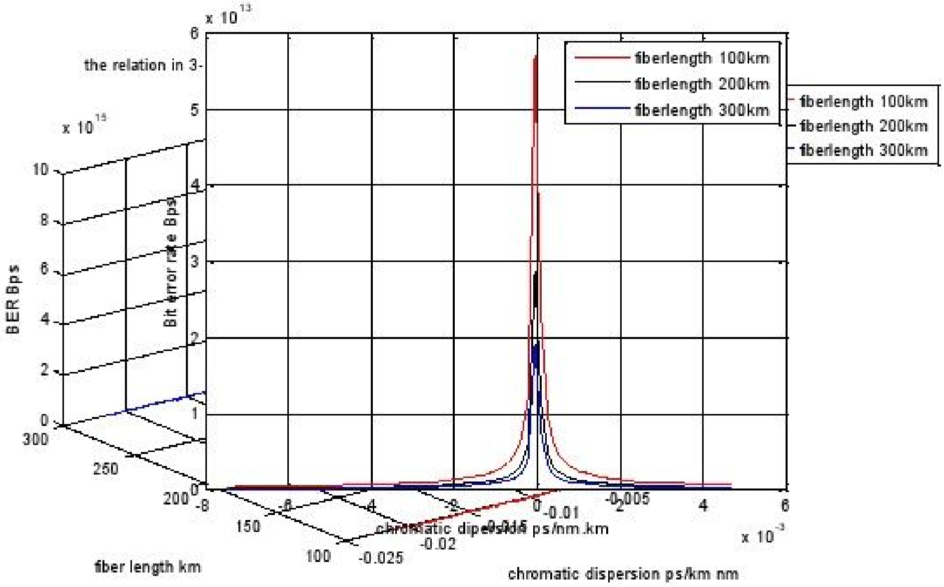

Figure (6) The relation in 3-D between chromatic dispersion and Bit error rate and fiber length of Barium high index (BAH) fiber

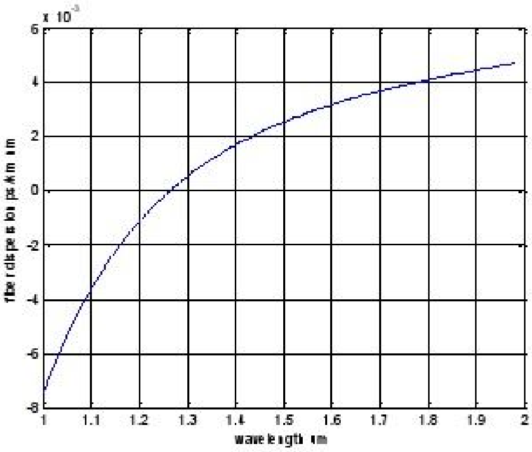

Figure (7)The relation between Pure silica (SiO2) fiber dispersion and wavelength

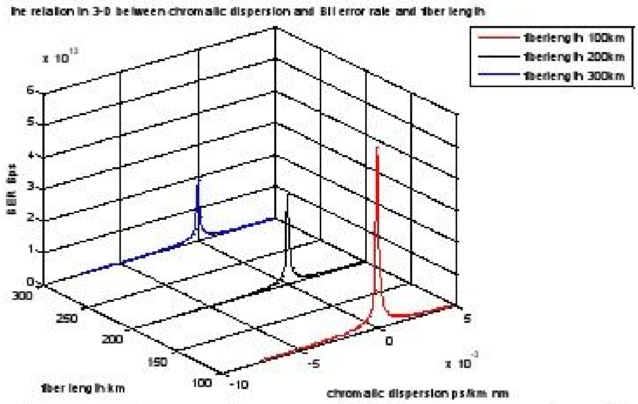

Figure (8) The relation between dispersion and Bit error rate of pure silica (SiO2) fiber

3- Conclusion

The propagation loss of the electromagnetic wave in free space is greater than in good conductor fiber. Transmission capacity (bit error rate), of an optical fiber is dependent upon dispersion characteristics of an optical fiber. This parameter varies with wavelengths. A number of different fiber types have been used such as ((Phosphate crown (PK), Barium high index (BAH) and pure silica (SiO2)). The transmission in FK, QK, SiO2 fibers were carried out with zero dispersion at 1500nm, 1500nm, 1300nm respectively. the relation between BER & fiber length (L) is inversely proportional i.e. when the fiber length increases the BER will be decreases, that means the PK fiber is better than BAH and SiO2 fibers in transmission because it has low chromatic dispersion.

Table(1) Phosphate Crown (PK) material fiber with n=1.5253

Wavelength λ(μm)	Chromatic dispersion(ps/km.nm)	BER(Tb/s km) at fiber length=100km	BER(Gb/s km) at fiber length=200km	BER(Gb/s km) at fiber length=300km
1	-.0101	0.002	0.12	0.08
1.1	-0.0091	0.0004	0.21	0.14
1.2	-0.0035	0.0007	0.36	0.24
1.3	-0.0018	0.0014	0.7	0.47
1.4	-0.0006	0.0041	2.06	1.37
1.5	0.0002	0.0112	5.59	3.73
1.6	0.0011	0.0022	1.12	0.74
1.7	0.0013	0.0019	0.97	0.65
1.8	0.0016	0.0015	0.76	0.51
1.9	0.0019	0.0013	0.65	0.43
2	0.0021	0.0012	0.59	0.39

Table(2) Barium, high index (BAH) material fiber with n=1.6342

Wavelength λ(μm)	Chromatic dispersion(ps/km.nm)	BER(Tb/s km) at fiber length=100km	BER(Tb/s km) at fiber length=200km	BER(Tb/s km) at fiber length=300km
1	-0.0212	0.0001	0.0001	0.000
1.1	-0.0129	0.0002	0.0001	0.0001
1.2	-0.0077	0.0003	0.0002	0.0001
1.3	-0.0043	0.0006	0.0003	0.0002
1.4	-0.0019	0.0011	0.0006	0.0004
1.5	-0.0003	0.0092	0.0046	0.0031
1.6	0.0015	0.0016	0.0008	0.0005
1.7	0.0019	0.0013	0.0007	0.0004
1.8	0.0026	0.001	0.0005	0.0003
1.9	0.0031	0.0008	0.0004	0.0003
2	0.0035	0.0007	0.0004	0.0002

Table(3) Pure Silica (SiO2) material fiber with n=1.45

Wavelength λ(μm)	Chromatic dispersion(ps/km.nm)	BER(Gb/s km) at fiber length=100km	BER(Gb/s km) at fiber length=200km	BER(Gb/s km) at fiber length=300km
1	-0.0075	0.335	0.167	0.112
1.1	-0.0042	0.696	0.380	0.232
1.2	-0.0011	2.245	1.122	0.748
1.3	0.0005	4.57	2.289	1.526
1.4	0.0017	1.466	0.733	0.489
1.5	0.0025	0.981	0.49	0.327
1.6	0.0035	0.714	0.357	0.238
1.7	0.0037	0.677	0.339	0.226
1.8	0.0041	0.609	0.305	0.203
1.9	0.0045	0.561	0.281	0.187
2	0.0047	0.531	0.266	0.177

4- Reference

[1] Shailendra K. Varshney, M. P. Singh, R. K.Sinha, “Propagation Characteristics of Photonic Crystal Fibers”, J. of Opt. Commun. vol. 24, pp. 856 (2003).
[2] Kristen Lantz Reichenbach and Chris Xu, “The effects of randomly occurring nonuniformities on propagation in photonic crystal fibers,” Opt. Express, Vol. 13, No. 8, 18 April 2005.
[3] Abd El-Naser A. Mohammed, Ahmed Nabih Zaki Rashed, Gaber E. S. M. El-Abyad and Abd El-Fattah A. Saad, “High transmission bit rate of a thermal arrayed waveguide grating (AWG) module in passive optical networks”, International journal of computer science and information security, Vol. 1 No. 1 May 2009.
[4] Claton R. Paul, Keith W. Whites,, “Introduction to electromagnetic fields”, 1997
[5] J. C. Knight, T. A. Birks, P. St. J. Russell, and D. M. Atkin, “All-silica single-mode optical fiber with photonic crystal cladding,” Opt. Lett., vol. 21, pp. 1547–1549, 1996.
[6] B. Saleh and M. Teich, “Fundamental of Photonics”, New York, Wiley & Sons, 1991.
[7] H. Tanzer, Course materials for EEE 167, California State University Sacramento, 2002.
[8] J. Wilson and J. Hawkes, “Optoelectronics”, An introduction, 3rd ed., London, Prentice Hall Europe, 1998.
[9] M. Fujita, Course materials for EEE 165, California State University Sacramento, 2001.