ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering &Technology (IJARCET)
Volume 2, Issue 10 , October 2013

An Accurate Model for Chromatic Dispersion in Optical Fibers under Radiation and Thermal Effects

Ahmed Nabih Zaki Rashed[1*], Abd El-Naser A. Mohamed[1], Imbaby I. Mahmoud[2],
Mohamed S. El_Tokhy[2], Osama H. Elgzar[2]

[1]Electronics and Electrical Communications Engineering Department
Faculty of Electronic Engineering, Menouf 32951, Menoufia University, EGYPT
[1*]E-mail: ahmed_733@yahoo.com
[2]Engineering Department, Nuclear Research Center, Atomic Energy Authority, P.O. 13759, Inshas, Egypt

***Abstract** - Radiation and temperature influence the optical fiber characteristics. These influences such as increasing the chromatic dispersion were studied and shown to result from the refractive index changes occurring within the fibers induced by radiation and thermal effects. In this paper we present a model and a simulation results to reveals the effect of radiation and temperature on the optical fiber chromatic dispersion by using Vissim environment. We demonstrate the importance of waveguide dispersion in the reduction of the total chromatic dispersion. This formulated treatment provides a mean to control the optical characteristics of fibers in radiation environments. The results are validated against published experimental work and showed good agreement.*

***Keywords**- Optical Fiber, Radiation Environments, Thermal and Gamma Radiation Harmful Effects, Chromatic Dispersion, Optical Communication System.*

I. INTRODUCTION

Nowadays the growing demand for high data rate applications, is requires a reliable transmission media such as optical fibers [1]. Optical fiber is the basic element in the modern high capacity and high-bit-rate optical telecommunication systems [2-3]. Optical fibers advantages over other electrical media, including [4], capability to work under strong electromagnetic fields, possibility to carry multiplexed signals (time, wavelength multiplexing); small size and low mass [5], ease of integration [6], the large packing density, mass replication, fast data rate, high signal-to-noise ratio, and high immunity to defects especially when short lengths and flexibility are required [7]. Optical fibers can be classified in to two basic types from the point of view of propagation: single-mode fibers, and multimode fibers [8]. Single-mode optical fiber is extensively used in the telecommunication system because it provides a bandwidth of about 30 GHz [3]. In optical fibers, studies mainly focused on the understanding and on the modeling of radiation-induced attenuation and luminescence. Therefore, it has become essential to investigate the influence of ionizing radiation on the characteristics of many fiber-optic components [9]. Moreover, the investigation of the refractive index changes induced by gamma radiation is of crucial importance in the design of fiber-optic systems including fiber-optic gyroscopes, laser ranging systems for space, and intrasatellite high-speed optical links [9]. Another effect of gamma radiation on optical fiber is the dispersion. It plays a critical role in optical signal propagations of optical pulses through fibers [10]. That subdivided into chromatic and modal dispersion [11]. Chromatic dispersion is resulted from the variations in group velocity for different optical spectral components traveling in an optical fiber [12]. It has several limitations on the optical fiber link. Such as pulse broadening, limiting the data rate of an optical communications system [12], restrict the available wavelength region [13], increasing of bit-error rates [3], and affect transmission performance [14]. Additionally, it determines the maximum bandwidth that can be transmitted through the optical fiber [8]. Chromatic dispersion consists of waveguide and material dispersion. The waveguide dispersion can be adjusted by choosing an appropriate refractive index profile of the fiber. However, the material dispersion is an invariable characteristic of a specific material [15]. Thus, it is important to know the dispersion characteristics of the optical fibers [16]. Consequently, we are interested with evaluation of chromatic dispersion that enables us to calculate the degradation that occurs in optical fiber transmission characteristics under irradiation environment. In addition, it allows predicting operating wavelength, thermal and radiation harmful effects. The arising effects of both material and waveguide dispersion are indispensable in designing high-bit-rate optical communication systems. This work is done by using VisSim environment. VisSim is a Windows-based program for modeling and simulating complex dynamic systems. VisSim combines an intuitive drag-and-drop block diagram interface with a powerful simulation engine. The visual interface offers a simple method for constructing, modifying, and maintaining complex system models. With VisSim, we can rapidly develop software prototypes of systems or processes to demonstrate their behavior prior to building the physical prototype. Furthermore, all modeling and simulation tasks can be completed without writing a line of code. This leads to significant savings in both development time and costs, and a greater assurance that the resultant product will perform as specified. This paper is organized as follows: Section II presents the basic assumptions and modeling of radiation induced dispersion, Section III describes the model results. However section IV is devoted to conclusion.

II. BASIC ASSUMPTIONS AND MODELING OF RADIATION INDUCED DISPERSION

A pulse, during its propagation through the fiber, experiences a temporal spread known as temporal dispersion or, dispersion as shown in Fig. (1). Therefore, in any communications link through an optical fiber it is observed that the dispersion is the parameter that determines the maximum bandwidth that can be transmitted through the optical fiber [8]. The factors that contribute to the waveform distortion are basically material dispersion, and waveguide dispersion, these two types of dispersion can be grouped together with the name chromatic or intramodal dispersion. Material dispersion and waveguide dispersion will be studied and we will reveal the effect of thermal irradiation environments on the change of refractive index and how this leads to the dispersion. We will demonstrate the effect of the waveguide dispersion on the total chromatic dispersion. In this model output signal bandwidth is neglected, e.g., the sources are assumed to overfill the fiber so that all mode groups are present and the Differential Modal Attenuation (DMA) of the fiber is assumed to be zero.

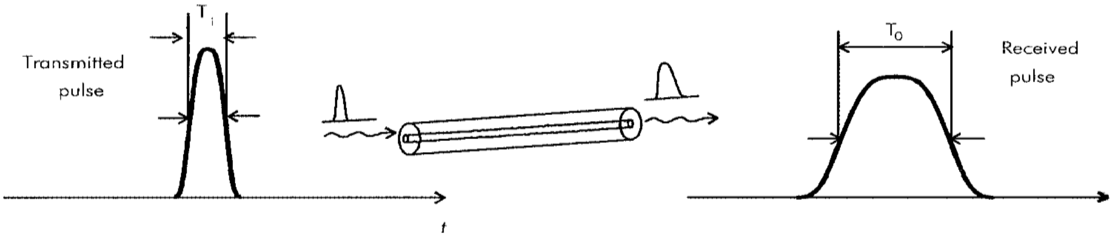

Fig. 1. Temporal dispersion in optical fiber.

The refractive index of any optical material can be interpolated by the Sellmeier formula, which has a physical basis based in the Lorentz oscillator model [17]. So the refractive index of material base fiber link can be expressed as a function of temperature T, operating optical signal wavelength λ and irradiation fluencies of Gamma rays γ as the following formulas [11].

$$n^2(T,\lambda,\gamma)=A(T,\gamma)+\frac{B(T,\gamma)\lambda^2}{\left(\lambda^2-C(T,\gamma)\right)}+\frac{D(T,\gamma)\lambda^2}{\left(\lambda^2-E\right)} \qquad (1)$$

where λ, T, and γ denote the wavelength, temperature, and irradiation fluencies of Gamma rays respectively. The first and second terms represent the contributions to the refractive index due to the higher and lower energy gaps of electronic absorption band, respectively, and the last term accounts for the lattice vibrational absorption. The constant E is not critical since the material stop transmitting long before the onset of the lattice absorption frequency. Usually, it is used the value 100μm^2 [18]. Therefore, equation (1) can be simplified as follows [11].

$$n(T,\lambda,\gamma)=\left[A(T,\gamma)+\frac{B(T,\gamma)\lambda^2}{\left(\lambda^2-C(T,\gamma)\right)}+\frac{D(T,\gamma)\lambda^2}{\left(\lambda^2-E\right)}\right]^{1/2} \qquad (2)$$

where the coefficients A(T,γ), B(T,γ), C(T,γ) and D(T,γ) are temperature and radiation dose functions with the forms

$$A(T,\gamma)=A(\gamma)F_A(T) \qquad (3)$$

$$B(T,\gamma)=B(\gamma)F_B(T) \qquad (4)$$

$$C(T,\gamma)=C(\gamma)F_C(T) \qquad (5)$$

$$D(T,\gamma)=D(\gamma)F_D(T) \qquad (6)$$

However the coefficients A (γ), B (γ), C (γ) and D (γ) are radiation dose functions with the forms

$$A(\gamma)=1.329631+2.7\times10^{-4}\exp\left(\frac{\gamma}{0.319319}\right) \qquad (7)$$

$$B(\gamma)=0.82863+7.7\times10^{-4}\exp\left(\frac{\gamma}{0.440013}\right) \qquad (8)$$

$$C(\gamma)=0.01105+4.7\times10^{-6}\exp\left(\frac{\gamma}{0.391139}\right)\mu m^2 \qquad (9)$$

$$D(\gamma)=0.98481+1.1\times10^{-3}\exp\left(\frac{\gamma}{0.964926}\right) \qquad (10)$$

where γ is the radiation dose in MGy. Although the coefficients F$_A$ (T), F$_B$ (T), F$_C$ (T) and F$_D$ (T) are temperature functions with the forms

$$F_A(T)=\frac{1.338922-3.7\times10^{-4}(T-T_0)}{1.338922} \qquad (11)$$

$$F_B(T)=\frac{0.819526-3.843\times10^{-4}(T-T_0)}{0.819526} \qquad (12)$$

$$F_C(T)=\frac{0.011127-3.1\times10^{-6}(T-T_0)}{0.011127} \qquad (13)$$

$$F_D(T)=\frac{1.055995-2.8\times10^{-3}(T-T_0)}{1.055995} \qquad (14)$$

Where T is the ambient temperature in K, and T$_0$ is the room temperature in K, finally the second order differential equation of the optical fiber core refractive index is given by

$$\frac{d^2n}{d\lambda^2}=-0.25\frac{\left[\frac{2B\lambda}{\lambda^2-C}-\frac{2B\lambda^3}{\left(\lambda^2-C\right)^2}+\frac{2D\lambda}{\lambda^2-E}-\frac{2D\lambda^3}{\left(\lambda^2-E\right)^2}\right]^2}{n^{\frac{3}{2}}}+0.5\frac{\left[\frac{2B}{\lambda^2-C}-\frac{10B\lambda^2}{\left(\lambda^2-C\right)^2}+\frac{8B\lambda^4}{\left(\lambda^2-C\right)^3}+\frac{2D}{\lambda^2-E}-\frac{10D\lambda^2}{\left(\lambda^2-E\right)^2}+\frac{8D\lambda^4}{\left(\lambda^2-E\right)^3}\right]}{n} \qquad (15)$$

In optical fiber communication, the wavelength depends on the velocity of propagation of signals on the bulk material of which the fiber is made. Because every optical signal has a finite spectral width, material dispersion is one of the dispersion parameter, which results in spreading of the signal. In classical optics, dispersion is used to denote the wavelength dependence of refractive index in matter, (dn/dλ), where n is the refractive index and λ is the wavelength caused by interaction between the matter and light [19]. The material dispersion is then defined as [17].

$$D_{md}=\frac{-\lambda}{c}\frac{d^2n}{d\lambda^2} \qquad (16)$$

The waveguide dispersion for a step index single mode optical fiber is given by [18].

$$D_{wd}=-\frac{n-n_2}{c\lambda}\left[V\frac{\partial^2(b.V)}{\partial V^2}\right] \qquad (17)$$

where n_2, c are the cladding refractive index and speed of light in vacuum respectively. The term between square brackets can be computed, through an asymptotic expansion, by [18].

$$V\frac{\partial^2(bV)}{\partial V^2} = 0.080 + 0.5439(2.834 - V)^2 \qquad (18)$$

Where V is the normalized waveguide parameter and is given by [18].

$$V = \frac{2\pi}{\lambda} a\left[n^2 - n_2^2\right]^{\frac{1}{2}} \qquad (19)$$

where a is the core mode field diameter. The cladding refractive index can be obtained via the following relation [18].

$$n_2 = 0.9979\, n \qquad (20)$$

The total dispersion coefficient D_t could be written as [2].

$$D_t = D_{md} + D_{wd} \qquad (21)$$

III. SIMULATION RESULTS AND DISCUSSIONS

We have demonstrated the transmission characteristics changes of optical fiber communication systems in thermal Gamma irradiated environments. We illuminate the effect of those environments on the change of core and clad refractive indices and how this leads to the occurrence of chromatic dispersion. The reference values of the model parameters are shown in Table 1. These values of the calculations are taken from [11], [17-18].

Table 1: Operating parameter's values used in the model were as the following [11, 17, 18]:

Symbol	Operating parameter	Value
γ	radiation dose	0.1-1.5 MGy
T	ambient temperature	280 - 400 K
λ	optical signal wavelength	1000-2000 nm
T_0	room temperature	298 K
a	core mode field diameter	4.361 μm

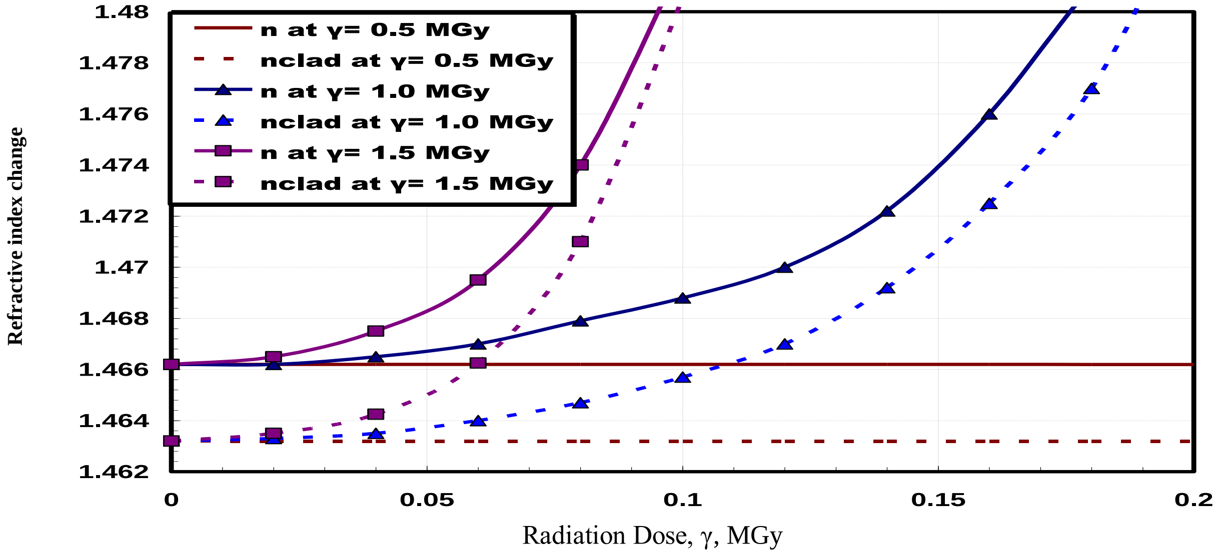

Fig. 2. Variations of the refractive index change against radiation dose with T=310 K, λ=1000 nm, and core mode field diameter (a) = 4. 361 μm.

Figure (2) reveals the relation between the radiation dose (MGy) and the core, clad refractive indices from this figure we note that the core, clad refractive indices is increases with the increasing of the radiation dose without saturating. Moreover there is a convergence between values of the core refractive index and values of the core refractive index as the radiation dose increases this changes in the core, clad refractive indices effects on the total internal reflection of the light in the fiber and as a result the dispersion occurs. The continues change in the core, clad refractive indices leads to a more dispersion until a certain point at which the core, clad refractive indices coincides with each other and this means the optical fiber has been deformed and can not carry any data. From the figure we note that at the environments that have high radiation the optical fiber reaches to the deformation point rapidly than that of lowest radiation. In case (1) the radiation dose is 0.5 MGy, in case (2) the radiation dose is 1.0 MGy, in case (3) the radiation dose is 1.5 MGy, so the optical fiber in case (3) reaches to the deformation point firstly before that in case (2) and case (1).

In germanosilicate fibers the Ge have (1) color center at 281 nm was assumed to be the principal responsible of the radiation-induced absorption in the single-mode fiber at 1300 nm (10 dB/km at 10 kGy), which resulted in an estimated refractive index change for an SMF28 Fiber of about10-4 at 10 kGy. Then, the refractive index growth slows down, without saturating [9].

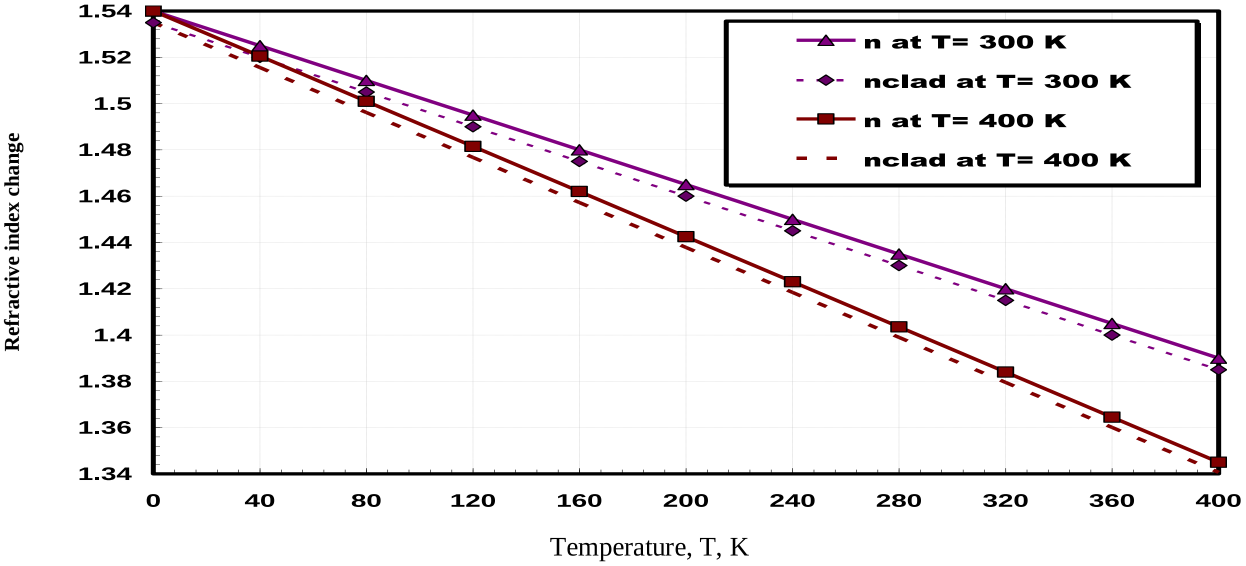

Fig. 3. Variations of the temperature and refractive index change with γ=0.1 MGy, λ=1000 nm, and Core mode field diameter (a) = 4. 361 μm.

Figure (3) depicts the relation between the temperature (K) and the core, clad refractive indices from this figure we note that the core, clad refractive indices are decreases with the increasing of the temperature without saturating. And there is a covariance between values of the core refractive index and the clad refractive index as the temperature increases this changes in the core, clad refractive indices effects on the total internal reflection of the light in the fiber and as a result the dispersion occurs. The continues change in the core, clad refractive indices leads to a more dispersion until a certain a certain point at which the core, clad refractive indices coincides with each other and this means the optical fiber has been deformed and can not carry any data. From the figure we note that at the environments that have high temperature the optical fiber reaches to the deformation point rapidly than that of lowest temperature. In case (1) the temperature is 300 K, In case (2) the temperature is 400 K, so the optical fiber in case (2) reaches to the deformation point firstly before that in case (1). So the temperature induced refractive index variations [18]. And as a result the temperature of the fiber has a high contribution in the performance of the optical systems [18].

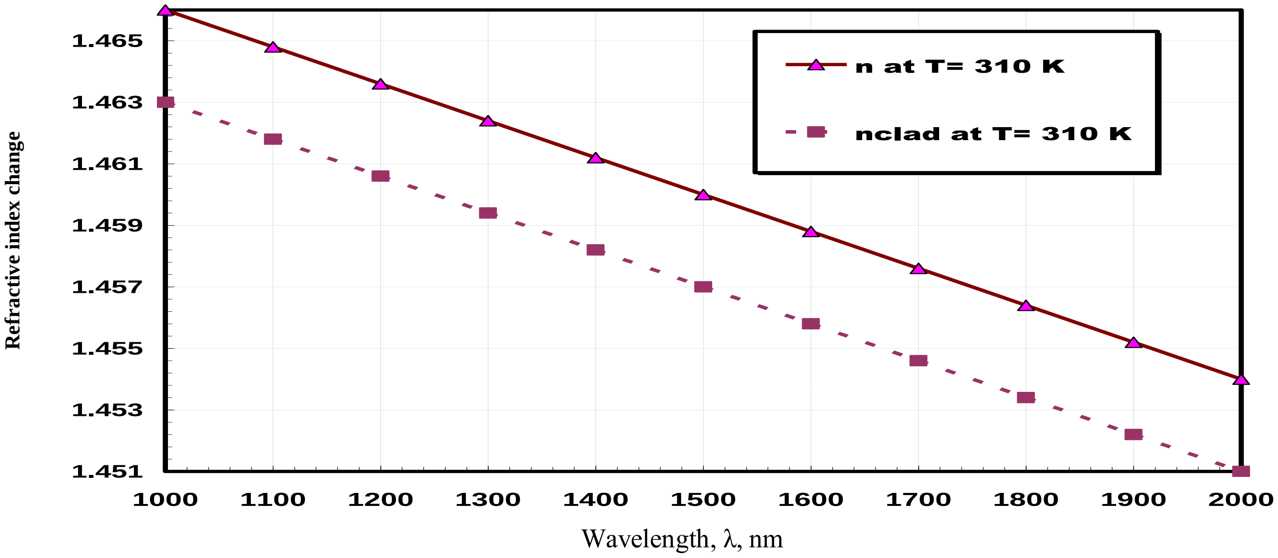

Fig.4. Variations of the chromatic dispersion against wavelength with γ= 0.1 MGy, T=310K, and core mode field diameter (a) = 4. 361 μm.

Figure (4) reveals the relation between the operating wavelength and the core, clad refractive indices from this figure the core, clad refractive indices are increases as the operating wavelength decreases. In optical fiber communication, the wavelength depends on the velocity of propagation of signals on the bulk material of which the fiber is made. Because every optical signal has a finite spectral width, material dispersion is one of the dispersion parameter, which results in spreading of the signal. In classical optics, dispersion is used to denote the wavelength dependence of refractive index in matter, (dn/dλ), where n is the refractive index and λ is the wavelength caused by interaction between the matter and light [19].

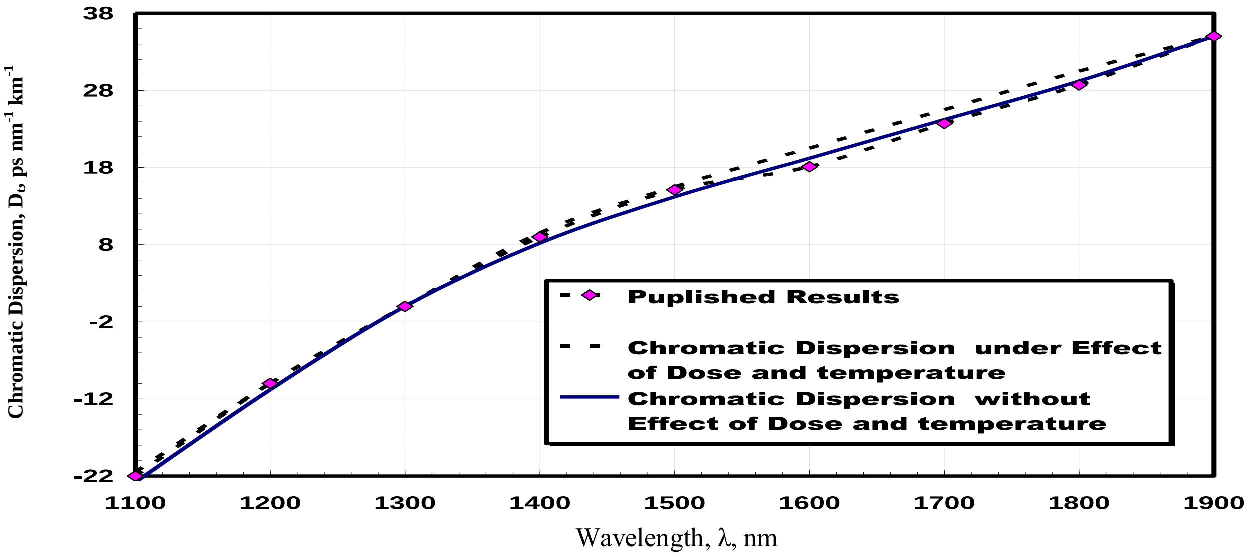

Fig.5. Variations of the chromatic dispersion against wavelength with γ= 0.1 MGy, T=310K, and Core mode field diameter (a) = 4. 361 μm.

In figure(5) the typical computed values for the total chromatic dispersion under the thermal irradiation environment effect, without the thermal irradiation environment effect, and experimental values are represented in the above figure that shows a good agreement between the resulted curve and the published experimental curve.

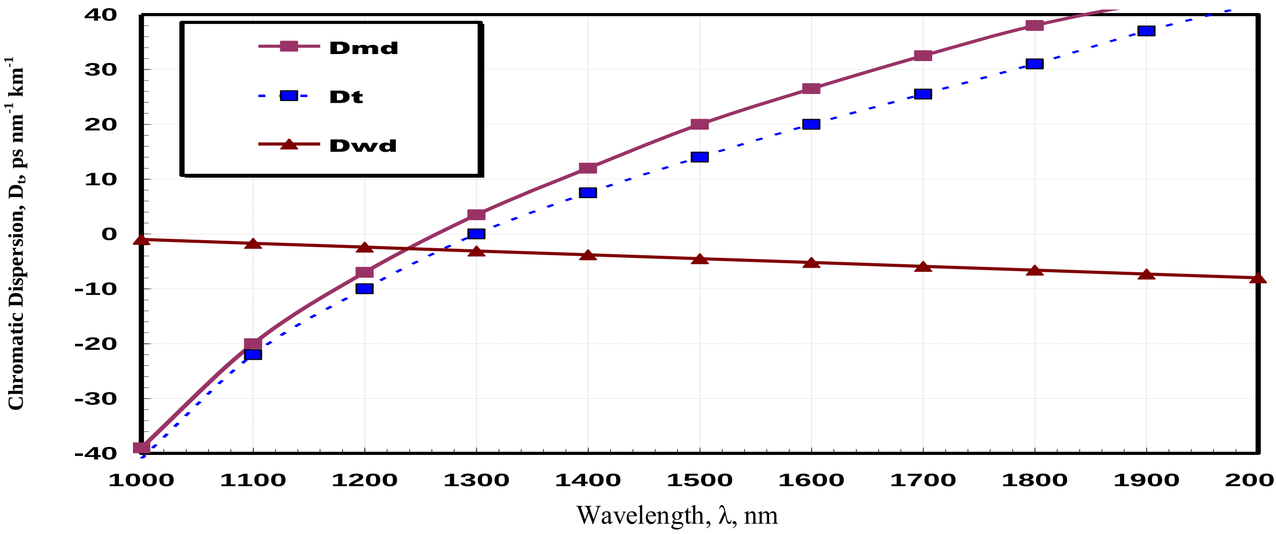

Fig. 6. Variations of the chromatic dispersion against wavelength with γ= 0.1 MGy, T=310K, and core mode field diameter (a) = 4. 361 μm.

Figure (6) shows D_{md}, D_{wd}, and their sum $D_t = D_{md} + D_{wd}$, for the optical fiber. The above figure reveals that D_{wd} is negative in all wavelength range. On the other hand, D_{md} is negative for wavelengths below λ_{ZD} and becomes positive above that. The main effect of waveguide dispersion is to shift λ_{ZD} the zero-dispersion wavelength, in which ($D_{md} = 0$ at $\lambda = \lambda_{ZD}$) near the operating wavelength. The dispersion parameter D_{md} is negative below λ_{ZD} and becomes positive above that. So that the total dispersion is zero near 1310 nm. It also reduces D_t from its material value D_{md} in the all wavelength range 1300–1600 nm that is of interest for optical communication systems.

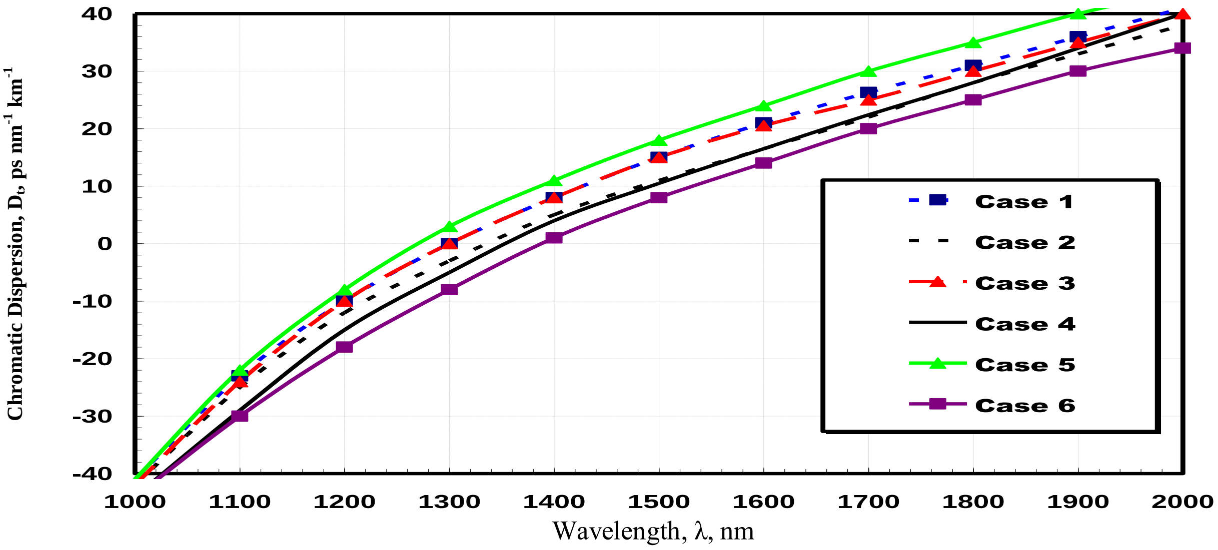

Fig.7. Variations of the chromatic dispersion against wavelength with different cases of γ (MGy), T (K), and Core mode field diameter (μm).

Table 2: Operating parameter's values used to determine minimum dispersion conditions as a function of radiation dose, temperature and fiber core diameter are as follows:

Case number	Operating parameter value		
	Radiation dose (MGy)	Temperature(K)	Fiber core diameter(μm)
1	0.2	310	4.361
2	1.0	340	4.361
3	1.0	340	5.361
4	1.0	310	3.361
5	1.0	310	5.361
6	0.2	340	3.361

Figure (7) reveals the relation between the total chromatic dispersion and the operating wavelength as a function of radiation dose and the temperature the resulted curves represented different cases that are considered to demonstrate the minimum dispersion condition in order to improve the maximum transmission bandwidth and performance of the optical fiber link. This figure is divided into two regions: (1) Firstly in the short operating wavelength region (1000-1650 nm) the lowest dispersion is observed at low radiation dose and low temperature and the dispersion is increases if the radiation dose and or the temperature increases at fixed core diameter .For a fixed radiation dose and the temperature the lowest dispersion is observed at the lower core diameter, since the higher core diameter indicate that the higher NA which indicate more modes we have this means that rays bounce at greater angles and therefore there are more of them. This means that the larger core diameter the greater will be the dispersion of this fiber, (2) secondly in the high operating wavelength region (1650-2000 nm) for the case of fixed high radiation dose and temperature it is observed that the lowest dispersion case is obtained with the larger core diameter.

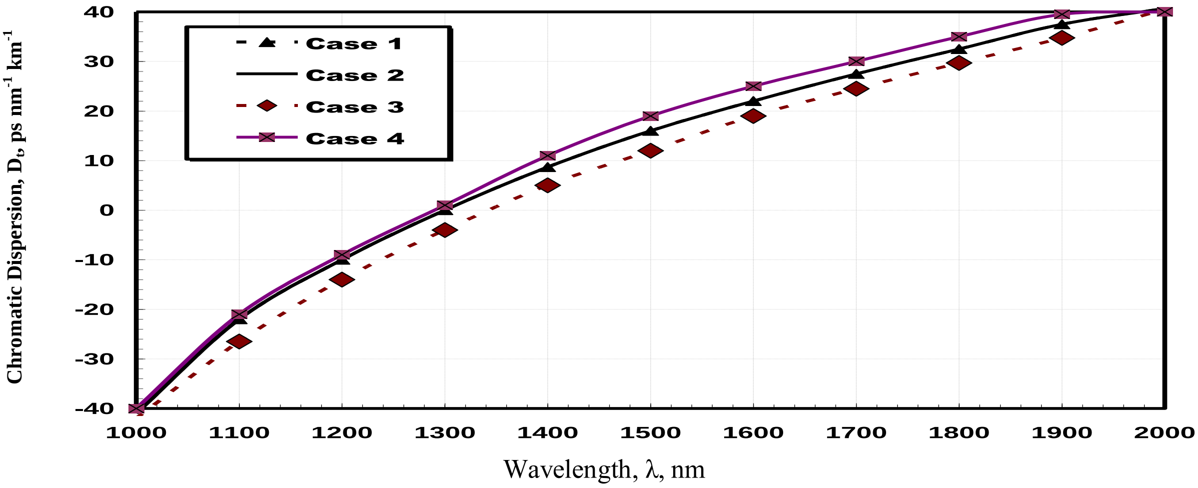

Fig.8. Variations of the chromatic dispersion against wavelength with different cases of γ (MGy), and core mode field diameter (μm), at T = T_0 (K).

Table 3: The operating parameter's values used to determine minimum dispersion condition as a function of radiation dose and fiber core diameter are as follows:

Case number	Operating parameter value		
	Radiation dose (MGy)	Temperature (K)	Fiber core diameter(μm)
1	0.2	298	4.361
2	1	298	4.361
3	0.2	298	3.361
4	1	298	5.361

Figure (8) reveals the relation between the total chromatic dispersion and the operating wavelength as a function of radiation dose only. In this figure there are two cases: (1) First case at which the radiation dose is small the lowest dispersion is observed at larger core diameter. (2) Second case at which the radiation dose is high the lowest dispersion is observed at lower core diameter. In general the lowest dispersion is observed at the low radiation dose with large core diameter. Low radiation dose means that there is no much change in the refractive index and so the dispersion will have small effective value, and when we uses an optical fiber with large core diameter this indicate much data can be transmitted . But in case of high radiation dose this will leads to a significant refractive index change and with the use of higher core diameter optical fiber which means that the higher NA which indicate more modes we have this means that rays bounce at greater angles and therefore there are more of them. This means that the larger core diameter the greater will be the dispersion in this fiber.

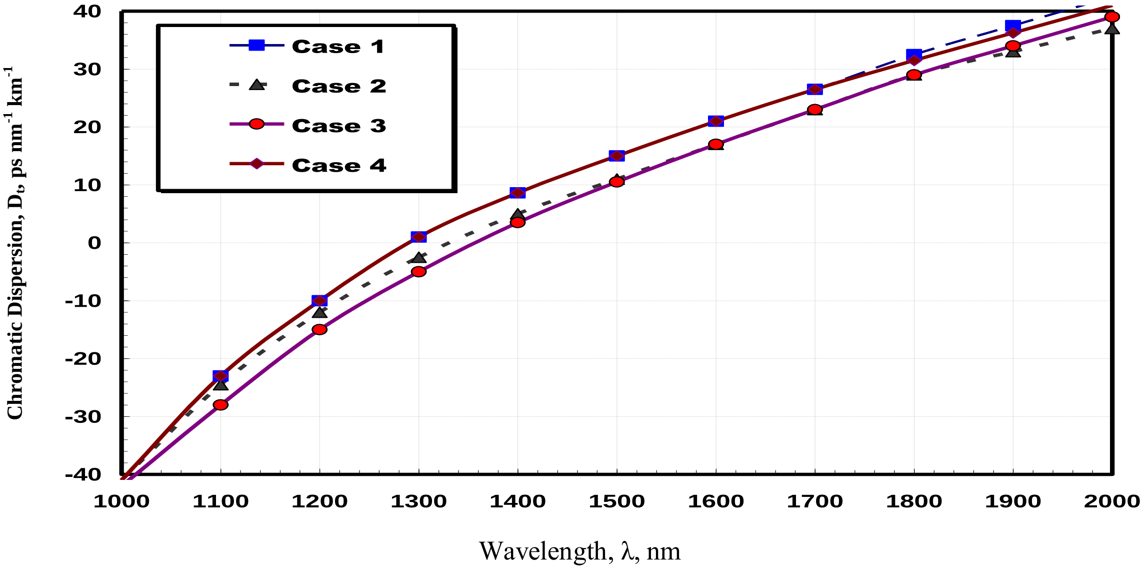

Fig.9. Variations of the chromatic dispersion against wavelength with different cases of T (K), and core mode field diameter (μm), at $\gamma = 0$ (MGy).

Table 4: Operating parameter's values used to determine minimum dispersion conditions are as follows:

Case number	Operating parameter value		
	Radiation dose (MGy)	Temperature (K)	Fiber core diameter(μm)
1	0.0	310	4.361
2	0.0	340	4.361
3	0.0	310	3.361
4	0.0	340	5.361

Figure (9) reveals the relation between the total chromatic dispersion and the operating wavelength as a function the temperature. This figure is divided into two regions: (1) First in the short operating wavelength region (1000-1650 nm) the lowest dispersion is observed at low temperature and the dispersion is increases with the temperature increasing at fixed core diameter. For a fixed low temperature the lowest dispersion is observed at the larger core diameter and for affixed high temperature the lowest dispersion is observed at the lower core diameter, (2) second in the high operating wavelength region (1650-2000 nm). It is observed that the lowest dispersion case is obtained with the optical fiber that has lower core diameter at higher temperature. In general the lowest dispersion is observed at the low temperature with large core diameter. Low temperature means that there is no much change in the refractive index and so the dispersion will have small effective value, and when we uses an optical fiber with large core diameter this indicate much data can be transmitted . However in case of high temperature this will leads to a significant refractive index change and with the use of higher core diameter optical fiber which means that the higher NA which indicate more modes we have this means that rays bounce at greater angles and therefore there are more of them. This means that the larger core diameter the greater will be the dispersion in this fiber.

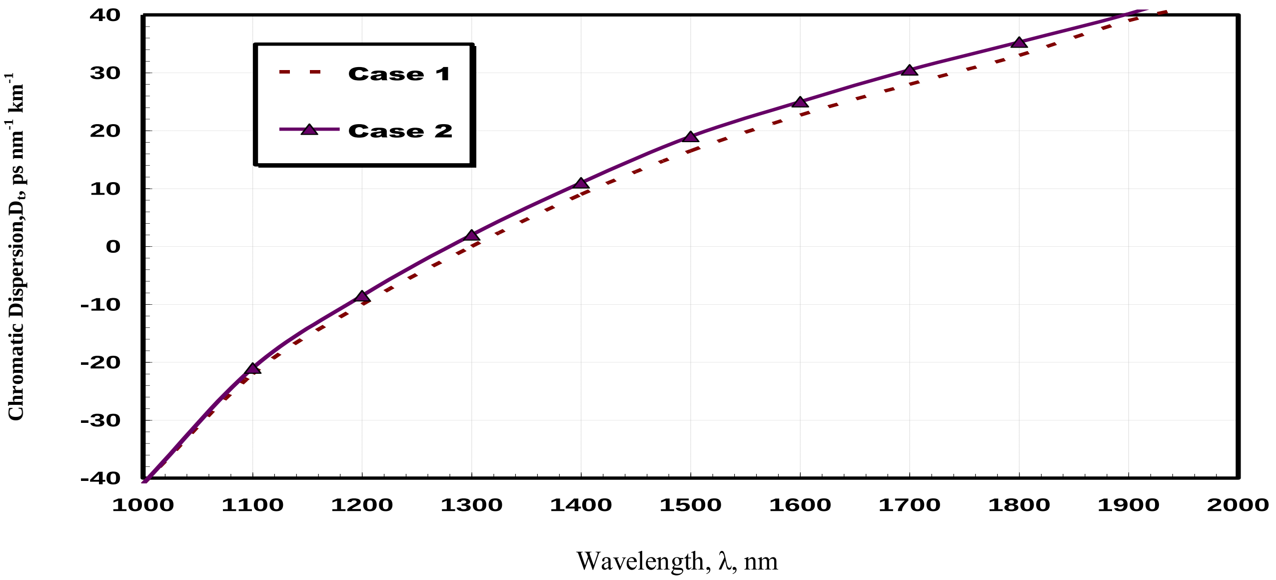

Fig.10. Variations of the chromatic dispersion against wavelength with different cases of core mode field diameter (μm), at γ = 0 (MGy), T = T_0 (K).

Table 5: Operating parameter's values used to determine minimum dispersion condition as a function of fiber core diameter are as follows:

Case number	Operating parameter value		
	Radiation dose (MGy)	Temperature (K)	Fiber core diameter(μm)
1	0.0	298	4.361
2	0.0	298	5.361

Figure (10) reveals the relation between the total chromatic dispersion and the operating wavelength without the effect of the radiation dose and the temperature. From the figure the lowest dispersion is observed at the optical fiber that has lower core diameter.

IV. CONCLUSION

In this paper a block diagram model treating the radiation and temperature effects on the characteristics of the optical fibers is proposed to provide a mean to control the optical properties of fibers in radiation environments. The radiation dose and the temperature dependence of chromatic dispersion for the optical fibers were studied by using VisSim environment. The effect of refractive index change under radiation dose and temperature on the dispersion that shows a high contribution in the performance of the optical fiber links is demonstrated. The dependence of waveguide dispersion on fiber structure parameters such as the core radius is discussed. We verify that the waveguide dispersion term has a high contribution for the total chromatic dispersion variation, and cannot be ignored. The waveguide dispersion is used to shift the zero dispersion wavelength (λ_{ZD}) so that the total dispersion is zero near 1310 nm. We conclude that small core diameter in wavelength rang from 1000-1650 nm achieves the lowest dispersion at high radiation dose and temperature because small core diameter increase the negative waveguide dispersion so that the total dispersion is reduced. Different cases are considered for both radiation dose and temperature to obtain minimum dispersion in order to improve maximum transmission bandwidth and performance when optical fibers are selected for use in a radiation field. The results are validated against the published experimental work and good agreement is observed.

REFERENCES

[1] H. Mrabet, I. Dayoub, R. Attia, and W. Hamouda, "Wavelength and beam launching effects on silica optical fiber in local area networks", Optics Communications, Vol. 283, pp. 4234–4241, 2010.

[2] R. Guobin, W. Zhi, L. Shuqin, and J. Shuisheng, "Analysis of dispersion properties of high-index-core Bragg fiber", Optical Fiber Technology, Vol. 11, pp. 81–91, 2005.

[3] F. El-Diasty, H. A. El-Hennawi, and M. A. Soliman, "Chromatic and opto-mechanical dispersion of some characteristic parameters of optical fiber undergoing macrobending", Optics Communications, Vol. 267, pp. 394–401, 2006.

[4] A. Honda , K. Toh, S. Nagata, B. Tsuchiya, and T. Shikama, "Effect of temperature and irradiation on fused silica optical fiber for temperature measurement", Journal of Nuclear Materials, Vol. 367, pp. 1117–1121, 2007.

[5] D. Sporea, A. Sporea, and C. Oproiu, "Effects of hydrogen loading on optical attenuation of gamma-irradiated UV fibers ", Journal of Nuclear Materials, Vol.423, pp. 142–148, 2012.

[6] A. Kalavagunta, R. Schrimpf, and M. Neifeld, "Design considerations for optical systems in ionizing and nonionizing radiation environments", IEEE Transactions on Nuclear Science, Vol. 51, pp. 3595–3602, 2004.

[7] A. Abu EL-Fadl, A. S. Soltan, and A. A. Abu–Sehly, " Effect of gamma doses on the optical parameters of Se76Te15Sb9 thin films", Journal of Physics and Chemistry of Solids, Vol. 68, pp. 1415–1421, 2007.

[8] J. Zubia, and J. Arrue, "Plastic optical fibers: An introduction to their technological processes and applications", Optical Fiber Technology, Vol.7, pp. 101–140, 2001.

[9] A. F. Fernandez, B. Brichard, and F. Berghmans, "In situ measurement of refractive index changes induced by gamma radiation in germanosilicate fibers", IEEE Photonics Technology Letters, Vol. 15, pp. 1428–1430, 2003.

[10] J. Lee, "A modified fiber dispersion model using continuous β2 over wavelength for numerical simulation of Optical pulse propagation through dispersive nonlinear fibers in WDM systems", Optical Fiber Technology, Vol. 11, pp. 46–55, 2005.

[11] A. N. Z. Rashed, "Harmful effects of gamma irradiation on optical Fiber communication system links under thermal environment effects", International Journal on Electronics and Communication Technology, Vol. 3, pp. 71–75, 2012.

[12] H. Chi, and J. Yao, "Fiber chromatic dispersion measurement based on wavelength–to–time mapping using a femtosecond pulse laser and an optical comb filter", Optics Communications, Vol. 280, pp. 337–342, 2007.

[13] Z. Liu, X. Liu, S. Li, G. Zhou, W. Wang, and L. Hou, "A broadband ultra flattened chromatic dispersion microstructured fiber for optical communications", Optics Communications, Vol. 272, pp. 92–96, 2007.

[14] M. Zhou, and J. Ma, "The influence of fiber dispersion on the transmission performance of a quadruple-frequency optical millimeter wave with two signal modulation formats", Optical Switching and Networking, Vol. 9, pp. 343–350, 2012.

[15] O.V. Butov, K. M. Golant, A. L. Tomashuk, M. J. N. V. Stralen, and A. H. E. Breuls, "Refractive index dispersion of doped silica for fiber optics", Optics Communications, Vol. 213, pp. 301–308, 2002.

[16] P. Hlubina, T. Martynkien, and W. Urbanczyk, "Measurements of birefringence dispersion and intermodal dispersion in a two-mode elliptical-core optical fibre using an interferometric method", International Journal for Light and Electron Optics, Vol. 115, pp. 109–114, 2004.

[17] X. Feng, F. Poletti, A. Camerlingo, F. Parmigiani, P. Petropoulos, P. Horak, G. M. Ponzo, M. Petrovich, J. Shi, W. H. Loh, and D. J. Richardson, "Dispersion controlled highly nonlinear fibers for all optical processing at telecoms wavelengths", Optical Fiber Technology, Vol. 16, pp. 378–391, 2010.

[18] P. S. Andre, A. N. Pinto, and J. L. Pinto, "Effect of temperature on the single mode fibers chromatic dispersion", IEEE, Vol. 5, pp. 231–234, 2003.

[19] A. A. Hamza, A. E. Belal, T. Z. N. Sokkar, H. M. EL-Dessouky, and M. A. Agour, "Interferometric studies on the influence of temperature on the optical and dispersion parameters of GRIN optical fibre", Optics and Lasers in Engineering, Vol. 45, pp. 145–152, 2007.

Author's Profile

Dr. Ahmed Nabih Zaki Rashed was born in Menouf city, Menoufia State, Egypt country in 23 July, 1976. Received the B.Sc., M.Sc., and Ph.D. scientific degrees in the Electronics and Electrical Communications Engineering Department from Faculty of Electronic Engineering, Menoufia University in 1999, 2005, and 2010 respectively. Currently, his job carrier is a scientific lecturer in Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia university, Menouf. Postal Menouf city code: 32951, EGYPT. His scientific master science thesis has focused on polymer fibers in optical access communication systems. Moreover his scientific Ph. D. thesis has focused on recent applications in linear or nonlinear passive or active in optical networks. His interesting research mainly focuses on transmission capacity, a data rate product and long transmission distances of passive and active optical communication networks, wireless communication, radio over fiber communication systems, and optical network security and management. He has published many high scientific research papers in high quality and technical international journals in the field of advanced communication systems, optoelectronic devices, and passive optical access communication networks. His areas of interest and experience in optical communication systems, advanced optical communication networks, wireless optical access networks, analog communication systems, optical filters and Sensors. As well as he is editorial board member in high academic scientific International research Journals. Moreover he is a reviewer member in high impact scientific research international journals in the field of electronics, electrical communication systems, optoelectronics, information technology and advanced optical communication systems and networks. His personal electronic mail ID (E-mail:ahmed_733@yahoo.com). His published paper under the title **"High reliability optical interconnections for short range applications in high performance optical communication systems"** in Optics and Laser Technology, Elsevier Publisher has achieved most popular download articles in 2013.