Estimate the Attenuation and Simulation of dispersion Gaussian pulses propagation in a Single Mode Optical Fiber

Mubarak Hamad Oglah
Dept. of controlling petroleum systems , College of Petroleum & Minerals Engineering , Tikrit University , Iraq
E-Mail: Aukla_mubarak74@yahoo.com

Abstract

we studied Attenuation in Fiber Optics, we used two type of Fibers (Plastic and glass) with length (0.5,5,20m) and (1,20,100m) respectively and used two wavelength laser (660nm, 850nm), we found attenuation increase with 850nm wavelength and 660nm wavelength are the best for the plastic fiber optics, in addition the attenuation which occur from axial gap, axes rotation, inclination angle, transversal displacement are investigated. Influence three values of linear dispersion on Pulse propagation along fiber at seam distance is investigated by simulation using Fourier Method using MATLAB.

Keywords: Single Mode Optical Fiber, Attenuation and Dispersion Simulation.

Introduction and review

As discussed by [1][2] There are many reasons causing attenuation in the fiber optics like absorption, dispersion, scattering, core and cladding, bending, splicing and connectors, as well as can be affected by temperature [3]. There are three sources majority of light used in fiber optics emits light at one of different wavelengths: 850nm, 1310nm and 1550nm , these wavelengths are attracted because they offer the least amount of attenuation in the glass fiber.

The attenuation for 850nm wavelength for long distance around 3dB/km but, for 1310 nm wavelength is given by 0.35dB/km while 1550 nm wavelength is 0.23dB/km [4] [5].

There are many theoretical and experimental studies on the subject of the attenuation in the fiber optics, where, K.A. Lathief discussed how measure the attenuation using Optical Time Domain Reflectometer he found the attenuation limit achieved is 0.43dB/ Km for both 1310 nm signal & for 1550 nm [6].

Sabah Hawar Saeid Al-Bazzaz presents a simulation, using VC++, for testing outputs of some of optical communication components like amplifiers, used in single mode optical fiber systems for compensating the attenuation and dispersion caused by the long distance, he found that The results indicate that these effects increase with increasing the distance through the fiber optic length [7].

M. Grabka et al were investigated the suspended--core microstructured optical fiber. The fiber exhibits a very high numerical aperture which originates from high refractive-index contrast built-in into the fiber structure. they found experimentally demonstrated that light-coupling efficiency and mode distribution strongly depend on relative position of the fiber's core and a light beam and light polarization.[8]

M. F. M. Salleh & Z. Zakaria studied and examine the reliability of Optical Ground Wire as long distance telecommunication backbone and to discuss the possible factors that contribute to the findings. they found the relationship between bend loss and optical power attenuation on long distance optical fibre and reliability [9].

A. Zendehnam and et al study used different radii of curvature and also up to 40 wrapping turns have been employed, to investigate their effects on bending loss. And also wrapping turns has been suggested, which shows good agreement with the experimental results. they found Influence of torsion stress on core and clad structure. [10]

In this study, we will focus on the attenuation in the single mode optical fiber such as dispersion, splicing and connectors experimentally, as well as the effect of the attenuation coefficient on the pulse amplitude transmitted through the optical fiber using MATLAB simulation at same conditions.

The simulation will examine the reliability a long distance telecommunication and amplitude of the signal pulse.

Theory

Attenuation

Attenuation is natural phenomenon in the optical fiber manufacturing, which is defined as a logarithm relationship between the optical input power and the optical output power in a fiber optical system [11,12] which measure of the signal decay, or losses in the power of ligth, that occurs as propagate pulses through the fiber length. This decay can be written as:

$$I(x) = I(0)e^{\frac{-\alpha x}{10}} \dots\dots (1)$$

Where (x) represent length in kilometers, and the attenuation coefficient(α) is given in decibels per kilometer (dB/km). Because the designers of the fiber optic systems need to know how much light will remain in a fiber after propagating a given distance, one of the most important specifications of an optical fiber is the fiber's attenuation. In particular, the fiber attenuation is the easiest of all fiber measurements to make. All that is required is to launch power from a source into a long length of fiber, measure the power at the far end of the fiber using a detector with a linear response, and then, after cutting off a length of the fiber, measure the power transmitted by the shorter length. The reason for leaving the short length of the fiber at the input end of the system is to make sure that the loss that is measured is due solely to the loss of the fiber Fig. 1 shows a schematic illustration of the measurement system.

The transmission through the fiber is written as :

$T = \frac{P_0}{P_i} \ldots\ldots (2)$

where we can substituted Pi (power incident) and Po (power output) for I(0) and I(x), respectively A logarithmic result for the loss in unit decibels (dB), is given by:

$$X(dB) = -10Log\left(\frac{P_0}{P_i}\right) \ldots\ldots (3)$$

The attenuation coefficient, α, in dB/km is found by dividing the loss, x , by the length of the fiber, x. The attenuation coefficient is then given by:

$$\frac{\alpha dB}{Km} = \left(\frac{1}{x}\right)\left[-10Log\left(\frac{P_0}{P_i}\right)\right] \ldots\ldots (4)$$

The total attenuation for all losses in fiber optics can then be found by multiplying the attenuation coefficient α by the fiber length, giving a logarithmic result, in decibels (dB), for the fiber loss.

Fiber-material properties with fiber structure influence All mechanism of losses. However, losses are presents at fiber connections. As continue propagation of attenuation increases Ultimately, the propagating signal are attenuated until to it is at some minimal could be detectable. So that, the signal is attenuated until to it can just sensed by the receiver in the presence of whatever interference are expected[13].

The fiber optics have to be able to deliver at least the minimal detectable of output signal to the receiver. So , assume the signal has been attenuated to the minimal detectable signal yet, it have still not arrived to the receiver.

The output signal in this location can then be regenerated again. The signal could be boosted back up to its original energy by using optical amplifiers. It could be repeated and then continue to diffusion on its way to the receiver[14].

Splicing / connection & Inclination losses

There is also an unsure due to the fact that the measured loss will depend on the characteristics of the way in which light is injected into the fiber. Like distance between source and fiber face and the coupling axis.

assembly and Interconnection between fibers is a necessary requirement to the signal networks. with via demountable, physical coupling or by irreversible splicing techniques (fusion splicing) alignment of the fiber cores is critical to minimize losses associated with the connection [15].

The light emerging from the other end of the fiber is projected on a face of another fiber, For short distance, the dispersion does not play too much role and the resolution is independent of the distance. However, for longer lengths, the resolution worsens as a function of distance.

In general context, connections successful shall minimize side offset of the core centers,tilt, angular misalignment, and longitudinal displace this means a create a gap. Also It is possible that coupling the fibers to be joined have a different of core dimensions and varied in the core-clad diameter ratios as well as different of core and cladding glass compositions. Figures (1) and (2) are indicate of the types of alignment, lateral offset and tilt, respectively.

This alignment errors could have a significant effects on the fiber coupling efficiency in the optical fiber cable.

When a fiber is overfilled, many high-order and radiation modes are launched. These modes are more highly attenuated than are low-order modes. When a fiber is under filled, mostly low-order modes are launched and lower losses occur.

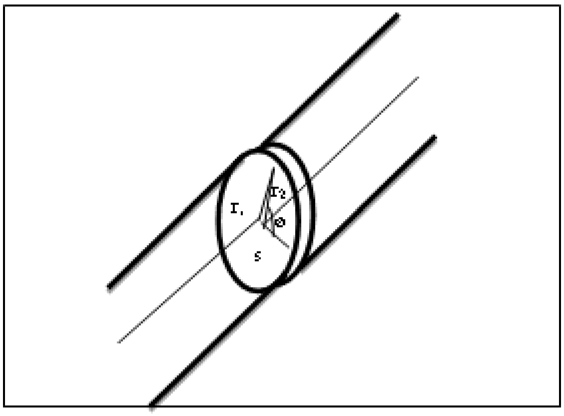

Figure (1): Attenuation introduced by axial gap or Lateral offset of spliced fibers and transversal displacement of fiber axes

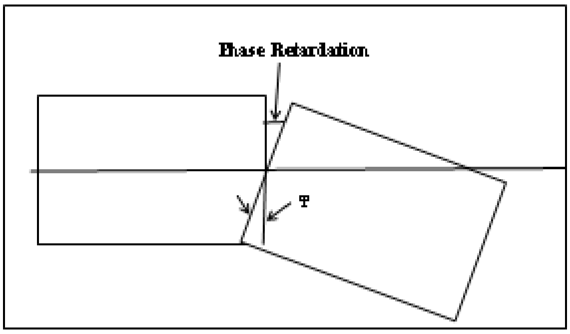

Figure (2) : Attenuation introduced by axes rotation or Tilt angle of two spliced fibers

Experimental Method

A basic system of fiber optic consists of three blocks, shown in figure (3), one of them is a transmitting device that converts an electrical signal into a light signal. We used two type of single mode optical fiber (plastic and glass), core 125μm, with different lengths (0.5,5,20m) and (1,20,100m) respectively.

Transmitters, we used laser (660 nm) wavelength and (850 nm) wavelength the controller unit is set to operate the diode laser in the Continue Mode (CM). To avoid nonlinear , photodiode work area must be known before launch the sine wave within the optical fiber.

Block diagrams which is used to study Attenuation by axial gap size, transversal displacement and inclination angle are shown in figures (4)(5)(6) respectively.

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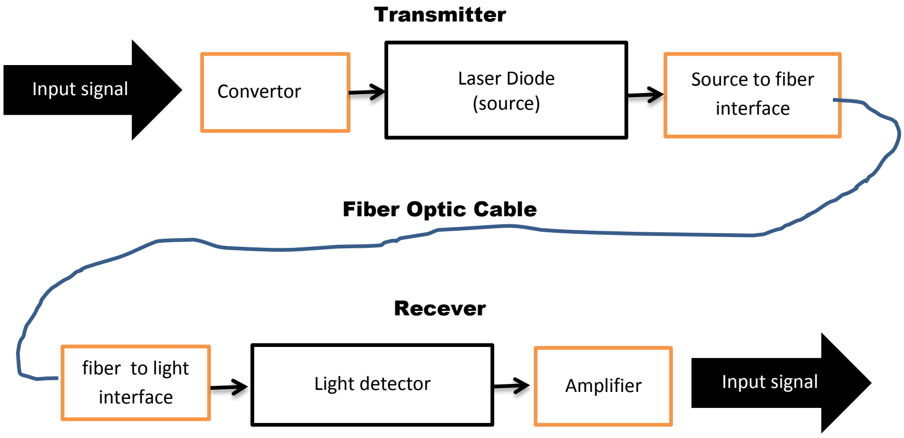

Figure (3) : Schematic of laboratory set-up to determining fiber attenuation

Attenuation dependence on axial gap size :

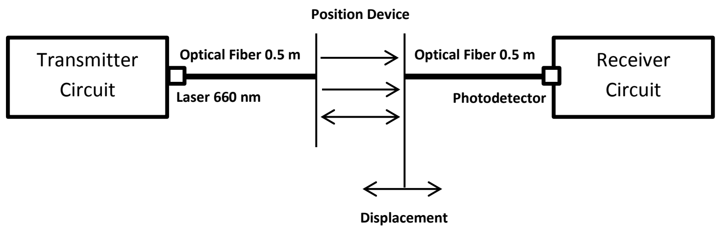

Figure (4) : Block diagram the Measurement of attenuation dependence on axial gap size

Attenuation introduced by transversal displacement :

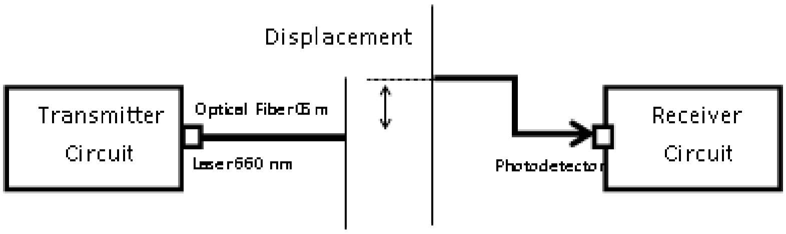

Figure (5) : Block diagram for attenuation measurement introduced by transversal displacement.

Attenuation by inclination angle:

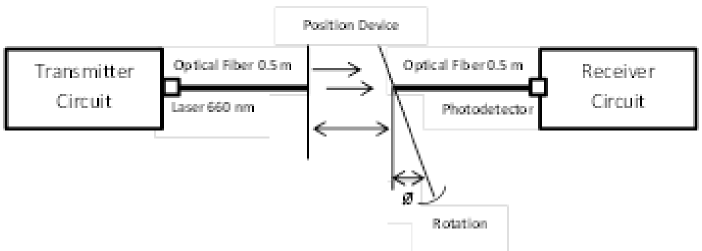

Figure (6) : Block diagram for Measurement of attenuation dependence on angle deviation and measurement of numerical aperture

Gaussian Pulse & Simulation

For more explain, we used numerical simulation for the equation of Gaussian pulse propagation in the fiber for a same distance which used in the experimental setup with unchirping, then we just want to explain the shape of the pulse under three values of dispersion along the distance.

In our work the simulation is the single mode optical fiber of computer model a link system, includes dispersion, attenuation, and propagation function.

In the following of the attenuation and dispersion effective equations [16], are used in the simulation.
we have described the evolution of the pulse in space (z) and time (T or t) using the temporal field envelope [17]:

$$A(z,t) = \sqrt{P_0}U(z,t) \dots\dots\dots (1)$$

$$\frac{\partial A}{\partial z} = -\frac{i}{2}\beta_2 \frac{\partial^2 A}{\partial T^2} \quad \dots\dots.. (2)$$

For the linear pulse using Fourier methods, we put equation (2) in operator :

$$\grave{D} = -\frac{i}{2}\beta_2 \frac{\partial^2}{\partial T^2} \dots.. (3)$$

Where D is a differential operator responsible for the dispersion of a linear medium.
So that we obtain :

$$A(z,T) = \grave{D}A(0,T) \dots\dots (4)$$

Where A(z,T) is the out put pulse.
By mathematical treatment for the above equations with assume that slowly varying of the field in equation (1).
We find :

$$U(T,0) = \exp(-\frac{(1+iC)}{2}(\frac{T}{T_0})^2) \dots\dots(5)$$

$$\frac{T_1(z)}{T_0} = \left[\left(1 + \frac{Cz\beta_2}{T_0^2}\right)^2 + \left(\frac{z}{L_D}\right)^2\right]^{\frac{1}{2}} \dots..(6)$$

Equation (6) gives brouden coefficient of the pulse [18] [19].
Where T_0 is in ps, and β2 is in ps^2/m, and. The code as written is specifically for propagation of a Gaussian pulse of pulse width T_0 and chirp parameter C and length z in km, LD is dispersion length .
where t_0 is the pulse of full the width at half maximum (FWHM), The input pulse is the Gaussian pulse as [20]:

$$A(t) = exp\left(-\frac{1}{2}(\frac{t}{t_0})^2\right) \dots\dots.(7)$$

Results and discussion

From the results obtained through the experiments in table (1) , different are observed between attenuation of 660nm and 850nm wavelength. The difference are shown in Figure (7)(8). There is only 4.3 dB increase of attenuation encountered by power of 660nm wavelength while power of 850nm wavelength has attenuated by 30 dB in the same distance. This indicates that, 850nm wavelength has been affected more by the losses that contribute to this problem[2,9].
In table (2) we obtained only 1.08dB increase of attenuation encountered by power of 850nm wavelength for 0.1Km distance but using glass optical fiber as shows in figure (9) which explain increase in the output signal in the case optical fiber glass used for all wavelengths and least when used a multi-source lengths wave.
The output decreases continuously, while the distance increase between the optical fiber edges and optical source at the injection light, for all the longest[12] [21].
In the figures (10)(11)(12) we note too decreasing the output value strongly in the case of a deformation of the coupling points the fibers (Splicing and connectors), this is mean increase the attenuation[15].
It is clearly from the comparison between all results which explain that the attenuation of dispersion and the nonlinearly effects proportional increase when the distance of communication during the optical fiber is increase. This results are Illustrated in the figures (13)(14) which are shows the output signal when using a wavelength of 660 nm at lengths (0.5, 5m), in the same context, the figures (15)(16) shows the output when using a wavelength of 850nm at the lengths (0.5, 5m).
In our simulation, the Gaussian pulse has considered as input signal to be launched through the fiber and studies the effect that change its amplitude due to coefficient of attenuation. the output taken at a distance (0,08km) and studied by simulation (MATLAB). The effect of attenuation in the same distance (0.08Km) with unchirped C=0, and three values of dispersion (0,10,25 Ps2/Km) coefficient is shown in Figure (17).
We observe a large decrease in the amount of pulse amplitude at increasing the amount of optical attenuation coefficient[7][18].

Table (1)

VA , PE are the external voltage and the power output from the end of the fiber and the attenuation coefficient.						
Table (1)	**Fiber Optics Type (Plastic) , Laser wavelength (850nm) , vi=(10mv), if=22mA**			**Fiber Optics Type (Plastic) , laser wavelength (660nm) , vi=(10mv), if=22mA**		
Length (m)	**VA(v)**	**PE/dBm**	**a/dB**	**VA(v)**	**PE/dBm**	**a/dB**
0.5	10.6	-13.7	0	10	-13.56	0
5	0.83	-24.6	10.809	6.88	-15.24	1.624
20	0.01	-47.8	30	3.65	-18.54	4.377

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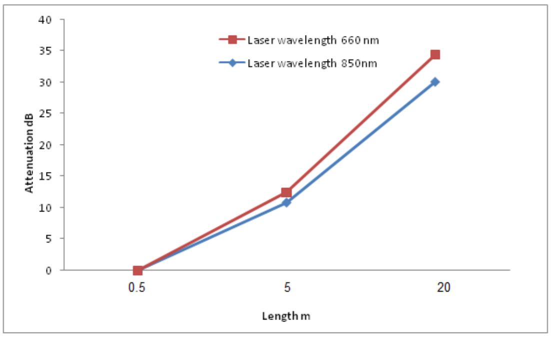

Figure (7): attenuation versus fiber Length at 660nm and 850nm wavelength

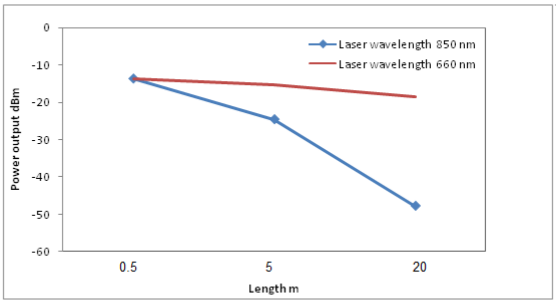

Figure (8): Power output versus fiber Length at 660nm and 850nm wavelength

Table (2)

Fiber Optics Type (class) , laser wavelength (850nm) , vi=(10mv), if=22mA			
Length (m)	**VA(v)**	**PE/dBm**	**a/dB**
1	5.1	-17.69	0
20	4.64	-17.79	0.41
100	3.97	-17.9	1.08779

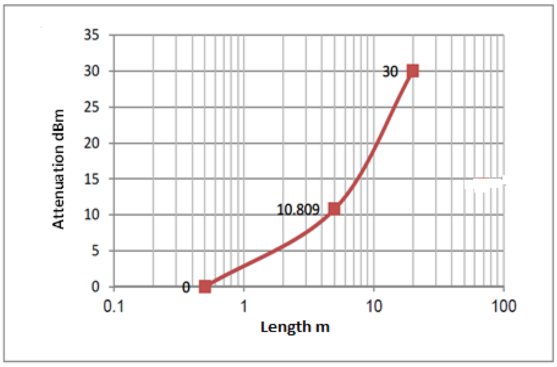

Figure (9): Semi-log chart of Attenuation versus fiber Length at 850nm wavelength

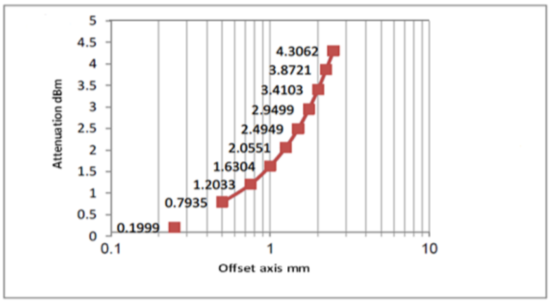

Figure (10): Semi-log chart of Attenuation versus distance between end two faces of fibers at 660nm wavelength

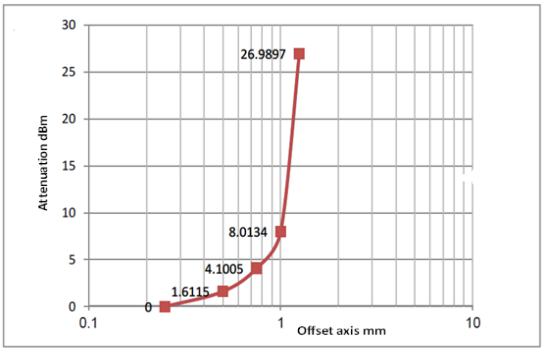

Figure (11): Semi-log chart of Attenuation versus axis offset between end two faces of fibers at 660nm wavelength.

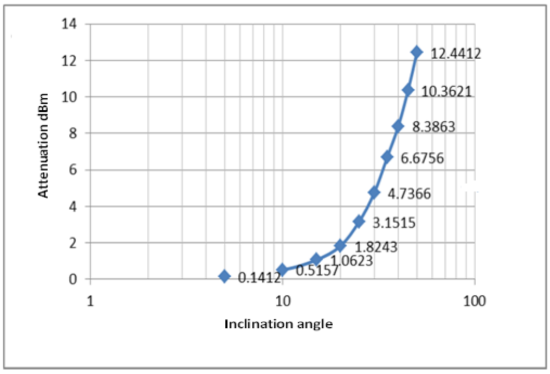

Figure (12): Semi-log chart of Attenuation versus inclination angle between end two faces of fibers at 660nm wavelength.

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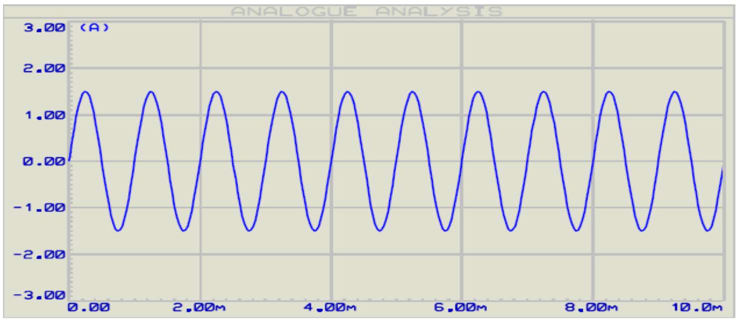

Figure (13): Attenuation in analog sine wave 660nm wavelength & fiber (plastic) where v_0=3v , T=10Sec , v (offset)=0.8v , V (gain)=0.22v and length = 0.5m.

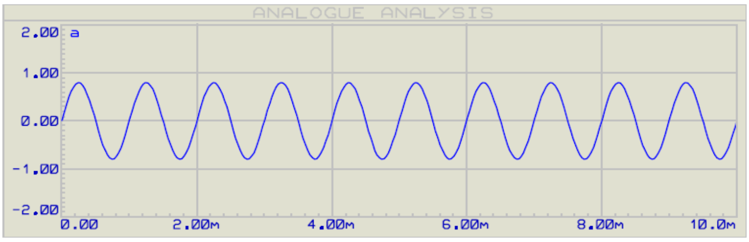

Figure (14): Attenuation in analog sine wave 660nm wavelength & fiber (plastic) where v_0=3v , T=10Sec , v (offset)=0.8v , V (gain)=0.22v and length = 5m.

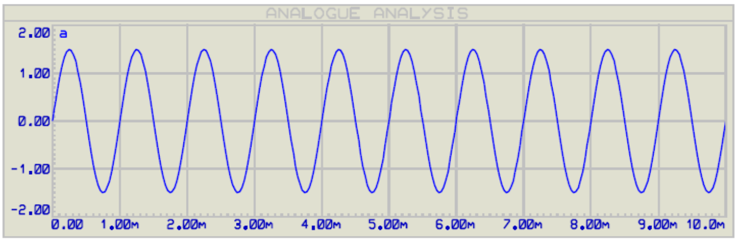

Figure (15): Attenuation in analog sine wave 850nm wavelength & fiber (plastic) where v_0=3v , T=10Sec , v (offset)=0.8v , V (gain)=0.04v and length = 0.5m.

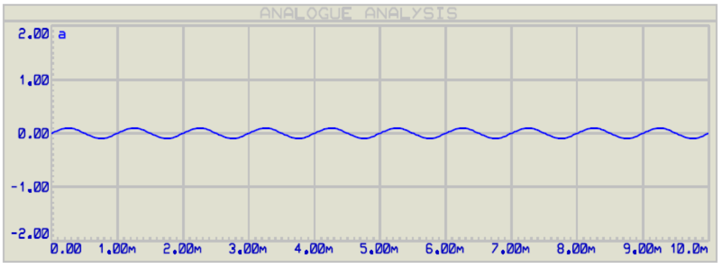

Figure (16): Attenuation in analog sine wave 850nm wavelength & fiber (plastic) where v_0=0.2v , T=10Sec , v (offset)=0.8v , V (gain)=0.04v and length = 5m.

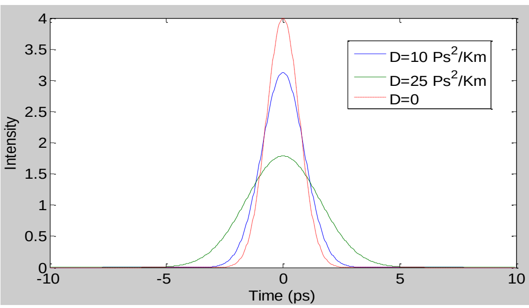

Figure (17) : Unchirped Gausian Pulses at Deferient Values of Dspersion along Fiber Optic, nt=512,Tmax=17, z=0.08Km.

Summary

In this research, we found that the attenuation is less significantly when use a wavelength of 850 nm compare with 660 nm, While the wavelength of 660 nm suitable for plastic fiber.

Attenuation increases when there are abnormalities in a private fiber optic at the points of convergence between the fiber cable or when there is a deviation in the opposite extremes when connecting cables.

For their access to the full description of the effects of attenuation and dispersion on the pulse of light transmitted through the optical fiber we used numerical simulation of the spread of Gaussian pulse and study the dispersion and attenuation for a distance of 0.08 km, It found that these effects are increased with increasing distance at three values of attenuation coefficient.

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تقدير التوهين ومحاكاة التشتت الحاصل في انتشار نبضات جاوس داخل ليف بصري احادي النمط

مبارك حمد عكلة

قسم هندسة سيطرة المنظومات النفطية ، كلية هندسة النفط والمعادن ، جامعة تكريت ، تكريت ، العراق

الملخص

تم دراسة التوهين في الالياف الضوئية باستخدام نوعين من الالياف (بلاستيك وزجاج) مع الاطوال (0.5،5،20 متر) و(100،20،1 متر) على التوالي وتم استخدام ليزر ذو الطول الموجي (850،660 nm)، حيث وجد ان التوهين يقل باستخدام الطول الموجي 850nm، وان الطول الموجي 660nm مناسب جدا للالياف البلاستيكية، وتم دراسة التوهين الناتج بسبب الازاحة وعدم التراصف المحوري والزاوي بين وجهي الالياف. كما تم دراسة تاثير ثلاثة قيم لعامل التشتت الخطي على نبضة التوزيع الجاوسي لنفس طول الالياف المستخدمة في التجربة بطريقة المحاكاة العددية لنموذج فورييه باستخدام الماتلاب.