

Measurements of Intermodal Dispersion In Graded Index Optical Fiber

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Abstract

The aim of this research is to examine experimentally the laser pulse transmittance in graded index optical fiber. However attention is paid on the evaluation of intermodal dispersion. Four signals ($\lambda=680\text{nm}$ and power= 0.1mW) of different frequencies (138.889, 277.778, 645.16, and 1369.863 Hz), of pulse widths (7.2, 3.6, 1.55, and 0.73 ms) respectively are sent through a 400m multimode graded index fiber. A p-i-n detector is used to receive output signals. Intermodal dispersion has been noticed and the pulse width broadening for each frequency is recorded. They are (7.22, 3.61, 1.555, and 0.732 ms) that lead to frequencies of (138.504, 277.008, 643.08, 1366.120 Hz) respectively. That change in frequency has to be taken into account whenever fiber optic dependence communication, guidance, or control systems are considered.

قياس التشتت الموجي في ليف بصري متدرج الانكسار متعدد الأنماط

الخلاصة

يهدف هذا البحث الى اختبار انتقال نبضة الليزرية خلال ليف بصري متدرج الانكسار عمليا وبالأخص التركيز على حساب التشتت المتضمن . يتم إرسال أربع إشارات ($\lambda = 680$ نانو متر وبقدرة 0.1 ملي واط) عبر ليف ضوئي نوع متدرج الانكسار متعدد الأنماط الموجية بطول 400م وبترددات مختلفة (138.889 ، 277.778 ، 645.16 ، و 1369.86 هيرتز) عرض نبضة (7.2 ، 3.6 ، 1.55 ، و 0.73 ملي ثانية) على التعاقب. أستعمل الكاشف p-i-n لأستلام الإشارة المرسله. تم ملاحظة تشتت المتضمن وتم قياس الاتساع لعرض النبضة لكل تردد . حيث كان عرض النبضات (7.22 ، 3.61 ، 1.555 ، و 0.732 ملي ثانية) وهذا يؤدي الى ترددات (138.504 ، 277.008 ، 643.08 ، 1366.120 هيرتز). يجب أن يؤخذ هذا التغير في التردد بنظر الاعتبار عند التعامل مع منظومات الاتصالات أو التوجيه أو السيطرة.

Introduction

Advances in any field of science and technology are dependent on the ability to make accurate measurements on the objects being investigated. The field of fiber optics is certainly no

exception to this rule and has properties that must be evaluated. Intermodal dispersion is one of these properties which act as a critical factor in optical fiber data transmission.

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P. Hlubina, et al. (2003), reported a work in which low-resolution spectrometer is used in measurement of the intermodal dispersion in optical fibers [1]. H. Wu, et al. (2003), indicated that intersymbol interference (ISI) caused by intermodal dispersion in multimode fibers is the major limiting factor in the achievable data rate or transmission distance in high-speed multimode fiber-optic links for local area networks applications[2]. R. A. Panicker et al. (2007) presented a work in which a transmitter-based adaptive optics and receiver-based single-mode filtering are combined to compensate modal dispersion in multimode fiber (MMF) [3]. R. A. Panicker et al. (2007), proposed a provably optimal technique for minimizing intersymbol interference (ISI) in multimode fiber (MMF) systems using adaptive optics via convex optimization [4]. I. Kamitsos and N. K. Uzunoglu, (2007), showed that multimode fibers can be characterized by multipath propagation of optical signals and this leads to severe intersymbol interference at the output of the fiber [5].

This research aims to study the intermodal dispersion introduced when laser signals of different frequencies are launched into multimode graded index fiber. Results are beneficial in designing and building optical fiber guiding systems.

Theoretical background

The width (duration) of the pulse propagating in an optical fiber increases with distance of propagation. The pulse of light is composed of wavelengths; the propagation velocity is not the same for all wavelengths. This phenomenon is called intermodal dispersion [6].

Intermodal dispersion in practical results from the propagation delay differences between modes within a multimode fiber (MMF). As the different modes which constitute a pulse in multimode fiber travel along the channel at different group velocities, the pulse width at the output is dependent upon the transmission times of slowest and fastest modes [7]. On the contrary of multimode the refractive index of the core in graded-index fibers is not constant but decreases gradually from its maximum value n_1 at the core center to its minimum value n_2 at the core-cladding interface. Intermodal dispersion in multimode fibers is minimized with the used graded index fiber [8].

Experimental setup

The optical fiber arrangement shown in Figure (1) is exploited here to carry out the experiment. It consists of three parts mainly the transmitter, optical fiber and receiver.

A. Figure (2) shows the diagram of the transmitter circuit. It consists of laser of wavelength (λ) of 680nm. This circuit works at pulsed laser mode operating at four different frequencies that can be changed from frequency to another by a selector. The transmitter circuit is divided into two parts, the first part is a frequency modulator and the second part is a laser diode drive. Frequency is implemented by using astable IC 555 timer circuit operates as an astable multivibrator as in Figure (2). In the present application four frequencies are required; therefore four capacitors at the values 1 μ F, 2.2 μ F, 4.7 μ F, and 10 μ F are used instead of C2 to get different frequencies.

B. A duplex optical fiber of length 200m with core / cladding diameter 62.5 /125 μ m, numerical aperture 0.275, and Sc connector is utilized here in order to obtain a single fiber of 400m length. This is done simply by connecting two adjacent ends of the duplex fiber together using Sc adapter. The design goal for any transmitter is to couple as much light as possible into the optical fiber. In practice, the coupling efficiency depends on the type of optical source as well as on the type of fiber: LD and multimode graded fiber are used here.

C. Figure (3) shows the diagram of the receiver circuit that uses p-i-n photodiode as the detector, which is connected to a current to voltage converter. The current from the p-i-n detector is usually converted to a voltage before the signal is amplified. The current to voltage converter is perhaps the most important section of any optical receiver circuit. In this circuit IC 741 comparator is used with feedback resistance as shown in Figure (3).

Measurements and Results

The intermodal dispersion introduced by launching four laser signals of different frequencies is examined.

The pulse width of the first signal (of frequency 138.889 Hz) is measured to be 7.2ms before launching. The pulse width of the signal is altered to 7.22ms (138.504Hz) after being transmitted into fiber, Figure (4). Thus intermodal dispersion is introduced and can be evaluated as follows:

$$dT_g = T_o - T_i$$

$$\therefore dT_g = 7.22 \times 10^{-3} - 7.2 \times 10^{-3} = 0.02ms$$

Intermodal dispersion

$$= \frac{dT_g}{L} = \frac{20 \times 10^{-6}}{400}$$

where T_o is the output pulse width, T_i is the input pulse width, and L is the fiber length.

The second unlaunched signal pulse width is 3.6ms (277.778Hz) and the transmitted signal pulse width is 3.61.ms (277.008Hz), Figure (5). Hence the pulse width difference between T_o and T_i and the introduced intermodal dispersion are 10 μ s and 25 ns/m respectively.

The pulse width of the third unlaunched signal (645.1613Hz) is 1.55ms and the transmitted signal pulse width (643.0868Hz) is 1.555ms, Figure (6). In this case δT_g is found to be 5 μ s and the intermodal dispersion is equal to 12.5ns/m.

The pulse width of the fourth unlaunched signal (1369.86Hz) is 0.73ms and the pulse width of the transmitter signal is 0.732ms (1366.120Hz). The difference between the pulse width of the unlaunched signal and the pulse width of the transmitted signal is found to be 4 μ s and the intermodal dispersion is equal to 5ns/m.

Conclusions

The facts derived from the practical results at this work are agreed with the theoretical aspectation and can assure the practicability of adopting these results in designing and building fiber optics guided system.

1. 1300 and 1500nm wavelength are recommended in optical fiber

communication system however visible, laser 680nm can be utilized in short distances optical fiber guidance systems.

2. By using short distance optical fiber the intermodal dispersion is minimized to the case where it can be used in certain application, rather than communication.
3. When high bit rate is sent the intermodal dispersion is reduced.
4. Using optical fiber graded index leads to the decreasing of the intermodal dispersion.

Acknowledgment

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References

- [1]P. Hlubina, T. Martynkien and W. Urbańczyk, "Measurements of intermodal dispersion in few-mode optical fibers using a spectral-domain white-light interferometric method" Meas. Sci. Technol, vol 14, pp 784-789, April 2003.
- [2]H. Wu, J. A. Tierno, P. Pepeljugoski, J. Schaub, S. Gowda, J. A. Kash, and A. Hajimiri, "Integrated transversal equalizers in high-speed fiber optic systems" IEEE J. Solid-State Circuits, vol. 38, pp. 2131–2137, Dec. 2003.
- [3]R. A. Panicker, J. P. Wilde, J. M. Kahn, D. F. Welch and I. Lyubomirsky, "10 x 10 Gb/s DWDM transmission through 2:2 km multimode fiber using adaptive optics" IEEE Photon. Technol. Lett., vol. 19, no. 15, pp.1154-1156, August 1, 2007.

[4]R. A. Panicker, J. M. Kahn, and S. P. Boyd, "Compensation of Multimode Fiber Dispersion using Adaptive Optics via Convex Optimization" Lightwave Technology, May 2007.

[5]I. Kamitsos and N. K. Uzunoglu, "Improvement of Transmission Properties of Multimode Fibers Using Spread Spectrum Technique and a Rake Receiver Approach" Progress In Electromagnetics Research, PIER 76, pp. 413–425, 2007.

[6]W. Hamid, "Analysis, Design and Performance Evaluation of Multi Layer Single Mode Optical Fiber" M.Sc thesis, University of Technology, 2007.

[7]J. Senior, Optical Fiber Communications: Principles and Practice, 1st, Prentice Hall International, Inc. 1985.

[8] G. P. Agrawal, Fiber-Optic Communications Systems, 3rd ed. John Wiley & Sons, Inc., 2002.

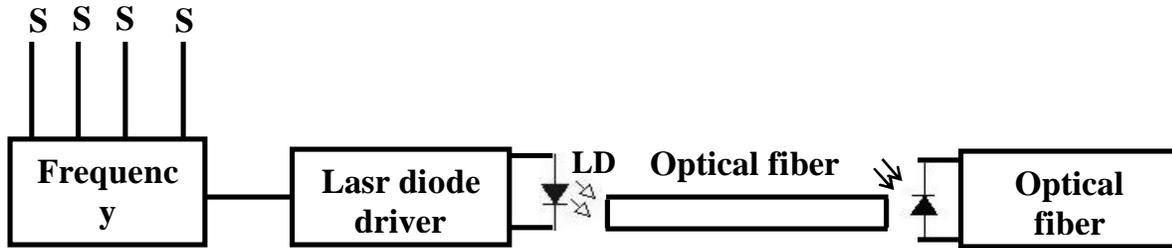


Figure (1) Block diagram of optical fiber arrangement.

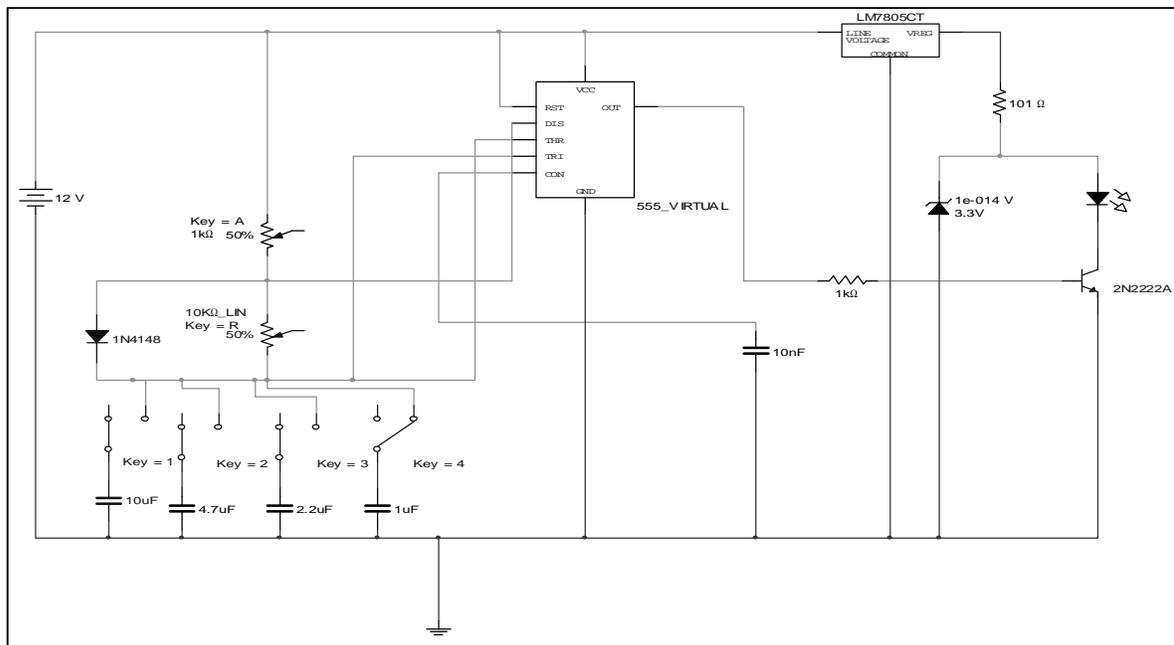


Figure (2) Transmitter circuit diagram

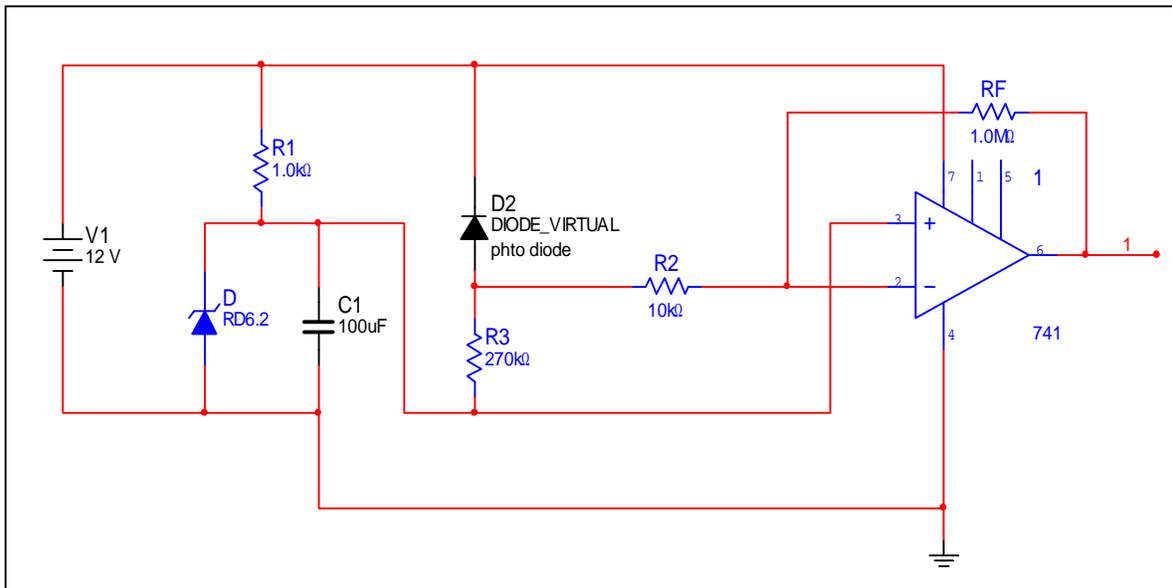


Figure (3) Optical fiber receiver

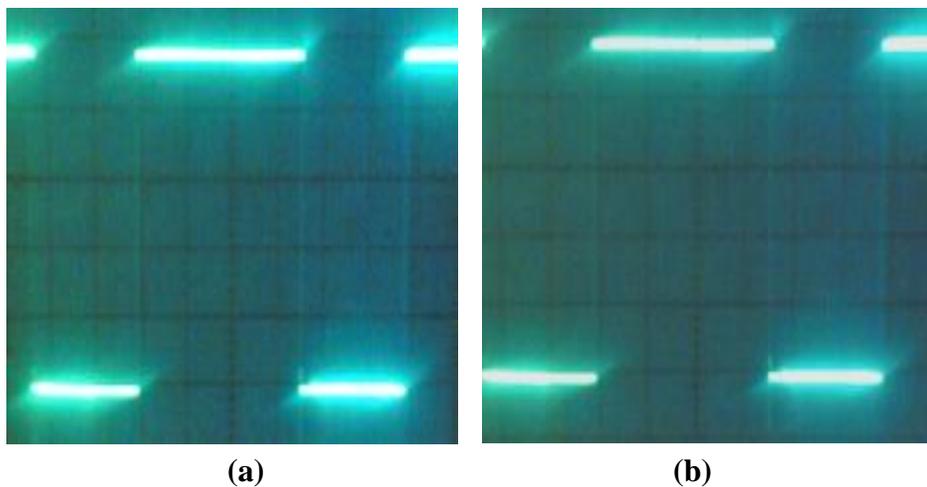


Figure (4) Illustrates the (a) unlaunched signal 7.2ms (138.889Hz) and
(b) launched signal 7.22ms (138.405Hz) (1V/div, 2ms/div).

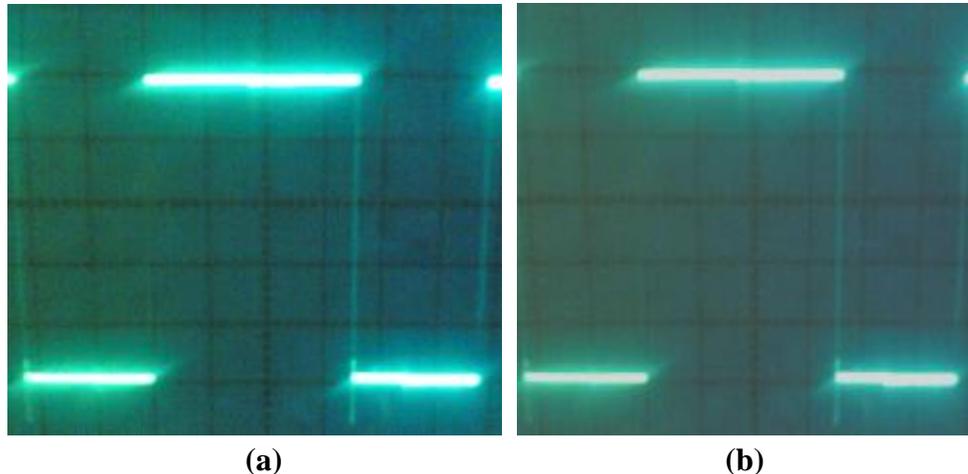


Figure (5) Demonstrates the (a) input signal before being launched (277.778Hz, 3.6ms) (b) the output signal after being transmitter into the fiber (277.008Hz ,3.61) (1V/div, 1ms/div).

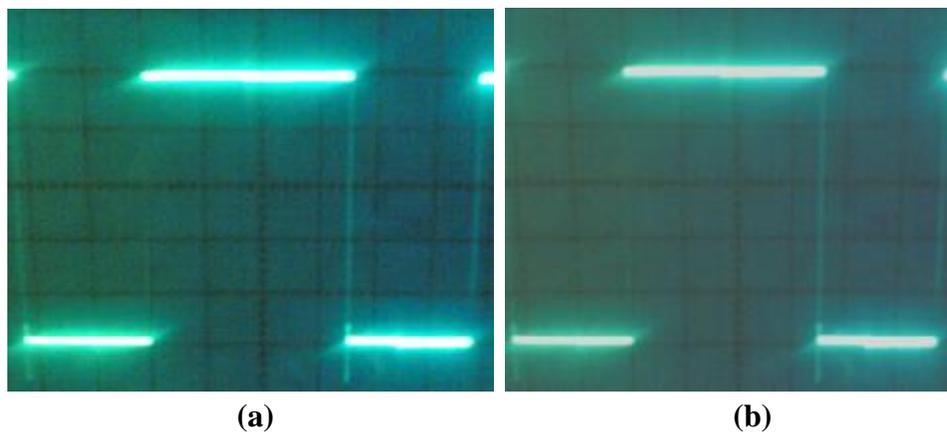


Figure (6) shows the unlaunched and transmitted signals (a) the unlaunched signal is of (645.1613Hz) 1.55ms pulse width. (b) the transmitted signal is of (643.0868Hz) 1.555ms pulse width (1V/div, 0.5ms/div).

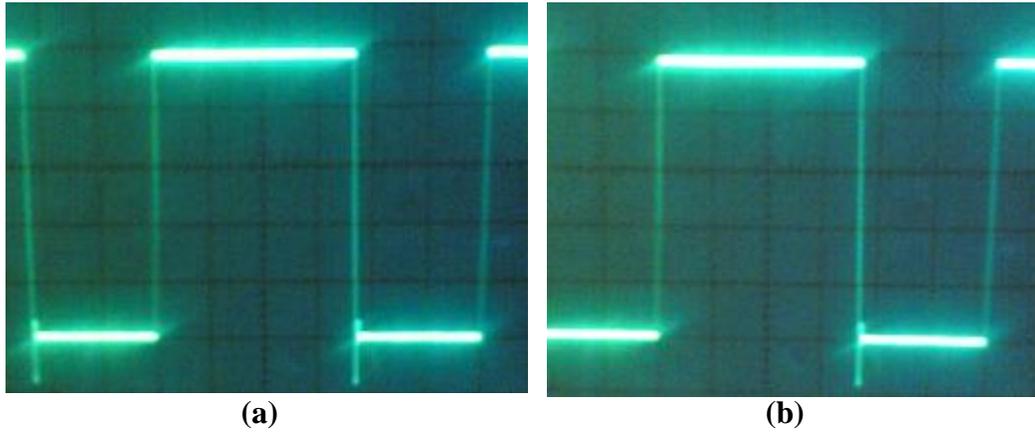


Figure (7) Pulse shapes of (a) the unlaunched signal of a pulse width (0.73ms), and frequency (1369.86Hz) and (b) of the transmitted signal of pulse width (0.732ms), frequency (1366.120Hz) (1V/div, 0.2ms/div)