Compensation of Dispersion with Fiber Bragg Grating in Optical Fiber Communication

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Abstract— This paper is based on a simulation of optical transmission system in optical fiber. Over the recent years, fiber Bragg grating have become popular due their extremely firm characteristics. The Fiber Bragg Grating (FBG) is a periodic structure fabricated inside the core of the optical fiber. The periodicity could be mechanical like variation of the core diameter or it could be electrical like variation of the refractive index of the core. The optical fiber is always used in telecommunication system due to its characteristics which include small size or dimension, low loss and low interferences from outside environment. There are various types of optical fiber, the Fiber Bragg Grating (FBG) is commonly chosen as important components to compensate the dispersion in optical communication system. FBG is very simple, has low cost filter for wavelength selection and low insertion loss, it has also customized reflection spectrum and wide bandwidth. The simulated transmission system will be analyzed on the basic of different parameters by using OptiSystem simulator.

Keywords: Optical Transmission System, Fiber Bragg Grating (FBG), Telecommunication System Dispersion Compensation, OptiSystem Simulator

I. INTRODUCTION

A fiber optic transmitter and receiver, connected by fiber optic cable – has great benefits that are not offered by traditional copper wire or coaxial cable. These include:

- It is able to carry much more information and deliver it with greater fidelity than either copper wire or coaxial cable. Also, Fiber optic cable can support much higher data rates, and at greater distances, than coaxial cable, making it ideal for transmission of serial digital data.
- The fiber is immune to virtually all kinds of interference, including lightning, and will not conduct electricity. It can therefore come in direct contact with high voltage electrical equipment and power lines. It will also not create ground loops of any kind.
- Since fiber is made of glass, it will not corrode and remains unaffected by most chemicals. It can be buried directly in most kinds of soil or exposed to most corrosive atmospheres in chemical plants without significant concern.
- Since the only carrier in the fiber is light, there is no possibility of a spark from a broken fiber. Even in the most explosive of atmospheres, there is no fire hazard, and no danger of electrical shock to personnel repairing broken fibers.
- Fiber optic cables are virtually unaffected by outdoor atmospheric conditions, allowing them to be lashed directly to telephone poles or existing electrical cables without concern for irrelevant signal pickup.
- A fiber optic cable, even one that contains many fibers, is usually much smaller and lighter in weight than a wire or coaxial cable with similar information carrying capacity. It is easier to handle and install, and uses less duct space. (It can frequently be installed without ducts.)
- Fiber optic cable is ideal for secure communications systems because it is very difficult to tap but very easy to monitor. In addition, there is absolutely no electrical radiation from a fiber. How are fiber optic cables able to provide all of these advantages?

Fiber optic cable works as a ”light guide,” guiding the light incident at one end of the cable through to the other end. The light source can either be a light-emitting diode (LED) or a laser. The light source is pulsed on and off, and a light-sensitive receiver on the other end of the cable converts the pulses back into the digital ones and zeros of the original signal. Even laser light shining through a fiber optic cable is considered to be loss of strength, primarily through dispersion and scattering of the light, within the cable itself. The faster the laser fluctuates, the greater the risk of dispersion. Repeaters which are the Light strengtheners, may be necessary to refresh the signal in certain applications. While fiber optic cable itself has become cheaper over time - a equivalent length of copper cable cost less per foot but not in capacity. Fiber optic cable connectors and the equipment needed to install them are still more expensive than their copper counterparts.

II. FIBER BRAGG GRATINGS

Fiber Bragg Grating (FBG) is very simple and low cost filter for wavelength selection which has various applications to improve the quality and diminish the costs in optical networks .FBG executes some operations like reflection and filtering with high efficiency and low loses. FBG acts as a dispersion compensator in transmission optical system which is used to compensate chromatic dispersion. Thus, the final expected effect is compression in incident pulse and can be appropriate to compensate chromatic dispersion in a communication link. FBG is single mode which will expose the core to the periodic pattern of intense ultraviolet light. The exposure will increase the refractive index and thus the refractive index is permanently increased. Then the exposure pattern will create a fixed index modulation that called grating. When periodic refraction is changed, a small reflected light will be produced. Then, the small reflected light will be combined into a large reflected light at a certain wavelength. The certain wavelength is when the grating period is approximately half the input light’s wavelength which is called Bragg’s wavelength. The other light (except the Bragg’s light) will be transparent. When a light pulse propagates down an optical fiber, it is dispersed, that is the width of the pulse broadens because the longer wavelength light lags the shorter wavelength light. Consequently, at sufficiently high data rates and fiber lengths, the pulses in a data stream will begin to overlap. In this way, fiber dispersion limits the maximum data that can be transmitted through a fiber.

The fundamental principle behind the operation of an FBG is Fresnel reflection, where light traveling between media of different refractive indices may both reflect and refract at the interface. The reflected wavelength (λb), called the Bragg wavelength, is defined by the relationship.

$$\lambda b = 2ne\Lambda$$

Where, ne = effective refractive index of the grating in the fiber core Λ = the grating period

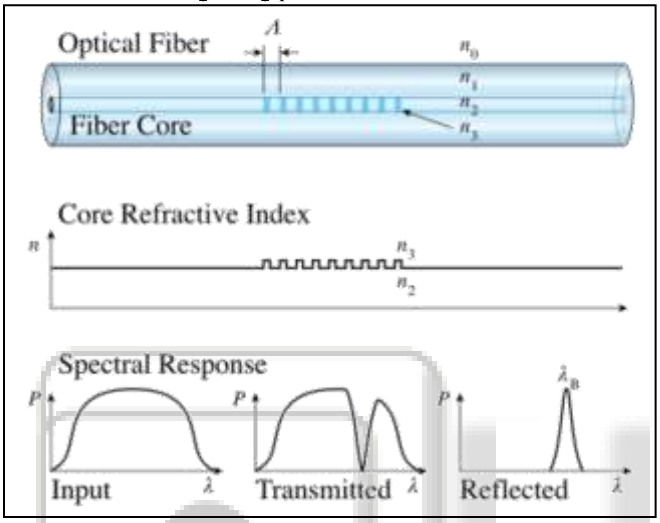


Fig. 1: Principle of bragg's light

III. OPTISYSTEM SOFTWARE

OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. It is a system level simulator based on the realistic modeling of fiber-optic communication systems. A comprehensive Graphical User Interface (GUI) controls the optical component layout and netlist, component models, and presentation graphics. OptiSystem allows for the design automation of virtually any type of optical link in the physical layer, and the analysis of a broad spectrum of optical networks, from Long-Haul Networks, Metropolitan Area Networks (MANs) and Local Area Networks (LANs). OptiSystem includes an extensive library of sample optical design (.osd) files that can be used as templates for optical design projects or for learning and demonstration purposes. OptiSystem capabilities can be extended with the addition of user components, and can be seamlessly interact with a wide range of tools.

A. *OptiSystem -Main Features*

1) *Component Library:*

The OptiSystem Component Library includes hundreds of components, all of which have been carefully validated in order to deliver results that are comparable with real life applications.

2) *User-defined components:*

The user can create new components based on subsystems and user-defined libraries, or use co-simulation with a third party tool such as MATLAB or Simulink.

3) *Mixed signal representation:*

OptiSystem handles mixed signal formats for optical and electrical signals in the Component Library.

IV. DESIGN CONSIDERATION

The system is operated with the basic optical communication which consists of a transmitter, transmission link and a receiver. The system transmits information using optical carrier wave from transmitter to receiver via optical fiber. The input signal contains electrical data that is represented by 0's and 1's has been generated by a non-return-zero (NRZ) pseudorandom binary sequence. Then the input signal is modulated with semiconductor laser that is represented by Continuous Wave (CW) laser through Mach-Zehnder modulator. CW laser supplies input signal with 1550 nm wavelength and input power of 5dBm which is externally modulated at 10 Gbits/s with a non-return-zero (NRZ) pseudorandom binary sequence in a Mach-Zehnder modulator with 5 dB of extinction ratio. The optical fiber used is single mode fiber because single mode fiber can yield higher data rate, less dispersion and also can operate in long haul distance, so it is suitable to be used as transmission link.For the dispersion compensator, the fiber Bragg grating will be used. The length grating that will be used is 6 mm since the most proper length for proposed model is equal to l = 6 mm by try and error method. After dispersion compensation the signal will pass through optical amplifier that represented by

Erbium-doped fiber amplifier (EDFA). Optical amplification is required to overcome the fiber loss and also to amplify the signal before receive by Photo detector PIN at the receiver part. order to operate as the optical transmission system: Input power 5Db, Reference wavelength 1550nm, fiber length 15km, Attenuation coefficient of cable 0.2dB/km.

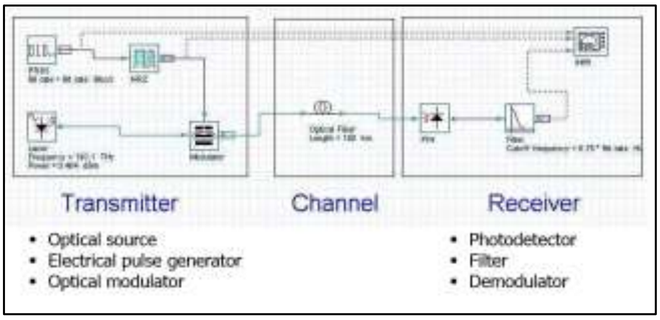


Fig. 2: Optical system components

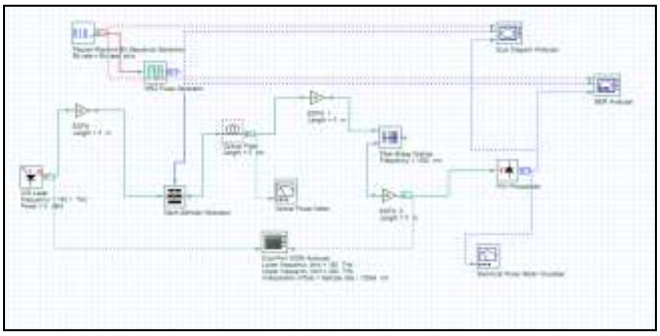


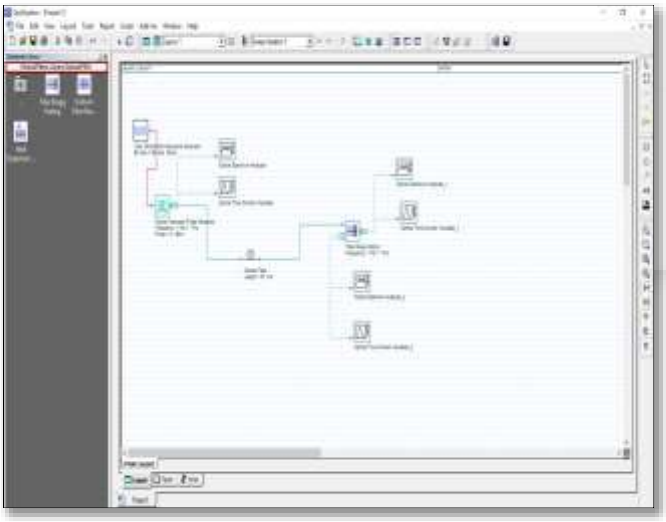
Fig. 3: The designed model of simulated system

Input power	5Db
Reference wavelength	1550nm,
fiber length	15km
Attenuation coefficient of cable	0.2dB/km.

Table 1

V. RESULTS AND DISCUSSIONS

It is important to say that all measurements were done using Optisystem 8 software. The process was quite interactive, with many changes in the system code. This procedure was adopted in order to improve the program efficiency and to improve its implementation.



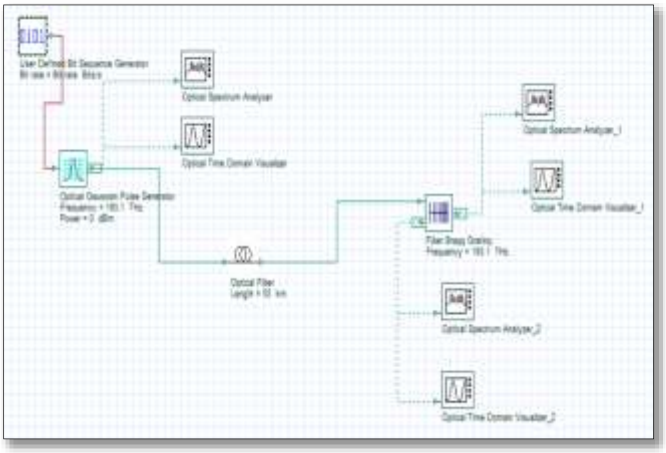


Fig. 4: Project Layout for dispersion compensation with Fiber Bragg grating component in OptiSystem

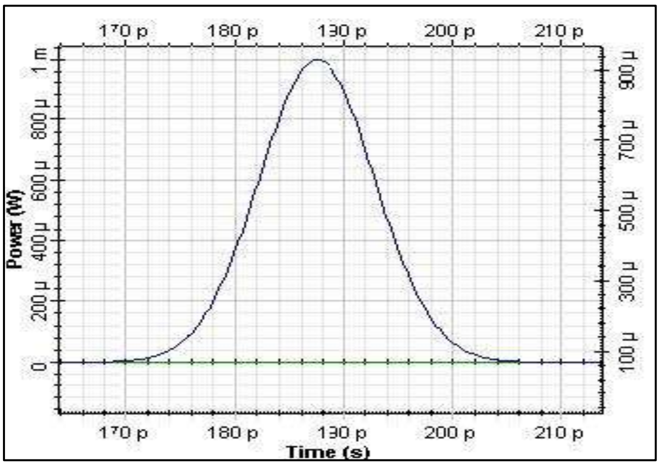


Fig. 5: Initial Gaussian pulse

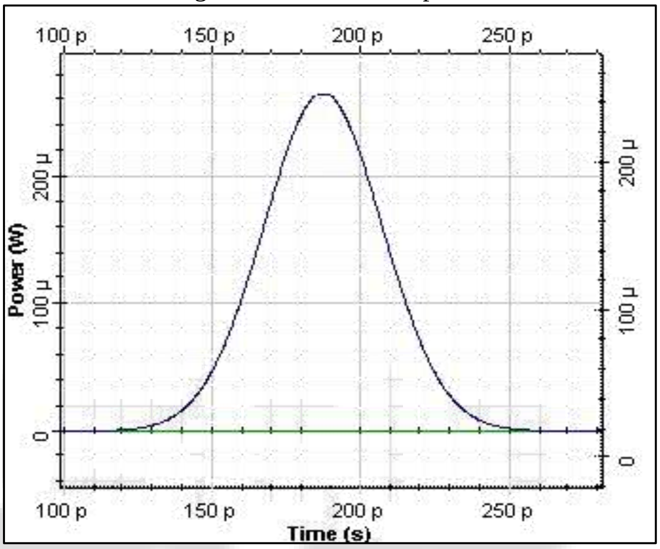


Fig. 6: Gaussian pulse after 10 km propagation in SMF

The result of dispersion compensation performed from this fiber grating component is obtaining of a pulse with approximately 20 ps width.

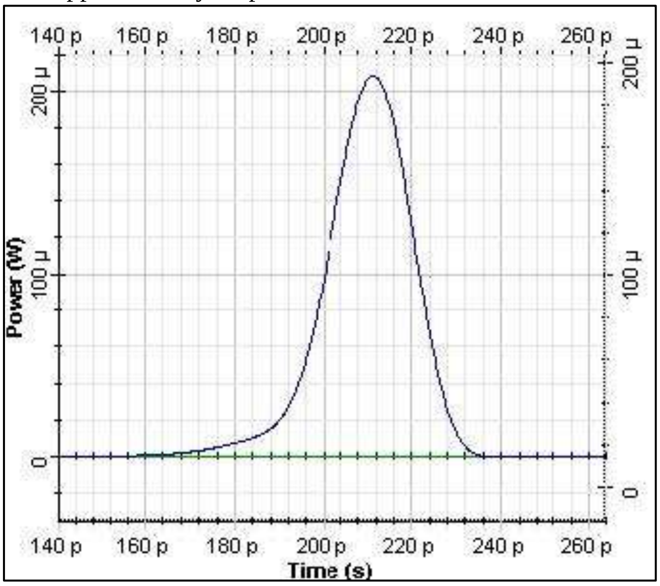


Fig. 7: Pulse after dispersion compensation with fiber grating with uniform apodization and linear chirp

VI. Conclusion

This project demonstrate a very important concept. If a FBG can be easily characterized in order to its rectivity and transmissivity with a white light source, a circulator and a Optical Spectrum Analyzer, the group delay cannot be measured this way. For the group delay there is the phase-shift setup, and, with our system, the measurement of the group delay is automated. Besides that, we believe that this method has greater accuracy in the calculus of the rectivity and transmissivity, because there is no risk of losing linearity due the white light source. Also, the method used by the setup that we developed is useful not only to characterize has the group delayed of FBG, but as well as the group delay of others optical devices.

Working in this project, I acquired greater sensibility in matters as optical transmission in single-mode fibers, in the subject of attenuation and dispersion, and methods to compensate these problems. More precisely, the use of chirped

FBG for dispersion compensation, allowed to further understand this method and all effects produced, and above all, the importance of the characterization of these devices.

With my system accomplishing most of requested tasks, it was possible, in early stages of development, to test it with other projects in development. This interaction allowed us to be more sensitive to the actual/future user requests to further improve our system for a higher satisfaction level. It also allowed us to invest all knowledge already acquired in the process of development of this project.

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