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Determination of ideal Fibre Bragg Grating (FBG) length for Optical Transmission System

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Abstract: The optical fibre is used in telecommunication system because of its small dimension, low transmission loss and low interferences from outside environment. There are various types of optical fibres. The Fibre Bragg Grating (FBG) is commonly chosen to compensate the dispersion in optical communication system. It is very simple, has low cost filter for wavelength selection and low insertion loss. It has customized reflection spectrum and wide bandwidth. The simulation of transmission system will be analysed based on the length of the FBG by using OptiSystem simulator. By simulating a model of communication system and using the most suitable settings of the system which include input power (decibel metre), fibre cable length (kilometre) and attenuation coefficient (decibel per kilometre) at cable section, the three different parameters which will be investigated are output power (Watt), Bit error rate, and Q factor at receiver. On the other hand, the frequency at transmitter (gigahertz) and cut-off frequency (Bit rate Hz) at receiver will be fixed earlier as initial setting for the simulation.

Keywords-Optical Transmission System, Fibre Bragg Grating (FBG), OptiSystem simulator

I. INTRODUCTION

The transfer of data in the electrical era via coaxial cables, twisted pair or point to point communication has some serious shortcomings such as attenuation. Thus the need for transfer of data with minimal attenuation and a high data rate has led to the optical era, where optical fibres and optical amplifiers have a crucial role to play. An optical communication system uses a transmitter, channel and a receiver. The transmitter encodes the message into an optical signal and sends it to the channel, which carries the signal to its destination and the receiver decodes the message from the received optical signal.

Fibre Bragg Gratings (FBG) is a key component in optical communication system. FBG are passive, linear and compact, retain strong dispersion in both reflection and transmission. In the transmission section, the gratings are placed in the line with the fibre to achieve the maximum compression ratio [2]. OptiSystem Simulator Software is an advanced, innovative and powerful software simulator tool for the design, testing and optimization of virtually any type of optical link. These links are in the physical layer of a broad spectrum of optical networks from ultra-long-haul system to local area networks (LANs) and metropolitan (MANs) [1]. OptiSystem offers optical transmission system design and planning from component to system level and present the analysis and scenarios visually. It helps the users to plan, test and simulate several applications. OptiSystem is based on realistic optical fibre modelling as a communication system. There are hundreds of official components in OptiSystem component library.

In this paper, the simulation of the optical transmission system in optical fibre has been discussed by analysing the effect of the components in data receiver by using different parameters setting. The value of parameters has been investigated are output power (Watt), Bit error rate, and Q factor at receiver.

II. DESCRIPTION OF COMPONENTS

Fiber Bragg Grating (FBG)

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 [1]. FBG executes some operations like reflection and filtering with high efficiency and low loses [1]. 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 [1]. 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 [3].

Non-return-zero (NRZ) pulse generator is used in producing the electrical data signal for the modulation process. It has the ability to fix the bits in the state as the voltage is changing. Therefore, it is easy to indicate where the bits should start and stop. Besides, the NRZ pulse generator has an advantage on controlling bandwidth. This is due to the characteristic of the generator that the returning signals to zero between bits will not wasting the bandwidth of the data signal. Pseudo-random bit sequence generator is used to scramble data signal in terms of bit rates [4]. Operation mode controls the algorithm used to generate the bit sequence, probability: random number generator is used with parameter mark probability of ones in the sequence. Order: a sequence of ones is generated. Zeros: a sequence of zeros is generated. Continuous Wave (CW) laser is applied in the design and externally modulated with a non-return-zero (NRZ) pseudorandom binary sequence in a Mach-Zehnder modulator with the specified extinction ratio. Mach- Zehnder modulator is a modulator based on a principle of interferometry. Constructive and destructive interference at the output ate determined by different paths regarding on the voltage supplied. Thus, the output signal could be modulated regarding to the voltage. Single mode optical fibre is used to allow one mode of light to propagate at a time within a small core radius. It is suitable for a long distance transmission with high speed data. A single data signal could be transmit from 25 to 100km in range of fibre length. It is used to transmit the transmission of a single ray or mode of light as a carrier in transmitting an optical signal. Fibre Bragg Grating (FBG) is used to compensate chromatic dispersion of common fibres. FBG is a part of common single mode fibre that is like a grating. Erbium doped fibre amplifier (EDFA) is used to compensate loses in optical transmission system. Photo detector (PIN Photodiode) is used for detection of light (photons) at the receiver by converting light directly into electric current. One photon yields one electron [5].

III. DESIGN CONSIDERATIONS

A basic optical communication which consists of a transmitter, transmission link and a receiver is used. The system transmits information using optical carrier wave via optical fibre. 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. The input signal is modulated with semiconductor 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 30 dB of extinction ratio. The optical fibre used is single mode fibre as it is suitable to be used as transmission link. For the dispersion compensator, the fibre Bragg grating will be used. The length grating that will be determined using trial and error method [1]. The lengths used are 0.99m, 2mm, 3mm, 4mm and 6mm. The most suitable length of FBG is determined. After dispersion compensation the signal will pass through optical amplifier that represented by Erbium-doped fibre amplifier (EDFA). Optical amplification is required to overcome the fibre loss and also to amplify the signal before receive by photo detector PIN at the receiver part.

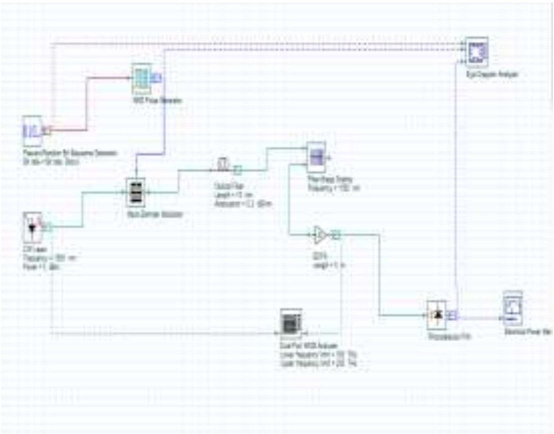

Figure 1: - Designed System using OptiSystem

IV. RESULTS AND DISCUSSIONS

The simulation of the network is done using OptiSystem simulation software. The eye diagrams and results of Output power (dBm), Bit Error Rate and Quality Factor are tabulated into a table by using different lengths of Fibre Bragg Grating.

Length of FBG (mm)	Bit Error Rate	Q factor	Output Power (dBm)
0.99	2.248E-40	13.2155	5.236
2	8.153E-203	30.347	7.224
3	8.384E-271	35.1239	7.658
4	0	40.8629	7.884
6	0	53.8539	8.081

Table: - Comparison of parameters for different length of Fibre Bragg Grating.

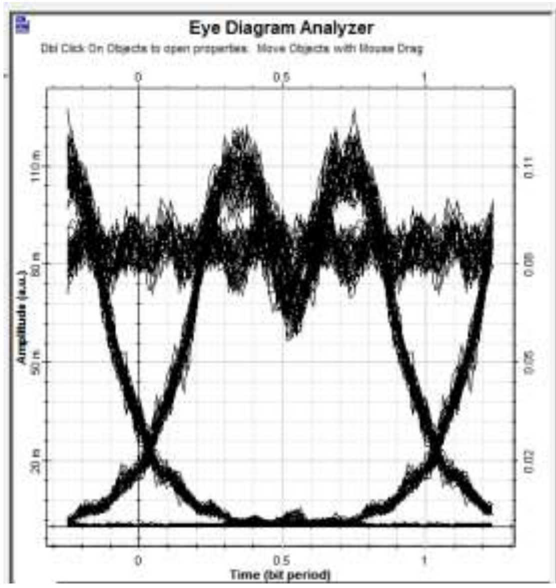

Figure 2: Eye Diagram for FBG Length of 0.99mm

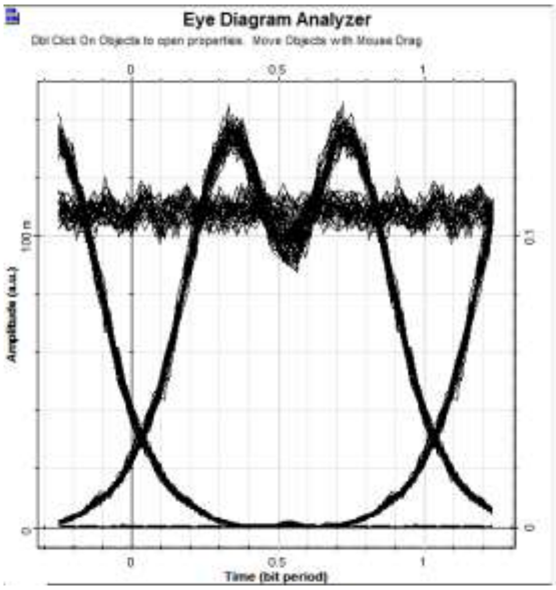

Figure 3: Eye Diagram for FBG Length of 2mm

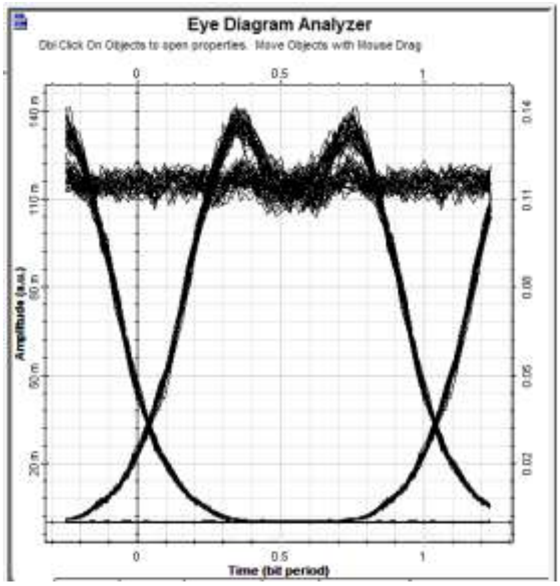

Figure 4: Eye Diagram for FBG Length of 3mm

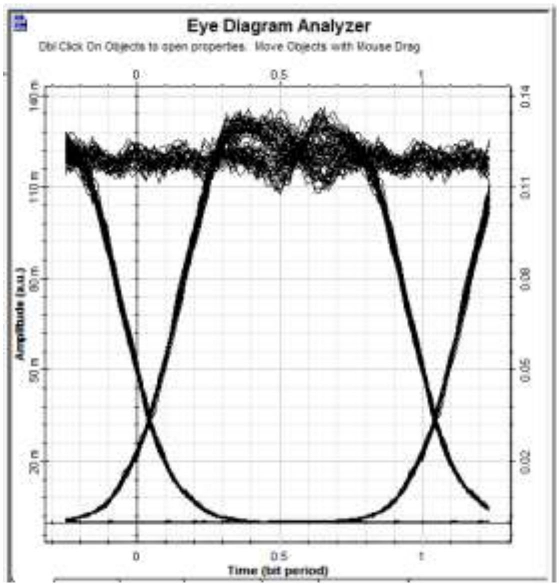

Figure 5: Eye Diagram for FBG Length of 4mm

Figure 6: Eye Diagram for FBG Length of 6mm

The transmission system is designed by setting certain parameters such that its performance is good. The optical fibre is used for transmitting the signal. From the design, the optical fibre transmission system can be combined with the modulator. Also, the transmission system consists of optical amplifier which can be used to reduce the fibre loss and amplify the signal before being received by photo detector PIN at the receiver part [6]. The length of the FBG is varied (lengths used are 0.99m, 2mm, 3mm, 4mm and 6mm) to determine which one of them is ideal for the optical communication system. The different values of bit error rate, quality factor and output power are tabulated to compare and determine the ideal FBG length. EDFA is used as the optical amplifier, output power will indicate that the optical amplifier will saturate or the gain has been compressed. The reason is that the power source of the amplifier, the number of excited erbium atoms or the number of available electron-hole pairs, is depleted.

V. CONCLUSION

An optical transmission system has common components such as information source (input), transmitter, transmission channel (fibre optic), receiver and the destination (output). The system will transmit information using optical carrier wave from transmitter to receiver via optical fibre. Based on the research, the transmission system has been designed which consists of laser light as the source, modulator, single mode optical fibre as the channel, fibre Bragg grating (FBG) as the dispersion compensator, optical amplifier and the photo detector as the light detector. The optical transmission system has been modelled by using OptiSystem simulator as shown in Figure 1 in order to investigate different parameters of the system. From the simulation result, it can be concluded that the bit error rate reduces as the length of the FBG increases. The value of bit error rate is zero for lengths greater and equal to 4mm. The Q factor increases as the length of the FBG increases. This infers that the quality of signal received is high. The output power increases as the length of the FBG is increased. It has also been noticed that beyond a certain length, the losses are high. (BER increases whereas Q factor and Output Power decreases).

VI. REFERNCES

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