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Dispersion Compensation in Optical Fiber Communication Using Fiber Bragg Grating

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Abstract - Optical fiber is one of the most important communications media in communication system. Due to its versatile advantages and negligible transmission loss it is used in high speed data transmission. Although optical fiber communication has a lot of advantages, dispersion is the main performance limiting factor. Dispersion severely degrades the performance of optical fiber. There are various methods for dispersion compensation. Due to some superior advantages Fiber Bragg Grating is a well known hot cake in the field of dispersion compensation in optical fiber communication. Generally Fiber Bragg Grating has a very narrow operating window. An effective method for broadening the window of Fiber Bragg grating is shown in this thesis work, which gives a satisfactory operating window. In this thesis paper a typical MATLAB simulation work is done to compensate dispersion up to a fiber length of 300 Km.

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DISPERSION COMPENSATION IN OPTICAL FIBER COMMUNICATION USING FIBER BRAGG GRATING

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Abstract - Optical fiber is one of the most important communications media in communication system. Due to its versatile advantages and negligible transmission loss it is used in high speed data transmission. Although optical fiber communication has a lot of advantages, dispersion is the main performance limiting factor. Dispersion severely degrades the performance of optical fiber. There are various methods for dispersion compensation. Due to some superior advantages Fiber Bragg Grating is a well known hot cake in the field of dispersion compensation in optical fiber communication. Generally Fiber Bragg Grating has a very narrow operating window. An effective method for broadening the window of Fiber Bragg grating is shown in this thesis work, which gives a satisfactory operating window. In this thesis paper a typical MATLAB simulation work is done to compensate dispersion up to a fiber length of 300 Km.

Index Terms : Dispersion, Fiber Bragg Grating, Pulse Broadening Characteristics, Window Broadening, Dispersion compensation.

I. Introduction

Dispersion is the main performance limiting factor in optical fiber communication. Dispersion greatly hampers the performance of optical fiber communication. Due to dispersion, broadens optical pulse as they travel in single mode fiber. Limiting the ultimate data rate supported by fiber which causes spreading and overlapping of chips and degrades system performance due to increase inter chip interference and reduced received optical power. So if dispersion can be minimized then a further performance can be obtained from optical fiber communication. There are a lot of methods of dispersion compensation. Fiber Bragg Grating is one of these.

When a pulse travels through an optical fiber due to dispersion it becomes broadened. The dispersion is proportional to the length of the fiber. If the length is increased the width becomes bulk and the magnitude reduces. We tested here for the length up to 700 km using interval of 100 km. For uniform grating period in reflectivity vs. detuning curve the window width increases with increase of coupling constant. In our thesis work we varied the value of coupling constant from one to six with interval one. We tested a Gaussian pulse passing through an optical fiber from one hundred to three hundred km long with an interval of fifty km with Fiber Bragg Grating and without Fiber Bragg Grating at receiving end. The performance we measured as dispersion with lengths when the Gaussian pulse travels through Fiber Bragg Grating and without Fiber Bragg Grating. Fiber Bragg gratings are created by "inscribing" or "writing" the periodic variation of refractive index into the core of a special type of optical fiber using an intense ultraviolet (UV) source such as a UV laser. Two main processes are used: interference and masking. Which is best depends on the type of grating to be manufactured. A special germanium-doped silica fiber is used in the manufacture of fiber Bragg gratings. The germanium-doped fiber is photosensitive, in that the refractive index of the core changes with exposure to UV light, with the amount of the change a function of the intensity and duration of the exposure. The first in-fiber Bragg grating was demonstrated by Hill in 1978. Initially, the gratings were fabricated using a visible laser propagating along the fiber core. In 1989, Meltz and colleagues demonstrated the modern transverse holographic technique from the side of the fiber utilizing the interference pattern of ultraviolet light.

II. Pulse Broadening Characteristics

We have used a super-Gaussian pulse whose RMS pulse width after transmission in a dispersive medium is given analytically. Its RMS width c normalized by initial RMS width 00 is given by, shown at the end of this paragraph, where r is the Gamma function. We have defined to = 1/(k . B), where B is the bit rate, k = 1.665 for m = 1 and 1.825 for m = 2 and LD= t_0^2 /|β2| is the dispersion length, so that FWHM of the pulse equals l/B. The equation of the broadening factor is shown in below

$$\frac{\sigma}{\sigma_0} = \sqrt{1 - \frac{\Gamma(1/2m)}{\Gamma(3/2m)}\frac{\alpha\beta_2 L}{t_0^2} + \frac{\Gamma(2-1/2m)}{\Gamma(3/2m)}\frac{(1+\alpha^2)(m\beta_2 L)^2}{t_0^4}}$$

$$\frac{\sigma}{\sigma_0} = \sqrt{1 - \frac{\Gamma(1/2m)}{\Gamma(3/2m)}\frac{\alpha\beta_2 L}{t_0^2} + \frac{\Gamma(2-1/2m)}{\Gamma(3/2m)}\frac{(1+\alpha^2)(m\beta_2 L)^2}{t_0^4}}$$

The variation of the broadening factor with respect to distance is shown in figure below

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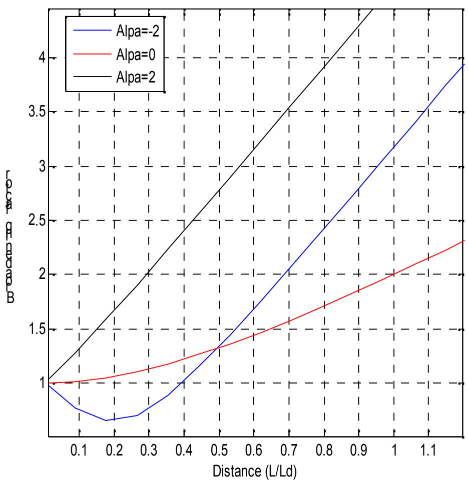

Fig 2.1: Variation of broadening factor with propagating distance for Gaussian input pulse when β2<0.

From the Fig 2.1 we see that the broadening increases linearly for positive value of alpha. The level of the broadening factor is minimum when distance L/LD =0.2 and α= -2. The variation of the broadening factor with respect to α is shown in figure below

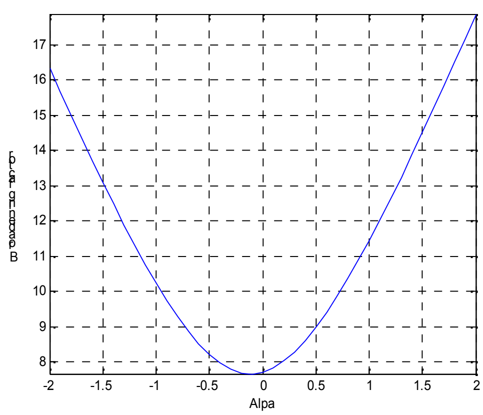

Fig 2.2 : Variation of broadening factor with α for Gaussian input pulse when $\beta_2 < 0$.

From Fig3.6.2 we see that with the increase of the positive value of α, the broadening increases. Also with the increase of the negative value of α, the broadening also increases. The broadening is minimum when α= 0.

III. Effect of the Length of the Fiber only Considering the Dispersion

The fiber dispersion index is directly proportional to the length of the fiber. With increasing the length of the fiber dispersion index also increases. The effect of the fiber length under transmitted data through the fiber are given below

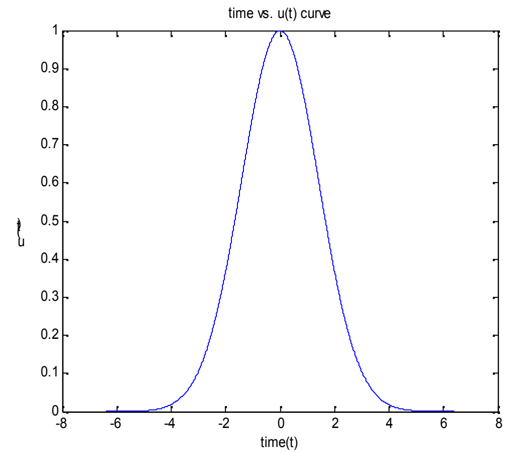

Figure 3.1 : Input data as a Gaussian Pulse

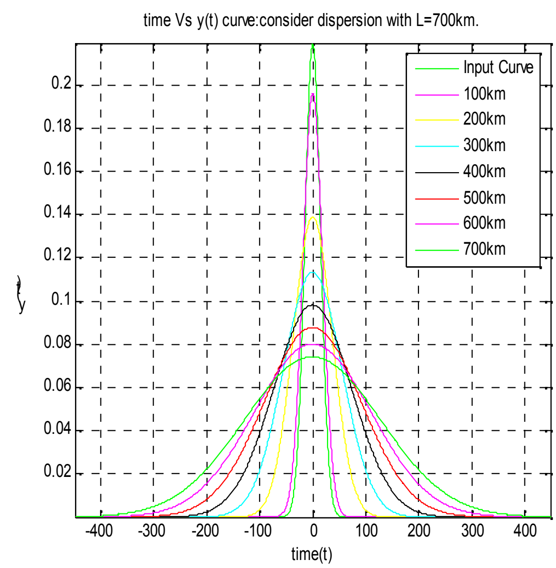

Fig 3.2 : Graphical representation of the effect of the fiber length in presence of dispersion of the transmitted signal when input data is a Gaussian pulse, bit rate B=10 Gbps, wavelength λ= 1.55μm.With increase in the length of the fiber broadening of the pulse will be increased. By MATLAB simulator, it is shown that above 700 km pulse broadening increases severely.

IV. Window Broadening Characteristics for Uniform Period Grating

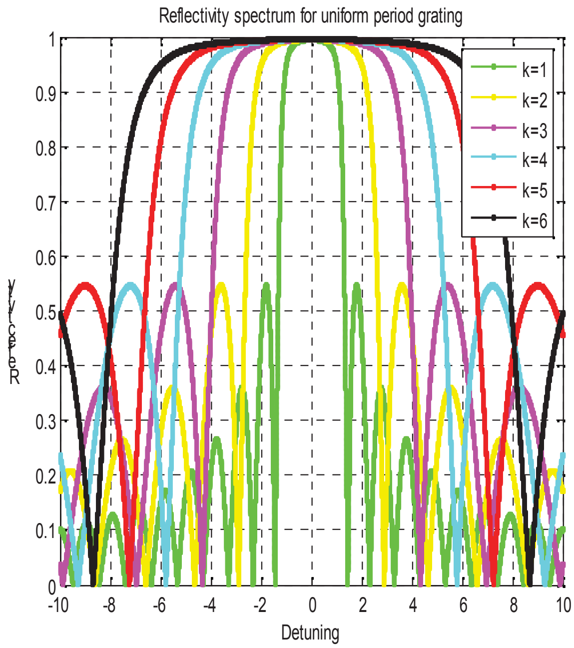

Figure 4.1 : Reflectivity of six gratings with coupling constants *KL* =1 to 6, as a function of normalized detuning. For KLg=1(green), KLG=2(yellow),KLg=3 (magenta) , kLg=4(cyan) ,KLg=5(red) ,KLg=6(black) .The side-mode structure increases rapidly for stronger gratings.

V. Dispersion Compensation

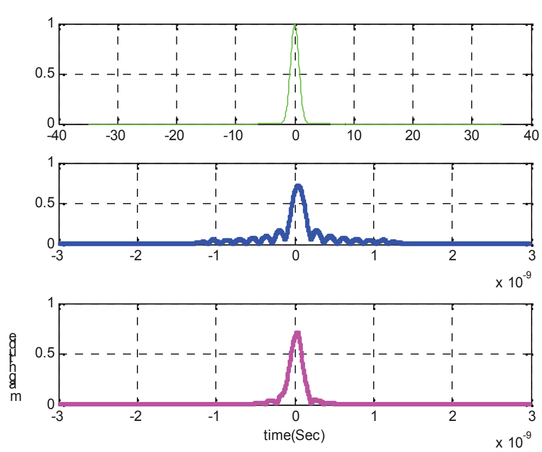

Figure 5.1 : Shows that the input data as a Gaussian pulse of bit rate B=10Gbps and wavelength **λ= 1.55μm** (Green figure), for 100 km length of fiber, Gaussian pulse after travelling through optical fiber without passing through Fiber Bragg Grating (Deep blue figure),Gaussian pulse after travelling through optical fiber and Fiber Bragg Grating (Magenta figure),

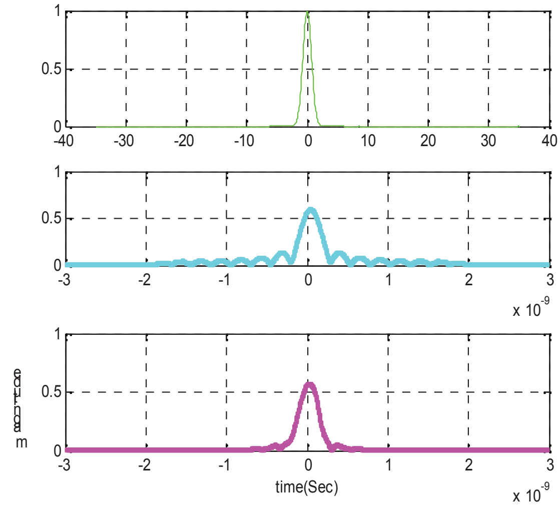

Figure 5.2 : Shows that the input data as a Gaussian pulse of bit rate B=10Gbps and wavelength **λ= 1.55μm** (Green figure), for 150 km length of fiber, Gaussian pulse after travelling through optical fiber without passing through Fiber Bragg Grating (cyan figure), Gaussian pulse after travelling through optical fiber and Fiber Bragg Grating (Magenta figure),

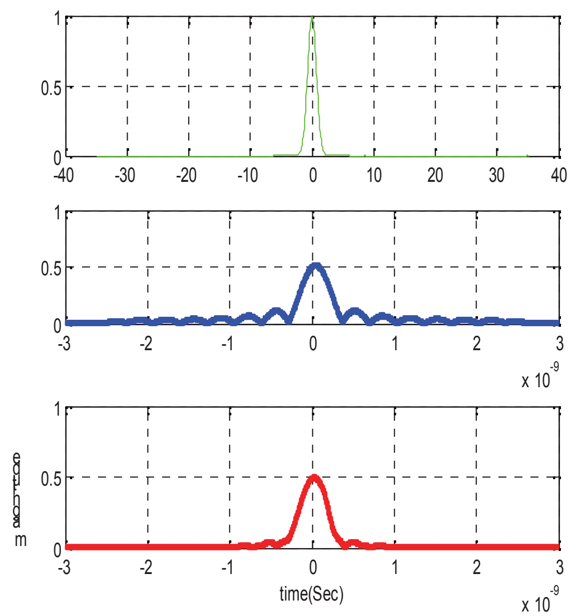

Figure 5.3 : Shows that the input data as a Gaussian pulse of bit rate B=10Gbps and wavelength **λ= 1.55μm** (Green figure), for 200 km length of fiber, Gaussian pulse after travelling through optical fiber without passing through Fiber Bragg Grating (Deep blue figure), Gaussian pulse after travelling through optical fiber and Fiber Bragg Grating (Deep red figure),

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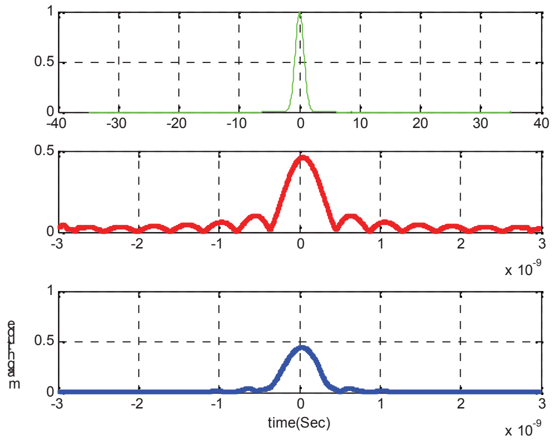

Figure 5.4 : Shows that the input data as a Gaussian pulse of bit rate B=10Gbps and wavelength λ= 1.55μm (Green figure), for 250 km length of fiber,Gaussian pulse after travelling through optical fiber without passing through Fiber Bragg Grating (Deep red figure), Gaussian pulse after travelling through optical fiber and Fiber Bragg Grating (Deep blue figure),

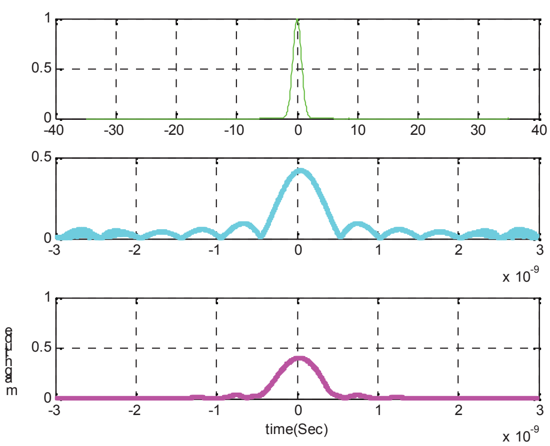

Figure 5.5 : Shows that the input data as a Gaussian pulse of bit rate B=10Gbps and wavelength λ= 1.55μm (Green figure), for 300 km length of fiber, Gaussian pulse after travelling through optical fiber without passing through Fiber Bragg Grating (cyan figure),Gaussian pulse after travelling through optical fiber and Fiber Bragg Grating (Magenta figure),

VI. Measurement of Dispersion and Comparison

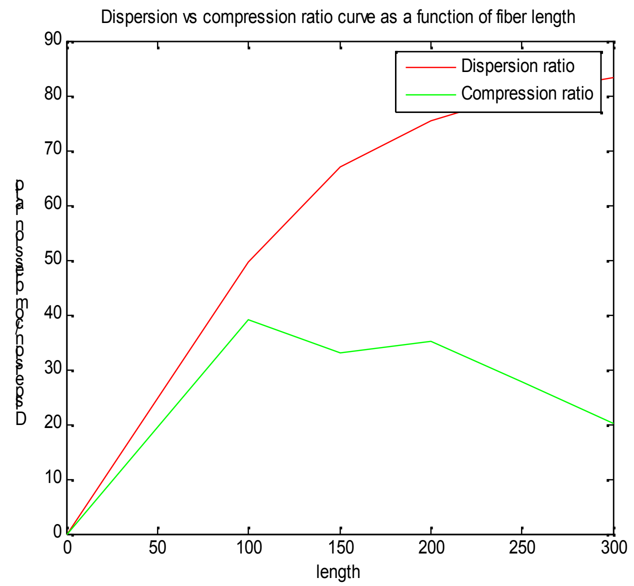

Figure 6.1 : Dispersion Vs Compression ratio curve as a function of fiber length without FBG (red curve) after FBG (green curve).

Table : Simulation Results for the FBG dispersion compensation of uniform grating period receiver

Length In Km	Dispersion without compensation (ps/nm/km)	Dispersion after compensation (ps/nm/km)
100	49.5	39
150	66.9	33.1
200	75.5	35.1
250	80.5	27.69
300	83.2	20.23

VII. Conclusion

It is shown in this thesis that the recent advances in Fiber Bragg grating technology now allow the realization of a highperformance, high speed optical fibers with good in line dispersion compensation. The characteristic of optical fiber is analyzed. The dispersion is computed by sending a Gaussian pulse as an input. For 200km length of fiber this is observed that dispersion is approximate 75.5ps/nm/km. This is quite impossible to remove but in our thesis we have succeeded to compensate dispersion up to 33.8 for 150

Km length of fiber. That's why Fiber Bragg Grating is worthy compensation system in optical fiber communication. A narrow bandwidth is observed for data transmission in Fiber Bragg Grating. This is widened in our thesis at a satisfactory value. But for length more than 300 Km the result is not satisfactory. In this thesis this is resulted that for a length of 500 Km the dispersion compensation is not satisfactory. So the future work of thesis is chosen as to solve the problem using Fiber Bragg Grating beyond 500 Km length of fiber.

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