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Dispersion Compensation and Power Optimization using FBG-EDFA in Optical Communication System

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Abstract- **Dispersion Compensation (DC) and Power Optimization (PO) are highly required parameters in Optical Communication System (CS).The proposed communication model shows Dispersion Compensation using Fiber Bragg Grating (FBG) with Erbium Doped Fiber Amplifier (EDFA).Other than Dispersion Compensation we optimized almost same power at the receiver end. Dispersion and power is clearly visualized at various points especially at input side (after the Mech-Zehnder modulator), after the 20 km optical fiber and at the receiver end (After the EDFA). Dispersion loss is successfully compensated almost 85% and power output is same 46 µWatt as input.FBG is set at 193.1 THz frequency (near to 1550 nm Bragg Wavelength). At input side the bit sequence generator, Gaussian pulse generator and Mech-Zehnder modulator (MZM) is used. The power is measured by Optical power Meter (OPM) and Dispersion is visualized by optical time domain visualizer (OTDV).**

Keywords **- Dispersion compensation (DS), dispersion-compensating fiber (DCF), Fiber Bragg Grating (FBG), Mech-Zehnder modulator (MZM), Erbium Doped Fiber Amplifier (EDFA), Optical power Meter (OPM), Optical Time Domain Visualizer (OTDV). Wavelength-Division Multiplexing (WDM)**

I. INTRODUCTION

Communication system service providers have to fulfill continuously growing bandwidth demands in all networks areas. The new installing communication links would require huge investments, Communication system carriers prefer to increase the capacity of their existing fiber links by using various methods in optical communication system[1]. By minimizing the losses we can increase the capacity of the system. Dispersion is one of the major parameter in losses. The broadening of light pulses, called dispersion, is a critical factor limiting the quality of signal transmission over optical links. Dispersion is a major consequence of the physical properties of the transmission medium. Single-mode fibers, used in high-speed optical networks, are subject to Chromatic Dispersion (CD) that causes pulse broadening depending on wavelength, and to Polarization Mode Dispersion (PMD) that causes pulse broadening depending on polarization. Excessive spreading of light pulse will cause bits to “overflow” their intended time slots and overlap adjacent bits. At the receiver side it may have difficulty to interpret adjacent bits, increasing the Bit Error Rate. To preserve the transmission quality, the maximum amount of time dispersion must be limited to a small proportion of the signal [2].

II. SYSTEM COMPONENTS

These tight tolerances of high-speed networks mean that every possible source of pulse spreading should be addressed. Companies need to measure the dispersion of their networks to assess the possibility of upgrading them to higher transmission speeds or to evaluate the need for compensation [3].

EDFAs, single-channel repeater less transmission at very high speed across over several Km. It works with single-channel point-to-point links to be state-of-the-art and an accomplished fact, albeit with many improvements possible which has the potential for much higher speeds and longer distances communication. The required rates of data transmission among many users have been increasing at an impressive pace for the past several years, it is a highly desirable goal to eventually connect many users with a high-bandwidth optical communication system by employing wavelength-division multiplexing (WDM) technology, a simple multiuser system may be a point-to-point link simultaneously [4].

EDFA owing to the large gain (which can be greater than 30 dB), the low noise characteristics, and the low insertion loss, the EDFA has been the predominant choice for implementing the optical preamplifier receiver in long-haul system experiments, particularly at high bit rates. The preamplifier in the optical front end is an analog circuit with a fixed-gain preamplifier. The front-end output signal level will follow the variation of the input optical power [5].

A fiber Bragg grating (FBG) is a periodic variation of the refractive index of the fiber core along the length of the fiber. The principal property of FBGs is that they reflect light in a narrow bandwidth that is centered about the Bragg wavelength, λ_B, which is given by

$$\lambda_B = 2N_{eff}\Lambda, \qquad (1)$$

where, Λ = spatial period (or pitch) of the periodic variation,

N_{eff} = effective refractive index for light propagating in a single mode.

The refractive index variations are formed by exposure of the fiber core to an intense optical interference pattern of ultraviolet light. The capability of light to induce permanent refractive index changes in the core of an optical fiber has been named photosensitivity [6].

Bragg gratings have a periodic index structure in the core of the optical fiber. Light propagating in the Bragg grating is backscattered slightly by fresnel reflection from each successive index defects. Normally, the amount of backscattered light is very small except when the light has a wavelength in the region of the Bragg wavelength, λ_B. At the Bragg wavelength, each back reflection from successive index defects is in phase with the next one. The back reflections add up coherently and a large reflected light signal is obtained. The reflectivity of a strong grating can approach 100 percent at the Bragg wavelength, whereas light at wavelengths longer or shorter than the Bragg wavelength pass through the Bragg grating with negligible loss. The optical pitch ($N_{eff}\Lambda$) of a Bragg grating contained in a strand of fiber is changed by applying longitudinal stress to the fiber strand [7-9].

The grating is assumed to have a sinusoidal perturbation of constant amplitude, Δn. The reflectivity of the grating is determined by three parameters:

(1) coupling coefficient, κ,

(2) mode propagation constant,

$$\beta = 2\pi N\text{eff}/\lambda, \qquad (2)$$

(3) grating length, L.

The coupling coefficient, κ, which depends only on the operating wavelength of the light and the amplitude of the index perturbation, Δn, is given by

$$\kappa = (\pi/\lambda)\Delta n. \qquad (3)$$

The most interesting case is when the wavelength of the light corresponds to the Bragg wavelength. The grating reflectivity, R, of the grating is then given by the simple expression,

$$R = \tanh^2(\kappa L), \qquad (4)$$

The product κL can be used as a measure of grating strength. For κL = 1, 2, 3, the grating reflectivity is, respectively, 58, 93, and 99 percent. A grating with a κL greater than one is termed a strong grating, whereas a weak grating has κL less than one shows the typical reflection spectra for weak and strong gratings [10].

The other important property of the grating is its bandwidth, which is a measure of the wavelength range over which the grating reflects light. The bandwidth of a fiber grating that is most easily measured is its full width at half-maximum, $\Delta\lambda_{FWHM}$, of the central reflection peak, which is defined as the wavelength interval between the 3-dB points. That is the separation in the wavelength between the points on either side of the Bragg wavelength where the reflectivity has decreased to 50 percent of its maximum value. However, a much easier quantity to calculate is the bandwidth,

$$\Delta\lambda_0 = \lambda_0 - \lambda_B, \qquad (5)$$

where λ_0 is the wavelength where the first zero in the reflection spectra occurs. This bandwidth can be found by calculating the difference in the propagation constants,

$$\Delta\beta_0 = \beta_0 - \beta_B, \qquad (6)$$

Where, $\beta_0 = 2\pi N_{eff}/\lambda_0$ is the propagation constant at wavelength λ_0 for which the reflectivity is first zero, and $\beta_B = 2\pi N_{eff}/\lambda_B$ is the propagation constant at the Bragg wavelength for which the reflectivity is maximum. [11]. Tapering of the coupling coefficient along the grating length can also be used for dispersion compensation when the signal wavelength lies within the stop band, and the grating acts as a reflection filter. FBG can be used for dispersion compensation if the wavelength of the incident signal is offset from the center of' the stop band such that the signal spectrum sees a linear variation of the group delay [12].

III. SYSTEM DESIGN

The proposed optical system is designed by using the above methodology provides an all-optical, fiber-based solution for the dispersion problem. So this special kind of fiber, known as the dispersion-compensating fiber (DCF), was developed for this purpose. Dispersion-induced degradation of the optical signal is caused by the phase factor acquired by spectral components of the pulse during propagation inside the fiber.

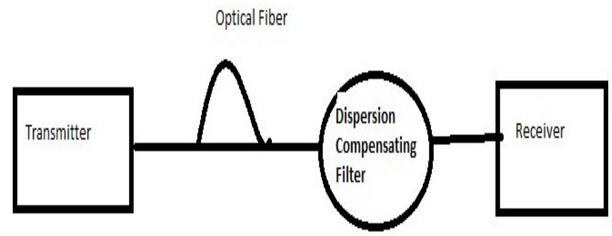

Fig. 1 Dispersion compensation using DCF

All dispersion-management schemes implement an optical dispersion-compensating "filter". If nonlinear effects are negligible, such a filter can be placed at the transmitter end, or at the receiver end, or somewhere along the fiber link. Consider the simplest situation shown schematically in Fig. 1, where a dispersion-compensating filter is placed just before the receiver. All the operation is tuned to the wavelength 1550 nm. Fig. 2 shows the system diagram of optical communication system for dispersion compensation.

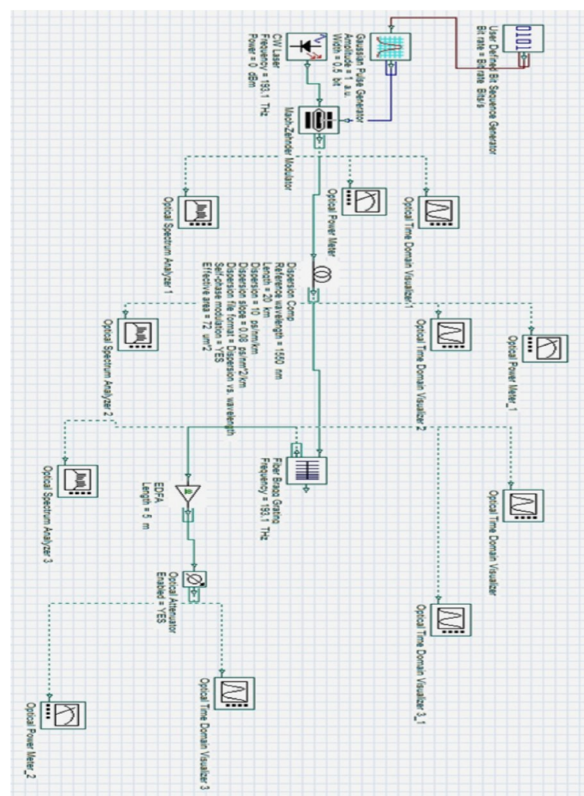

Fig.2 Plot of optical communication system for dispersion compensation

IV. SIMULATIONS AND RESULTS

The complete work represents the method to recover the losses which occur due to dispersion. The proposed design System helpful to compensate the losses using EDFA-FBG model. The Gaussian Light Beam is generated at the input end with user defined sequence. The power loss and the dispersion loss is successfully recovered. We measured the power and light beam at input, output and before the receiver. The result shows that we received the almost same power 46 µWatt at the output as applied at input. The Dispersion losses are also minimized and it is shown in Fig.3 measured by OTDV at input, mid and output level. Similarly, the Fig.4 shows the measured power at the same end.

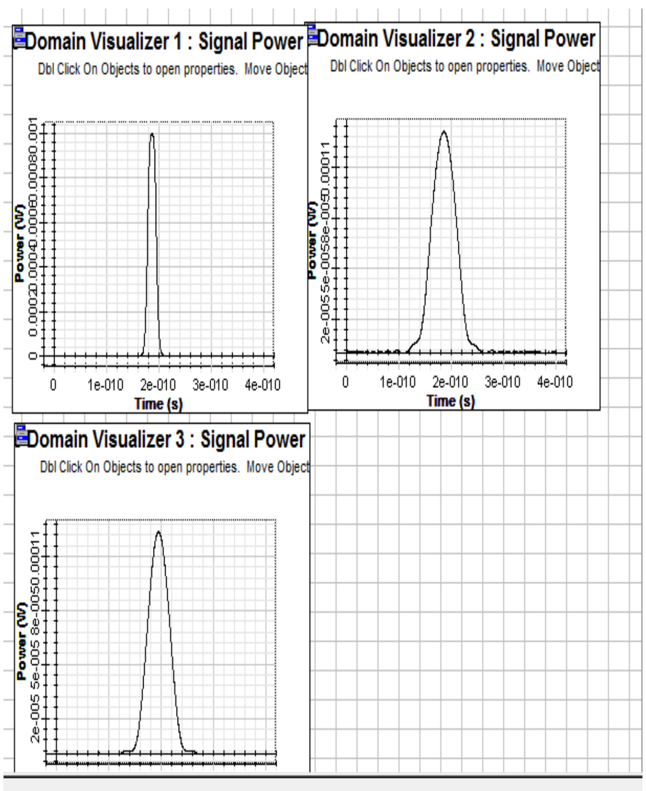

Fig.3 Plot of waveform which shows dispersion loss and compensation at input, middle and the output sides

Fig.4 Plot of measured power at input middle and the output side

V. CONCLUSION

The plots for the designs under investigation depict that device designed with FGB and EDFA will compensate the Dispersion losses up to 85%. Using FBG-EDFA model we successfully recovered the same power as inserted at the input end. The proposed system can be further modified using similar devices with different parameters.

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