# COMPENSATION OF DISPERSION IN OPTICAL FIBER USING FIBER BRAGG GRATING (FBG)

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## ABSTRACT

*This paper deals with the compensation of dispersion in optical fibers with the help of Fiber Bragg Grating (FBG). In this paper we have analyzed the dispersion compensation using Fiber Bragg Grating at different fiber lengths, we will also analyze the Q-Factor at different fiber lengths. We will see before using the Fiber Bragg Grating the Q-Factor will decrease continuously as fiber length increases, but after using the Fiber Bragg Grating the Q-factor will improve continuously as the fiber length increases. We will see the difference in Q-factor with the help of eye diagrams at different fiber length and subsequent graph. All the results are analyzed using OPTSIM simulation at 10 Giga bits per second (Gb/s) transmission systems.*

***Keywords – Optical Fiber, FBG, Optsim, Dispersion, Q-Factor***

## I INTRODUCTION

Dispersion is a source of pulse broadening which can become a limiting factor for optical fiber communications at higher transmission rates. In optics, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency [1]or alternatively when the group velocity depends on the frequency. Media having such a property are termed dispersive media. Dispersion is sometimes called chromatic dispersion to emphasize its wavelength-dependent nature, or group-velocity dispersion (GVD) to emphasize the role of the group velocity. Dispersion is most often described for light waves, but it may occur for any kind of wave that interacts with a medium or passes through an inhomogeneous geometry (e.g., a waveguide), such as sound waves.

Dispersion in optical fibers is caused by a variety of factors [2]. Intermodal dispersion, caused by the different axial speeds of different transverse modes, limits the performance of multi-mode fiber. Because single-mode fiber supports only one transverse mode, intermodal dispersion is eliminated [3]. In single-mode fiber performance is primarily limited by chromatic dispersion (also called group velocity dispersion), which occurs because the index of the glass varies slightly depending on the wavelength of the light, and light from real optical transmitters necessarily has nonzero spectral width (due to modulation). Polarization mode dispersion, another source of limitation, occurs because although the single-mode fiber can sustain only one transverse mode, it can carry this mode with two different polarizations, and slight imperfections or distortions in a fiber can alter the propagation velocities for the two polarizations [4,5,6]. This phenomenon is called fiber birefringence and can be counteracted by polarizationmaintaining optical fiber. Dispersion limits the bandwidth of the fiber because the spreading optical pulse limits the rate that pulses can follow one another on the fiber and still be distinguishable at the receiver [7].

Dispersion in optical fiber can be removed by dispersion compensating fibers or fiber bragg grating (FBG). This works by using a specially prepared length of fiber that has the opposite dispersion to that induced by the transmission fiber, and this sharpens the pulse so that it can be correctly decoded by the electronics.

## II FIBER BRAGG GRATING

A fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others [8]. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength specific dielectric mirror. A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector. Fiber Bragg grating can be used as a MUX/DEMUX device in WDM systems for extracting a signal (channel) with a particular wavelength from a stream of signals (channels)

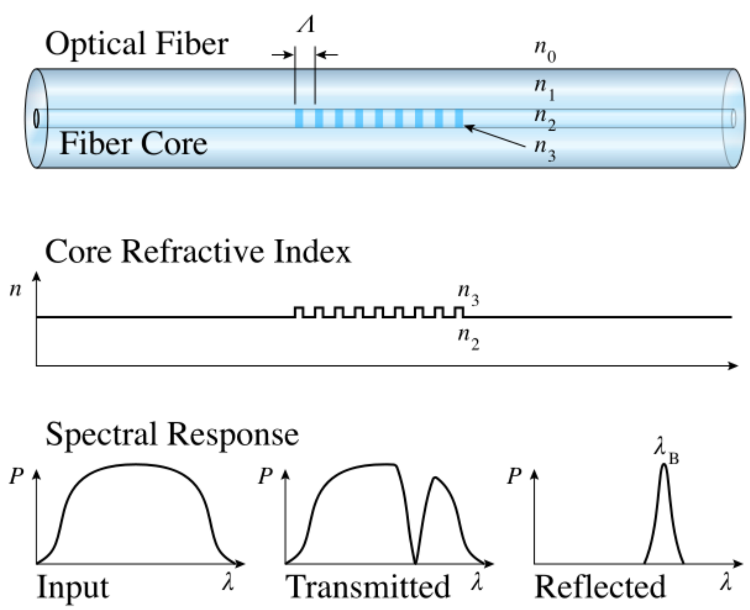



**Figure 1.1: A Fiber Bragg Grating Structure, With Refractive Index Profile and Spectral Response**

The fundamental principle behind the operation of fiber Bragg grating (FBG) is Fresnel reflection. Where light traveling between media of different refractive indices may both reflect and refract at the interface. The fiber Bragg grating will typically have a sinusoidal refractive index variation over a defined length. We have seen the definition of Bragg wavelength $\lambda_B$ from the previous section. The wavelength spacing between the first minima, (as shown in above figure), or the bandwidth $\Delta\lambda$ is given by,

$$\Delta\lambda = \left[\frac{2\delta n_0 \eta}{\pi}\right]\lambda_B$$

Where,

$\delta n_0$ is the variation in the refractive index ($n_3$-$n_2$), and

$\eta$ is the fraction of power in the core.

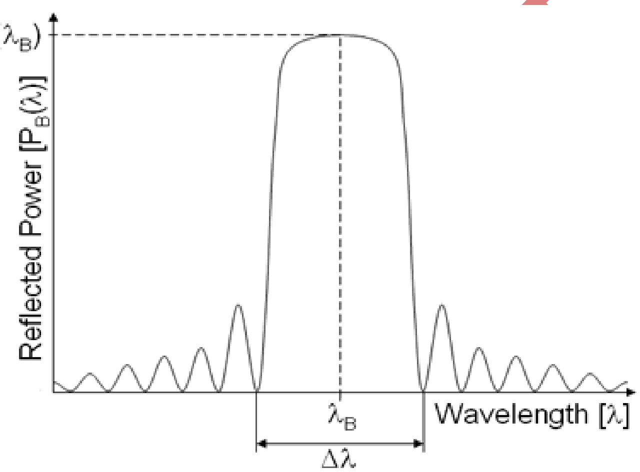



**Figure 1.2: Graph for Reflected Power versus Wavelength**

## III SIMULATION SETUP FOR DISPERSION COMPENSATION

The layout shown in Figure 1.3 has been implemented by using the software called *OPTSIM* which is one of the costliest simulation software's, exclusively meant for the optical communication purposes. It is specially designed, supported and marketed worldwide by RSOFT Design Group. It is also focused entirely on productivity tools for telecommunication and data communication engineering.

The components in the layout are for single channel. The data source used here is a Pseudo Random Binary Sequence (PRBS) generator. The period of the waveform, duty cycle, amplitude levels and data rates can be set in this generator. The light carrier is generated by Lorentzian laser source at the 1550 nm wavelength. The transmitter output is boosted up by the fixed gain Erbium Doped Fiber Amplifier (fixed_output_power). The Direct modulator laser component normally simulates a simplified continuous wave laser and a modulator component, which generates a continuous wave of constant amplitude and modulates the signal. Generally a fiber is after all a transmission medium which should bring the same status of the signal (both if the time domain as well as in frequency domain) at the input and output. At the transmitter end the bit rate 10 Gb/s, the center frequency is 193.55. The fiber used in this experiment is of length 100 km. The attenuation, dispersions such as chromatic and PMD dispersions, Raman effects, SPM, birefringence effects can be set in the fiber, as parameters the system is the PIN (Receiver, PIN) receiver, which uses the PIN (p-intrinsic-n) diode as a detector.

The pin photodiode simulated had 70% quantum efficiency. The dark current was simulated at 0.1 nA. The output of the receiver is given to the measurement devices which are fed through the electrical splitter, the electrical scope and the Q estimator.

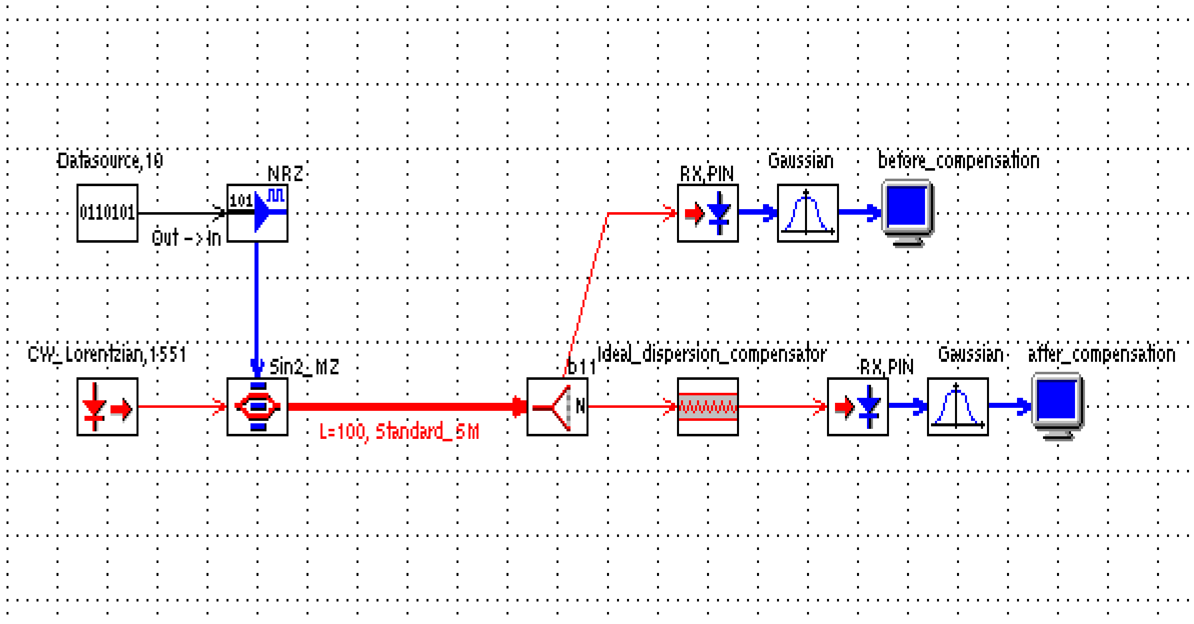
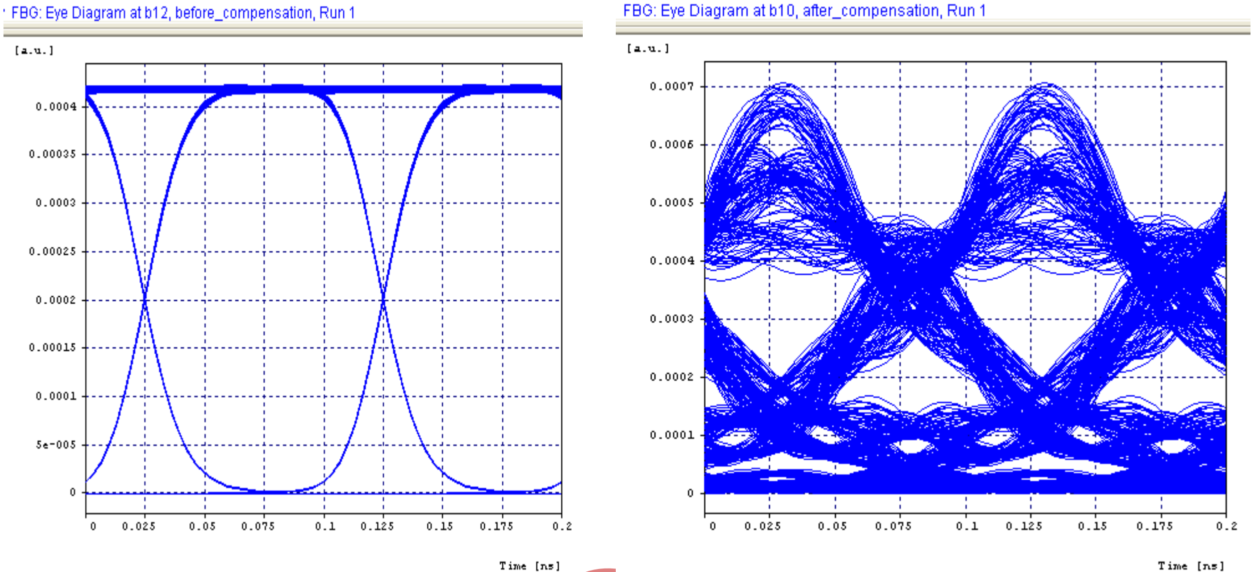



**Figure 1.3: OPTSIM Layout For Dispersion Compensation Using Fiber Bragg Grating (FBG).**

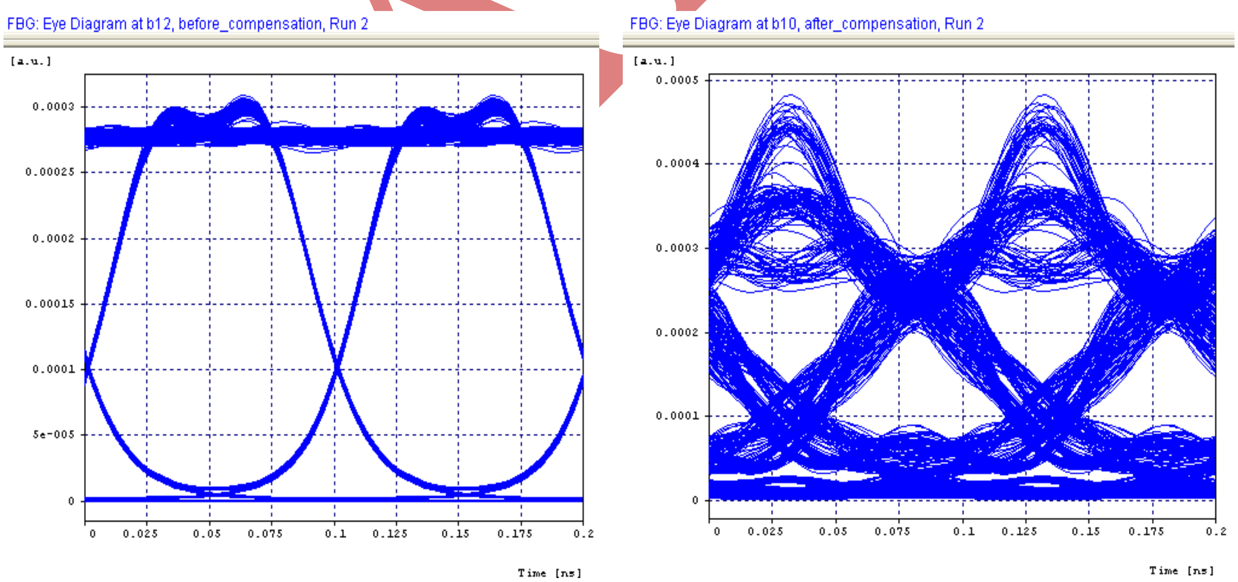
The optical spectrum of the signal is observed from optical spectrum analyzer (input and output) by splitting the signal from fiber link with the use of optical splitters. At the receiving end the optical fiber is divided into two parts. In first case we will directly take the results without using the fiber bragg grating (FBG). The results will be seen with the help of Eye diagrams. We will see as the fiber length is increased the Quality Factor of the fiber decreases subsequently. In the second case we received signal will pass through fiber bragg grating (FBG). From the optical splitter signal will go to the fiber compensator which will compensate the dispersion present in the fiber. Now the signal is received by the PIN photodiode detector. The system is the PIN (Receiver, PIN) receiver, which uses the PIN (p-intrinsic-n) diode as a detector. The pin photodiode simulated had 70% quantum efficiency. The dark current is very low in this diode. From here the detected signal is passed through the filter to remove the unwanted harmonics present in the signal. Finally we will see the various parameters of the received signal at the electrical spectrum. Here we will see the received results with the help of eye diagrams and subsequent quality factor value. The different results of the simulation are shown below.

## IV. FIGURES AND GRAPH



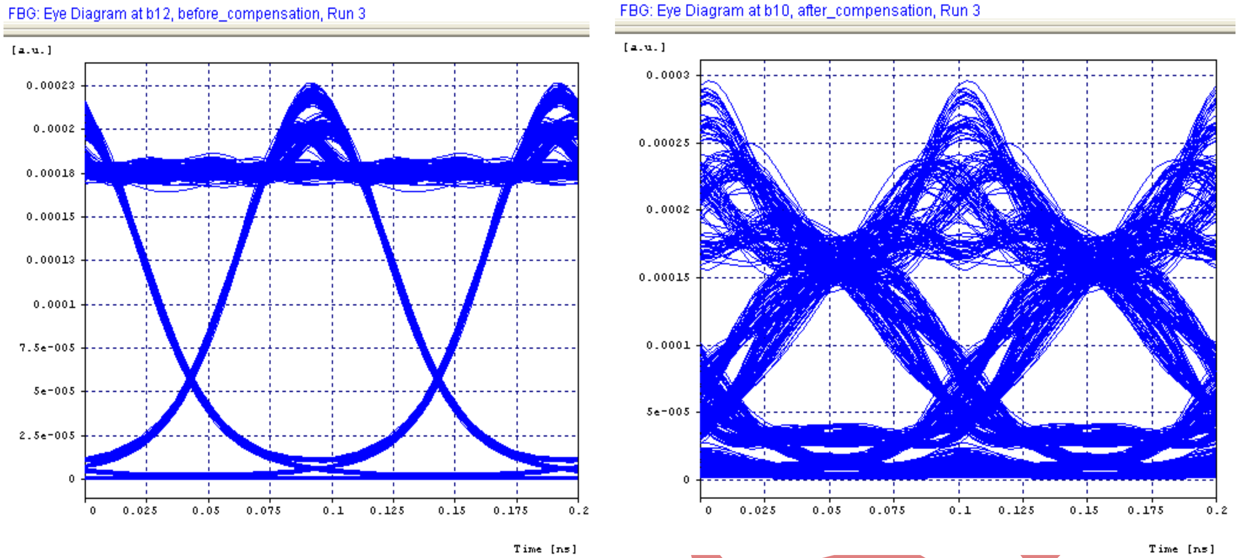

(a) (b)

**Figure 1.4: For optical fiber of length 1 km at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG**



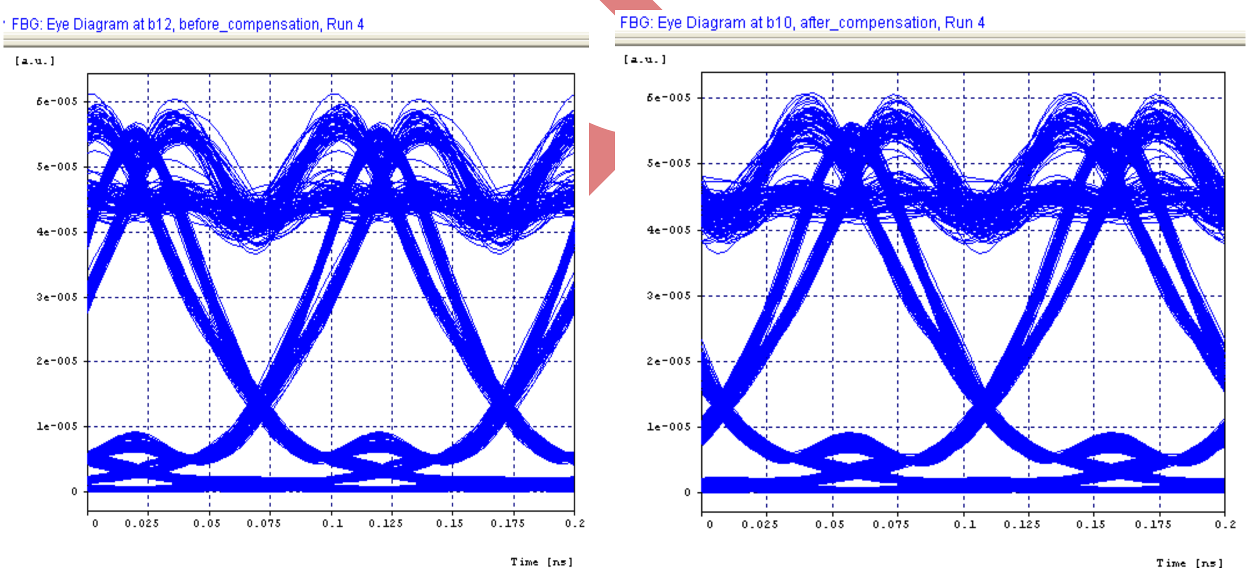

(a) (b)

**Figure 1.5: For optical fiber of length 10 kilometers at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG**



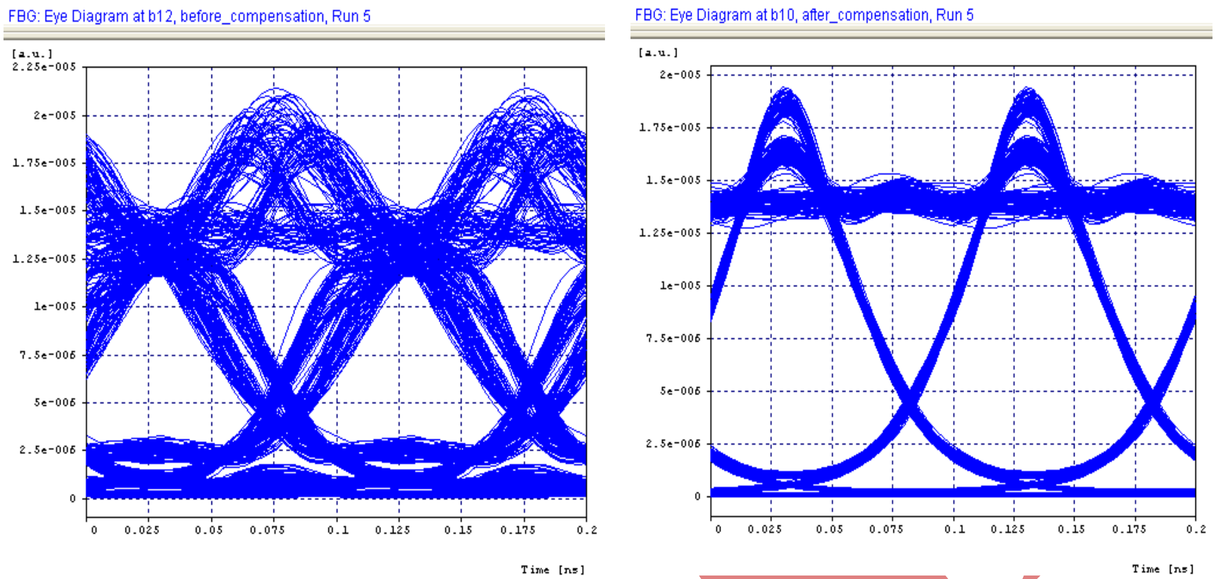

(a) (b)

**Figure 1.6: For optical fiber of length 25 kilometers at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG**



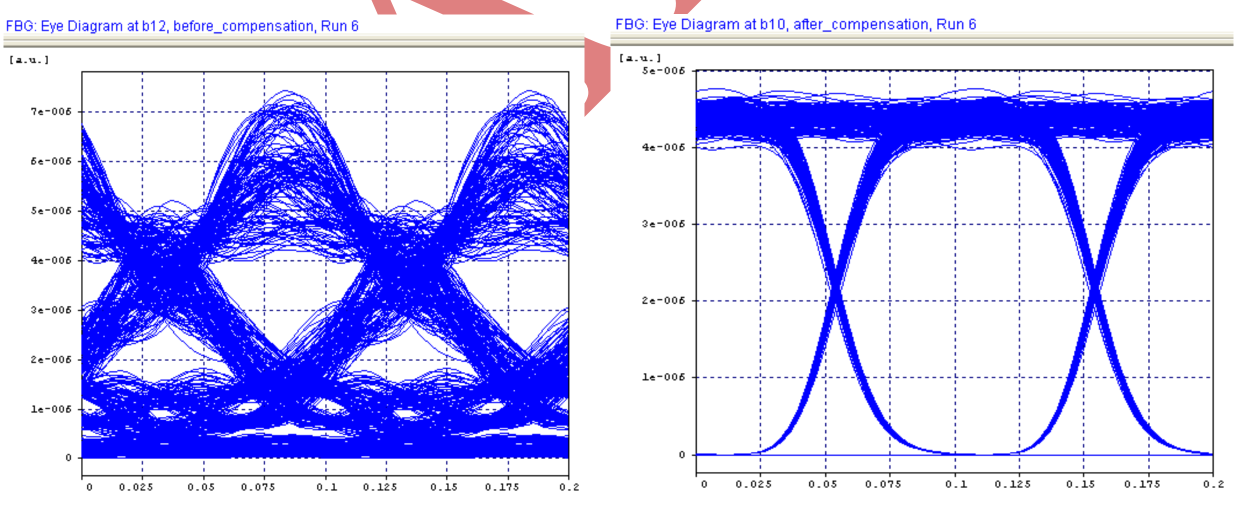

(a) (b)

**Figure 1.7: For optical fiber of length 50 kilometers at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG**




**(a)** **(b)**

**Figure 1.8: For optical fiber of length 75 kilometers at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG**




**(a)** **(b)**

**Figure 1.9: For optical fiber of length 100 kilometers at bit rate of 10 Gbps (a) Eye diagram before using FBG (b) Eye diagram after using FBG.**

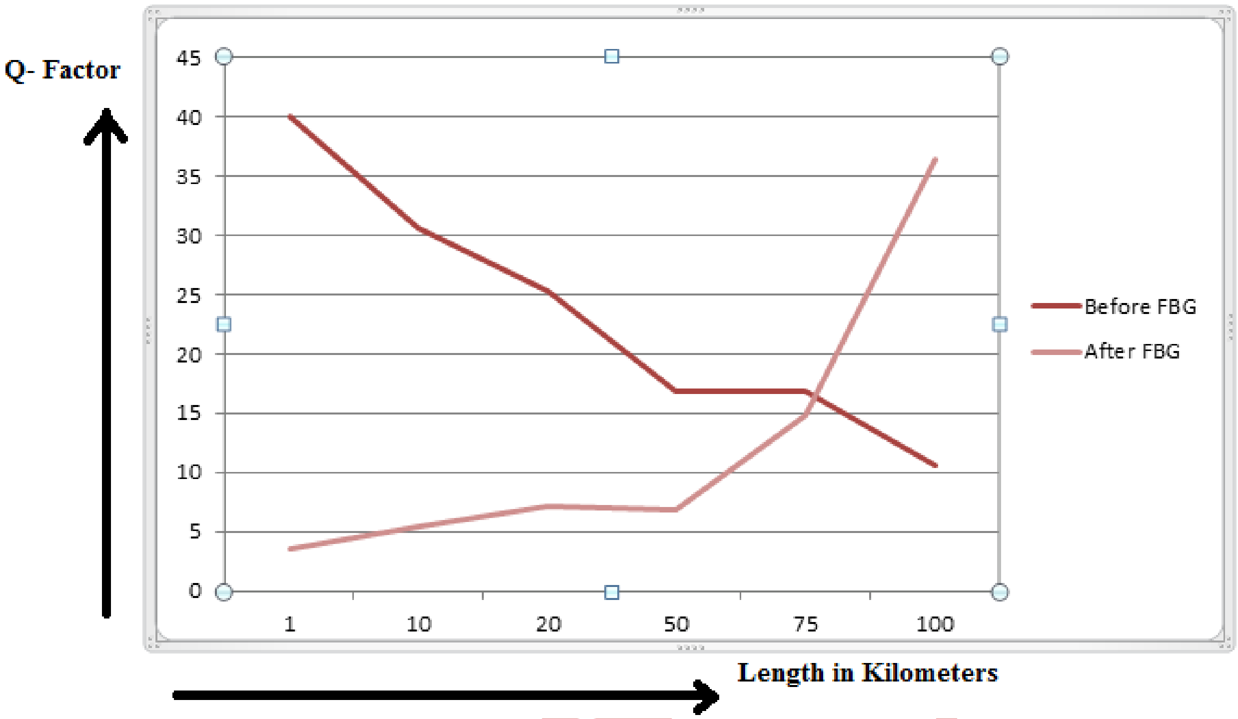



**Figure 1.10: Graph for Quality factor versus length in kilometers before using Fiber Bragg Grating (FBG) and after using Fiber Bragg Grating (FBG) at different values.**

## V. CONCLUSION

The effect of dispersion at different optical fiber lengths are reported in this paper. These effects are seen with the help of eye diagrams drawn for the different values of fiber lengths. Furthermore we have also shown the results with the help of graph comparing both the techniques one without using FBG and second using FBG. We have seen that with the help of Fiber Bragg Grating (FBG), the dispersion in optical fiber can be reduced to greater extent. But we are still not able to completely remove the dispersion from the optical fiber especially at higher bit rates, which is a topic of research and a challenge for the various scientists in the optical fiber field.

## V. ACKNOWLEDGEMENTS

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