Effect of Chromatic Dispersion on Multimode Fiber with varying Profile for Optical Access Networks

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Abstract: Optical networks are driving today and future generation networks due to high speed , low latency and high bandwidth.These networks can either work as a backbone networks or acess networks covering wide area network, metropolitical area network and local area network. This paper focusses on LAN area where multimode fiber is employed due to its inherent properities of low cost , but this type of fiber undergoes many signal loses like dispersion, attteunation etc. Through this paper the effect of chromatic dispersion on the multimode fiber with varying refractive index profiles is measured using trial version of optiwave software.The system is setup using inbuilt components from the softwae library at 10Gbps data rate and opearted at 850nm wavelength.The results obtained in this paper are used to compare BER, Eye diagram and LP modes travelling in MM fiber using NRZ modulation format using optical time domain visualizer and spatial visualizer.

Keywords: NRZ- Not Return to Zero, LP-linear polarized, MM- multimode fiber , LAN- local area network, BER- bit error rate,CD-chromatic dispersion,WDM,OCDMA , FTTH -fiber to the home covering optical line terminal (OLT) and optical network unit (ONU), LP-linearized polarized modes.

I. INTRODUCTION

Optical Networks have become reality beacause of the use of fiber as a transmission medium. Depending upon the applications, suitable fiber is added to the network for maximum quality transmission of the signals. Fiber is classified based on its refractive index and dimensions of core and cladding.When the dimensions of core are small in comparision to cladding the fiber is termed as single mode because of the restriction of propagation of higher order modes through the fiber [1,2]. To manufacture this type of fiber precise manufacturing controls are needed. Once fabricated this fiber can be used for long distance communication due to its inherint ability to overcome dispersion and other losses and can be employed in WAN and MAN networks and hence is can be used in all backhaul networks.The Other type of fiber is multimode fiber where the core dimensions are in comparable to cladding and is termed as multimode fiber and are generally employed in LAN configurations. The main advantage of MM fiber is low manufacuring cost. But the loses are more in comparision to single mode fiber because of multiple modes travelling in the fiber [1]. Multimode fiber is further classified based on its reflective index profile as will be discussed in coming sections.

A. *Optical networks***:** Optical networks are telecommunications network of very high capacity. They are based on optical technologies like WDM,OCDMA, FTTH covering optical line terminal (OLT) and optical network unit (ONU) and other fiber based components, which are used to route,amplify,restore and modify wavelength levels to desired power level so that minimum acceptable BER can be achieved. Based on the distance covered optical networks are broadly classified as LAN,WAN and MAN. Fig 1 shows the broad view of optical networks interconnected globaly. For MAN and WAN configuration single mode fiber is the preferred technology as transmission mode for optical networks and for LAN , multimode fiber is preferred due to its low cost.

B. *Reflective index profile***:** Any fiber is defined by its core and cladding reflective index. For total internal reflection to take place and hence light to propagate, core refractive index should be high over the cladding refractive index. If the change in refractive index from core to cladding is abrupt then this type of fiber is called as step index fiber and if there is a gradual change in the profile then it is termed as graded index fiber. Variation of profile from core to cladding is a subject of research which will minimize the losses and the signal will propagate through the fiber efficiently with minimal losses

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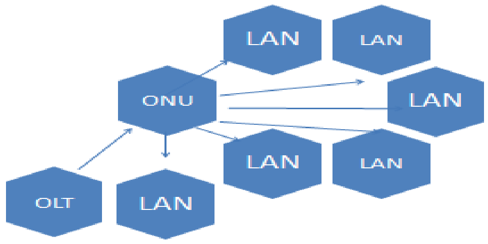

Fig 1: Optical Networks

While the signal is propagating in the fiber, signal undergoes attenuation, dispersion etc. to minimize these effects, proper index variation is desired from core to cladding [3, 4]. In this paper, we have considered three different refractive index profile fibers. a) Step index b) alpha=2 and c) parabolic index as shown in figure 2. In multimode fiber, the refractive index of the core is a quadratic function of the distance from the optical fiber axis, i.e., the variation is such that the refractive index within the core at any distance from the axis, r, is given by the relation

$$n_r = n_l(1 - br^2)^{1/2} \qquad \text{(i)}$$

where n_1 is the refractive index at r = 0, at the axis, r is the radial distance from the axis, and b is a constant given by the relation $b = 2\ \Delta/a^2$ where a is the value of r for which the refractive index becomes uniform, i.e., the radius of the core or half of the core diameter, and Δ is given by the relation

$$\Delta = (n1^2 - n2^2)/2n1^2 \qquad \text{(ii)}$$

where n^1 again is the refractive index at r = 0, i.e., at the axis, and n^2 is the refractive index at the outer edge of the core, i.e., at r = a.where n_1 is the parameter Refractive peak index at the fiber center, n_2 is the refractive index in the cladding, is the relative refractive index difference, a is the core radius and (b-a) is the cladding thickness

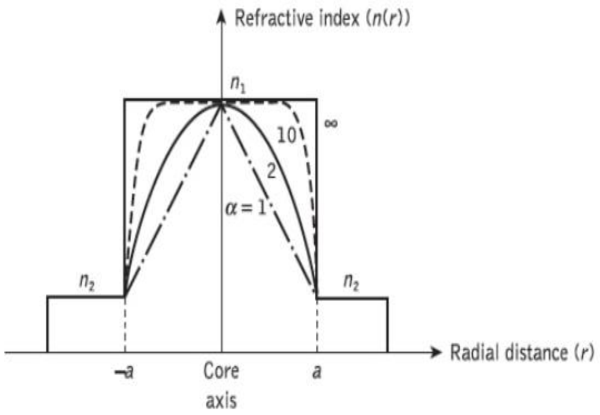

Fig 2: Refractive index profile with varying value of alpha: step index, alpha and parabolic index

C. *Dispersion:* Dispersion is the spreading out of a light pulse in time as it propagates in the fiber. Dispersion may cause inter symbol interference (ISI) and hence wrong reception of bits/ data. Dispersion may be handled carefully for successful transmission of signals. Depending upon the type of fiber, dispersionis classified as modal dispersion, material dispersion and waveguide dispersion. Material dispersion and waveguide dispersion together are termed as chromatic dispersion. In the present work, since multimode fiber is chosen as a transmission media, both chromatic and inter modal dispersion are present. We have tried analyzing the effect of total dispersion on varying refractive index profiles of the MM fiber at 10Gbps for LAN.

Figure 3 shows the phenomena of dispersion in multimode fiber[5,6,7]. The signal gets distorted due to many modes travelling in the fiber. The dispersed sinusoidal signal is shown here for reference.

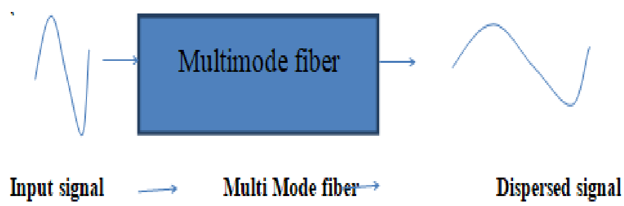

Fig 3: Dispersion Phenomena in multimode fiber

II. SYSTEM DESIGN

The LAN system is designed using spatial optical transmitter, index multimode fiber and spatial optical receiver in Optiwave photonic tool (trial version). The data is measured using optical time domain visualizer, spatial visualizer. The signal follows not return to zero modulation formats at 10Gbps at 850 nm wavelength with intermodal dispersion as -100ps/nm/km.The system under consideration,switches between intermodal dispersion only and both chromatic dispersion and intermodal dispersion modes. The simulation is run for three refractive index profiles for local area access networks. Fig 4 shows the layout of LAN system design at 10Gbps data rate using NRZ Modulation. The input values used for simulation are tabulated in Table 1 [8,9,10].

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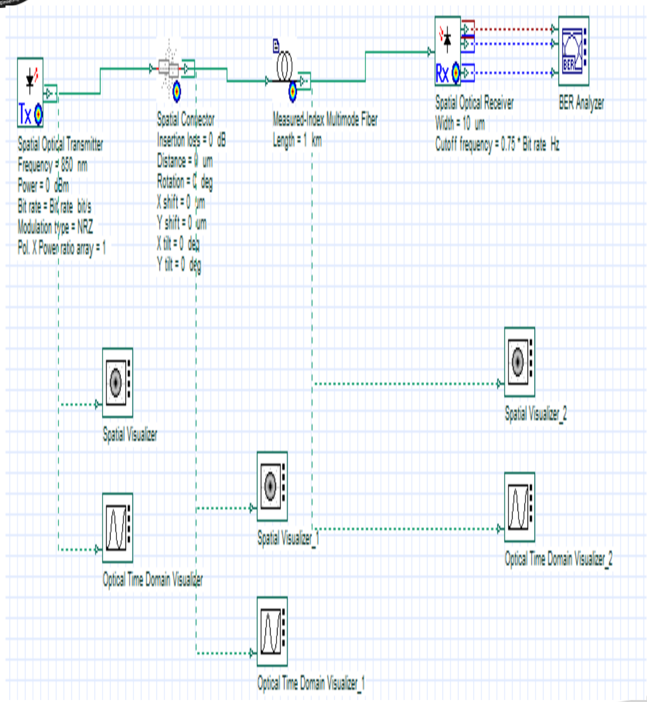

Fig 4: LAN system design at 10Gbps data rate using NRZ Modulation

Table 1: Design Parameters

S.NO	PARAMETER	VALUE
1)	Operating Wavelength	850nm
2)	Bit Rate	10Gbps
3)	Dispersion	-100ps/nm/km
4)	Modulation Format	NRZ
5)	Sequence Length	128
6)	Sample Per Bit	64
7)	Sensitivity	-100dBm
8)	Distance	1km
9)	Attenuation	2.61dB/km
10)	Alpha	2
11)	Parabolic	Core radius =25 µm Cladding thickness=10 µm

III. RESULTS AND DISCUSSIONS

In this section, the simulated results for variable refractive index profiles for two different dispersion parameters are presented in terms of bit sequences, linearly polarized modes and eye diagrams. Fig 5 and 6 showsbit sequence and LP modes at the output of transmitter and MM fiber for alpha as refractive index profile with intermodal dispersion and with internal dispersion and chromatic dispersion.Fig 7 and 8 shows similar graphs for parabolic profile and Fig 9 and 10 for step index. Fig 11 shows the results in terms of eye diagrams and the computer BER values.

Table 2 : Results in term of BER with varying fiber profile index

Profile index of MM fiber	**Dispersion**	**BER**
Alpha	Intermodal Dispersion	4.27e-188
	CD+ Intermodal Dispersion	9.25e-187
Parabolic	Intermodal Dispersion	1.24e-241
	CD+ Intermodal Dispersion	1.37e-240
Step	Intermodal Dispersion	2.8e-27
	CD+ Intermodal Dispersion	4.3e-27

It is observed from the simulated plots and the eyes diagrams that the signal deteriorates more when the chromatic dispersion is involved over inter modal dispersion for every profile. Further, among the three profiles under consideration it is observed from Fig 11 that the parabolic profile shows the best opening of eye over other two refractive index profiles. Hence among parabolic, step and alpha refractive index profiles, mm fiber with parabolic profile has the capability to minimum distort the signal over the step and graded profile. Further, step profile performance is too poor and the same can be observed from the Table 2 values of BER. Hence, for the chosen parameters parabolic profile and alpha should be used for MM fiber as a transmission media and compromise can be made over cost of choosing parabolic over alpha as refractive index profile. Hence priority can be given to parabolic profile for transmitting signals over LAN networks.

IV. CONCLUSION

For deriving today's communication networks in access areas for LAN preferred mode of transmission is multimode fiber because of lower manufacturing cost and high bandwidth. In this paper, MM fiber with different refractive index profiles are analyzed for various dispersion parameters at 850nm with 10Gbps data rate. The system is designed in photonics system design software. The results are analyzed in terms of bit sequences, LP modes, eye diagrams and BER. After simulating the designed system it is observed that MM fiber with parabolic refractive index is preferred index with minimum bit error rate for signal transfer considering both intermodal dispersion and chromatic dispersion.

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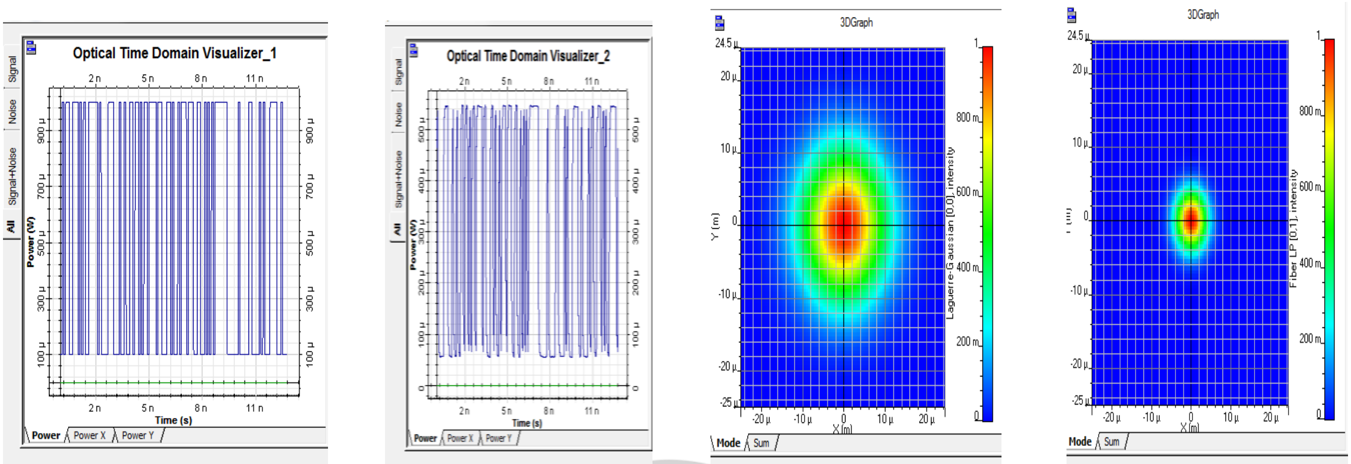

Fig 5: Bit sequence and LP modes at the output of transmitter and MM fiber for alpha as refractive index profile with intermodal dispersion without consideration of chromatic dispersion

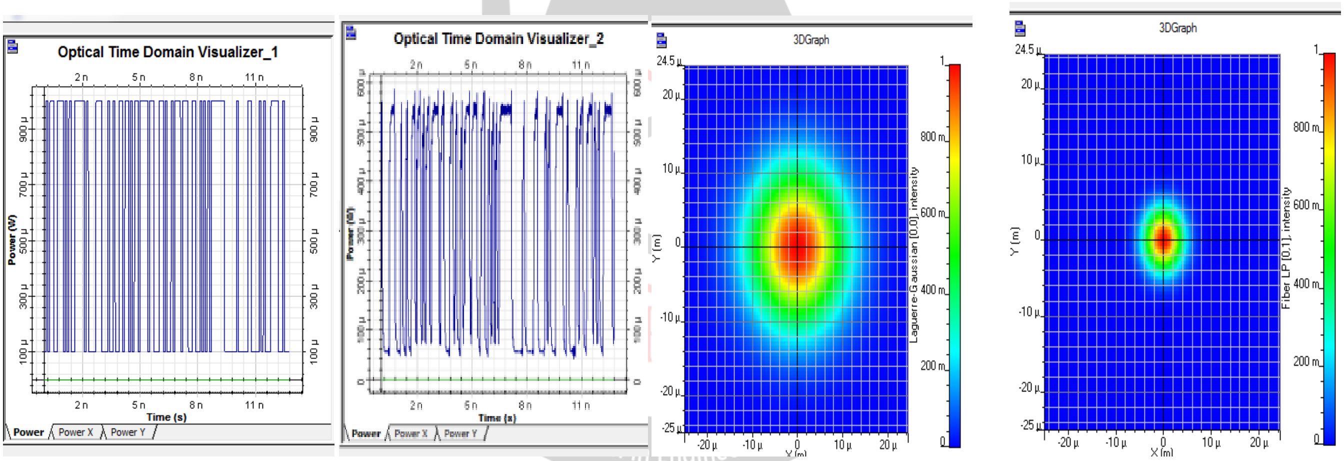

Fig 6: Bit sequence and LP modes at the output of transmitter and MM fiber for alpha as refractive index profile with intermodal and chromatic dispersion

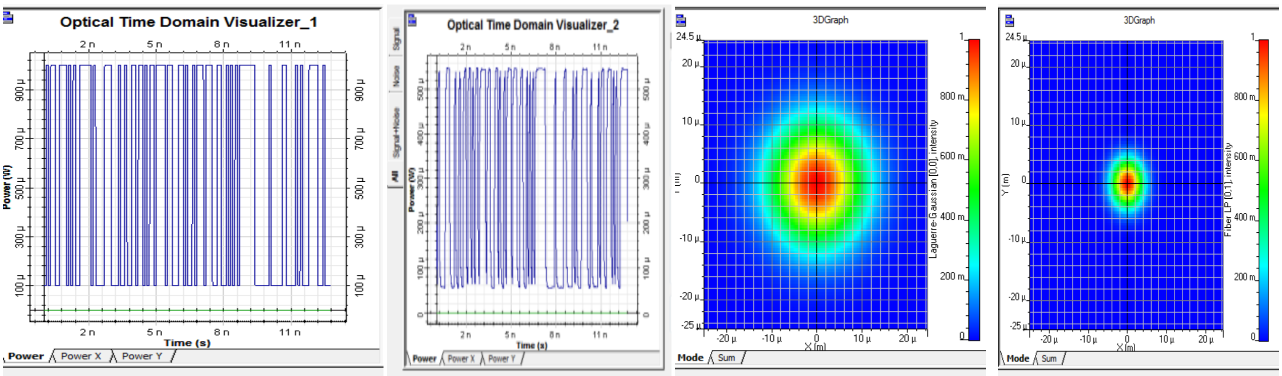

Fig 7: Bit sequence and LP modes at the output of transmitter and MM fiber for parabolic as refractive index profile with intermodal dispersion without consideration of chromatic dispersion

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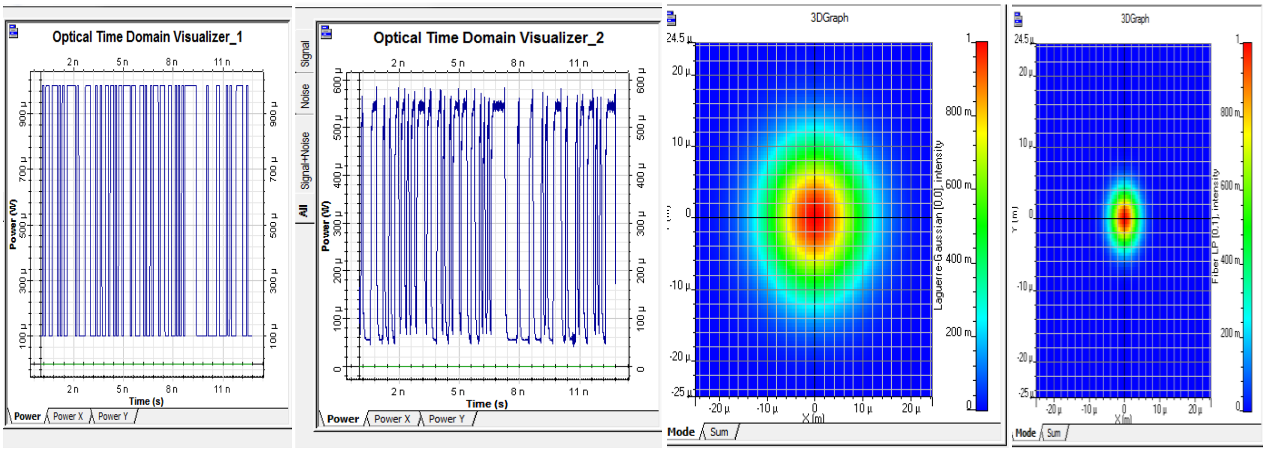

Fig 8: Bit sequence and LP modes at the output of transmitter and MM fiber for parabolic as refractive index profile with intermodal dispersion and chromatic dispersion

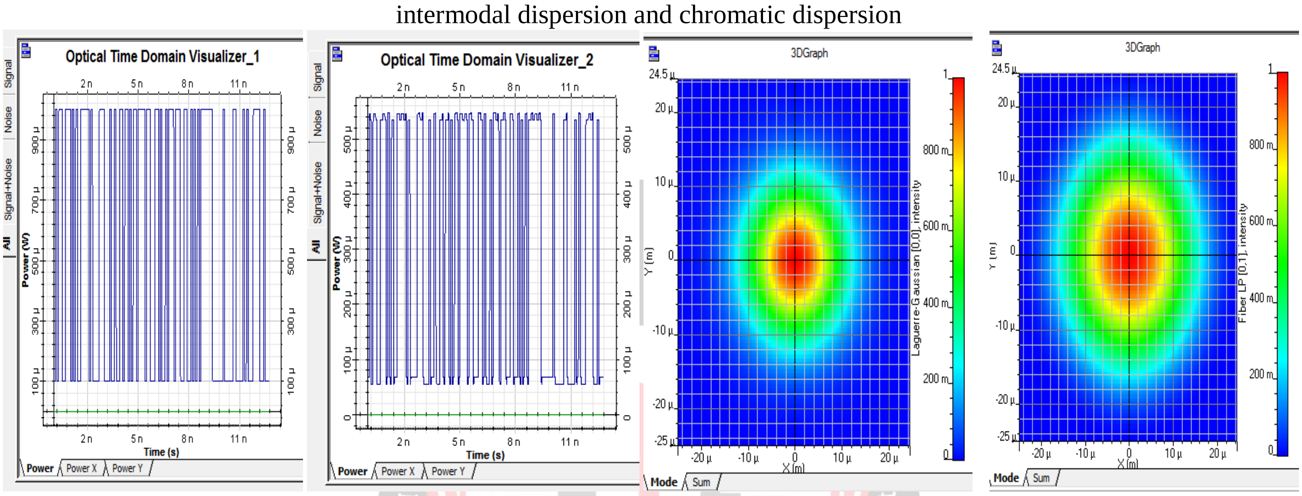

Fig 9: Bit sequence and LP modes at the output of transmitter and MM fiber for step refractive index profile with intermodal dispersion without consideration chromatic dispersion

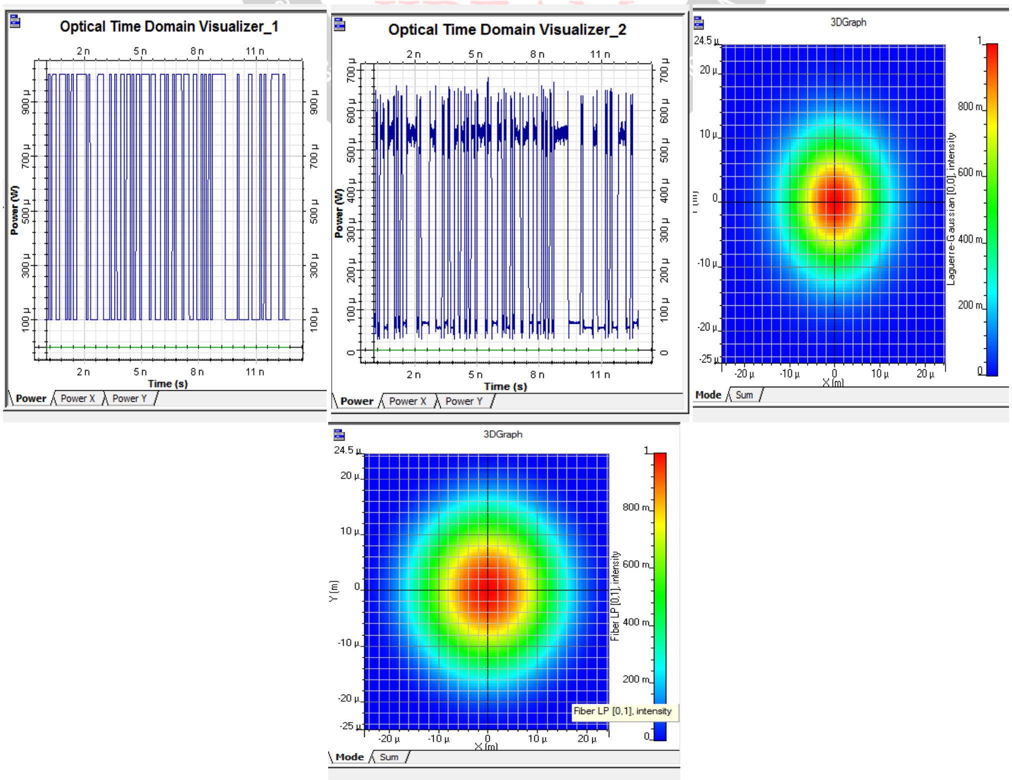

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Fig 10: Bit sequence and LP modes at the output of transmitter and MM fiber for step refractive index profile with intermodal dispersion and chromatic dispersion

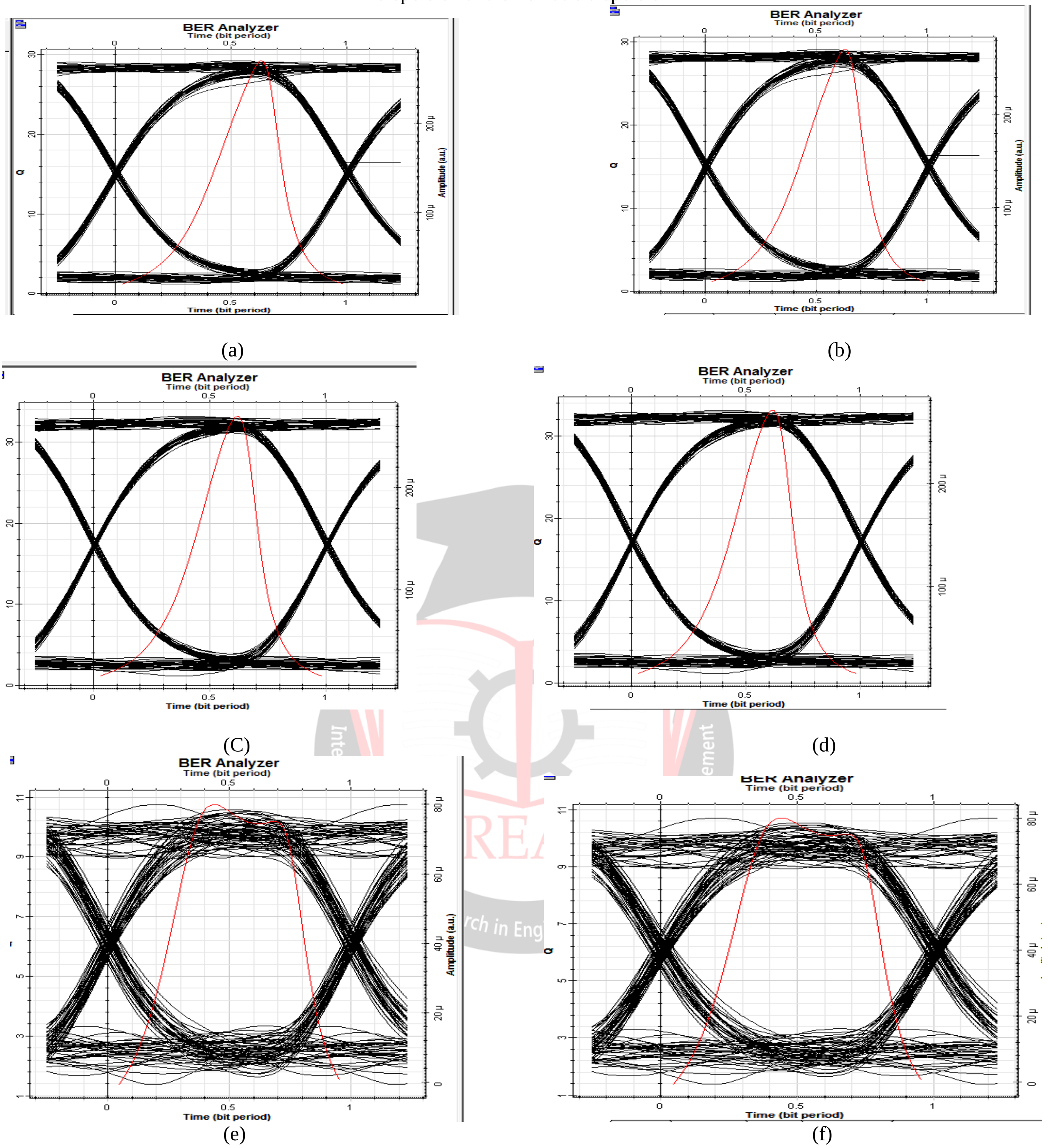

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Fig 11: Eye Diagrams for Alpha (a,b),Parabolic (c,d) & Step (e,f) Index Profile without and with chromatic dispersion for MM Fiber.

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