A Study of Signal Integrity in Multimode Fiber Links with Vortex Phase Launches

Jiajie Wu
Finisar Cooperation
No.66 Huiqing Rd. Shanghai China

Abstract- **In this paper, vortex launch scheme for coupling light into the skew ray of a gradient index multi-mode fiber (MMF) was studied. Simulation shows that with proper control of vortex order, signal integrity at the receiver end can be dramatically improved in case defects exist in MMF.**

I. Introduction

Fiber communication is widely used for local area networks (LAN's) applications. This has led to considerable demands in Ethernet links. However, for cost reasons, a majority of the installed fiber base today is composed of gradient index MMF [1]. In attempting to achieve higher data rates, a dominant limiting factor is the inter-symbol interference (ISI) caused by modal dispersion (MD) [2]. MD depends not only on launch conditions at the input of the fiber, but also on the variances in the fiber profiles that present themselves as various defects. Thus, a pulse of light that excites multiple modes inside the fiber arrives as several pulses at the output of the fiber, a phenomenon known as MD [3] which dominants the signal integrity in optical communication based upon MMF.

In transceiver design, electrical equalization [4] are widely used to mitigate the ISI caused by MD. However, this will also bring other issues such as noise enhancement and degradation of achievable bit-error ratio (BER) [5].

An alternative efforts to electrical equalization is to couple laser power into the MMF with phase adjustment [1]. Rather than focus majority of optical power into MMT by merely illuminating a small central fiber core area and hence a small number of low order modes are excited, this method excite higher order modes to reach better MD control [6].

In this paper, numerically simulated signal integrity in MMF links with different launched mode are discussed.

II. Simulation Setup

Fig. 1 shows the simulation setup with an 850nm laser as an output of 10Gbps optical signal. This optical signal is coupled by a vortex lens into a 300m 50/125 MMF and received by a photo diode. (Fig. 1).

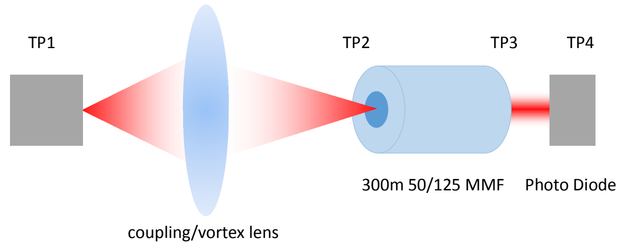

Fig. 1. Simulation Setup

The laser source has a spatial component constructed as fundamental Gaussian mode (Laguerre-Gaussian mode LG_{00}) with beam spot size of 25um. Which represents a radial overfilled launch condition. Output from laser is connected to coupling/vortex lens model, which applies radial/vortex transformation of phase front and focusing of incoming signal. The focal length is constantly set to ~500um and order of vortex will be discussed in result part.

In MMF links, refractive index (RI) profile always plays a crucial role in the propagation of optical signal. Two fibers were simulated, one MMF with ideal RI profile, and one MMF with RI dip defects in the center area (Index profile are shown in Fig. 2.).

For comparison, an exactly same type of photo diode is also place in TP2 (not illustrated) which show an input signal as shown in Fig. 3.

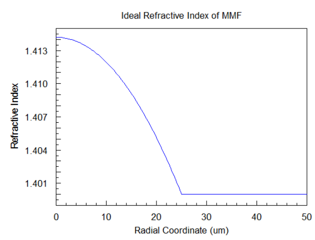

Fig. 2a

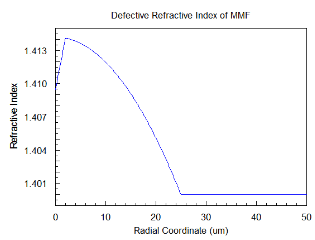

Fig. 2b

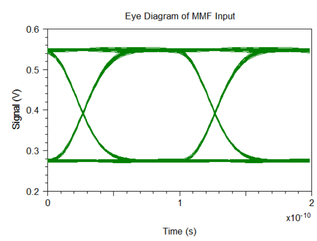

Fig.3.

978-1-4799-8379-7/151$31.00 ©2015 IEEE

III. Numerical Results

We compare the link performance difference ranges from vortex order m=0 to m=10. For m=0 case, this is typically a traditional focusing lens with output phase diagram made up by concentric circles (Fig. 4a.) and intensity distribution of LG_{00} unchanged (Fig. 4b.).

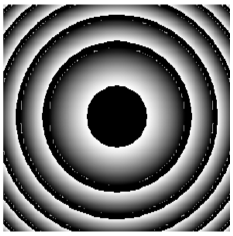

Fig. 4a

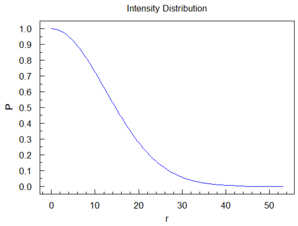

Fig. 4b

Under this launch mode, though the eye diagram in the receiver end is quite good after transmitting through an ideal 300m MMF (Fig. 5a) and basically have no bit-error-ratio (BER) at all (~10^{-145}). Eye diagram become really badly (Fig. 5b) with BER soaring up to ~10^{-5}.

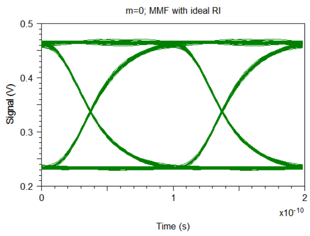

Fig. 5a

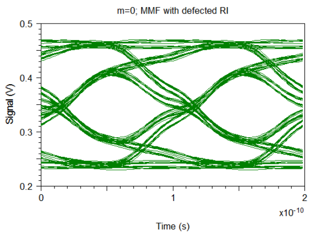

Fig. 5b

With vortex order increase from m=0 to m=10. Position of intensity maximum at the TP2 shift from 0um (central position) to 7um (Fig.6). Since higher optical orders inside the fiber are excited due to this intensity distribution shift produced by phase shift (Fig.7). The impact of RI defects shown in Fig. 2b is largely mitigated and obvious signal integrity improvement is observed by comparing Fig. 8 with Fig. 5b.

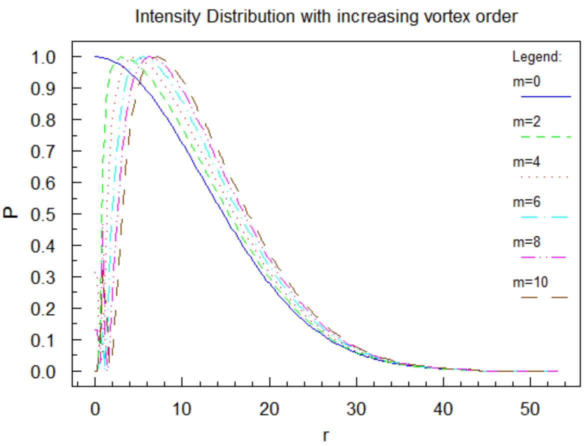

Fig. 6.

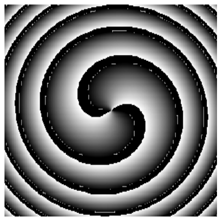

Fig. 7a. (m=2)

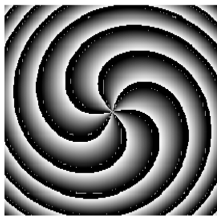

Fig. 7b. (m=6)

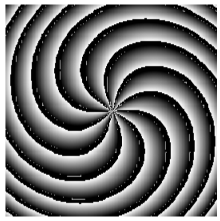

Fig. 7c. (m=10)

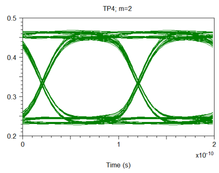

Fig. 8a. (m=2)

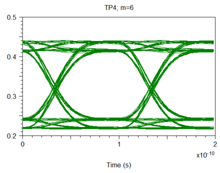

Fig. 8b. (m=6)

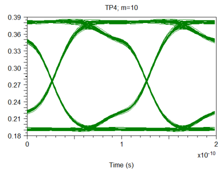

Fig. 8c. (m=10)

A plot of BER vs. vortex mode (Fig. 9) also shows that utilizing vortex phase into MMF launch mode can help to improve the BER.

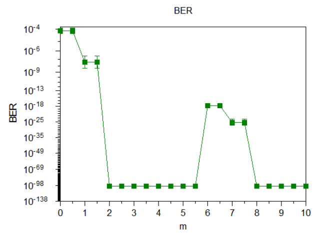

Fig. 9

IV. Conclusion

Our study shows that applying vortex launch can help to overcome the defects in MMF and significantly improve the signal integrity.

V. Reference

[1] E. G. Johnson, J. Stack, and C. Koehler, "Light Coupling by a Vortex Lens into Graded Index Fiber," *Journal of Lightwave Technology*, vol. 19, No.5, May 2001

[2]G. P. Agrawal, *Fiber-optic Communications Systems*, New York: Wiley, 2002

[3] R. A. Panicker, A. P. T. Lau, J. P. Wilde, and J. M. Kahn, "Experimental Comparison of Adaptive Optics Algorithms in 10-Gb/s Multimode Fiber Systems", *Journal of Lightwave Technology*, Vol. 27, No.24, December 15, 2009

[4] H. Wu. J. A. Tiemo, P. Pepeljugoski, J. Schaub, S. Gowda, J. A. Kash, and A. Hajimiri, "Integrated transversal equalizers in high-speed fiber-optic system," *IEEE J. Solid-State Circuits*, vol. 38, pp. 2131-2137, Dec. 2003

[5] J. G. Proakis, *Digital Communication,* New York: McGrawHill, 2001

[6] M. Webster, L. Raddatz, I. H. White, and D. G. Cunningham, "A Statistical Analysis of Conditioned Launch for Gigabit Ethernet Links Using Multimode Fiber," *Journal of Lightwave Technology,* vol. 17, No. 9, Sept. 1999