4 X 2.5Gbps-10GHz WDM-MDM Ro-FSO with Spiral-Phased LG-HG Modes

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Abstract – Radio-over-free-space optics (Ro-FSO) is a remarkable technology for seamless integration of wireless and optical networks. In this work, hybrid wavelength division multiplexing (WDM) and mode division multiplexing (MDM) of spiral-phased Laguerre-Gaussian (LG) and Hermite-Gaussian (HG) modes is adopted for transmitting four independent channels. Each channel carries 2.5Gbps-10GHz data over a free-space link of 2km.

Index Terms – mode division multiplexing, wavelength division multiplexing, radio-over-free space.

I. INTRODUCTION

Optical transmission systems have witnessed remarkable growth over the last decade across the world. With the increased popularity of online services, the demand for bandwidth has increased, resulting in a rise in the number of subscribers. This sudden growth in the number of subscribers and data bandwidth has led to the scarcity of radio frequency (RF) spectrum among wireless operators [1]. In such cases, Ro-FSO technology can be used for eliminating RF spectrum congestion in current wireless networks. Ro-FSO transmits RF signals through a high-speed optical carrier without expensive optical fiber cabling or RF licensing [2-5]. Moreover, Ro-FSO, either centralized or shared by the base stations, can be used in a number of processes including RF up-down conversion, switching, handoff, coding, and multiplexing [6]. This technology is highly compatible with the existing mobile cellular network architecture with several advantages such as RF signal distribution at high bandwidth, low attenuation losses and low power consumption [7].

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Recent update on Ro-FSO technology include experimental measurements [8-10] and statistical modeling [11, 12] under various atmospheric turbulence effects. Multiplexing of wavelength [13], intensity [14], and phase dimensions [15] have been demonstrated to increase the capacity of Ro-FSO systems. In order to replace wired connectivity with backhaul option of point-to-point communication between two base stations, two spectrum bands, lower (10.15 – 10.30 GHz) and upper (10.50 – 10.65 GHz) with 10 GHz frequency spectrum are used for fixed wireless access in Malaysia [16].

In this work, hybrid wavelength division multiplexing (WDM) and mode division multiplexing (MDM) of spiral-phased LG and HG modes are adopted for the transmission of 4 independent 2.5Gbps-10GHz data carrying channels over a free-space optical link of 2km which has not been reported in any previous work to the authors’ best knowledge.

The rest of the paper is divided as follows: Section II describes system description; Section III presents results and discussion followed by Section IV which depicts conclusion.

II. SYSTEM DESCRIPTION

Fig.1 shows proposed hybrid 4 x 2.5 Gbps-10GHz WDM-LG-HG system simulated in OptiSystem™ V13 software. Four independent non return to zero (NRZ) based channels are transmitted over free space channel having span of 2 km. Each channel carrying 2.5 Gbps NRZ data and 10 GHz radio signal is modulated simultaneously by a LiNbO3 optical modulator. Spiral phases LG and HG modes are generated with the aid of a spatial laser having power of 0 dBm and vortex lens with parameter m = 0. Two channels are operated on spiral phases LG 00 and LG 01 modes with optical wavelength of 850 nm whereas remaining two channels are operated on spiral phases HG 00 and HG 01 modes with optical wavelength of 851 nm. The output of all channels are combined and transmitted over free space link followed by pre and post optical amplifier to minimize
nonlinear effects. The FSO link is assumed to operate in clear weather condition with the transmitter and receiver aperture of 15cm and 20cm respectively.

At receiver end, modes are de-multiplexed by using a mode selector with the corresponding wavelength. A spatial Avalanche photodiode is used to recover original transmitting signal. Finally, a bit error rate (BER) tester is used to evaluate BER of recovered transmitted signal.

III. RESULTS AND DISCUSSION

In this section, results obtained from simulation are presented and discussed. Fig. 2 depicts the (a) Q factor and (b) BER measured at output of Channel 1 and Channel 2 by BER Tester. The value of Q factor for Channel 1 operating on LG 00 Mode is noted as 35.12dB, 14.22dB and 7.87dB whereas for Channel 2 operating on LG01, the Q factor is noted as 27.12dB, 9.12dB and 5.11dB at a FSO range of 500m, 1250m and 2000m respectively. Similarly, the value of log of BER for Channel 1 is noted as -281.12, -46.11 and -14.18 whereas for Channel 2, the BER is noted as -161.11, -71.43 and -7.12 at FSO range of 500m, 1250m and 2000m respectively. It is been concluded from Fig. 2 that LG mode 00 performs better as compared to LG 01 mode as the latter mode more affected by multipath fading effect.

![Fig.1 Proposed 4 x 2.5Gbps-10GHz Hybrid Spiral Phases LG–HG Transmission System](image1)

![Fig. 2 Performance Evaluation of Channel 1 and Channel 2](image2)
Fig 3 represents the (a) Q factor and (b) BER measured at output of Channel 3 and Channel 4. The value of Q factor for Channel 3 operating on HG 00 mode is noted as 33.11dB, 14.08dB and 8.35dB whereas for Channel 4 operating on HG 01 mode, the Q factor is noted as 29.17dB, 10.36dB and 5.45dB at FSO range of 500m, 1250m and 2000m respectively. Similarly, the value of log of BER for Channel 3 is noted as -244.43, -44.13 and -15.68 whereas for Channel 2, the BER is noted as -187.16, -24.53 and -7.18 at a FSO range of 500m, 1250m and 2000m respectively.

![Figure 3](image)

**Fig. 3 Performance Evaluation of Channel 3 and Channel 4 (a) Q Factor versus FSO Range (b) BER versus FSO Range**

It is observed from Fig. 3 that HG mode 00 performs better as compared to LG 01 as the latter mode is more affected from multipath fading effect. The clear eye diagrams measured at FSO range of 2000m shows successful transmission of 4 x 2.5Gbps-10GHz data as illustrated in Fig.4.

![Figure 4](image)

**Fig. 4 Measured Eye Diagrams at FSO range of 2000m (a) Channel 1 (b) Channel 2 (c) Channel 3 (d) Channel 4**
IV. CONCLUSION

In this work, four independent channels, carrying 2.5Gbps-10GHz each, are transported over a FSO link having a span of 2km. Hybrid combination of spiral-phased LG and HG modes are used for transmission. The results are reported in terms of Q a factor, BER and eye diagram, which show that all channels are transported and successfully retrieved at receivers. LG 00 and HG 00 modes perform better compared to LG 01 and HG 01 modes as the latter modes are more affected by severe multipath fading.

References


