A 50 m/40 Gbps 680-nm VCSEL-based FSO communication

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Abstract: A 50 m/40 Gbps 680-nm VCSEL-based free-space optical communication employing three-stage injection-locked technique and afocal scheme is proposed and experimentally demonstrated. Three-stage injection-locked technique, which can significantly increase the resonant frequency of VCSEL, is expected to provide higher transmission rate in an FSO communication.

1. Introduction

Free-space optical (FSO) communications transmit high quality signal and high-speed data rate by laser light propagation in free-space links. The main features of FSO communications are high directivity, unlicensed bandwidth, easy installation, and multi-gigabit mobile applications by using flexibility through a free-space link [1], [2]. FSO communications have attracted a lot of attention as one of the promising candidates for wireless communications due to several advantages over the conventional radio frequency (RF)-based wireless communications. FSO communications are therefore developed with high expectation to overcome the wireless connection issues. A 10 m/25 Gbps two-stage injection-locked 680-nm vertical-cavity surface-emitting laser (VCSEL)-based light-based WiFi (LiFi) transmission system was demonstrated previously [3]. Three-stage injection-locked technique has been used in optical fiber networks to improve the transmission performance of systems [4]. In this paper, a 680-nm VCSEL-based FSO communication employing three-stage injection-locked technique and afocal scheme is proposed and experimentally demonstrated.

2. Experiments and discussions

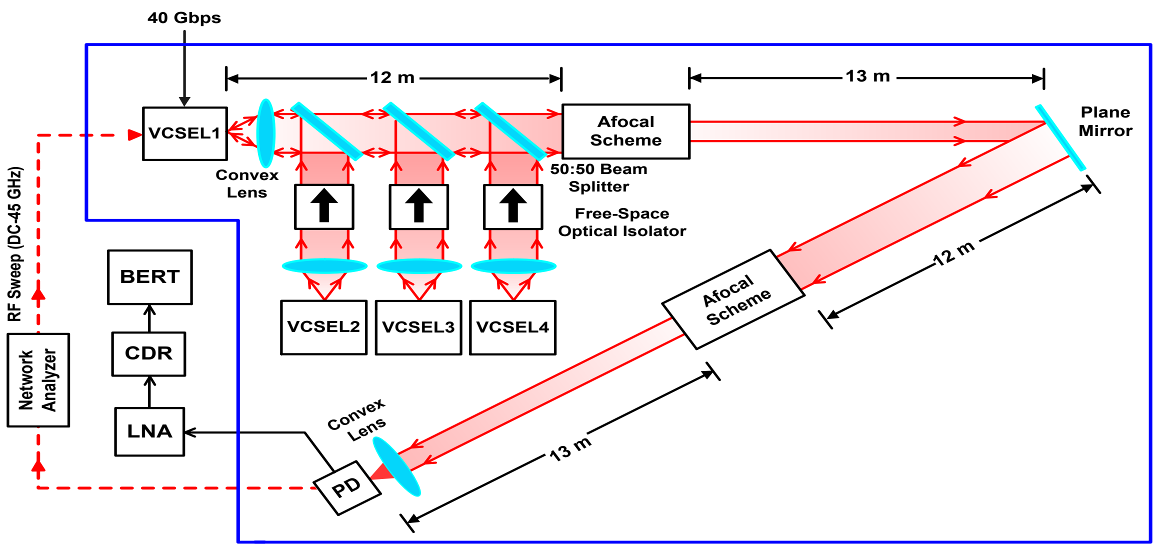

Fig. 1. The experimental configuration of the proposed 50 m/40 Gbps 680-nm VCSEL-based FSO communication that employs three-stage injection-locked technique and afocal scheme.

The experimental configuration of the proposed 50 m/40 Gbps 680-nm VCSEL-based FSO communication that employs three-stage injection-locked technique and afocal scheme is shown in Fig. 1. The VCSEL1, with 3-dB bandwidth/wavelength range/color of 5.2 GHz/681.74–682.12 nm/red, is directly modulated by a 40 Gbps pseudorandom binary sequence (PRBS) of 215-1. For the three-stage injection locking, the VCSEL2 is used as the first injection light source with an injection power level of 4.4 dBm. Light is injected through a convex lens, a free-space optical isolator with an isolation of 38 dB, and a 50:50 beam splitter. The function of the beam splitter is to split a beam of light in two. In addition, the VCSEL3 and VCSEL4 are used as the second and third injection light sources with injection power levels of 6.2 dBm and 6.4 dBm, respectively. Lights are also injected through convex lenses, free-space optical isolators, and 50:50 beam splitters. After light emitted from the three-stage injection-locked VCSEL1, the light is divergent, fed into the convex lens, passed through three beam splitters, launched into an afocal scheme, and reflected by a plane mirror. Over a 50-m (25+25 m) free-space link, the visible laser light with a data stream of 40 Gbps is reached to a photodiode (PD). Fig. 2 illustrates the afocal scheme, comprising two convex lenses with different focal lengths of 10 cm (f_1) and 5 cm (f_2), which employed in the 680-nm VCSEL-based FSO communications. For an afocal scheme, the separation distance (d) of two convex lenses is equal to the sum of the focal lengths ($d = f_1 + f_2$). Since the diameter of the collimated beam has been reduced, yet the free-space transmission distance of FSO communications can be further extended.

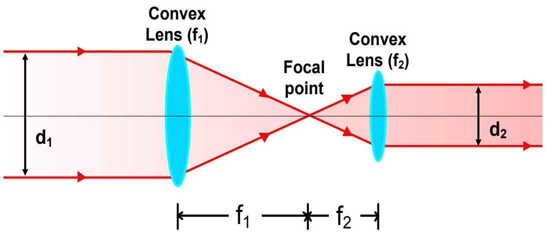

Fig. 2. The afocal scheme, which employed in the FSO communications.

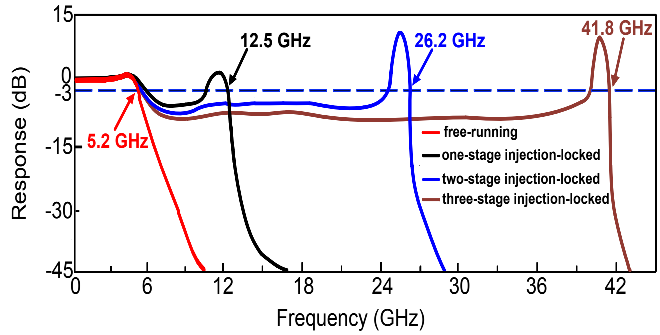

Fig. 3. The frequency response of the injection locking scenarios

The frequency response of the 680-nm VCSEL-based FSO communications for free-running, one-stage injection locking, two-stage injection locking, and three-stage injection locking scenarios are presented in Fig. 3. For free-running scenario, the 3-dB bandwidth is 5.2 GHz; for three-stage injection locking scenario, however, the 3-dB bandwidth is increased up to 41.8 GHz as anticipated. This finding shows that the three-stage injection-locked 680 nm VCSEL transmitter is powerful enough for 40 Gbps transmission.

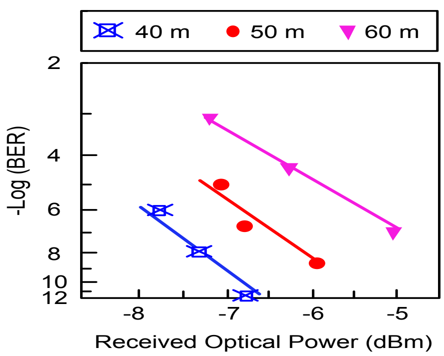

Fig. 4. The measured BER curves of the FSO communications.

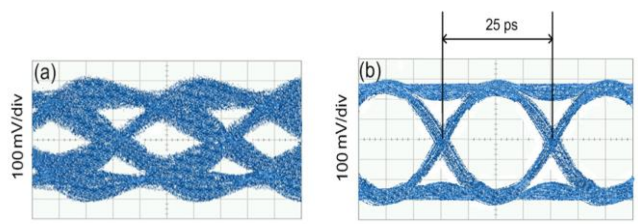

Fig. 5. The eye diagrams of the 40 Gbps data stream over a 50-m free-space link (a) without employing LNA and CDR; (b) with employing LNA and CDR concurrently.

The measured BER curves of the 680-nm VCSEL-based FSO communications at a data stream of 40 Gbps over 40 m/50 m/60 m free-space transmission distances, as LNA and CDR are employed simultaneously, are shown in Fig. 4. As shown, as the free-space transmission distance increases the BER value increases as well. As the free-space transmission distance is larger than 50 m, the BER value is higher than 10^{-9}. The eye diagrams of the 40 Gbps data stream over a 50-m free-space link without/with employing LNA and CDR are displayed in Figs. 5(a) and 5(b), respectively.

3. Conclusions

A 50 m/40 Gbps FSO communication based on a three-stage injection-locked 680 nm VCSEL transmitter and afocal scheme is proposed and demonstrated. With the help of LNA and CDR at the receiving site, low BER operation and clear eye diagram are achieved.

4. References

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