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DWDM FSO COMMUNICATION WITH AFOCAL SCHEME

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Abstract: This paper proposes and presents the experimental demonstration of 320-Gb/s free-space optical (FSO) communication based on dense-wavelength-division-multiplexing (DWDM) technology and afocal scheme. To the best of our knowledge, this is the first one that adopts DWDM technology and afocal scheme to successfully demonstrate 50-m/320-Gb/s FSO communication. Results show that the free-space transmission distance is greatly increased by the afocal scheme and that the free-space transmission rate is significantly enhanced by the DWDM technology. DWDM FSO communication over a 50-m free-space link with a total transmission rate of 320 Gb/s is achieved. With the aid of a low-noise amplifier and clock/data recovery at the receiving site, good bit-error-rate (BER) performance and clear eye diagram are obtained at a 50-m/320-Gb/s operation. Such 50-m/320-Gb/s DWDM FSO communication provides the advantages of optical wireless communications for long transmission distance and high transmission rate, which is thoroughly useful for long-haul and high-speed light-based WiFi (LiFi) applications.
Index Terms: Afocal scheme, dense-wavelength-division multiplexing, free-space optical communication.

I. INTRODUCTION

FREE-space optical (FSO) communications are being developed to create high-speed, high security, and friendly communications employing high bandwidth and a high capacity light signal instead of traditional radio-frequency (RF) communications. FSO communications have many attractive characteristics, such as worldwide available and license-free bandwidth, non-interference with radio bands, and the promotion of multi-Gigabit optical wireless applications by facilitating flexibility through free-space transmissions. Therefore, the development of FSO communications is expected to overcome the wireless connection issues. For a real and practical implementation of FSO communication, long transmission distance and high transmission rate are the major interests of system designers. In this paper, a 320-Gbps FSO communication with afocal scheme and dense-wavelength-division-multiplexing (DWDM) technology is proposed. The free-space transmission distance is greatly increased by the afocal scheme, and the free-space transmission rate is significantly enhanced by the DWDM technology. Afocal scheme, which can reduce the beam size of laser beam, is expected to provide a long free-space transmission distance in an FSO communication . DWDM technology, which can fully utilize the free-space bandwidth, is expected to enhance the transmission rate of an FSO communication.A DWDM FSO communication that utilizes different optical wavelengths to deliver the combined data streams would be quite useful for providing higher transmission rate. This study demonstrates a DWDM FSO communication by using an 8-wavelength system as an example, with each wavelength carrying a data stream of 40 Gbps. A DWDM FSO communication over a 50-m free-space link with a total transmission rate of 320 Gbps is obtained. As far as we know, it is the first time to successfully establish a 50 m/320 Gbps FSO communication that employs afocal scheme and DWDM technology. With the help of low noise amplifier (LNA) and clock/data recovery (CDR) at the receiving site,good bit error rate (BER) performance and clear eye diagram are achieved at a50 m/320 Gbps operation. This proposed 50 m/320 Gbps DWDM FSO communication is shown to be a prominent one and not only provides the advantages of optical wireless communications for long transmission distance and high transmission rate but reveals its feasibility for long-haul and high-speed light-based WiFi (LiFi) applications as well. The proliferation of wireless communications stands out as one of the most significant phenomena in the history of technology. Wireless devices and technologies have become pervasive much more rapidly than anyone could have imagined thirty years ago and they will continue to be a key element of modern society for the foreseeable future. Today, the term "wireless" is used almost synonymously with radio-frequency (RF) technologies as a result of the wide-scale deployment and utilization of wireless RF devices and systems. The RF band of the electromagnetic spectrum is however fundamentally limited in capacity and costly since most sub-bands are exclusively licensed. With the ever-growing popularity of data heavy wireless communications, the demand for RF spectrum is outstripping supply and the time has come to seriously consider other viable options for wireless communication using the upper parts of the electromagnetic spectrum. Optical wireless communication (OWC) refers to transmission in unguided propagation media through the use of optical carriers, i.e., visible, infrared and ultraviolet band. Signalling through beacon fires, smoke, ship flags and semaphore telegraph can be considered the historical forms of OWC. Sunlight has been also used for long distance signaling since very early times. The earliest use of sunlight for communication purposes is attributed to ancient Greeks and Romans who used their polished shields to send signals by reflecting sunlight during battles . In 1810, Carl Friedrich Gauss invented the heliograph which involves a pair of mirrors to direct a controlled beam of sunlight to a distant station. Although the original heliograph was designed for geodetic survey, it was used extensively for military purposes during the late 19th and early 20th century. In 1880, Alexander Graham Bell invented the photophone, known as the world's first wireless telephone system. It was based on the voice caused vibrations on a mirror at the transmitter.

II. LITERATURE SURVEY

An innovative free-space optical (FSO) link using laser light propagation to achieve transmission rate of 40 Gb/s at a wavelength of 1550 nm is proposed and experimentally demonstrated. Over a 20-m free-space link, brilliant bit-error-rate performance and clear eye diagram are obtained in the proposed 1550-nm distributed feedback (DFB) laser diode (LD)-based FSO links. As far as we know, it is the first time that a 1550-nm externally modulated laser transmitter cascaded with an erbium-doped fiber amplifier and a pair of fiber collimators to successfully set up a 20-m/40-Gb/s FSO link has been employed. Compared with the 680-nm vertical-cavity surface-emitting laser-based FSO link, this proposed 1550-nm DFB LD-based FSO link is attractive not only because it has longer free-space transmission distance but because it supplies higher bandwidth operation as well. Such a 1550-nm DFB LD-based FSO link provides the benefits of optical wireless communications for longer transmission distance and higher transmission rate, which is thoroughly helpful for optical wireless network applications. The main characteristics of free-space optical (FSO) links are high directivity, which provides high power efficiency and isolation from other interferences, unlicensed bandwidth, easy installation, and the promise of multi-gigabit mobile applications by using flexibility through free-space links . An FSO link, by which using laser light propagation in free-space to deliver high quality signal and high-speed data rate, is therefore developed with high expectation to conquer the wireless connection issues. The FSO link has attracted a lot of attention as a potential candidate for optical wireless communications because it has several advantages over the traditional radio frequency (RF)-based wireless communications. For a real and practical implementation of FSO link, long free-space transmission distance and high free-space transmission rate are the major concerns of system engineers and designers. A 10 m/25, Gb/s two-stage, injection-locked 680-nm vertical-cavity surface-emitting laser (VCSEL)-based light-based WiFi (LiFi) transmission system was demonstrated previously . However, sophisticated two-stage injection locking technique is required, and it will increase the complexity of LiFi transmission systems. Moreover, it is difficult to obtain good free-space transmission performance due to modal noise induced from the multi-mode VCSEL. The free-space transmission distance and transmission rate can be further improved by 1550-nm distributed feedback (DFB) laser diode (LD)-based FSO links. To compare with the two-stage injection-locked 680-nm VCSEL-based FSO link, the 1550-nm DFB LD-based FSO link is attractive not only to have higher optical power launched into the free-space, but also to provide larger bandwidth operation to FSO links. We successfully demonstrate that a 40-Gb/s data stream can be transmitted to a 20-m free-space link. To the best of our knowledge, it is the first one that employs a 1550-nm externally modulated laser transmitter cascaded with an erbium-doped fiber amplifier (EDFA) and a pair of fiber collimators to establish a 20 m/40 Gb/s FSO link successfully. Over a 20-m free-space link,good bit error rate (BER) performance and a clear eye diagram are achieved in the proposed 1550-nm DFB LD-based FSO links with a transmission rate of 40 Gb/s.

III. PROPOSED SYSTEM

The experimental configuration of the proposed 50 m/320 Gbps DWDM FSO communications that employs afocal scheme and DWDM technology. The output of the amplified spontaneous emission (ASE) broadband light source(BLS) is amplified by an erbium-doped fiber amplifier (EDFA) and efficiently split into eight optical channels by a 1 × 8 arrayed wave guide grating (AWG) demultiplexer (DEMUX) with a channel spacing of 0.4 nm (50 GHz).

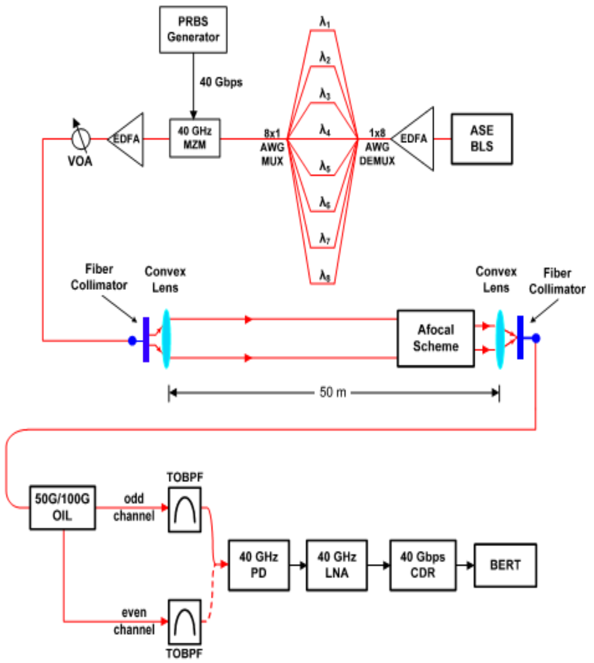

Fig.1. DWDM FSO communication with afocal scheme

Eight wavelengths of λ1 to λ8 from the AWG DEMUX output are multiplexed in to a 40-GHzMach Zehnder modulator (MZM) by a 8×1 AWG multiplexer (MUX). The MZM is modulated by a 40-Gbps pseudorandom binary sequence (PRBS) generated by a PRBS generator. It means that the same PRBS sequence is transmitted over all eight channels. A variable optical attenuator (VOA) is positioned at the start of the second-stage EDFA so that the optical power launched into the free-space can be optimized to obtain the best transmission performances. Given that EDFA can only amplify optical signals in the 1550 nm region, thereby, such DWDM FSO communications are enhanced by the introduction of 1550 nm technology. A pair of fiber collimators is used to collimate light from a fiber to form a collimated optical beam and to guide a collimated optical beam from the free-space into an optical fiber. The fiber collimators connected to single-mode fibers play an important role in forming an optical beam to transport optical signal through the free-space between the two sides. This fiber collimator has an operating wavelength range of 1050–

1620 nm, a fiber-to-lens distance of 7.5 mm, and a focal length of 7.5 mm. The light emitted from the first-stage fiber collimator is launched into the first-stage convex lens, delivered in the free-space, inputted into an afocal scheme, and fed into the second-stage convex lens to concentrate on the second-stage fiber collimator. The function of the first-stage convex lens is to transform the divergent beam into the parallel beam, the function of the afocal scheme is to reduce the beam size of the collimated optical beam, and the function of the second-stage convex lens focusses the reduced parallel beam into a point. Over a 50-m free-space link, the eight laser lights with a total data stream of 320 Gbps (40 Gbps/λ×8λ) is reached to a 50G/100G optical interleaver (OIL). An OIL is deployed at the receiving site to separate odd and even optical sidebands of the optical signal. The OIL has two output ports; one output port provides the optical signal only with the odd optical sidebands, and the other output port provides the optical signal only with the even optical sidebands. The OIL used in this experiment has an input channel spacing of 50 GHz and an output channel spacing of 100 GHz. Following the OIL output with odd (even) optical sidebands, the optical sidebands are separated by a spacing of 100 GHz and fed into a tunable optical band-pass filter (TOBPF) with a 3-dB bandwidth of 0.32 nm, to select the desired wavelength. The selected optical wavelength is then detected by a 40-GHz photodiode (PD) with a responsivity of 0.55 mA/mW (at 1550 nm) and amplified by a 40-GHz LNA with a small signal gain of 20 dB (measured at 40 GHz) and a noise figure of around 2 dB. It is necessary for an LNA to amplify the data stream while adding as little noise and distortion as possible. After LNA amplification, the data stream is recovered and regenerated by a 40-Gbps CDR and fed into a bit error rate tester for BER performance analysis. The function of the CDR is to recover and regenerate the data stream from the distorted data stream. Considering that the BER will increase as the receiver cannot discriminate between noise and transmitted data, a CDR is necessary at the receiving site.

IV. CONCLUSION

A DWDM FSO communication that adopts afocal scheme and DWDM technology is proposed.The free-space transmission distance and transmission rate are greatly increased by afocal scheme and DWDM technology. A total transmission rate of 320 Gbps is successfully delivered over a 50-m free-space link. The proposed DWDM FSO communications are experimentally demonstrated with low BER operation and clear eye diagram. The findings demonstrated that such a DWDM FSO communication can provide the advantages of optical wireless links for long transmission distance and high transmission rate.

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