Wavelength-Controlled Beam Steering for Optical Wireless Transmission Using an In-Fiber Diffraction Grating

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Abstract: Passive beam steering for optical wireless transmission based on wavelength tuning using a novel in-fiber diffraction grating featuring compactness, high diffraction efficiency and inherent fiber-compatibility, is proposed and experimentally demonstrated for the first time.
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1. Introduction

Free-space indoor optical wireless transmission using near-infrared (NIR) laser beams provides multi-gigabits per second of data rate with the advantages of unlicensed spectrum, ultra-wide bandwidth, being physically secure as light waves do not penetrate walls, no electromagnetic interference, and low power consumption.

The capability of steering laser beams is crucial for high-speed optical wireless links to provide large coverage area, track mobile users, and avoid obstructions. Recently, wavelength-tuning based passive optical beam steering has become a promising solution for high data-rate in-door optical wireless communications [1]. Different types of passive diffractive optical devices have been used to steer optical beams by diverging different wavelengths into different spatial positions, such as diffraction gratings [2], and polymer polarization gratings [3]. However, these free-space diffractive devices share drawbacks such as high coupling loss between free space and fiber links, limited diffraction efficiency (up to 75%), bulky configuration and high cost. In this work, we report the first experimental demonstration using a 45° tilted fiber grating (TFG) [4] as a highly efficient, low cost and compact in-fiber diffractive device for passive optical beam steering in indoor optical wireless transmission. In a proof-of-concept experiment, free-space transmission over 1.4 m serving two users with data rate of 9.6 Gb/s per beam has been demonstrated using 2.4 GHz bandwidth signals.

2. Experiment and results

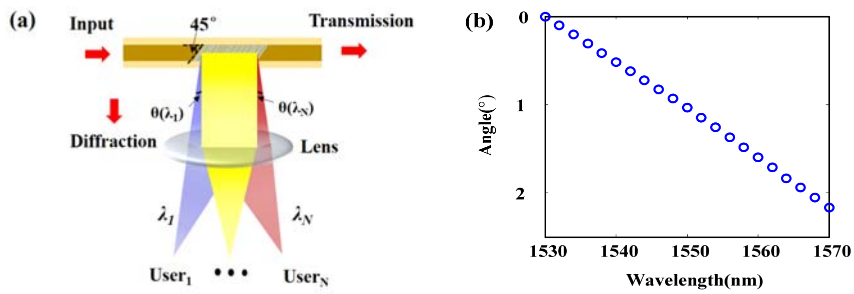

Fig. 1. (a) The structure of a 45° TFG and its application for passive beam steering; (b) Angular dispersion of the 45° TFG across a wavelength range between 1530 and 1570 nm.

The structure of a 45° TFG and the concept of using the TFG as an in-fiber diffraction grating for passive beam steering is shown in Fig. 1(a). The measured beam divergence angle from the 45° TFG due to wavelength tuning from 1530 to 1570 nm is shown in Fig. 1(b). The angular dispersion of the TFG is 0.054° /nm without optical magnification. Due to strong tilted reflection, the TFG offers an enhanced diffraction efficiency as high as 93.5%.

Fig.2 depicts the experimental setup of the beam steering system for indoor optical wireless transmission using the 45° TFG as an in-fiber diffraction grating. A 2.4 GHz bandwidth orthogonal frequency-division multiplexing (OFDM) 16-quadrature amplitude modulation (16 QAM) encoded data stream at 9.6 Gb/s is generated on a 2 GHz radio carrier using an arbitrary waveform generator (AWG, Tektronix 7122C) with a sampling rate of 12 GS/s. This radio signal is amplified and modulated on an optical carrier using a Mach-Zehnder modulator (MZM), which is biased at quadrature point. The modulated and amplified optical carrier is then diffracted into free space via the 45° TFG with appropriate polarization control to ensure the maximum diffraction efficiency [4]. Beam steering for different users is achieved by simply tuning the wavelength of the optical carrier, and a lens set is used to control the beam size. Two wavelengths of 1530 and 1550 nm are used to steer the laser beam to serve two users that are 0.2 m apart. After a free-space transmission of 1.4 m, light is received using a fiber collimator and detected by a 3 GHz photo-detector (PD) at each user. The recovered radio signal is captured by a 50 GS/s real-time oscilloscope, and the data is decoded and analyzed via off-line digital data processing.

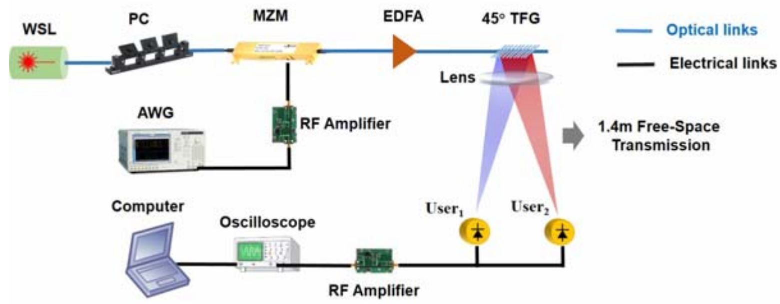

Fig. 2. Schematic of the beam steering system for free space indoor optical wireless transmission using a 45° TFG. AWG: arbitrary waveform generator; RF: radio frequency; MZM: Mach-Zehnder modulator; WSL: wavelength swept laser; PC: polarization controller; EDFA: Erbium doped fiber amplifier; 45° TFG: 45° tilted fiber grating.

Performance of two beam-steered optical wireless channels is evaluated. When the received optical power is -4 dBm, the constellation of the decoded OFDM 16 QAM data for channel 1 (1550 nm) is shown in Fig. 3(a). The error vector magnitude (EVM) is estimated as 9.6%. Fig. 3(b) represents EVM performance for both channels with respect to received optical power. The EVM limit for 16 QAM is 12.5%, as shown by the red line. With a bandwidth of 2.4GHz, our system demonstrates an aggregate data rate of 9.6 Gb/s per beam, limited by the sampling rate of the AWG used. It could be easily improved using a higher sampling rate.

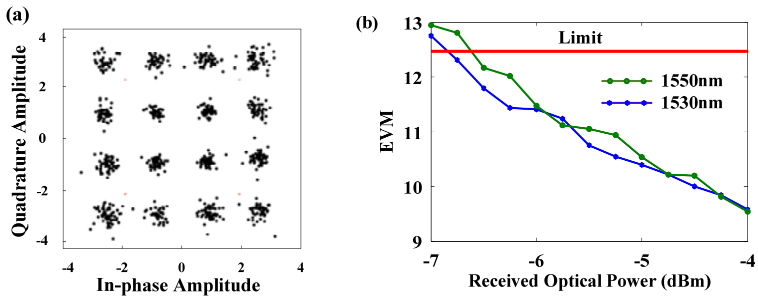

Fig. 3. (a) Constellation of the decoded OFDM 16-QAM signal for one channel (1550 nm) with received optical power of -4 dBm. (b) EVM performance for both channels with respect to received optical power.

3. Summary

We presented the first experimental demonstration of the use of a 45° TFG as an in-fiber diffraction grating for passive beam steering in optical wireless transmission links. Compared to conventional free-space diffractive devices, the TFG provides significant advantages of high diffraction efficiency, compactness, low cost and inherent fiber-compatibility. As a proof-of-the-concept, 1.4 m free-space transmission distance with data rate of 9.6 Gb/s per beam serving two users was demonstrated.

4. Acknowledgement

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5. References

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