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Dual-band Airy Beams Enabled Full Duplex Free-space Photonic Interconnection

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Abstract: We experimentally demonstrate a proof-of-concept dual-band 2D Airy beams enabled 100 Gbps full duplex free-space photonic interconnection over 40 cm free-space link with a receiver sensitivity of -17.3 dBm at bit error ratio of 1e-9.

1. Introduction

High speed free-space photonic interconnection (FSPI) is an effective strategy to overcome the bottleneck of short-reach electronic interconnection from chip scale to board level, due to its wide bandwidth, high energy efficiency, low latency and high interconnect density. Accelerating beam moves along a curved trajectory (self-acceleration) with invariant intensity profiles (diffraction-free) while being resilient to perturbations (self-healing), thus, they have excellent prospects for FSPI. Recently, Airy beam [1] based image transmission [2] and optics communication experiments [3], which can propagate through a disordered medium and circumvent the obstacle, have been reported. However, full duplex FSPI is highly desired for practical application, especially the wavelength division multiplexing (WDM) technique enabled full duplex FSPI is regarded as an effective strategy to further enhance the interconnection capacity. In this talk, based on Airy beam which is a typical accelerating beam, a proof-of-concept dual-band 2D Airy beams enabled 100 Gbps full duplex FSPI over 40 cm free-space optical link is demonstrated.

2. System architecture

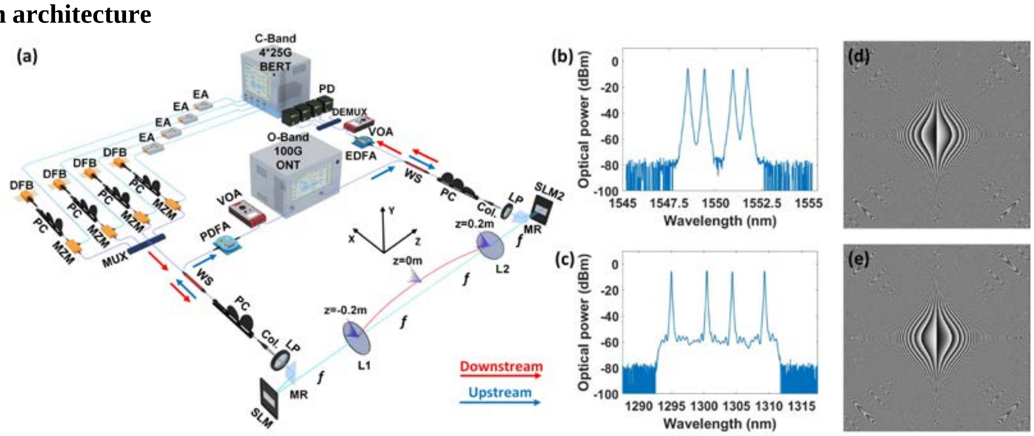

Fig. 1. (a) Experimental setup. Col., collimator; LP, line polarizer; MR, mirror; SLM, spatial light modulator; WS, wavelength splitter; MZM, Mach-Zehnder modulator; BERT, bit error ratio tester; ONT, optical network tester. (b) Optical spectrum of downstream signal (c) and upstream signal (d). Phase mask loaded on SLM1 (d) and SLM2 (e).

As shown in Fig. 1(a), as for the downstream transmission of full-duplex FSPI, the generated 4×25.78 Gbps C-band WDM non-return-to-zero on-off-keying (NRZ-OOK) signal at wavelength of 1548.54 nm, 1549.34 nm, 1550.94 nm, and 1551.74 nm is multiplexed by MUX and collimated to a Gaussian beam with a radius of 1.05 mm for the free-space link. As for the upstream transmission, 4×27.77 Gbps NRZ-OOK signal at wavelengths of 1295.02 nm, 1300.44 nm, 1304.38 nm, and 1309.32 nm is generated by a commercial 100G network tester with an embedded optical transceiver. Two dual-band wavelength splitters (WS) are used to combine/split the downstream and upstream signals at C-band and O-band, respectively. At the receiver side, the power of received WDM signal is managed by an erbium-doped fiber amplifier (EDFA)/praseodymium-doped fiber amplifier (PDFA) and a variable optical attenuator (VOA). Finally, the BER is counted by the BER tester and the 100G network tester for downstream and upstream transmission, respectively. The full duplex FSPI scheme includes two SLM-based photonic antennas which are responsible for converting Gaussian beam to 2D Airy beam, and vice versa.

3. Generation and trajectory manipulation of dual-band 2D Airy beam by C-band SLM

A generation vector $\overrightarrow{Ph} = [x_0, n_x, l_x, y_0, n_y, l_y]$ for general trajectory manipulation of 2D Airy beam is proposed to describe the phase mask to be loaded on the spatial light modulator (SLM) [4]. Here, x_0 and y_0 are transverse scales, with unit of micro-meter, n_x , n_y , l_x and l_y are dimensionless coefficients. The phase-only SLM is a wavelength-sensitive device, indicating of different phase modulation responses for C-band and O-band. Here, we use the phase-shifting interferometry method [5] to characterize the used SLM. Then, the trajectory and beam quality of 2D Airy beam of O-band generated by the C-band SLM is characterized. The C-band SLM can still realize the linear phase response with input gray scale on O-band, but with a slightly larger modulation depth. Though the beam quality of O-band has a little degradation, it still has a preset trajectory and can be used for upstream transmission [4].

4. Real-time full duplex interconnection results

We demonstrate a real-time full duplex FSPI under generation $\overrightarrow{Ph} = [-142.09, 0, 1.48, -142.09, 0, 1.48]$. First, the real-time BER results under the condition of non-obstacle setting are presented in Fig. 2(a), where the received optical power of individual wavelength is recorded. The average BER of four channels is shown for the ease of presentation here. Due to the different performance of the optical amplifiers and receivers used for two bands, the receiver sensitivity of the O-band upstream signal (-22.4 dBm) is better than the C-band downstream signal (-17.3 dBm) at BER of 1e-9.

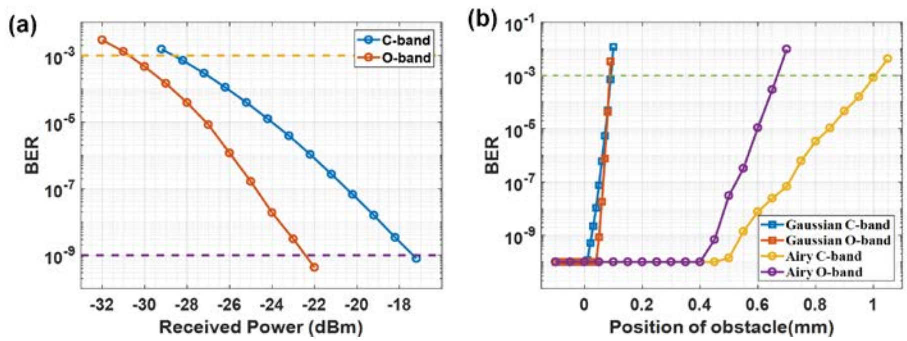

Fig. 2. Real-time BER performances for the full duplex FSPI (a) without and (b) with an obstacle.

Next, we set an opaque obstacle at z=0 which can be shifted along the X axis to evaluate the obstacle evasion ability of the proposed FSPI system. The distance from the edge of the obstacle to the optical axis is recorded as h , and the dynamic BER results with different h are shown in Fig. 2(b). For the ease of comparison, we also perform the BER measurement for the Gaussian beams under the same condition. If we assume that the photonic interconnection interrupts when BER is higher than 1e-3, the conventional dual-band Gaussian beam based FSPI is interrupted when the obstacle radius reaches 0.1 mm. The C-band 2D Airy beam can circumvent an obstacle with a height of 1mm. However, the maximum height of obstacle for the O-band signal is reduced to 0.67 mm, because of the degradation of O-band 2D Airy beam generation.

5. Conclusion

We propose a dual-band Airy beams enabled FSPI scheme and experimentally demonstrate a proof-of-concept 100 Gbps full duplex reconfigurable FSPI over 40 cm free-space link. Our results indicate that the proposed full duplex FSPI scheme has a receiver sensitivity of -17.3 dBm at BER of 1e-9, and better BER performance when an obstacle occurs at the free-space link, in comparison with the conventional Gaussian beam. With the development of silicon photonic devices, our proposed accelerating beam enabled FSPI strategy is promising for future 3D board-to-board level interconnection.

Reference

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