Two-channel data transmission on a polarization-maintaining highly elliptical core fiber without MIMO

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Abstract: We transmit two QPSK signals over a polarization maintaining highly-elliptical-core multimode fiber without recourse to MIMO processing. OSNR penalty is between 2.3 and 3.5 dB at 24 Gbaud.

1. Introduction

Mode division multiplexing (MDM) over few-mode fibers (FMFs) has been proposed as a promising candidate to overcome the anticipated capacity crunch of our communication systems [1]. However, FMFs are sensitive to mode coupling, and multiple-input multiple-output (MIMO) digital signal processing (DSP) has been typically applied to undo the channel crosstalk and recover data at the receiver. In short-reach data communication links, the cost and power consumption are critical parameters, so MIMO-free approaches are extremely desirable. Polarization-maintaining fibers (PMFs) play a significant role, since their high effective index differences between vector modes reduce the fiber crosstalk significantly. PMFs allow us to exploit the entire capacity of a single core fiber without the use of any MIMO processing. Over the last year, several PMF designs have been proposed, such as an elliptical ring-core fiber (ERCF) [2], PANDA ring-core fiber [3], or an ERCF with an inner hole [4] or with an air-hole structure [5]. Recently we fabricated a highly elliptical core fiber (HECF) following the design described in [6] but with a slightly larger core size of 36.1µm×7.17µm. Fiber characterization revealed that the combination of stress-induced birefringence and geometry-induced birefringence induce polarization maintaining properties (modal birefringence higher than 1.3×10^{-4}) in addition to separating spatial modes (effective index difference higher than 8.63×10^{-4}) [7]. In this paper, we present the first data transmission experiment over the fabricated HECF focusing on transmission over the two polarizations of each spatial modes to investigate cross-talk between these modes that are the closest in terms of effective index. We report BER vs. OSNR performance at 24 Gbaud. For a 1 km fiber length, the OSNR penalty varies from 2.3 to 3.5 dB. Finally, we sweep the baud rate from 16 to 32 Gbaud.

2. Data transmission experimental setup

Fig. 1 shows the experimental setup. A single polarization non-return-to-zero (NRZ) QPSK signal is generated by an IQ modulator driven by two pseudo-random binary sequence (PRBS) signals (2^{15}-1). The QPSK signal is split into two channels and time delayed (τ_1 and τ_2) to emulate two independent QPSK signals. A spatial light modulator (SLM) is used to generate the HECF modes from the input collimated Gaussian beams. The SLM is programmed by using a similar technique to that in [8]. After the SLM, the two free space channels are combined through a half wave plate (HWP) and a polarization beam splitter (PBS). A second HWP is added to align the input polarization with the HECF core axis. A 6-axis stage is then used to optimize the coupling between the free space beam and the

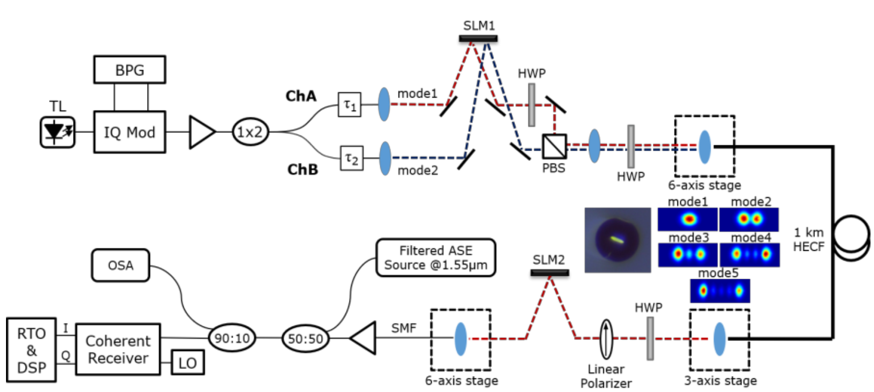

Fig. 1. Experimental setup for the transmission of two QPSK signals over the two orthogonal polarizations of the same spatial mode. Inset: Fiber cross section and mode intensity profiles.

1 km length HECF under test. The fiber supports five spatial modes with twofold degeneracy, for a total of ten channels. The inset of Fig. 1 shows the cross section of the HECF and the five spatial modes at the output of the fiber captured by a CCD camera. An HWP and a linear polarizer are used to align and maximize one polarization with respect to a second SLM, which converts the HECF output modes back to a fundamental Gaussian-like beam, which are finally coupled to a single mode fiber (SMF). It is worth mentioning that the 6-axis stage is very sensitive to ambient temperature and needs daily adjustment. The remaining optics and mechanical mounts are very stable for long periods. For BER measurement, a filtered amplified spontaneous emission (ASE) source is added through a 50:50 coupler to control OSNR, monitored through the use of an optical spectrum analyser (OSA). The signal is received by a coherent receiver, where it is mixed with an optical local oscillator. A real-time oscilloscope (RTO) captures the demodulated I and Q signals. The offline digital signal processing (DSP) consists of blocks of retiming, a constant modulus algorithm (CMA), frequency offset estimation, carrier phase recovery using 4^{th} power algorithm, decision-directed least mean squares (DD-LMS) algorithm, and finally BER estimation.

3. Results and discussion

Fig. 2(a) shows the results for BER vs. OSNR at a baud rate of 24 Gbaud. We first transmit data on a single polarization mode at a time (solid lines) and on the two polarizations of the same spatial mode (marked lines) simultaneously, for all the five supported spatial modes. Results show OSNR penalty between 2.3 and 3.5 dB at the forward error correction (FEC) threshold of 3.8×10^{-3}. We next capture BER when sweeping the baud rate, with an OSNR of 24 dB, see Fig. 2(b). BER is below the FEC threshold even at a baud rate up to 32 Gbaud.

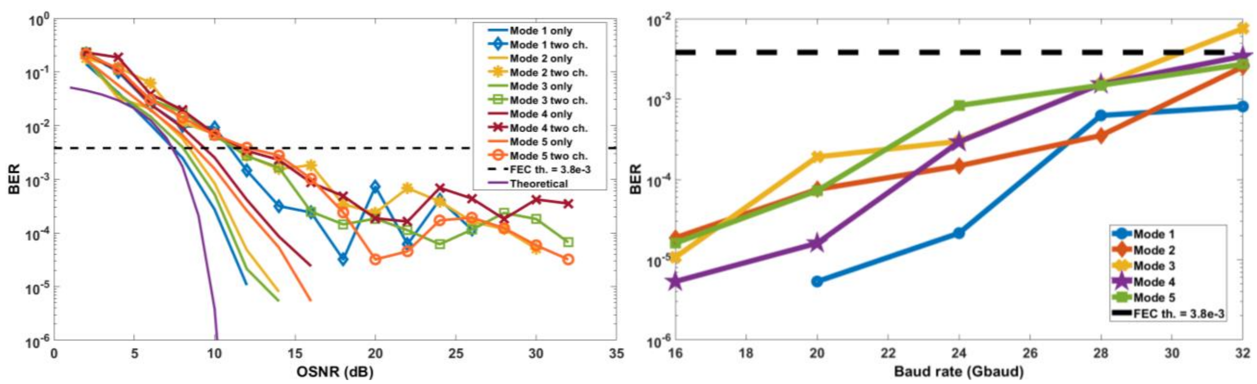

Fig. 2. (a) BER vs. OSNR when sending one polarization only and when sending both polarizations of the same spatial mode at 24 Gbaud; (b) BER vs. baud rate at OSNR of 24 dB.

In conclusion, we demonstrate that the proposed HECF has a sufficiently large effective index separation between the two orthogonal polarizations of each spatial mode to enable the transmission of QPSK signals over a distance of 1 km, without recourse to MIMO processing. The fiber crosstalk imposes a power penalty between 2.3 and 3.5 dB at the FEC threshold for a baud rate of 24 Gbaud. We show the possibility to have MIMO-free data transmission on the two orthogonal polarizations of the supported spatial mode for baud rates up to 32 Gbaud.

4. References

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