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Polarisation-insensitive 640 Gbit/s demultiplexing using a polarisation-maintaining highly non-linear fibre

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Abstract: Polarisation-insensitive 640 Gbit/s demultiplexing is demonstrated using a 100 m polarisation-maintaining highly non-linear fibre. Error-free performance is achieved with only 0.2 dB polarisation dependence.

Keywords: Demultiplexing, polarisation insensitive, optical time division multiplexing (OTDM), highly non-linear fiber

1. Introduction

All-optical demultiplexing is a key functionality in ultrafast serial optical communication systems based on optical time division multiplexing (OTDM). Up to date, 1.28 Tbit/s serial optical data demultiplexing has been demonstrated based on a non-linear optical loop mirror [1]. However, the polarisation of the data signal usually has to be adjusted before the demultiplexer. Polarisation-insensitive operation is one of the most desired features of an optical demultiplexer, enabling it to process incoming optical data signals with arbitrary states of polarisation [2-3].

In this paper, we report the first demonstration of polarisation insensitive 640 Gbit/s demultiplexing for OTDM data signals using a 100 m polarisation-maintaining highly non-linear fibre (PM-HNLF). The basic principle is based on four wave mixing (FWM) in a polarisation-maintaining fibre loop. Error free performance with low penalty is achieved with only 0.2 dB polarisation dependence.

2. Principle and Experiment

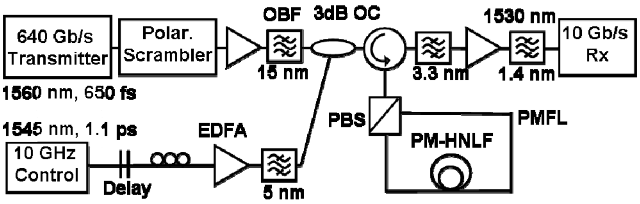

Figure 1: Experimental set-up.

Fig.1 shows the experimental set-up for the polarisation insensitive demultiplexing of a 640 Gbit/s signal to 10 Gbit/s. It mainly consists of a 640 Gbit/s transmitter, a 10 GHz control pulse source, a polarisation-maintaining fibre loop (PMFL), and a 10 Gbit/s receiver. An Erbium Glass Oscillator (ERGO) pulse source runs at 10 GHz and emits 1.5 ps pulses at 1550 nm, which are used to create a super-continuum in 400 m dispersion flattened highly non-linear fibre (DF-HNLF). The output from the DF-HNLF is used to generate the data and control signals by using two optical band-pass filters centered respectively at 1560 and 1545 nm. The 640 Gbit/s data signal is then generated in our standard OTDM transmitter [4]. An eye diagram of the 640 Gbit/s data, obtained with an optical sampling oscilloscope, is shown in Fig.2 (left). As shown in Fig.2 (right), the FWHM of the data and control pulses are 650 fs and 1.1 ps, respectively.

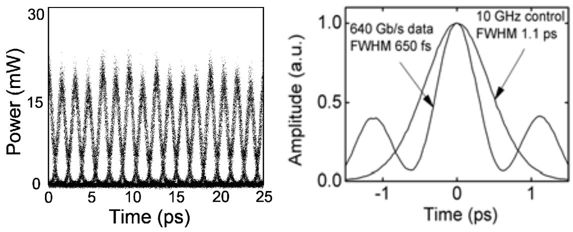

Figure 2: Eye diagram of the 640 Gbit/s OTDM signal (left), and autocorrelations of data and control signals (right).

The 640 Gbit/s data signal and 10 GHz control pulses were combined in a 3-dB coupler and then launched into the PMFL which includes a circulator, a polarisation beam splitter (PBS) and a 100 m PM-HNLF. The total passive loss of the PMFL is 4.5 dB. The PMFL can support bi-directional operation in the PM-HNLF, thus providing a polarisation diversity scheme. The fast axis of the PBS is rotated by 90˚ inside the PBS, so both output of the PBS are in the slow axis. All signals always propagate along the slow axis in the loop configuration. If the pump pulse is launched into the PBS with 45˚ polarisation, acquiring equal intensity in both directions of the loop, the four wave mixing conversion efficiencies (proportional to the data signal intensity and the square of the pump intensity) of both directions will be kept consistent with the data signal power in both directions. When the polarisation of the data signal changes, the total power of the FWM products will be kept constant. The FWM products are recombined in the PBS and output from the circulator. The principle of the PMFL is similar to the polarisation diversity scheme presented in [3] and [5].

At the input of the circulator, the data signal power is 17.1 dBm and the control pulse power is 14.6 dBm. Based on the four wave mixing in the PM-HNLF, the generated FWM product at 1530 nm represents a 10 Gbit/s data signal, being one of the 64 tributaries in the 640 Gb/s OTDM data. At the output of the circulator, the signals were launched into a 3.3-nm filter, a 1.4-nm filter and an EDFA in between to separate the FWM product from the residual original data and control signal. Finally, the demultiplexed 10 Gbit/s signal was detected by 10 Gbit/s receiver.

3. Experimental results

The spectrum at the input (dotted line) and the output (solid line) of the PMFL is shown in Fig.3. If the passive loss of the PMFL is not included, the FWM conversion efficiency is about -6 dB, taking into account that only one of 64 OTDM tributaries takes part in the FWM process. The FWM product is extracted by optical filtering and amplification to allow for the detection of the demultiplexed channel, Fig.3 (dashed line). A 27 dB spectral contrast is obtained between the demultiplexed signal and the residual control pulse.

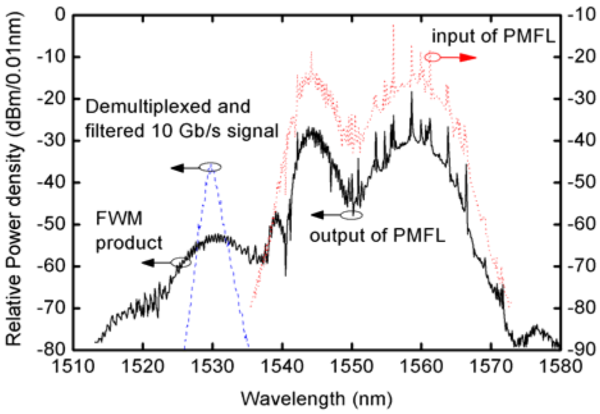

Figure 3: Spectra at the input (dotted) and output (solid) of the PMFL, and demultiplexed and filtered 10 Gb/s signal (dashed).

To characterise the residual polarisation sensitivity of the demultiplexer, we measured the power fluctuation of the demultiplexed signal versus time, with a high-speed (~113 kHz) polarisation scrambling.

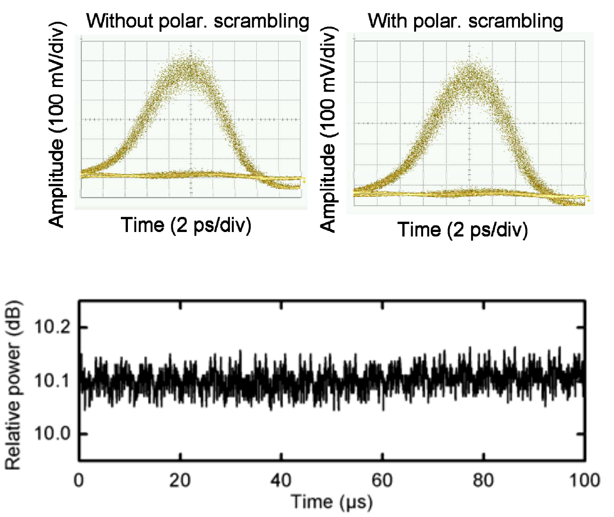

Figure 4: Eye diagrams (upper) and power fluctuations (lower) of the demultiplexed signal with polarisation scrambling.

The maximum fluctuation is less than 0.2 dB, making the 137 kHz period only barely discernible, as shown in Fig.4. The eye diagrams of the demultiplexed 10 Gbit/s of 640 Gbit/s OTDM data with and without polarisation scrambling are also shown in Fig. 4. The eye diagrams show negligible difference irrespective of whether the scrambler is on or off. To further characterise the performance of the polarisation-insensitive demultiplexer, bit error rate (BER) measurements are carried out, and the results are shown in Fig. 5. Error-free demultiplexing is achieved with an average power penalty at a BER of 10^{-9} of about 1 dB compared to the 10 Gbit/s back-to-back. Compared to the receiver sensitivity at a BER of 10^{-9} when the scrambler is on or off, there is only a 0.4 dB difference. Inset shows the receiver sensitivity at BER of 10^{-9} for five adjacent channels. Error free operations are achieved for all the channels.

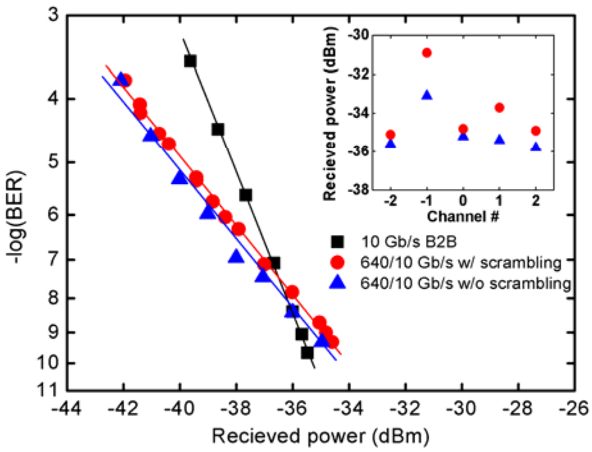

Figure 5: BER performance of demultiplexed 640 Gbit/s OTDM data with and without polarisation scrambling.

4. Conclusion

We demonstrated, for the first time, polarisation insensitive 640 Gbit/s demultiplexing for OTDM data signals based on a polarisation-maintaining fibre loop. Error free performance with low penalty was achieved with only about 0.2 dB polarisation dependence.

5. Acknowledgment

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