System Benefits of Temporal Polarization Interleaving with 100Gb/s Coherent PDM-QPSK

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Abstract *We demonstrate, over a NZDSF link, that the system benefits provided by the temporal interleaving of polarization tributaries of 100Gb/s coherent RZ-PDM-QPSK data depend on the WDM system configuration.*

Introduction

A growing interest arises from research works onto 100Gb/s technologies compliant with existing networks as carriers will need such technologies for future upgrade of their current networks operating at 10Gb/s to support the predicted long term trend of traffic growth. Among all proposed solutions, polarization-division-multiplexed (PDM) quaternary-phase-shift-keying (QPSK) paired with coherent detection is found very promising for upgrading optical legacy systems based on 50GHz wavelength slots thanks to its high spectral efficiency (2bit/s/Hz) and its resiliance to linear effects[1-3]. Another concern for the deployment of such a solution is the transmission reach of WDM systems, usually mainly limited by optical noise and nonlinear effects. The performance comparison of coherent systems using either optical or electrical dispersion compensation has been recently assessed. Particularly, the use of polarization interleaving technique with return-to-zero (RZ-) PDM-QPSK has been shown to be of interest to mitigate interchannel nonlinearities in dispersion-managed WDM coherent systems where all channels are identically modulated[4,5].

Here, we focus on the transmission of 100Gb/s coherent PDM-QPSK in different WDM configurations over 12x100km of non-zero dispersion shifted fibers (NZDSF) employing optical dispersion compensation. We particularly further investigate the advantage brought by interleaving polarization tributaries of RZ-PDM-QPSK data at 100Gb/s to mitigate nonlinear impairments, and we discuss on the origins of the system benefits brought by this technique.

Experimental test-bed

As depicted in Fig.1, our transmitter consists of 81 DFB lasers, spaced by 50GHz and separated into two independently modulated, spectrally interleaved combs, plus one narrow linewidth (~100kHz) tuneable laser (test channel), at 1546.52nm. The light from each set is sent to a QPSK modulator operating at 28Gbaud (or 56Gb/s). The modulators are fed by 2^{15}-1-bit-long sequences at 28Gb/s. The QPSK data are then passed through a 50% RZ pulse carver in order to produce 28Gbaud RZ-QPSK signals. Polarization multiplexing is finally performed by dividing the RZ-QPSK data into two tributaries and recombining them into a Polarisation Beam Combiner (PBC) with an approximate 300-symbol delay, yielding RZ-PDM-QPSK data at 112Gb/s. Here, by tuning a polarization-maintaining delay line before the PBC, the two orthogonal polarization tributaries can be either temporally aligned or interleaved by half a symbol period (~18ps). In the rest of the paper, aligned RZ-PDM-QSPK (resp. interleaved RZ-PDM-QPSK) refers to the case when orthogonal polarization tributaries are pulse-to-pulse aligned (resp. interleaved by half a symbol period). In both cases of aligned and interleaved polarization tributaries, the two generated combs are passed into respective low-speed (<10Hz) polarisation scramblers (PS) and combined with a 50GHz interleaver.

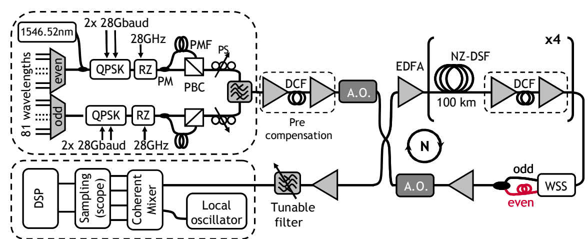

Fig.1: Experimental test-bed

The resulting multiplex is boosted through a dual-stage EDFA incorporating dispersion compensating fibre (DCF) for pre-compensation and sent into the re-circulating loop composed of four 100km-long spans of NZDSF, separated by dual-stage Erbium-doped fibre amplifiers (EDFA) including a spool of dispersion compensating fibre (DCF) for partial dispersion compensation. A wavelength selective switch (WSS) is also inserted in the loop to perform channel power equalization and emulate filtering from nodes. In all experiments, we vary the power per channel from -5 to +5dBm and we measure the performance after three loop round-trips, i.e. at a transmission distance of 1,200km. The test channel power is set at the same level as all the channels.

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At the receiver side, the channel under study is selected by a 0.4nm bandwidth filter and sent to the coherent receiver described in details in previous works[2]. The output signals from this receiver are detected by four balanced photodiodes, digitized by the four analog-to-digital converters of an oscilloscope, at 50Gsamples/s with 16GHz electrical bandwidth, and stored by sets of 2MSamples. Due to polarisation scrambling, each recording corresponds to an arbitrary received state of polarisation. For each bit-error rate (BER) measurement, four sets of 2MSamples are stored and processed off-line[2]. The computed BERs are averaged over the four sets and subsequently converted into Q^2 factors.

Experimental results

In a first step experiment, we measure and compare the tolerance to nonlinear effects of both aligned- and interleaved- RZ-PDM-QPSK signals. Fig.2 shows the performance of 100Gb/s interleaved (triangles) and aligned (circles) RZ-PDM-QPSK signals versus launched power for the test channel surrounded by neighbours of the same format, or by cw neighbours. This latter case corresponds to emulating the propagation of a single channel. We can see that interleaving polarization tributaries of RZ-PDM-QPSK signals does not bring significant advantage in the single channel performance. Nevertheless, moving to WDM system performance, the penalties induced by interchannel nonlinearities are of 2dB and 3dB respectively for interleaved and aligned RZ-PDM-QPSK data. The 1dB higher tolerance of interleaved RZ-PDM-QPSK data is attributed to the fact that interleaving polarization tributaries of WDM channels enables the reduction of cross nonlinear impairments, as demonstrated for 10Gbaud signals with differential detection[6].

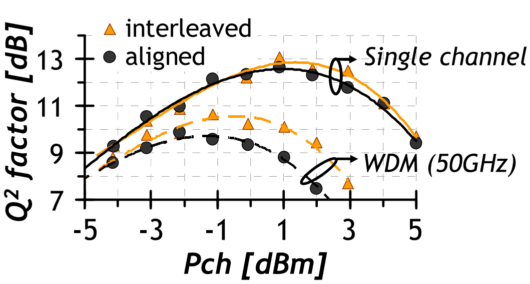

Fig.2: Tolerance to intrachannel (solid lines) and interchannel (dashed lines) nonlinear effects of interleaved RZ-PDM-QPSK and aligned RZ-PDM-QPSK after 1,200km.

To get more insight into this mechanism for coherent systems operating at 28Gbaud, we perform two extra experiments in which the test channel is surrounded either by time-aligned 100Gb/s RZ-PDM-QPSK or by 10Gb/s NRZ channels. In each experiment, when polarization tributaries of the test channel are tuned from temporal alignment to temporal interleaving, the nonlinear effects induced by neighbour channels onto the test channel are unchanged. For practical reasons, the experimental test-bed only involves now the even set of DFB sources and the test channel. DFB sources are modulated either with 100Gb/s aligned RZ-PDM-QPSK or 10Gb/s NRZ whereas the 100Gb/s test channel can be tuned from temporally aligned to temporally interleaved RZ-PDM-QPSK. The resulting multiplex with 100GHz spacing is then sent to the recirculating loop as previously described to measure the performance of the test channel after a 1,200km WDM transmission. Fig.3 depicts the measured performance evolution versus launched power. Contrary to the results of Fig. 2, similar Q^2 factors are found, whether the tributaries of the test channel are time-interleaved or not. This indicates that temporal interleaving brings maximum benefits when it is applied to the full multiplex. In other words, the benefits primarily come from the reduction of the impact of neighbouring channels.

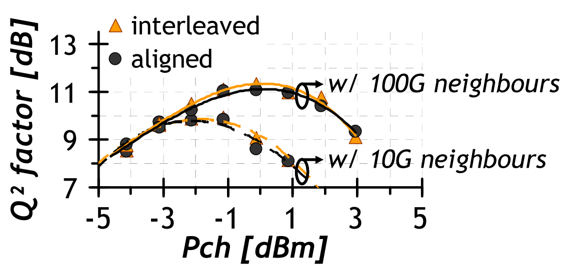

Fig.3: Performance evolution versus launched power for interleaved and aligned RZ-PDM-QPSK measured after 1,200km with identical interchannel impairments.

Conclusion

We have shown, over a dispersion-managed link relying on NZDSF and fed with coherent RZ-PDM-QPSK channels, that temporal interleaving of polarization tributaries is beneficial only because it induces less detrimental nonlinear effects onto co-propagating channels. Therefore, this technique brings valuable benefits only when surrounded by channels modulated of the same type and these benefits can be strongly reduced in hybrid WDM systems mixing different formats and bit-rates.

Acknowledgement

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