Application of Pulsed Pump Optical Parametric Amplifier for De-multiplexing of 107 Gb/s OTDM Signal

M. Karasek(1,2), Josef Vojtěch(2), Jan Radil(2)

(1) Institute of Photonics and Electronics, Academy of Sciences of the Czech Republic, Chaberska 27, 182 51 Prague, Czech Republic
(2) CESNET a.s.e., Zikova 4, 160 00 Prague 6, Czech Republic

Abstract: We present experimental results on de-multiplexing 107 Gb/s OTDM signal using pulsed pump optical parametric amplifier.

Keywords: optical fibre communications nonlinear optics, fibers; nonlinear optical signal processing

1. Introduction

The rapid increase of data communication services over the past few years resulted in significant growth of 10 Gb/s Ethernet. As data rates in Ethernet have historically grown in steps of ten, 100 Gb/s Ethernet is now being envisioned [1,2]. Electrical time division multiplexing (ETDM) is the most cost-effective way to increase the capacity of a single wavelength channel. Stable deployments of key high speed components like 40G SerDes chips will accelerate the development of 100Gbps optical transmission technologies. Significant progress in high-speed electronics and optoelectronics has recently been achieved enabling electrically time division multiplexing (ETDM) at 4x13.375 Gb/s. There have been many debates over which modulation format is the most appropriate for use in the 100 Gb/s serial data transmission service of optical transport interfaces. These formats include ASK NRZ VSB, NRZ-DPSK, CSRZ-DPSK, RZ-DQPSK, and others [3,4,5].

Although the optical time-division multiplexing (OTDM) will most likely not be commercially attractive it still is a valuable research tool for exploring some aspects of high-speed optical signal transport [6,7,8]. OTDM de-multiplexing schemes for high bit rate signals have been demonstrated using ultra-short flat-top pulses [6], nonlinear optical loop mirror [7], or pulsed pump optical parametric amplifier [8].

In this contribution we present experimental results on de-multiplexing 107 Gb/s OTDM signal to the original 13.375 Gb/s based on pulsed pump fiber optical parametric amplifier (FOPA). In difference to [8], we use one mode-locked laser diode (MLLD) for both the RZ signal and as a pump for the FOPA.

2. Experimental setup and results

The experimental set-up for the RZ OTDM 107 Gb/s signal generation and de-multiplexing is schematically shown in Fig. 1. In the transmitter, 1.7 ps pulses from a 13.375 GHz mode-locked laser diode with saturable absorber (MLLD) were generated. MLLD was tuned to 1555nm. The train of pulses was amplified to average power of 18 dBm and fed to 500 m of dispersion flattened highly nonlinear fibre (DF HNLF). Optical spectrum generated by self phase modulation (SPM) is shown in Fig. 2. The SPM signal was split in 50%/50% directional coupler. Peaks of SPM spectrum on both sides of the U2t wavelength were at 1548 and 1558nm, respectively. Signal and pump pulses were selected by OBPFs with FWHM = 3 nm close to the peaks of the SPM spectrum and were amplified.

Fig. 1: Schematic diagram of the experimental set-up.

Fig. 2: SPM spectrum at the input to 50%/50% directional coupler
Optical wave of the 1548 nm branch of SPM spectrum was split by 90%/10% directional coupler. The 10% part of the wave was converted to electrical signal in 10Gb/s digital optical receiver Rx, which drives clock recovery unit CR. PRBS generator was synchronized with the MLLD by CR. The PRBS sequence \((10^7 - 1)\) was amplified and the train of RZ pulses was modulated in Mach – Zehnder intensity modulator. Eye diagram of the 13.375Gb/s RZ signal at the input to optical time division multiplexer OMUX3 is shown in Fig. 3. It was recorded by Digital Communication Analyzer Infinnium DCA-J 86100C with precision time base 86107A and vertical unit 86116B. Modulated 13.375 Gb/s signal was multiplied 8 times in time domain in OMUX 3 multiplexer. Time coincidence between one of the 107 Gb/s tributaries and the 13.375 GHz pump pulses was adjusted by optical delay line ODL. Autocorrelation trace of 107 Gb/s signal recorded at the input to ODL, is plotted in Fig. 4.

Optical wave of the 1560nm branch of SPM spectrum was used as a pulsed pump. The 13.375 GHz pulses were compressed in 14 m of HNLF and 40 m of SMF 28.

The 107 Gb/s signal and 13.375GHz pump were combined in 50%/50% directional coupler and launched in 500 m of dispersion flattened DF HNLF.

Fig. 3: Eye diagram of 13.375 Gb/s signal at input port of OMUX3

Fig. 4: Autocorrelation trace of 107 GHz signal at the output of OMUX3

Fig. 5: Eye diagram of the pump recorded at the output of WC

Fig. 6: Optical spectrum at the end of HNLF (RBW=0.1nm)

Time coincidence between one of the 107 Gb/s tributaries and the 13.375 nm pump pulses was adjusted by optical delay line ODL. 107 Gb/s signal and 13.375GHz pump were combined in 50%/50% directional coupler and launched in 500 m of dispersion flattened DF HNLF. The parameters of the DF HNLF are as follows: fibre length 500 m ZDW 1558 nm, dispersion slope at 1550 nm \(S = 0.01 \text{ps/nm}^2/\text{km}\), nonlinear coefficient \(\gamma=10.5 \text{W}^{-1}\text{km}^{-1}\) and total loss 0.63 dB at 1550 nm. Two idlers were generated at \(f_{\text{idler,1}} = 2f_p - f_s = 195.4 \text{THz} \quad \text{(1534 nm)}\) and \(f_{\text{idler,2}} = 2f_{\text{idler,1}} - f_p = 193.8 \text{THz} \quad \text{(1571 nm)}\) as shown in Fig. 6. The average pump and signal powers were 22.7 dBm and 26.5 dBm, respectively. It can be seen that the peak power of idler \(\lambda_1\) at 1571 nm is about 10 dB higher that that of ider \(\lambda_1\) at 1534 nm. Part of idler \(\lambda_2\) spectrum was filtered out by OBPF, an L-band OBPF \(\lambda_0\) (OTF-300-12S2, HWHM = 0.9 nm) and converted to electrical signals in RX2 (Bookham PT10GC). Filtered part of idlr2 spectrum is shown in Fig. 7. On of differential outputs of RX2 drives the clock recovery unit CR2. The second output of is either displayed by DCA-J 86100C or the BER evaluated by Centellax 10G BERT TG1B1-A.
Fig. 7: Detail of spectrum of idler filtered out by OBPF (RBW=0.05nm)

Eye diagram of one of the 13.375 Gb/s tributaries after de-multiplexed from the RZ OTDM 107 Gb/s signal is shown in Fig. 8.

4. Conclusions

We demonstrated de-multiplexing of 107 Gb/s OTDM signal based on pulsed pump FOPA. Eye diagram of the de-multiplexed signal was only slightly deteriorated by the FOPA noise.

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References