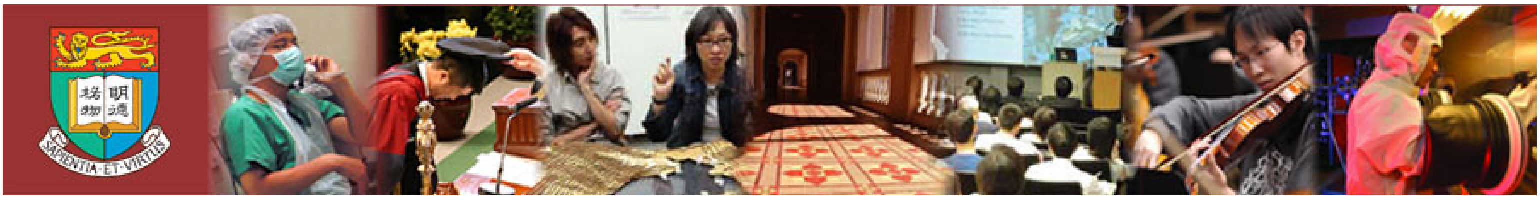

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Author(s)	Xu, X; LI, YC; Yuk, TI; Wong, KKY
Citation	The 16th OptoElectronics and Communications Conference (OECC 2011), Kaohsiung, Taiwan, 4-8 July 2011. In OptoElectronics and Communications Conference Proceedings, 2011, p. 822-823
Issued Date	2011
URL	http://hdl.handle.net/10722/135881
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Optically Powered RZ-DPSK Signal Transmission System with Distributed Parametric Amplification

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Abstract
Distributed parametric amplification (DPA) system for RZ-DPSK signal has been demonstrated. The residual pump was recycled to power up the receiver. Less than 1-dB power penalties at 10^{-9} BER are introduced with 10-dB parametric gain.

1. Introduction

Distributed parametric amplification (DPA) system with both single pump [1] and two pumps [2] for on-off keying (OOK) signal format were recently investigated. The most favorable merit of DPA lies in the signal power variation minimization along the transmission line, which provides the best tradeoff between the noise figure and the fiber nonlinearities [3]. In view of modulation format, comparing to OOK, differential phase-shift keying (DPSK) modulation requires 3-dB lower signal-to-noise ratio (SNR) to reach a given bit-error rate (BER) [4]. It is also less sensitive to the fiber nonlinearity effect and offers large tolerance to the signal power fluctuation in the receiver with balanced detection [4]. Furthermore, return-to-zero DPSK (RZ-DPSK) has higher immunity to four-wave mixing (FWM) -induced crosstalk over nonreturn-to-zero (NRZ) counterpart [5]. Hence, in order to further enhance the system performance in terms of both the energy efficiency and signal quality, RZ-DPSK signal with DPA is demonstrated with less than 1-dB power penalties at the BER of 10^{-9}.

2. Experiment

Fig. 1 shows the experimental setup. The input WDM channels, at 1542.87, 1543.77, 1544.63, and 1545.42 nm, were generated by four tunable laser sources (TLS1-4). They were intensity-modulated together by the Mach-Zehnder modulator (MZM), and then driven by a 10 GHz clock pulse train. The polarization controllers (PC1-4) were used to minimize the insertion loss of each channel by aligning the state-of-polarization (SOP) with the transmission axis of the MZM. The signals were then combined with the pump, at 1548.72 nm, and phase modulated by a $2^{31}-1$ pseudorandom binary sequence (PRBS) at the phase modulator (PM), which was utilized for both signal data modulation and pump phase dithering. The tunable optical delay line (ODL) was employed to align the clock signal with the PRBS launching into the PM.

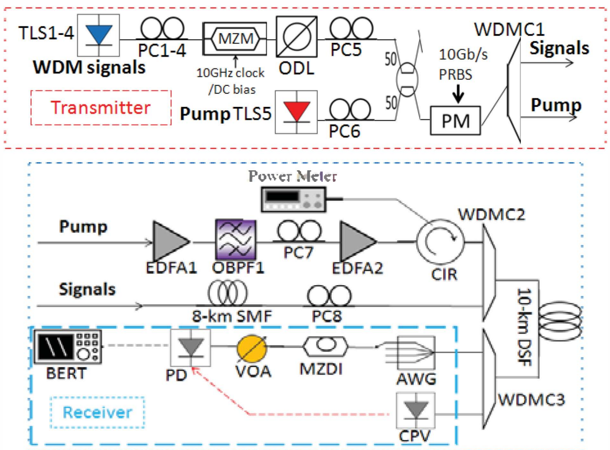

Fig. 1. Experimental setup of the proposed DPA system.

After the WDM coupler (WDMC1), a spool of 8-km single-mode fiber (SMF) was incorporated to de-correlate WDM channels in the time domain. On the pump branch, a double-stage erbium-doped fiber amplifier (EDFA) was employed to amplify the pump power up to 20.3 dBm before the transmission fiber. The optical band pass filter (OBPF1) was used to suppress the amplified spontaneous emission (ASE) noise from

This work was partially supported by grants from Research Grants Council of the Hong Kong S.A.R. China (Project No.: HKU 7179/08E, HKU 7183/09E).

EDFA1. A circulator (CIR) was inserted after EDFA2 to avoid the reflection and monitor the stimulated Brillouin scattering (SBS) level. After WDMC2, the pump and the signals were launched together into the dispersion-shifted fiber (DSF). Their SOPs were aligned by PC7 and 8 to attain the maximum parametric gain.

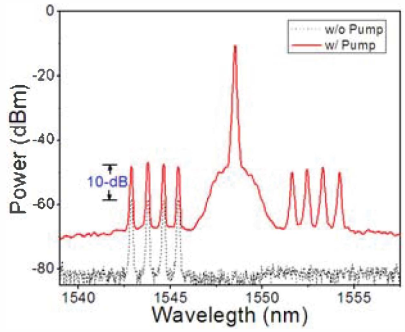

Fig. 2. Optical spectra at the output of DSF with and without pump (OSA resolution bandwidth: 0.06 nm).

The optical spectra at the DSF output with and without the pump are shown in Fig. 2. The signal powers at the DSF input were measured as -24.77, -24.36, -24.51 and -24.3 dBm, respectively, while the corresponding on-off gains were 10.65 to 11.82 dB. At the receiving end, after WDMC3, the 4 channels of 10-Gb/s WDM RZ-DPSK signal were de-multiplexed by an arrayed-waveguide grating (AWG) and demodulated by the Mach-Zehnder delay interferometer (MZDI). The performance of each channel was then quantified by the bit-error rate tester (BERT). Lastly, the residual pump of 16.5 dBm (44.7 mW) was converted by the concentrated photovoltaic (CPV) cell, with a typical power conversion ratio of 26%, to generate the electrical power for the single-ended photodetector (PD).

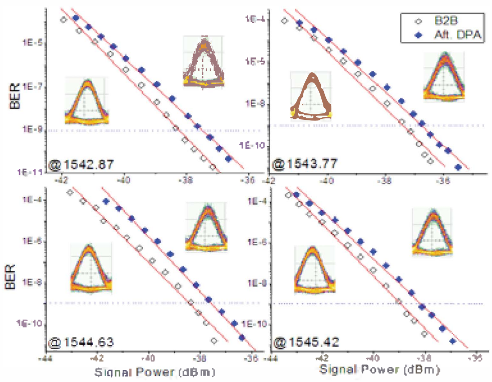

Fig. 3. The BER plots: B2B (left curves), after DPA (right curves), with eye diagrams.

3. Results and Discussion

The measured eye diagrams and BER plots of the demodulated 10 Gb/s RZ-DPSK signals are shown in Fig. 3. The corresponding eye diagrams and BER plots of each channel were obtained and compared against the back-to-back (B2B) signals. Error-free operations are fulfilled for all channels with less than 1-dB of power penalties at the BER of 10^{-9}. The measured response curve for the CPV cell is shown in Fig. 4, the output of the CPV cell was sufficient to serve as the bias voltage of the 5-V photodiode (PD) at the signal receiver.

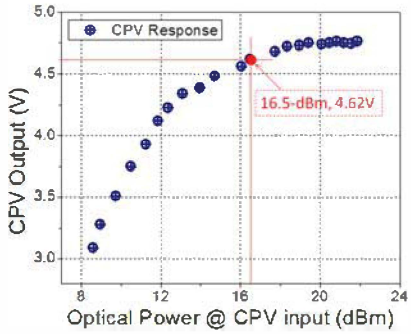

Fig. 4. The response curve of the CPV cell with the input pump at the wavelength of 1548.72 nm.

4. Conclusions

We have demonstrated an optically powered WDM RZ-DPSK signal transmission system by DPA. Power penalties at the BER of 10^{-9} were less than 1-dB for all channels at the presence of 10-dB parametric gain. And the residual optical parametric pump was successfully recycled as the power supply for the receiver component.

5. References

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