Performance study of a 100-Gb/s transmitter with high tolerance to chromatic dispersion and PMD

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ABSTRACT

A 100-Gb/s high-speed optical transmitter is proposed and experimentally demonstrated. Based on frequency-quadrupling technique, two sub-channels with a fixed 50-GHz spacing are obtained from one laser source. Using return-to-zero differential quadrature phase-shift keying (RZ-DQPSK) modulation format and polarization multiplexing (PolMux), only low-speed electronic devices of 12.5 GHz are needed for the 100-Gb/s transmitter. This eliminates the need of ultrahigh-speed optoelectronic devices and thus greatly reduces the cost. The experimental results show that this transmitter can achieve good performance in dispersion tolerance of a 25-km single mode fiber (SMF). The performance of the generated signal is also verified through simulation with respect to chromatic dispersion (CD), polarization mode dispersion (PMD) and nonlinearity.

Keywords: high-speed optical communication, 100GbE, differential quadrature phase-shift keying (DQPSK), polarization multiplexing, frequency quadrupling, chromatic dispersion, polarization mode dispersion, nonlinearity.

1. INTRODUCTION

The rapid development of data-centric services has promoted significant research for 100-Gb/s Ethernet (100GbE) [1-3]. There have been several methods demonstrated for 100GbE implementations at the physical layer[4-6]. These schemes need high speed optoelectronic devices with relatively high cost.

In this paper, we propose and experimentally demonstrate a 100-Gb/s transmitter implemented with low speed electronics of 12.5 Gb/s to reduce the system cost. The transmitter is investigated through experiment as well as simulation showing good performances with respect to chromatic dispersion (CD) and polarization mode dispersion (PMD).

2. SCHEME OF 100-GB/S SIGNAL GENERATION

The schematic diagram of our proposed 100-Gb/s transmitter is shown in Fig.1. A continuous-wave (CW) light from a tunable laser (TL) is firstly modulated by a 12.5-GHz electrical clock signal through frequency-quadrupling technique [7], generating two sub-wavelengths with a fixed spacing of 50 GHz. After separation by a 50/100-GHz inter-leaver, these two sub-wavelengths are modulated respectively. A Mach-Zehnder modulator (MZM) is biased at the quadrature point and driven by a 12.5-GHz clock, modulating each sub-wavelength to generate a 12.5-GHz optical return-to-zero (RZ) pulse train with a 50% duty cycle. The pulses are divided into two parts by a 3-dB coupler and each part is modulated by a differential quadratrue phase shift keying (DQPSK) modulator driven by two 12.5-Gb/s electrical data streams to generate 25-Gb/s RZ-DQPSK signals. Then the two RZ-DQPSK signals are polarization multiplexed by a polarization beam splitter (PBS). After the polarization multiplexing (PolMux), the two sub-channels are combined by a 50/100-GHz inter-leaver, resulting in a 100-Gb/s optical signal.

Optical Transmission, Switching, and Subsystems VI, edited by Ken-ichi Kitayama, Pierpaolo C. Ghiggino, Kim Roberts, Yikai Su, Proc. of SPIE Vol. 7136, 71361O · © 2008 SPIE · CCC code: 0277-786X/08/$18 · doi: 10.1117/12.804002

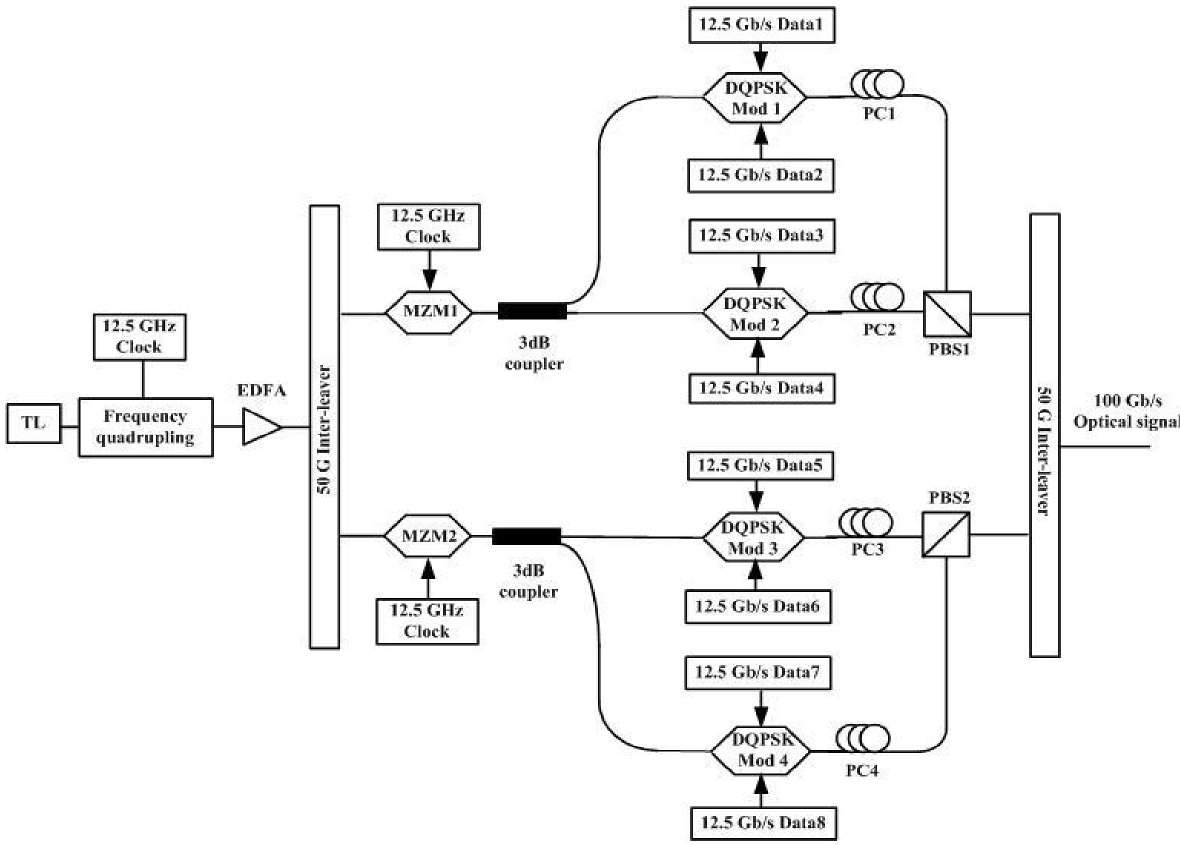


Fig. 1. diagram of the proposed transmitter

3. EXPERIMENTAL SETUP AND RESULTS

The experimental setup is depicted in Fig.2. The spectra after frequency-quadrupling are provided in Fig.3(a). Due to the lack of two DQPSK modulators, the two sub-wavelengths are not separated and we modulate them with the same patterns. The RZ-DQPSK eyediagrams before and after the PolMux are shown in Fig.4(a) and Fig.4(b), respectively. After PolMux, each sub-wavelength carries 50-Gb/s RZ-DQPSK signal. The spectrum of the 100-Gb/s signal is illustrated in Fig.3(b).

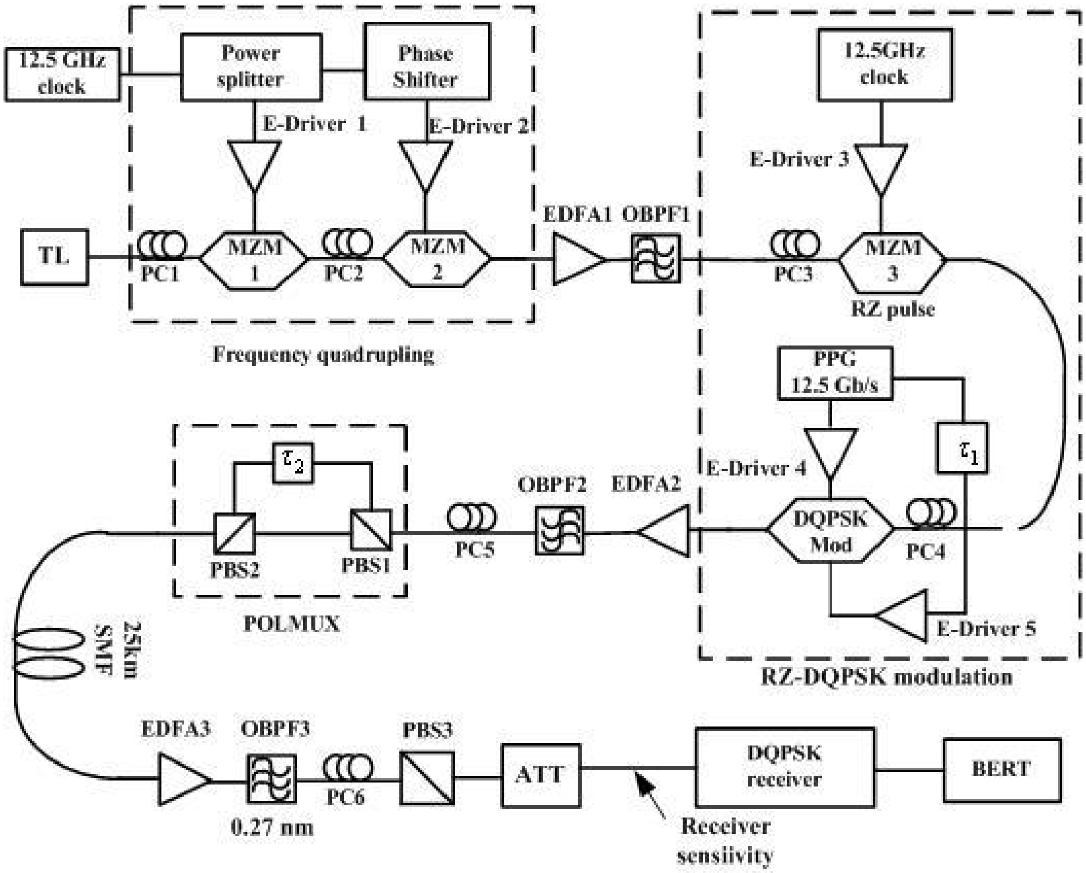
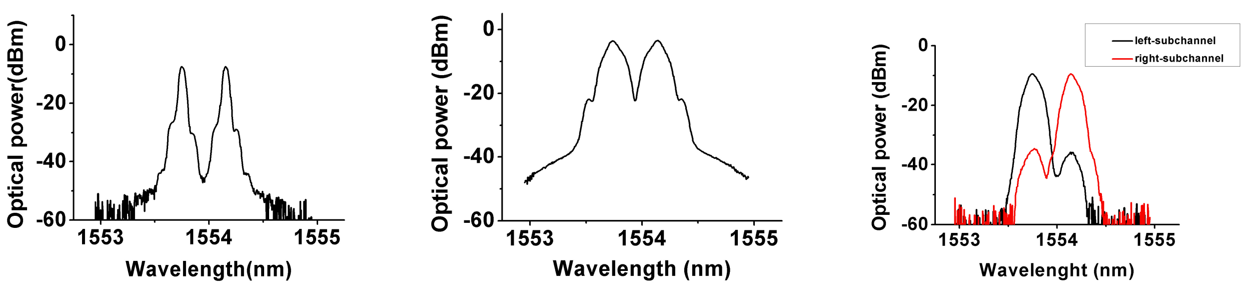


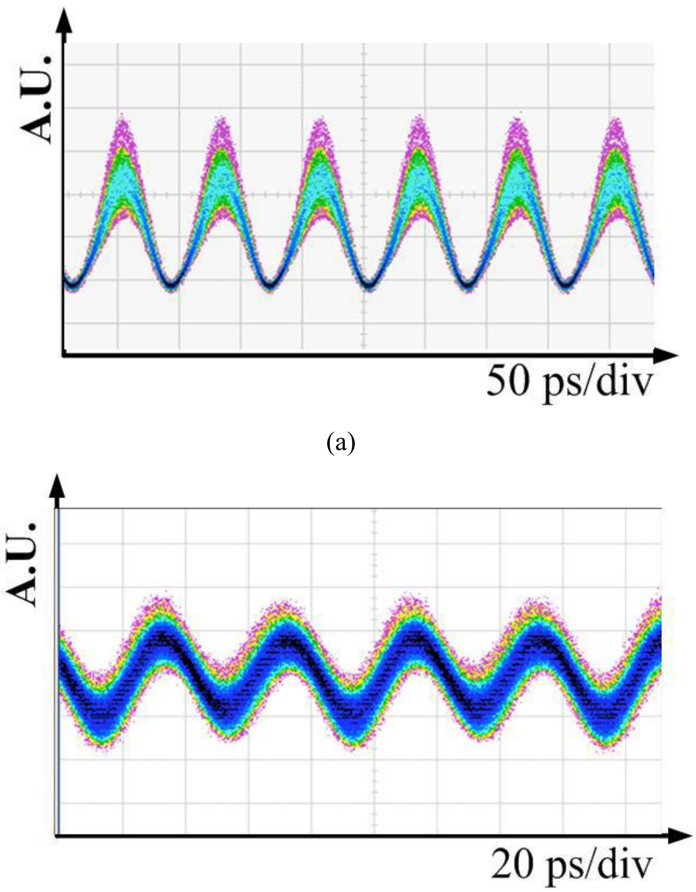
Fig.2. Experimental setup for the 100-Gb/s system

The performances of the generated 100-Gb/s signal are experimentally studied through a 25-km SMF transmission. At the receiver side, we use optical filtering and polarization demultiplexing (PolDemux) to select the desired channel. The spectra after filtering and PolDemux are provided in Fig.3 (c), showing that the two sub-channels are well separated.



(a) (b) (c)

Fig. 3. Optical spectra of (a) frequency quadrupling, (b) 100-Gb/s signal ,and (c) signal after wavelength filtering and PolDemux, with a resolution of 0.07 nm.

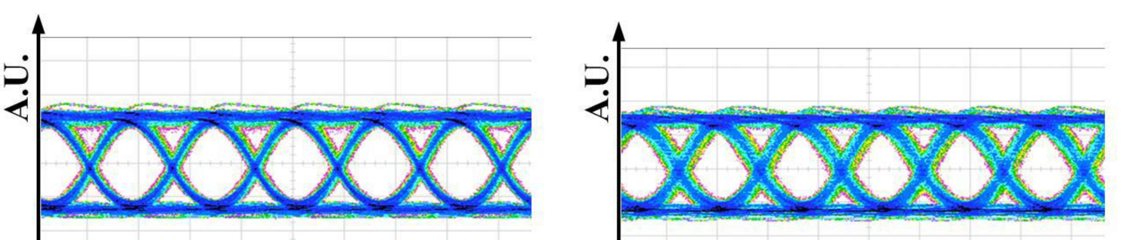


(a)

(b)

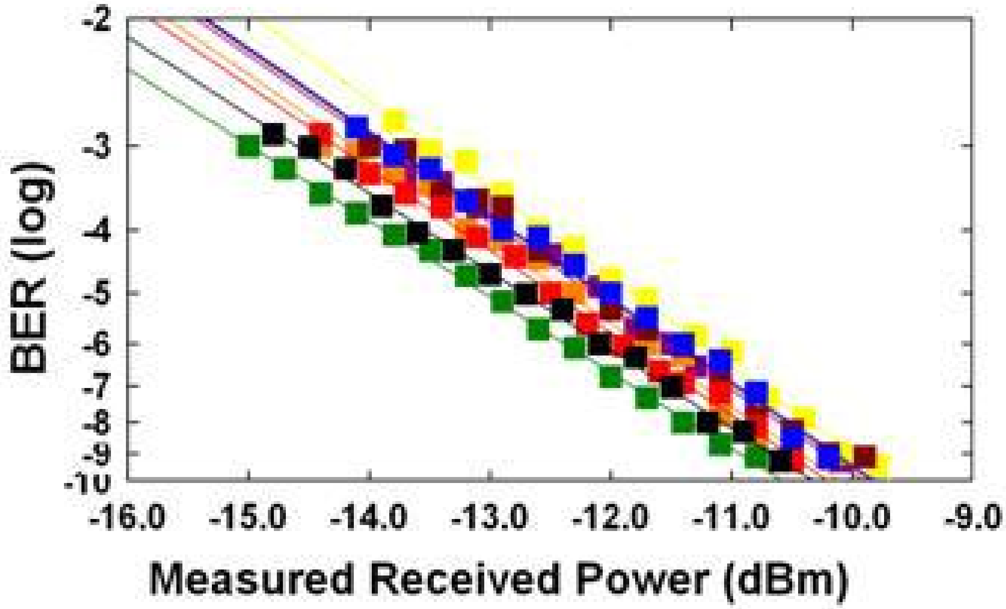
Fig. 4. Eyediagrams (a) before and (b) after PolMux.

The eyediagram after DQPSK demodulation is shown in Fig.5 (b) which is widely open. The measured BER curves as a function of input power are shown in Fig.6 (b), which indicate that all the eight tributaries have similar performances with sensitivities of ~ -8.7dBm at 10^{-9}. The back-to-back (BTB) BERs are also measured and depicted in Fig.6 (a) as a comparison. The power penalty after 25-km transmission is ~1.6 dB, which can be mainly attributed to the uncompensated chromatic dispersion.

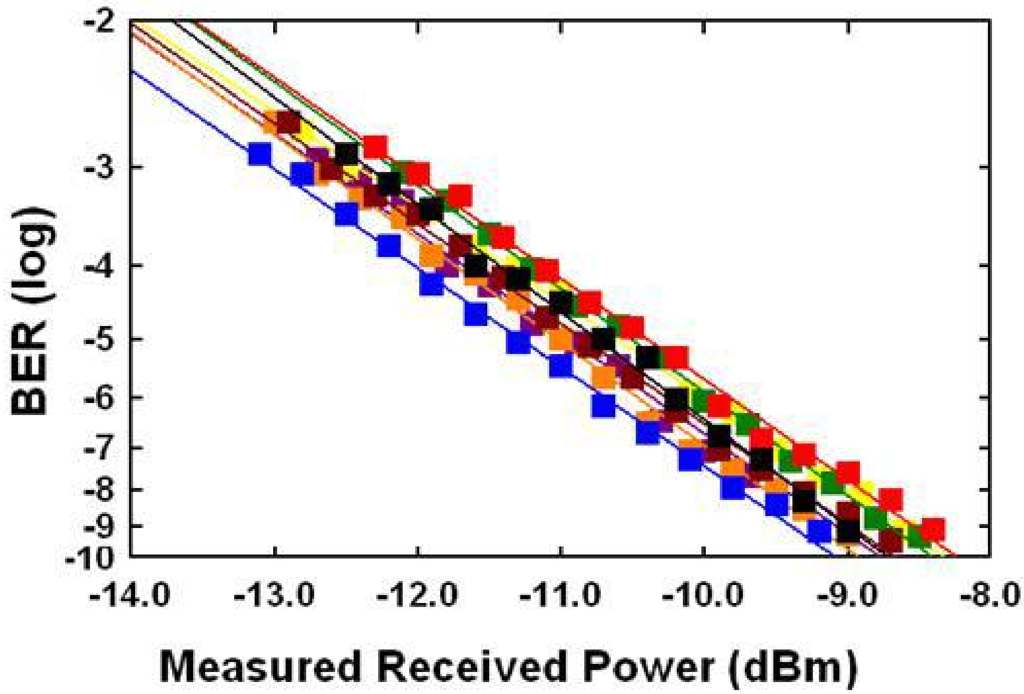


(a) (b)

Fig.5. Eye diagrams after demodulation: (a) B-T-B and (b) after 25-km transmission.



(a)



(b)

Fig.6. BER curves: (a) B-T-B and (b) after 25-km transmission.

4. SIMULATION SETUP AND RESULTS

We use VPI simulation tools to further evaluate the performances of the proposed 100-Gb/s transmitter. The tolerances towards chromatic dispersion (CD) and polarization mode dispersion (PMD) are studied with the setup shown in Fig.7. The degradation is assessed by the eye-opening penalty after demodulation. Only with large group velocity dispersion (GVD) of 680ps/nm, or a 25-ps differential group delay (DGD), the eyediagram is almost closed as shown in Fig.8 and Fig.9, respectively. These results prove the good transmission performance of the signal.

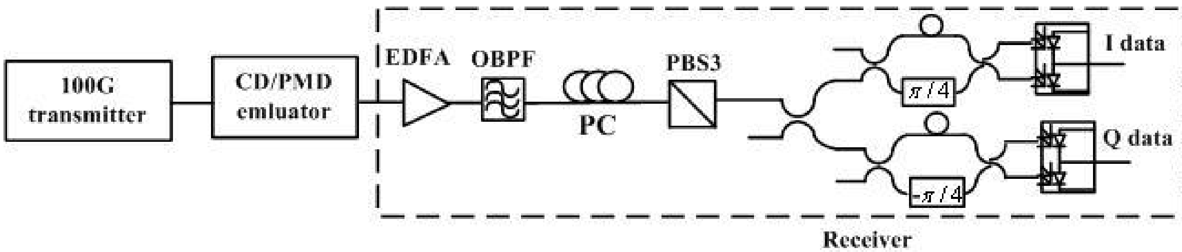
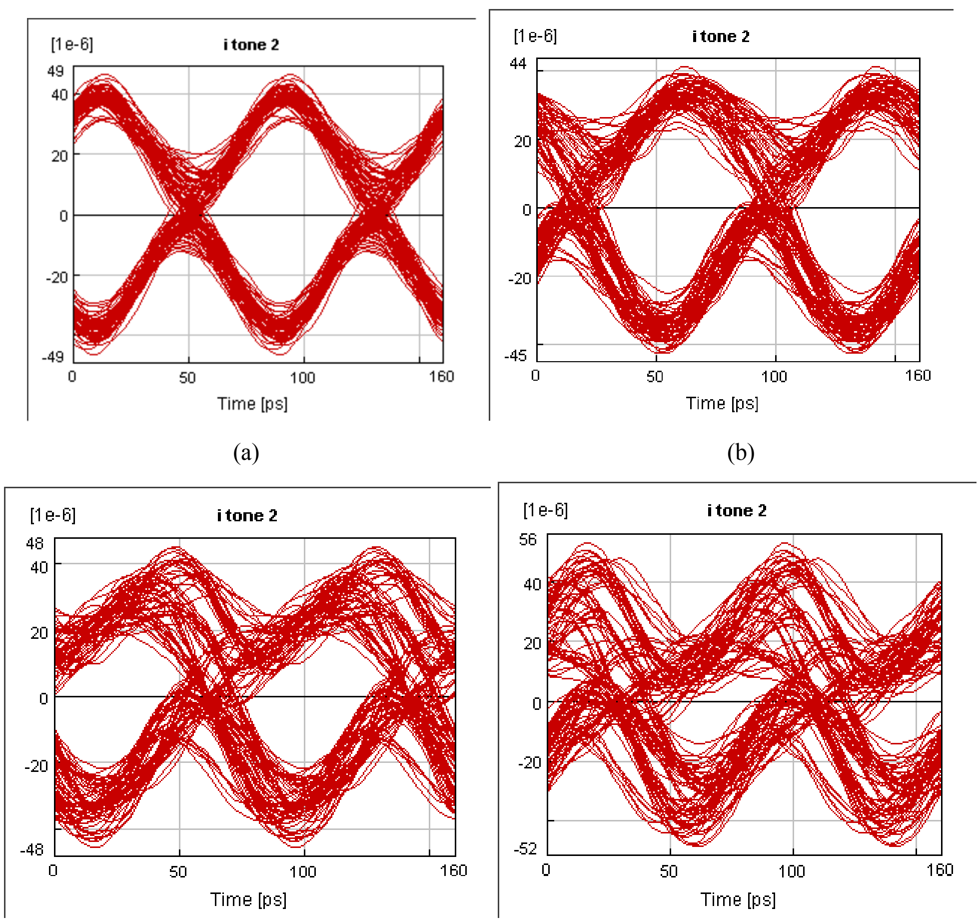


Fig.7. CD/PMD simulation setup



(a) (b) (c) (d)

Fig.8. Eyediagrams with different GVD: (a) 170ps/nm, (b) 340ps/nm, (c) 510ps/nm and (d) 680ps/nm.

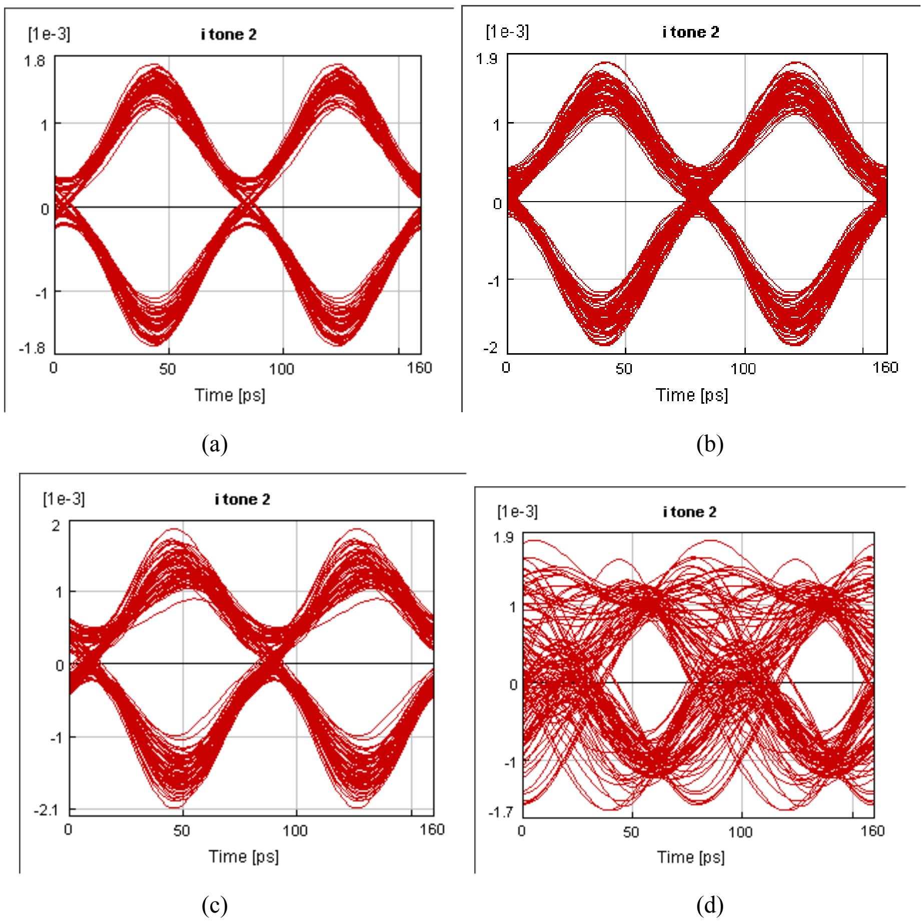


Fig.9. Eyediagrams with different DGD: (a) 5ps, (b) 10ps, (c) 20ps and (d) 25ps.

The setup in Fig.10 is also applied to investigate the nonlinear impairment by changing the optical power into an 80-km SMF. The results in Fig.11 suggest that in order to get a good performance, the optical input power should not exceed 20dBm.

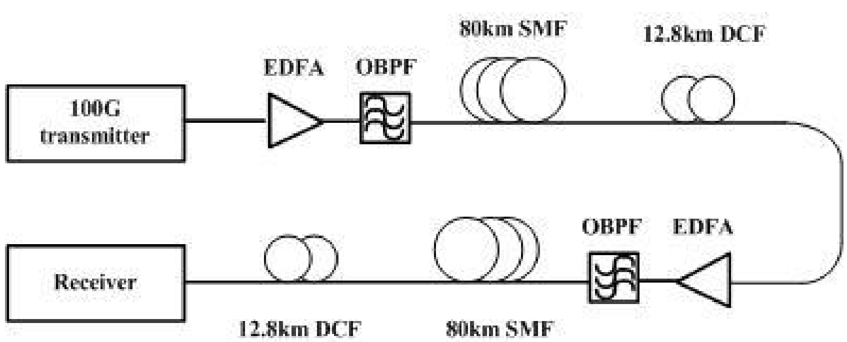


Fig.10. nonlinearity simulation setup

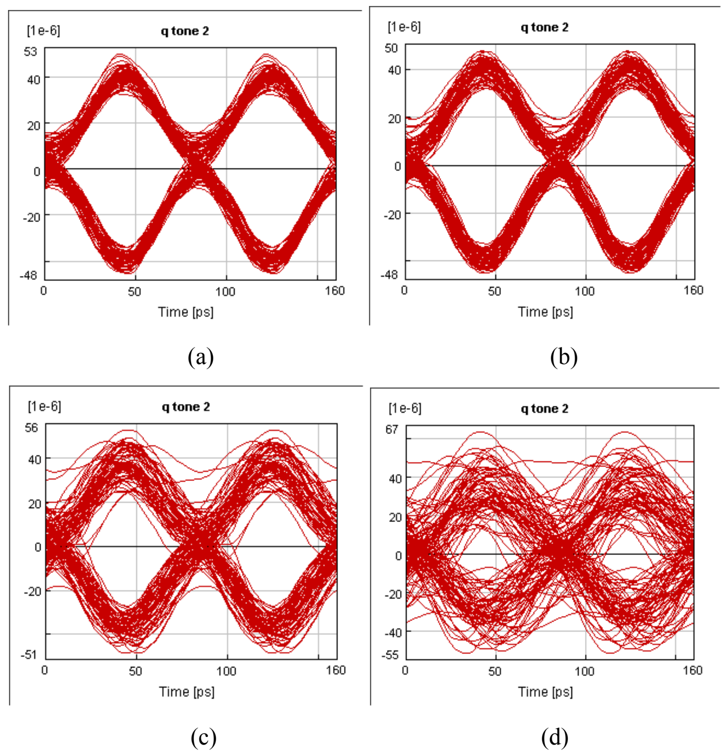


Fig.11.Eyediagrams with different optical input power: (a)10dBm, (b) 15dBm, (c) 19dBm and (d) 21dBm.

5. CONCLUSIONS

We have proposed and experimentally demonstrated a 100-Gb/s transmitter with low speed optoelectronic devices, which can be expected to potentially reduce the system cost. With the frequency quadrupling technique to obtain two sub-channels, the RZ-DQPSK modulation and the PolMux, the baud rate can be reduced to 12.5-GB/s. Simulation results indicate that the transmitter has good performances toward CD, PMD and nonlinear impairments.

REFERENCES

[1] Duelka, M., “Next-generation 100G Ethernet,” in Proceedings of ECOC 2005, Tu3.1.2 (2005).

[2] Fludger, C. R. S., Duthel T., and Schulien, C., “Towards Robust l00G Ethernet Transmission,” in Proceedings of LEOS 2007, ME1.2 (2007).

[3] Melle, S., Jaeger, J., Perkins, D. and Vusirikala, V., “Market drivers and implementation options for 100-GbE transport over the WAN,” IEEE Communications Magazine **11**, 18-24 (2007).

[4] Raybon, G., Winzer, P. J. and Deorr, C. R., “10 x 107-Gbit/s electronically multiplexed and optically equalized NRZ transmission over 400 km,” in Proceedings of OFC 2006, PDP32 (2006).

[5] Daikoku, M., Morita, I. I., Taga, H., Tanaka, H., Kawanishi, T., Sakamoto, T., Miyazaki, T. and Fujita, T., “100Gbit/s DQPSK transmission experiment without OTDM for l00G Ethernet transport,” in Proceedings of OFC 2006, PDP36 (2006).

[6] Yu, J., Zhou, X., Xu, L., Ji, P. N. and Wang, T., “A novel scheme to generate 100Gbit/s DQPSK signal with large PMD tolerance,” in Proceedings of OFC 2007, JThA42 (2007).

[7] Zhang, J., Chen, H., Chen, M., Wang, T. and Xie, S., “A photonic microwave frequency quadrupler using two cascaded intensity modulators with repetitious optical carrier suppression,” IEEE Photonics Technology Letters 19,1057 (2007).