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Experimental Demonstration of 125Gbit/s Half-Cycle 32QAM Nyquist-SCM Transmission System for Short Reach Communications

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***Abstract*—A 125Gbit/s single polarization half-cycle 32QAM Nyquist-SCM signal transmission over 2km was experimentally demonstrated using EML and direct detection with a receiver sensitivity of -5.2dBm at BER=3.8x10^{-3} over 2km of SSMF for short reach communications.**

***Index Terms*—32QAM, sub-carrier modulation, direct detection**

I. Introduction

With the fast increasing capacity demands of data center and other optical inter-connect applications, high-capacity short reach communication systems are desired in the near future, especially short reach transmission system with bit rate of 100Gbit/s per lane. Different from long-haul transmission system, factors of small form, power consumption and cost are important to be considered in short reach systems. In view of this, intensity modulation combined with direct detection (IM/DD) system is promising way to meet these requirements. In order to increase system capacity, advanced modulation formats such as PAM-4, CAP and DMT were employed and widely demonstrated in recent years [1-3]. An alternate advanced modulation format named half-cycle M-QAM Nyquist-subcarrier modulation (SCM) also attracts much attention in short reach applications. In our previous work, single channel 112Gbit/s half-cycle 16QAM Nyquist-SCM signal was demonstrated for short reach application employing 25G EML and direct detection [4]. Higher order modulation format can increase the bit-rate while keeping the bandwidth low. In this paper, we experimental demonstrated generation and transmission of a 25Gbaud/s (125Gbit/s) half-cycle 32QAM Nyquist-SCM signal over 2km of SSMF for short reach communications. Receiver sensitises of -5dBm and -5.2dBm were demonstrated for back-to-back and after 2km transmission, respectively. To the best of author's knowledge, this is the reported highest baud-rate of direct detected half-cycle 32QAM Nyquist SCM signal on single wavelength and single polarization.

II. Experimental Setup

The Experimental setup is shown in Fig.1. At Transmitter side, A 2^{16} de Bruijin bit sequence is used for QAM mapping and the generation of in-phase (I) and quadrature (Q) signal. A raised cosine Nyquist pulse shaping filter is employed to produce Nyquist I and Q signals. The 25GBaud/s (F_s=25GHz) I and Q signals are up-converted onto a 12.5GHz (F_s/2) subcarrier. F_s and T_s denote the baud-rate and symbol period respectively. Then the I and Q components are combined and fed into the DAC with a sampling rate of 50GS/s. The eye-diagram of the generated electrical half-cycle 32-QAM Nyquist SCM signal is shown in the inset (a) of Fig. 1. The electric driving signal is amplified to a 1.7V peak-to-peak by an electric linear amplifier and used to drive a commercial 25Gbps EML with a 3dB bandwidth of 20GHz. The bias voltage is optimized to be -1.5V. The optical spectrum of the generated signal is shown in the inset (b) of Fig. 1. The center wavelength of electrical absorption modulated laser (EML) is 1294.65nm, and the output power is 1dBm. A variable optical attenuator (VOA) is placed after standard single mode fiber (SSMF) to adjust the received optical power. At receiver side, the transmitted signal is detected by a PIN+TIA receiver with a 3dB bandwidth of 30GHz. The detected signal is sampled by a real-time scope with a sampling rate of 80GS/s and a bandwidth of 33GHz. The digital samples are normalized, down-converted and bandlimited to F_s/2 to separate I and Q components. Then the combined 32QAM signal was resampled to 50GS/s (2 samples per symbol). A digital square and filtering clock algorithm is used for retiming. The equalization consists of two stages: a T_s/2 spaced modified multi-radius modulus algorithm (MMCMA) and a T_s spaced decision directed least mean square algorithm (DD-LMS). Finally, symbol decision, symbol to bit mapping and BER is calculated by bit error counting. Fig.2 (a) shows the BER vs received optical power for 125Gbit/s half-cycle 32QAM Nyquist-SCM back-to-back and 2km transmission. The BER performance of back-to-back system is similar to that of 2km transmission. Receiver sensitivities at 7% FEC limit with a BER of 3.8x10^{-3} are demonstrated to be of -5.2dBm, -5dBm for back-to-back and 10km transmission, respectively. The recovered constellation at point A in Fig. 2(a) with a received optical power of -8dBm is shown in Fig. 2(b). The BER is 3.7x10^{-2}. The recovered constellation at point B in Fig. 2(a) with a received optical power of -4dBm is shown in Fig. 2(c). The BER is 3.78x10^{-3}.

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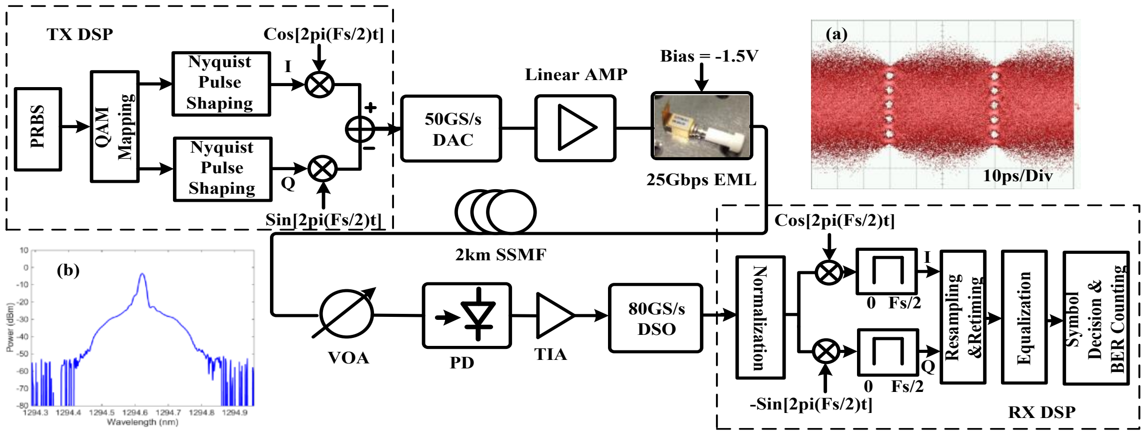

Fig. 1**:** Experimental setup of 125Gbit/s half-cycle 32QAM Nyquist-SCM transmission system. DAC: digital to analog converter, Linear AMP: Electrical Linear amplifier, EML: electric absorption modulated laser, SSMF: standard single mode fiber, VOA: variable optical attenuator, PD: Photo detector TIA: trans-impedance amplifier. (a) Eye-diagram of electrical 25Gbaud/s half-cycle 32QAM Nyquist-SCM signal. (b) Optical spectrum of half-cycle 32QAM Nyquist-SCM signal.

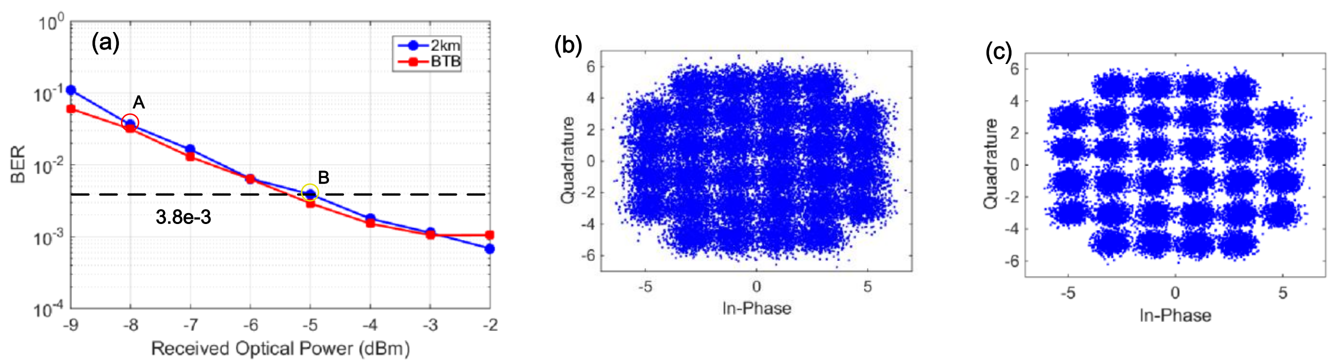

Fig.2. (a) BER vs Received Optical Power, (b)Recovered Constellation with a received optical power of -8dBm, (c) Recovered Constellation with a received optical power of -5dBm.

III. Conclusion

In this paper, we experimentally demonstrated a single channel 125Gbit/s half-cycle 32QAM Nyquist-SCM signal transmission over 2km for short reach communications with a receiver sensitivity of -5.2dBm. To the best of author's knowledge, this is the reported highest baud-rate of direct detected half-cycle 32QAM Nyquist-SCM signal on single wavelength and single polarization.

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References

[1] M. I. Olmedo, T. Zuo, J. B. Jensen, Q. Zhong, X. Xu, S. Popov, I. T. Monroy, "Multiband Carrierless Amplitude Phase Modulation for High Capacity Optical Data Links," J. Lightwave Technology, vol. 32, no. 4, p. 798 (2014).

[2] W. Yan, T. Tanaka, B. Liu, M. Nishihara, L. Li, T. Takahara, Z. Tao, J. C. Rasmussen, and T. Drenski, "100 Gb/s optical IM-DD transmission with 10G-class devices enabled by 65 Gsamples/s CMOS DAC core," Proc. OFC, OM3H.1, Anaheim (2013).

[3] K. P. Zhong, X. Zhou, Y. Gao, W. Chen, J. Man, L. Zeng, A. P. T. Lau and C. Lu, "140Gb/s 20km transmission of PAM-4 signal at 1.3um for short reach communications" Photonics Technology Letters, vol.27, no.16, pp.1757-1761, (2015).

[4] K. P. Zhong, X. Zhou, Y Gao, Y Yang, W. Chen, M. J. Wei, L Zeng, A. P. T. Lau, C. Lu, "Transmission of 112Gbit/s single polarization half-cycle 16QAM Nyquist-SCM with 25Gbps EML and direct detection" Proc. ECOC, p.129, Valencia (2015).