300-km SSMF Transmission of 10-Gb/s Chirp Managed Laser Signal with Pre-emphasis

Wei Jia and Chun-Kit Chan

jw009@ie.cuhk.edu.hk, Department of Information Engineering, The Chinese University of Hong Kong, Shatin, N. T., Hong Kong SAR

Abstract

We demonstrate the 10-Gb/s 300-km SSMF transmission at BER of 10^{-9}, using a directly modulated chirp managed laser (CML) with a simple and passive pre-emphasis driver, without any optical or electronic dispersion compensation.

I. Introduction

For optical access and metro networks with span up to 300 km, directly modulated chirp managed laser (CML) [1] is a promising transmitter for its low cost, small footprint, and high dispersion tolerance. The 10-Gb/s CML, comprising a distributed feedback (DFB) laser (DML) and an optical filter, has realized error-free 250-km standard single mode fiber (SSMF) transmission [2]. With an active 1-bit digital signal processing (DSP) driver for pulse shaping [3], the 10-Gb/s CML has extended SSMF reach to 360 km at bit-error-rate (BER) of 10^{-4}.

Here we experimentally demonstrate the 10-Gb/s 300 km SSMF transmission at BER of 10^{-9} using a CML with a simple and passive pre-emphasis driver. The 10-Gb/s standard CML signal without pre-emphasis could only be transmitted up to 220 km, in comparison. No expensive optical dispersion compensation module (DCM) or power-hungry electronic dispersion compensation (EDC) is used.

II. Operation Principle

Fig. 1 shows the structure of the proposed pre-emphasis driver, which comprises electrical splitter, inverter, attenuator, delay and combiner. Fig. 2 shows the simulated intensity and chirp characteristics for the standard CML signal without pre-emphasis and the CML signal with pre-emphasis before and after 300-km SSMF transmission with an input bit sequence of "0011001001011100". By tuning the spectral position of the narrow-bandwidth filter inside the CML, high extinction ratio (ER) signal can be obtained. However, in Fig. 2 (a), it is observed that the intensity of the single "1" bit is slightly reduced, compared with the consecutive "1" bits, i.e., double "1" bits and triple "1" bits. Fig. 2 (b) shows that the main reason limiting the BER performance for the standard CML signal after 300-km SSMF is that the single "1" bit collapses quickly, while the consecutive "1" bits grow and become sharp, due to the interference among the adjacent bits, thus inducing severe intensity fluctuations. By employing our proposed pre-emphasis driver, the intensity of the single "1" bit is enhanced, compared with the main part of the consecutive "1" bits, as depicted in Fig. 2 (c). Hence, the intensity differences

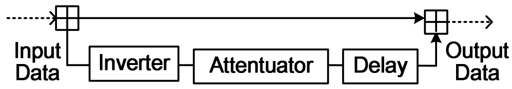
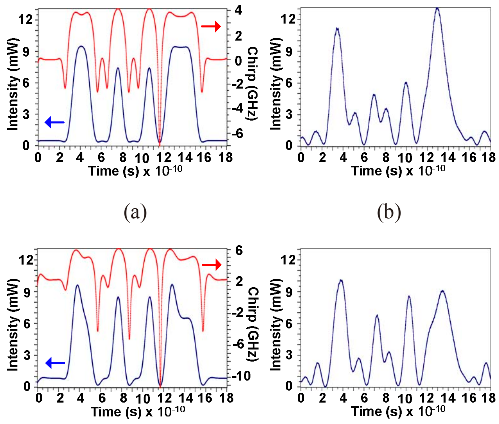


Fig. 1: Proposed pre-emphasis driver.



(a) (b)

(c) (d)

Fig. 2: Simulated intensity and chirp characteristics of (a) BtB standard CML signal, (b) standard CML signal after 300-km SSMF, (c) BtB CML signal with pre-emphasis, and (d) CML signal with pre-emphasis after 300-km SSMF with an input bit sequence of "0011001001011100".

between the single "1" bit and consecutive "1" bits are reduced after 300-km SSMF transmission, as shown in Fig. 2 (d). Besides, a large red shifted transient chirp at the falling edges of bit transitions is generated, while the blue shifted transient chirp at the rising edges of bit transitions is suppressed by tuning the spectral position of filter in CML, as shown in Fig. 2 (c). This uni-polar negative transient chirp also helps to increase the reach of CML [3].

III. Experiment and Results

We have experimentally verified the proposed scheme. Fig. 3 shows the experimental setup. The 9.953-Gb/s driving signal with pre-emphasis using 2^{31}-1 pseudorandom binary sequence (PRBS) was generated by combining the non-inverting data and the inverting data from the pulse pattern generator (PPG), via a combiner. The inverting data was attenuated by 8 dB and delayed by about 50 ps, compared with the non-inverting data. The peak-to-peak driving voltage V_{pp} was 0.9 V. A standard CML module (Finisar DM200-01) was employed in the experiment. The input impedance, the threshold current and the FM efficiency of the DFB laser were 50 ohms, 25 mA and 0.24 GHz/mA, respectively. The DFB laser was biased at 70 mA, high above the threshold to assure high output power, wide modulation bandwidth, and single

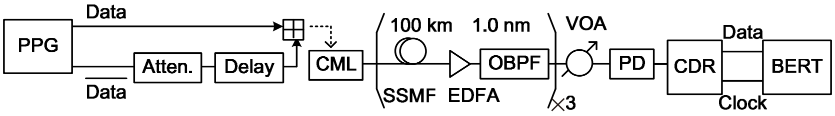


Fig. 3: Experimental setup for the 10-Gb/s CML transmission.

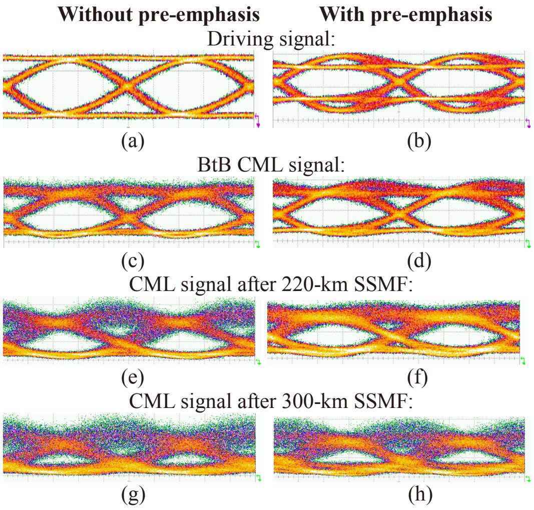


Fig. 4: Eye diagrams of the (a-b) driving signal, (c-d) BtB CML signal, (e-f) CML signal after 220-km SSMF, and (g-h) CML signal after 300-km SSMF. Time scale: 20 ps/div

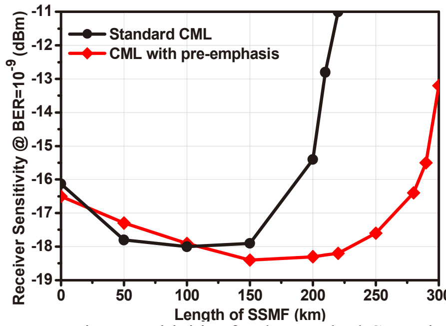


Fig. 5: Receiver sensitivities for the standard CML signal without pre-emphasis and the CML signal with pre-emphasis after various lengths of SSMF.

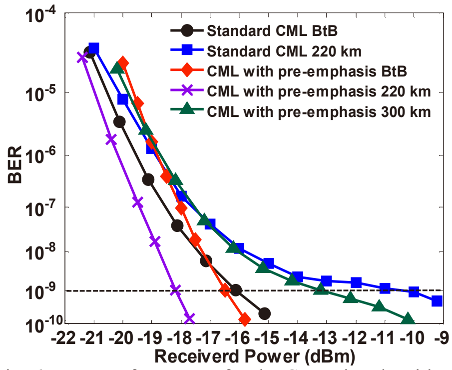


Fig. 6: BER performances for the CML signals with and without pre-emphasis.

mode operation [1]. The filter inside the CML had a 3-dB bandwidth of 7 GHz and a slope of 2.4 dB/GHz. The central wavelength, extinction ratio (ER) and optical power of the CML signal were 1556.9 nm, 7.4 dB and 0.95 dBm, respectively. The transmission line was composed of three spans of 100-km SSMF. An erbium-doped fiber amplifier (EDFA) was inserted after every span to boost up the optical power to 2 dBm. A tunable optical band pass filter (OBPF) with 1.0 nm bandwidth was placed after EDFA to eliminate excessive amplified spontaneous emission (ASE) noise. A variable optical attenuator (VOA) was used to adjust the input power of the receiver, which comprised a photo-detector (PD) and a clock-data recovery (CDR) circuit. The recovered data and clock were sent to the bit error rate tester (BERT). In the control setup for the standard CML without pre-emphasis driver, the DFB laser was also biased at 70 mA. The peak-to-peak driving voltage V_{pp} was 0.7 V to generate an adiabatic chirp of 4 GHz. The bias, driving voltage and spectral position of filter in CML were optimized for maximum SSMF transmission.

Fig. 4 shows the eye diagrams of the driving signal, back-to-back (BtB) CML signal, and CML signal after 220-km and 300-km SSMF before CDR, with and without pre-emphasis. Fig. 4 (f) and (h) show that the CML signals with pre-emphasis exhibited less mark noise and much wider eye opening compared with the standard CML signal in Fig. 4 (e) and (g), after 220-km and 300-km SSMF. We have also measured the transmission performances of fiber dispersion tolerance for the CML signals with and without pre-emphasis. Fig. 5 shows the receiver sensitivities at BER of 10^{-9} after various lengths of SSMF for the two cases. The CML signal with pre-emphasis realized 300-km SSMF transmission, with a power penalty of 3.3 dB, compared with its BtB receiver sensitivity of -16.5 dBm. It also showed a negative power penalty of -1.7 dB after 220-km SSMF transmission. This was attributed to the mitigation of the over-shoots at the rising and falling edges of the bit transitions and the ER enhancement of the CML signal with pre-emphasis, after SSMF. The standard CML signal could only be transmitted up to 220 km with a power penalty of 5.1 dB, compared with its BtB receiver sensitivity of -16.1 dBm. Fig. 6 shows the BER performances of the CML signals with and without pre-emphasis. The standard CML signal showed obvious error floor at BER of 10^{-10}, while the CML signal with pre-emphasis showed a straight BER curve after 220-km SSMF transmission.

IV. Conclusions

We have experimentally demonstrated the 10-Gb/s 300-km SSMF transmission at BER of 10^{-9} using a directly modulated CML with a simple and passive pre-emphasis driver. The transmission performance of fiber dispersion tolerance was investigated and compared with the standard CML.

References

[1] Y. Matsui et al., PTL, **18**, 385-388 (2006).
[2] D. Mahgerefteh et al., EL, **41**, 543-544 (2005).
[3] X. Zheng et al., Proc. OFC 2009, OThE5.