Advanced modulation format generation using high-speed directly modulated lasers for optical metro/access systems

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ABSTRACT

We discuss and experimentally demonstrate the optical signal generation of various advanced modulation formats at high-speed using a directly modulated chirp-managed laser (CML), including phase-shaped binary transmission (PSBT), inverse-return-to-zero duobinary (IRZ-duobinary), Manchester-duobinary, return-to-zero differential phase shift keying (RZ-DPSK) and return-to-zero differential quadrature phase-shift-keying (RZ-DQPSK). The generated optical signals have improved dispersion tolerance and their corresponding transmitters have the features of compactness, low power consumption and cost-effectiveness, which are desirable in optical metro/access systems. Their system applications are also discussed.

Keywords: direct modulation, chirp managed laser, modulation format, optical transmitter.

1. INTRODUCTION

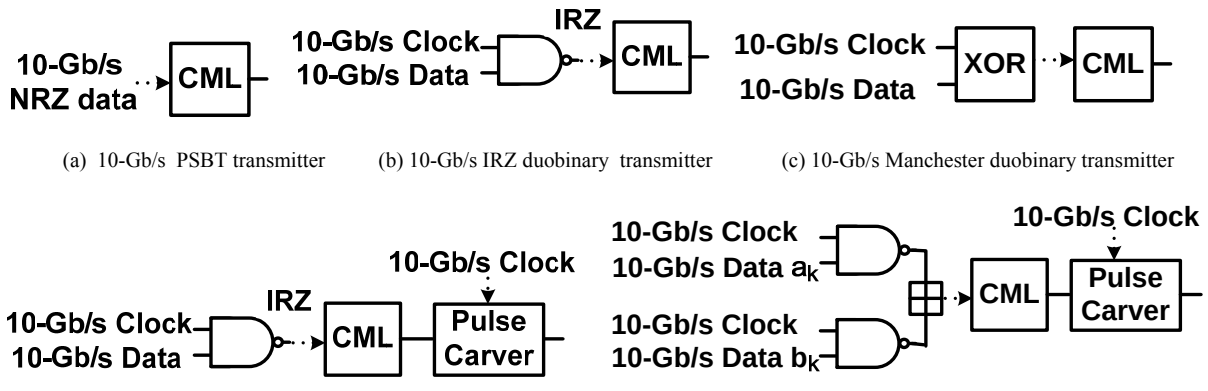
Optical metro/access networks with less than 200-km span require dispersion tolerant modulation format and cost-effective high-speed optical transceivers. Chirp managed laser (CML) [1], which integrates a directly modulated distributed feedback (DFB) laser and an optical band pass filter, is a promising candidate for high-speed optical signal generation at 10-Gb/s and above, in view of its much enhanced optical reach, as compared with the conventional directly modulated lasers. It also has the advantages of compactness, low cost, high performance and reduced power consumption. Besides, its inherent simultaneous intensity and phase coding property can be exploited to generate optical signals in various advanced modulation formats [2].

In this paper, we discuss and experimentally demonstrate high-speed optical signal generation in various advanced modulation formats including phase-shaped binary transmission (PSBT), inverse-return-to-zero (IRZ) duobinary, Manchester duobinary, return-to-zero differential phase shift keying (RZ-DPSK) and return-to-zero differential quadrature phase-shift-keying (RZ-DQPSK), by directly modulating a CML with our designed electrical driving signals.

Compared with the conventional schemes using external modulator, the proposed schemes not only simplify the electronic encoders, but also get rid of the costly and bulky external modulators partially or totally. The performance of the generated optical signals and their applications in optical metro/access network will also be discussed.

2. OPERATION PRINCIPLES

CML consists of a DFB laser and an optical band pass filter, integrated in single laser package. The DFB laser is usually biased at around five times of its threshold, which provides the benefits of high output power, wide modulation bandwidth and suppression of the unwanted transient chirp. The optical filter is used to adjust the optical signal extinction ratio (ER). Fig. 1 shows the proposed schemes for generating various modulation formats based on CML. Fig. 1(a) shows the 10-Gb/s PSBT generation by directly modulating CML with a NRZ electrical signal. The driving voltage V_{pp} is adjusted to induce adiabatic chirp of $\Delta f = 1/2T$. The adiabatic chirp generates phase shift $\Delta\phi = 2\pi \int_0^T \Delta f(t)dt = 2 \times 1/2T \times T =$ during the low level period of the signal. Much enhanced dispersion tolerant transmission was realized via optimization of operation conditions such as laser bias, driving voltage, and misalignment between the signal wavelength and the center wavelength of the filter. Fig. 1(b) illustrates the 10-Gb/s IRZ-duobinary signal generation by directly modulating CML with an IRZ electrical signal. The driving voltage V_{pp} is adjusted to induce adiabatic chirp of $\Delta f = 1/T$. Fig. 1 (c) shows the schematic of the proposed 10-Gb/s CML-based Manchester-duobinary transmitter, which comprises an electronic XOR gate and a CML [2]. The driving signal is an electrical Manchester signal and its driving amplitude V_{pp} is adjusted to generate adiabatic chirp of $\Delta f = 1/T$. Fig. 1 (d) depicts the proposed scheme of 10-Gb/s RZ-DPSK transmitter based on CML [3]. The transmitter consists of an IRZ driver, a CML, and a pulse carver. The driving voltage V_{pp} is adjusted to induce adiabatic chirp of $\Delta f = 1/T$. The pulse carver carves the second half-bit of the phase-modulated signal, thus generating the RZ-DPSK signal. The phase modulation is intrinsically differentially encoded. No differential encoder and phase modulator (PM) are needed. Fig. 1 (e) depicts the proposed 20-Gb/s CML-based RZ-



(a) 10-Gb/s PSBT transmitter (b) 10-Gb/s IRZ duobinary transmitter (c) 10-Gb/s Manchester duobinary transmitter

(d) 10-Gb/s RZ-DPSK transmitter (e) 20-Gb/s RZ-DQPSK transmitter

Fig. 1 Proposed schemes of various advanced modulation format generation using a CML

DQPSK transmitter consisting of two IRZ encoders, a passive RF combiner, a CML and a pulse carver [4]. The two input data streams are firstly encoded in IRZ format with different driving voltages and then combined by a passive RF combiner to generate a four-level IRZ signal to drive the CML. The pulse carver carves the second half-bit of the phase-modulated signal, thus generating the RZ-DQPSK signal. This scheme could be generalized to generate *M*-ary RZ-DPSK signal based on CML.

3. APPLICATIONS OF CML-BASED TRANSMITTERS IN OPTICAL METRO/ACCESS NETWORKS

The CML-based PSBT could realize transmission at 10-Gb/s from 0 to 200-km in standard single-mode fiber (SSMF) without dispersion compensation, which makes it a promising candidate in optical metro networks. The CML-based 20-Gb/s RZ-DQPSK signals could meet the increasing capacity demand in optical metro networks with the features of high receiver sensitivity, high nonlinearity robustness and high bandwidth efficiency [5]. The SSMF transmission distance of both 10-Gb/s CML-based IRZ-duobinary and RZ-DPSK signal are 80-km. The CML-based IRZ-duobinary signal can be used as the downstream signal format in a long-reach WDM passive optical network to facilitate data re-modulation at the optical network unit for upstream transmission. The CML-based RZ-DPSK signal can benefit from high receiver sensitivity using balanced detection and high nonlinearity tolerance. Thus, it is suitable for long-reach access network which requires high performance. The 10-Gb/s CML-based Manchester-duobinary signal increases the chromatic dispersion (CD) tolerance of the Manchester signal by three times, which makes it applicable in burst mode transmission and bi-directional optical access network [3].

4. CONCLUSIONS

We have discussed and demonstrated the optical signal generation in various advanced modulation formats, using a directly modulated CML at 10-Gb/s and above. The CML-based transmitters have the benefits of more compactness, lower cost, higher performance and less power consumption compared with the conventional ones. In addition, they have larger CD tolerance and thus are practical optical transmitters for different kinds of optical metro/access systems.

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