Dual MZI-SOA with Serial Configuration for Quadrature Phase Modulation

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A novel generation scheme of QPSK format using dual MZI-SOA in serial configuration is presented. The feasibility of 20 Gb/s QPSK signal with coherent detection is experimentally shown.

1. Introduction

Traditional intensity modulated with direct detection (IM DD) formats show reduced spectral efficiency (SE) and are inadequate for high capacity wavelength division multiplexing (WDM) applications. To transmit data at 100 Gb/s/channel, even more advanced modulation formats, such as coherently detected, polarization multiplexed quadrature phase-shift keying (CP-QPSK) [1], multilevel quadrature amplitude modulation (QAM) [2], and orthogonal frequency division multiplexing (OFDM) [3] are required. The use of advanced modulation formats allows increasing the bit rate of each channel without increasing significantly the spectral width of the transmitted signal. This allows using tight channel spacing and, consequently, increasing the capacity of a link. By using coherent detection, the amplitude, phase and state of polarization of the received signal are assessable. Thus, a much “smarter” receiver may be implemented using an advanced digital signal processing, thus overcoming many of the transmission impairments. Several generation schemes for multilevel QAM were proposed in [2], adjusting the number of modulation levels by adding an extra Mach-Zehnder modulator (MZM) or phase modulator (PM) in serial or parallel configurations. However, complex electrical control of this generation schemes is requested. In [4], all-optical conversion from non-return-to-zero (NRZ)-OOK to multi-level PSK was proposed by using the MZI-SOA where the electrical control is simple as for NRZ-OOK. However, to obtain higher levels modulation schemes with small electrical complexity is still a challenge.

In this paper, multi-level PSK generation scheme with low electrical complexity is proposed by implementing two MZI-SOA in serial configuration. Furthermore, the feasibility of 20 Gbps QPSK signal is analyzed experimentally.

2. System Description and Experimental Setup

In Fig. 1, the generation scheme of 4-QAM signals is shown. The 10Gb/s NRZ signal is generated at wavelength 1554.94 nm. The binary sequence of only 16 bits is used to allow the coherent detection with optical complex spectrum analyzer using the local oscillator at 2.5 GHz. Two MZI-SOAs connected in serial are used with the balanced arms in common mode configuration (XOR gate). At the input of the first MZI-SOA, a DFB laser at 1546.12 nm is applied with an average power of 3 dBm to keep the SOAs in nonlinear regime. The NRZ signal is first amplified then split by two 50 % couplers on four signals. The first two NRZ signals are applied to the 1st MZI-SOA arms and the next two NRZ signals are first synchronized with the output signal of 1st MZI-SOA after the filtering (delay between input #1 and input #2 of 2nd MZI-SOA should be a multiple of the bit period) and then applied to the 2nd MZI-SOA arms. Both pairs of NRZ signals, before to be implemented on MZI-SOA arms, are firstly synchronized between them by ODL and adjusted by VOA to the same average power (~2 dBm) to maintain the SOAs saturated. The signal after the 1st and 2nd MZI-SOA is filtered with narrow optical band-pass filters at 1546.12 nm to eliminate the optical channel used for NRZ signal generation. The experimental analyses are provided in back-to-back to measure the feasibility of intensity and phase modulation after each MZI-SOA.

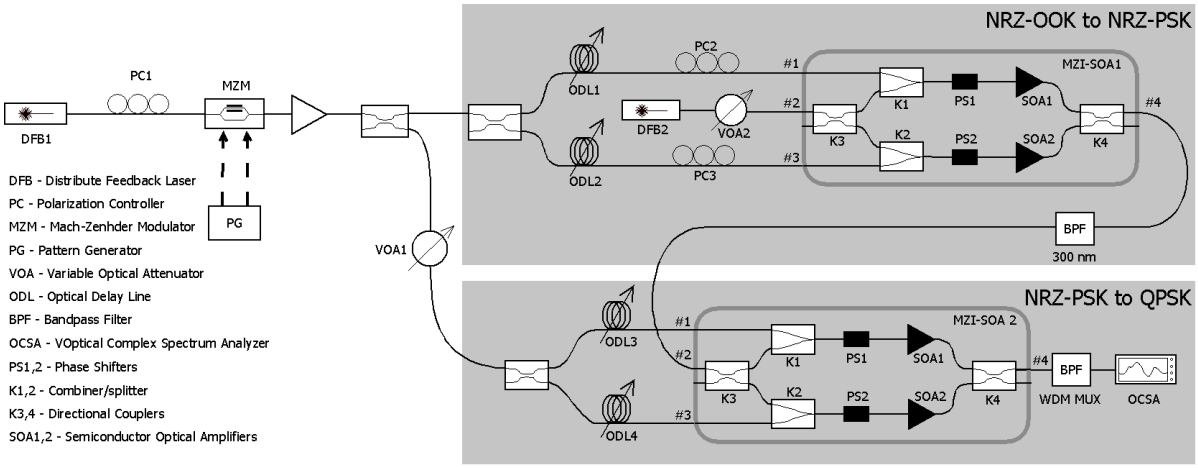

Figure 1: Experimental setup. Solid lines represent fiber-optic paths and dashed lines indicate electronic connections.

3. Results and Discussion

In Fig. 2 a) and b), the constellation diagrams at the output of the 1st and 2nd MZI-SOA are shown, respectively, after the band-pass filtering. Due to the lab restrictions (small number of bits, relatively high optical powers at the MZI arms, ...), the constellation diagram appears to be considerably imprecise. In Fig. 2 a), it can be observed that after the 1st MZI-SOA, the binary PSK signal is generated (2 constellation points). Similarly as it was shown in [4], an all-optical OOK to PSK conversion is achieved. By adding one more MZI-SOA in serial configuration, higher level PSK modulation can be achieved as it is demonstrated in Fig. 2 b) (4 points constellation diagram) by generating QPSK format. QPSK signal generated with the proposed scheme requests much less electrical components and control complexity, than the conventional schemes. Moreover, by using the SOAs in generation schemes not only the modulation but also the amplification is gained. Furthermore, since the OOK to PSK conversion is all-optical, it can be easily

applied not only at the transmission part of the network but also at the connection nodes between the access and metro or long-haul networks, making at the same time amplification, resynchronization, and conversion to the high level advanced modulation formats. By adding more MZI-SOAs in serial, higher-level advanced modulation formats can be achieved.

(a) (b)

Figure 2: Constellation diagram at the output of BPF1 (a) and at the output of BPF2 (b).

4. Conclusion

A novel generation scheme of QPSK format is presented by using the dual MZI-SOA. The feasibility of a 20 Gb/s QPSK signal with coherent detection is experimentally shown, using the proposed generation scheme. Not only the modulation but also the amplification using the SOA is inserted with much less electrical components and control complexity. With the novel scheme, the OOK to PSK and QPSK all-optical conversion is achieved, which can be easily applied in any part of the network, i.e. within access to metro or long-haul connection nodes, making at the same time amplification, resynchronization, and conversion to high level advanced modulation formats. By adding more MZI-SOAs in serial, higher-level advanced modulation formats can be achieved.

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