All-optical logic NOT gate
for Manchester encoded signal
using a reflective semiconductor optical amplifier

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We propose and experimentally demonstrate an all-optical Manchester NOT gate. A logic NOT signal is realized for a 10 Gb/s Manchester encoded signal, based on cross-gain modulation (XGM) in a reflective semiconductor optical amplifier (RSOA).

1. Introduction

Manchester code, also called the bi-phase code, is a kind of pulse-position-modulation (PPM) format. Since it has the advantages of level insensitive, simple clock extraction and high-level intensity fluctuation tolerance [1, 2], it is regarded as a promising code for high-speed burst mode transmission links. Combined with phase-shift keying (PSK), it is shown that Manchester code provides enhanced tolerance to beat interference noise in a passive optical network (PON) [3]. Furthermore, Manchester code can also be applied for optical code division multiple access (O-CDMA) systems in secured optical communication networks with reduced multiple access interference [4]. Thus, for the high speed applications in optical networks, all-optical logic operations for Manchester encoded signal are highly desirable, owing to the speed limit of the electronic components.

NOT gate is a basic logic unit for signal processing. In fact, all kinds of logic gates can be achieved by assembling of logic minterm or maxterm, which is constituted by the original signals and their logic NOT signals [5]. Nonlinear effects in semiconductor optical amplifier (SOA) have been widely investigated for realizing all-optical logic gates [5–7]. Especially, the effect of cross-gain modulation (XGM) can be expediently used to achieve logic NOT gate for non-return-to-zero (NRZ) format. However, all-optical logic gate for Manchester encoded signal has never been reported, which

is supposed to be widely used in the optical switching node in future all-optical networks.

Reflective SOA (RSOA) is a special kind of SOA with a high reflective facet, so it can only output by reflection [8]. Thus, the input lights will pass through the active area twice. That is to say, the effective length for the effect of XGM doubles. So RSOA brings better modulation performance than traditional SOA [9]. In the present paper, an all-optical Manchester NOT gate is proposed for the first time. By utilizing XGM in an RSOA, the logic NOT signal for a 10 Gb/s Manchester encoded signal is obtained.

2. Experimental setup and operation principle

The experimental setup for the Manchester logic NOT gate is shown in Fig. 1. A 10 Gb/s Manchester encoded signal is generated at wavelength λ_s, by a bit pattern generator (BPG) and a LiNbO$_3$ Mach–Zehnder modulator (MZM). A continuous wave (CW) at wavelength λ_c is coupled with the signal into an RSOA. Thus, the signal
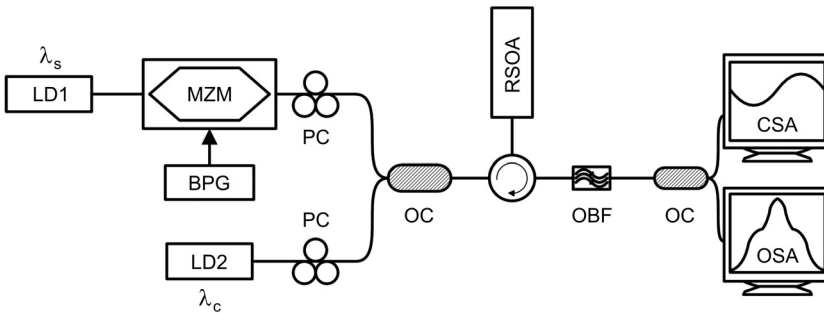

Fig. 1. The proposed Manchester NOT gate. LD – laser diode, PC – polarization controller, OC – optical coupler, OBF – optical bandpass filter.

information is modulated onto the probe wavelength with an inverted wave pattern through the effect of XGM in the RSOA. After an optical bandpass filter (OBF), the logic NOT signal is obtained at λ_c. The output spectra are monitored by an optical spectrum analyzer (OSA, Anritsu MS9710C) with the highest spectral resolution of 0.05 nm, and the optical pulses are observed through a communication signal analyzer (CSA, Tektronix CSA 8000B).

3. Experimental result and discussion

In the experiment, we choose λ_s = 1549.7 nm, and λ_c = 1539.9 nm. The bit patterns for 2^7-1 pseudorandom bit sequence (PRBS) of different optical waves are clearly displayed in Fig. 2. The output signal shows obvious inverted waveform, when
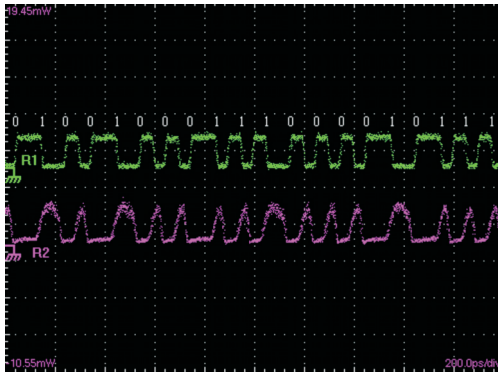
Fig. 2. Waveforms for the input and output signals. R1: input Manchester encoded signal; R2: output for the logic NOT gate.
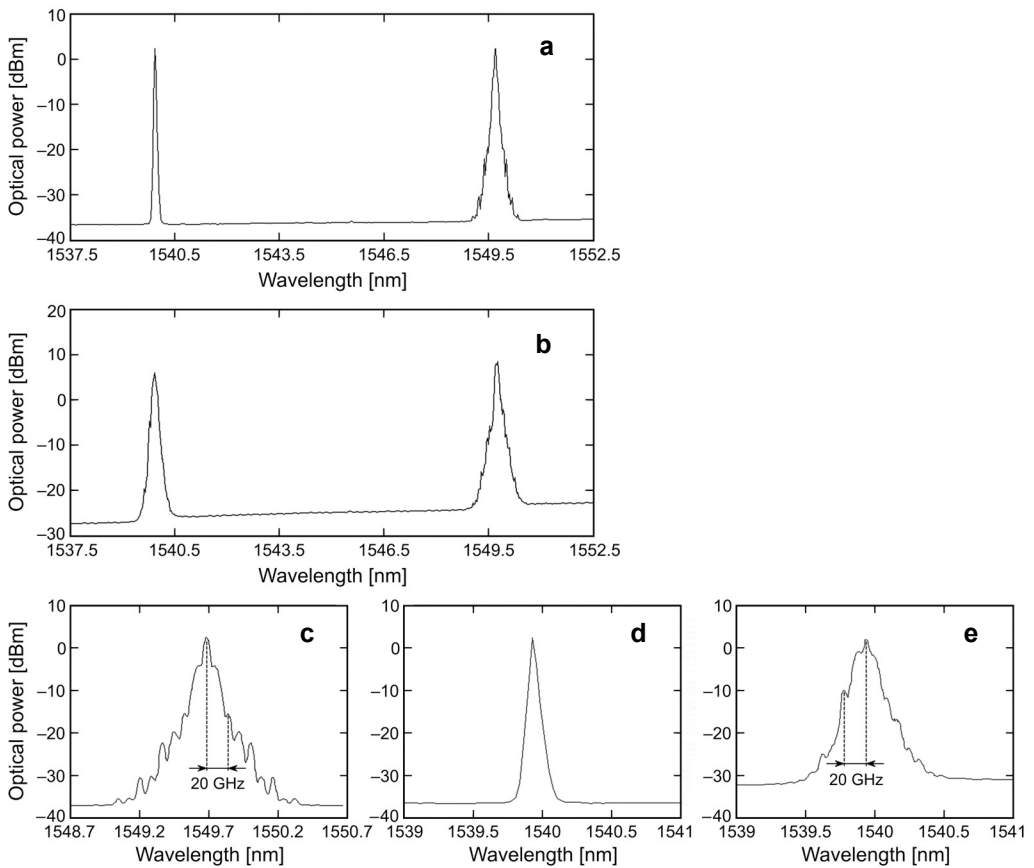

Fig. 3. Measured spectra at the input of the RSOA (**a**); spectra at the output of the RSOA (**b**); spectrum of the input Manchester encoded signal (**c**); spectrum of the input probe (**d**); spectrum of the output logic NOT signal (**e**).
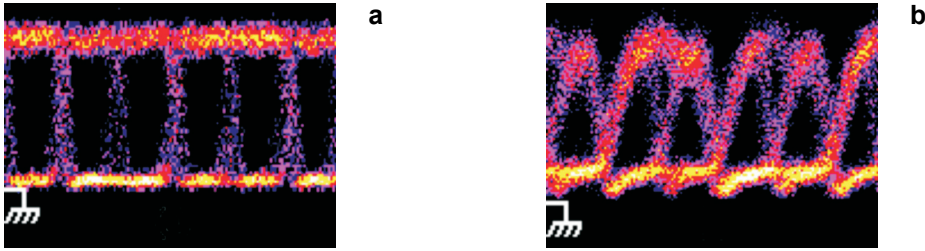
Fig. 4. Measured eye diagrams for: input Manchester encoded signal (**a**), output of the logic NOT gate (**b**).

compared with the input Manchester encoded signal. It has some slight pattern dependent distortions, which is introduced by the slow recovery of the carrier. But the distortion can be controlled to some extent by adjusting the injection current of RSOA. Here, the injected current is tuned at 220 mA. The input power of the RSOA is 2.4 dBm (λ_s) and 2.2 dBm (λ_c). The signal quality will not be degenerated much more, if longer bit pattern is employed, because the durations of the high power and low power pieces are always either half bit or a whole bit for the Manchester encoded signal. The distortion is not relevent to the length of the pattern. This is a great advantage of Manchester code in signal processing.

Figure 3 shows the input and output spectra. Since the Manchester code has a power transition in the half of each bit, it occupies double bandwidth compared with non-return-to-zero (NRZ) or return-to-zero (RZ) signal at the same bit-rate, as illustrated in Figs. 3**c** and 3**e**. From Fig. 3**e**, we find that the output signal of the Manchester NOT gate is also slightly distorted, due to the slow recovery of the carrier in the RSOA.

Figure 4 further depicts the eye diagrams for different waves. The input and output 10 Gb/s Manchester encoded signals show similar eye diagrams to 20 Gb/s NRZ signals, because of the power transition in the half of each bit, which was mentioned above. The results show that the input signal has an extinction ratio (ER) of 13.5 dB, and the ER of the output signal is 8.8 dB.

4. Conclusions

We have demonstrated an all-optical NOT gate for Manchester encoded signal. The logic NOT result is obtained for a 10 Gb/s Manchester encoded signal. The proposed Manchester logic NOT gate is expected to be used in the optical switching node in future all-optical networks.

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