10-Gb/s 53.1-km BPSK transmission of silicon Mach-Zehnder modulator

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Abstract: 25Gb/s BPSK modulation was presented employing 2mm Si Mach-Zehnder (MZ) modulator, by which the BPSK transmission was demonstrated through 53.1-km Single Mode Fiber (SMF) in 10 Gb/s under 6V_pp driving voltage.

OCIS codes: (130.0250) Optoelectronics; (130.4110) Modulator; (060.1660) Coherent communications

1. Introduction
Silicon modulators have attracted great attentions because of the reduced footprint and the compatibility with developed Complementary Metal-Oxide-Semiconductor (CMOS). High performance modulation has been demonstrated by silicon modulators, such as high speed [1], low-voltage [2] and compact footprint [3]. Meanwhile high-performance silicon modulators have already been studied in interconnection [4, 5]. Recently, long haul transmission based on silicon modulators, including silicon resonator (microring [6] and microdisk [7]) and MZ modulator [8], in OOK formats have been demonstrated. However, the transmission performance in BPSK formats only was demonstrated based on silicon microring modulator [9]. In this paper, we present the first demonstration of long-haul transmission employing silicon MZ modulator.

2. Design and fabrication
The phase shifter of the silicon MZ modulator is based on the 220nm rib waveguide with 600nm width in Fig. 1. The silicon MZ modulator was designed with 2mm phase shifter [10]. The length difference is 100μm between the two arms and a 1x2 multimode interferometer (MMI) is used to split and recombine the optical beam in the MZ modulator. A coplanar waveguide (CPW) was employed to drive the phase shifter, which was composed of one signal electrode and two ground electrodes as GSG type [11].

The measurement setup of the BPSK modulation is shown in Fig. 2. The CW laser is employed to generate the optical signal and the line width is 100KHz. The differential electric signals are generated by the Pulse Pattern Generator (PPG) and then amplified by a pair of 28GHz tunable amplifiers. Combining the Radio Frequency (RF) signal and the DC bias, the modulator’s both arms are driven by push-pull with the differential signal. In order to demonstrate the transmission performance, the G.652 standard single-mode optical fiber (SSMF) was employed after the silicon MZ modulator and set to 0-, 26-, 53-km long. The signal was received...
3. Experimental result

Firstly, 10Gb/s, 20Gb/s and 25Gb/s back-to-back BPSK were discussed with the 2mm long device. The PPG generated a $2^7-1$ pseudo-random bit sequence (PRBS). The narrow line width laser was employed at 1552.16nm. The differential RF signals were both amplified to 6V with DC bias of 3.6V and 3.4V. The data rate of 10Gb/s was demonstrated. The modulated signal was received by the commercial coherent receiver shown in Fig. 3. In our experiment the EVM of the 10Gb/s BPSK constellation diagram is 16.6 with the OSNR of 17dB. After fine tuning the Bias voltage, 20Gb/s BPSK was realized under 6V_{pp} driving with both DC bias of 3.6V. The EVM of the received signal is 20.0 with OSNR of 13.9dB. The 25Gb/s BPSK also was realized with EVM of 21.2 under 6V_{pp} driving voltage.

Then, we have investigated the transmission performance of this device. Employing the 2mm long Si MZ modulator, driving by 6V_{pp} voltage, 10Gb/s BPSK has been transmitted for 26.7km and 53.1km. After demodulating by the commercial receiver, we can find that the trajectory can’t always follow along the real axis after long-haul transmission shown in Fig. 4. The S-shape transitions were caused by the frequency chirp which is influenced by the imbalance of power between two arms. But the BPSK still can be demodulated by the commercial receiver. The EVM of the BPSK signal after 26.7km SSMF transmission is 23.2 with the OSNR of 15.1dB. After 53.1km SSMF transmission, the signal was also demodulated by the commercial receiver. The obvious signal degradation was caused by the residual fiber dispersion. The EVM of the BPSK signal after 53.1km SMF transmission is 33.3 with the OSNR of 9.7dB. The degradation can be partially corrected by the Dispersion Compensation Fiber (DCF).
4. Conclusion
We have realized 10 Gb/s, 20 Gb/s, and 25 Gb/s BPSK modulation employing the 2mm Silicon MZ modulator. And the 26.7km and 53.1km SSMF transmission in the 10 Gb/s BPSK format under 6Vpp driving voltage were both measured. This is the first to realize the long-haul transmission in BPSK formats based on silicon MZ modulator.

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5. References