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Ultra-compact Bragg Reflector Waveguide Modulator with Large Response Bandwidth and Low Power Consumption

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Abstract We propose and demonstrate an ultra-compact electro-absorption modulator based on a Bragg reflector waveguide. The peak-to-peak driving-voltage was below 1.0V. Small signal response over 13GHz and large signal modulation of 10Gbps were obtained. Much higher bandwidth is expected after reducing the device parasitic capacitance by further downsizing.

Introduction

Nowadays, much attentions are paid on optical interconnects with low power consumptions. There have been reports demonstrating modulators with driving voltage below 1 V, however, they are always at a cost of narrow optical bandwidths or long device lengths [1]. We previously proposed an electro-absorption (EA) modulator employing the quantum-confined Stark effect (QCSE) based on a Bragg reflector waveguide [2, 3]. It showed excellent characteristics but only DC characterization was carried out. In this paper, we carried out the high-speed and low-voltage modulation for the first time.

Device Structure and Principles

The proposed modulator is fabricated on a VCSEL epitaxial wafer. A schematic cross-section view of the device is shown in Fig. 1. An input light is coupled through a lensed fiber to the device and propagates along the waveguide. A so-called 'slow-light' mode is excited inside the waveguide and travels in a zigzag route. It can promote stronger light-matter interaction inside thus we can make the device several times smaller than conventional EA modulator.

Static and Dynamic Modulation Characterizations

We first measured the device static characteristics to see the extinction ratio (ER) versus bias voltages V_b. Devices with different modulator lengths were tested and compared (Fig.2). Over 10dB ER was obtained with a 35 μm device even below 0.8V. Figure 3 shows the small-signal response result measured on a 35 μm long modulator with a 965 nm input. The bias voltage is -0.5V. The modulation bandwidth (f_{3dB}) is over 13GHz. Large signal NRZ modulation was also carried out. Clear eye-open can be observed in Fig. 4, which shows the measurement result with a 10Gbit/s NRZ signal (PRBS 2^{31}-1, V_{pp} = 1.0V, V_b= -0.8V) input. The modulator length is 55 μm and the input wavelength is 970 nm. We also observed eye-open with V_{pp} of 0.5V but it is not as clear as the pattern in Fig. 4. It is because the extinction ratio is not large enough considering the PD noise. It is possible to further downsize the current device volume by a factor of 2~3. The parasitic capacitance will correspondingly decrease thus ultra-high-speed modulation beyond 40Gbps is prospective.

Conclusions

We demonstrated an ultra-compact modulator based on a Bragg reflector waveguide. The extremely small volume of the modulator reveals its potential in reaching ultra-high-speed modulation with low power consumptions. Our device can be laterally integrated with a VCSEL, enabling small-footprint, high-speed and low power consumption light sources for future data center photonics.

Acknowledgements

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References

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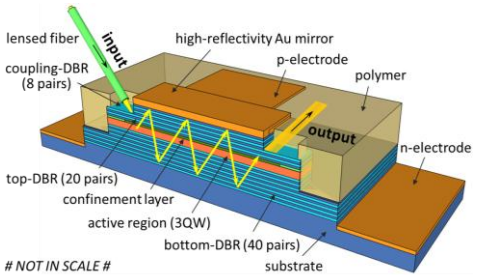

Fig. 1: A schematic cross-section view of the slow-light Bragg reflector waveguide modulator.

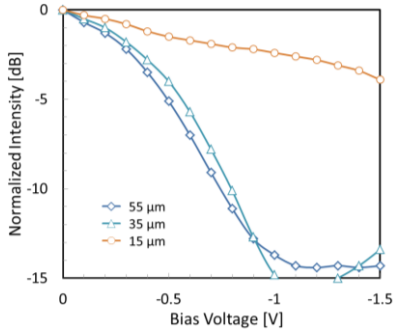

Fig. 2: Normalized intensity versus bias voltage for different modulator lengths for 965 nm input.

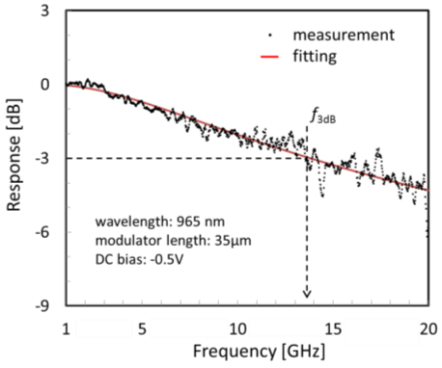

Fig. 3: Frequency response of the 35μm long Bragg reflector waveguide modulator.

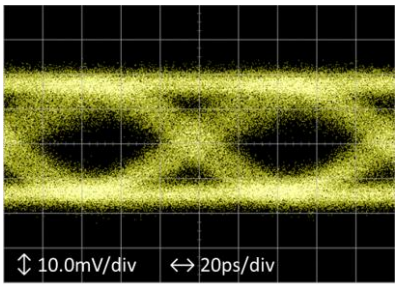

Fig. 4: Eye-pattern measured on a 55 μm modulator with 10Gbit/s NRZ signal (V_{pp}=1.0V, V_b= -0.8V, λ = 970nm).