Waveguide Electroabsorption Modulator on Si Employing Ge/SiGe Quantum Wells

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Abstract: We report the first waveguide optical modulator on Si that employs the quantum-confined Stark effect. For a 6 V swing, the contrast ratio is 7.72 dB at 1476 nm, and exceeds 3 dB over 14 nm bandwidth.

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Low-cost optical interconnects at chip-scale distances have been evaluated as an efficient alternative to electrical interconnects at high data rates in silicon CMOS chips. Optical modulators have been widely used as transmitters in optical interconnects. Due to lack of a strong physical mechanism in silicon, however, recent demonstrated optical modulators either were large or used high-Q resonator structures that require precise tuning. The recent demonstration of the quantum-confined Stark effect on silicon using Ge/SiGe quantum wells opened up the possibility of realizing small and power-efficient electroabsorption modulators on Si [1]. In this paper, we report the first waveguide modulator on Si substrate that employs the quantum-confined Stark effect. Waveguides are particularly interesting because of their relatively low power dissipation, high-contrast ratio, speed, and easy integrability with the mature silicon waveguide technology for on-chip optical interconnects.

Fig. 1 (a) shows the schematic of the device. The waveguide structure employs a SiGe p-i-n structure that is epitaxially grown on silicon with LPCVD. The total epitaxial thickness is about 1.7 μm , and 10 Ge quantum wells, each ~ 15 nm thick, are embedded in the i-region. The fabricated waveguides are 3 μm wide and 170 μm long and are realized by a 1.5 μm deep ridge etch. Light is guided by SiO_2/SiGe interfaces on the top and the sides, and by the SiGe/Si interface at the bottom.

Fig. 1. (a) Schematic of the waveguide cross section (not to scale) (b) Contrast ratio of the optical transmission change through the waveguide for TE modes with applied bias of 6 Volts

Fig. 1 (b) shows the contrast ratio of the optical transmission change through the waveguide for TE modes for zero to 6 V bias change. We observe a peak contrast ratio of 7.72 dB at 1476 nm and the modulator maintains 3 dB contrast ratio over 14 nm, from 1470 to 1484 for this voltage swing.

The waveguide modulator we present is not optimized and its performance can be improved by reducing the total thickness of the SiGe epi to provide a better overlap of the optical modes with the quantum-well absorption region and by optimization of the quantum well structure to achieve larger contrast ratios.

References

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