Optical Characterization of a Compact Carrier Injection-based silicon PIN Modulator

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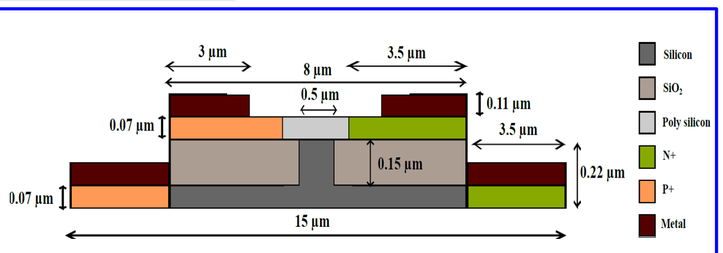
Abstract

- Carrier injection based Silicon PIN modulators are best suited for realizing compact photonic integrated circuits and optical modulators.
- Increasing the carrier injection rate can reduce the effective length of the modulator for required phase change.
- Our design was able to achieve an effective refractive index change of -0.0054, which will be able to produce a phase shift of 180^0 at a device length of 144µm.
- The device also exhibits an optical confinement of 81% and modulation capacity up to 38Gbps.

Introduction

- Silicon photonics is rapidly emerging as a promising technology with diverse applications in photonic integrated circuits, communication systems, LiDAR, bio-chemical sensing, and medical field.
- The demand for high speed electro-optic switching devices are also increasing day by day.
- An electro-optic modulator alters the phase of incoming optical signals in accordance with the high frequency electrical signals.
- Free carrier plasma dispersion effect is the most efficient method to induce high speed electro-optic effects in Silicon [2].



Proposed PIN modulator

$$\Delta n = -[8.8 \times 10^{-22}\Delta N + 8.5 \times 10^{-18}(\Delta P)^{0.8}]$$

$$\Delta \alpha = 8.5 \times 10^{-18}\Delta N + 6.0 \times 10^{-18}\,\Delta P$$

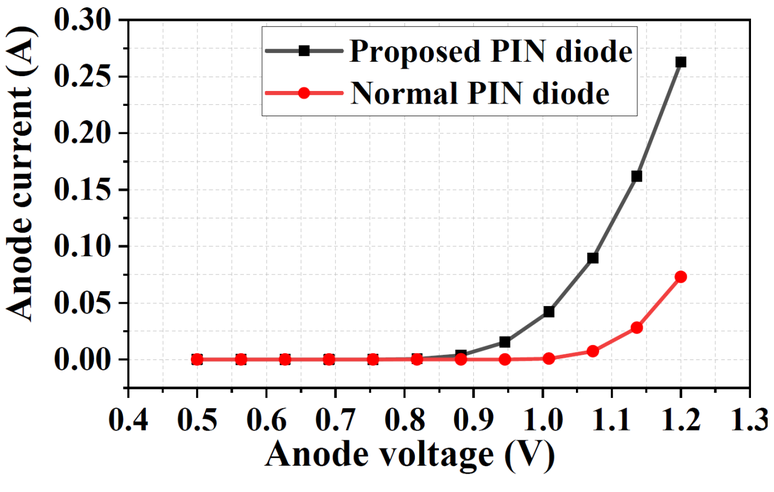
Δn = Change in refractive index

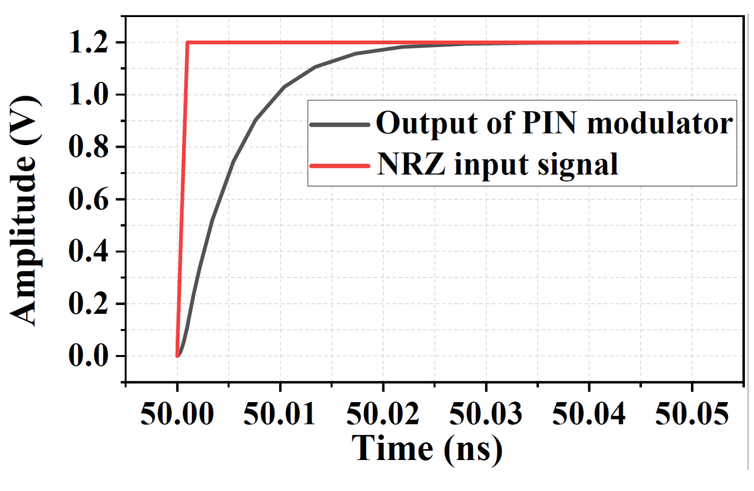
$\Delta \alpha$= Change in absorption coefficient

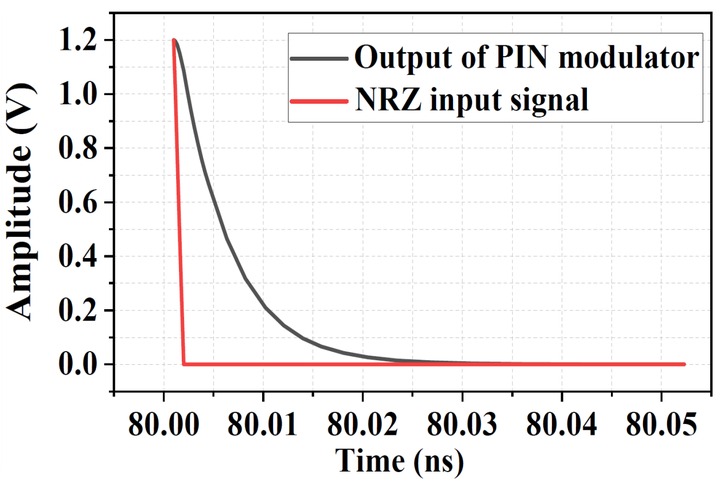
Soref & Bennett's equation [1]

Results and Discussion

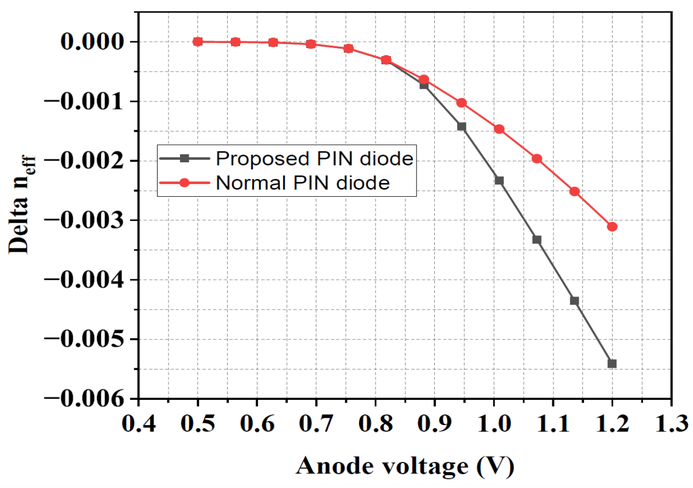
Electrical characterization

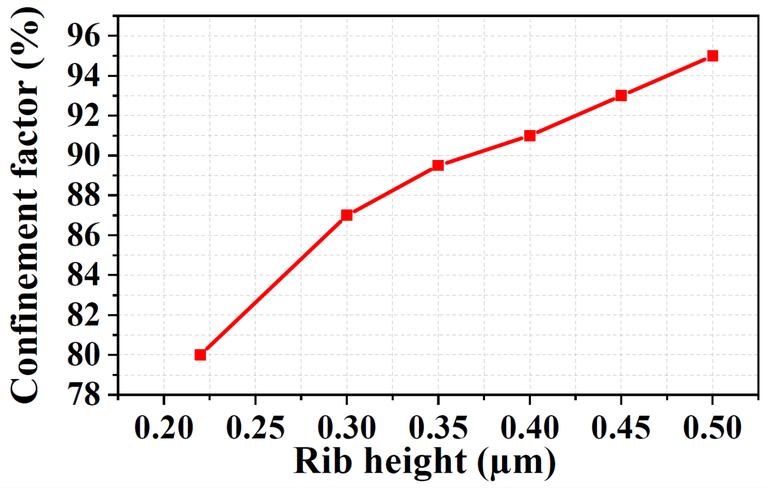


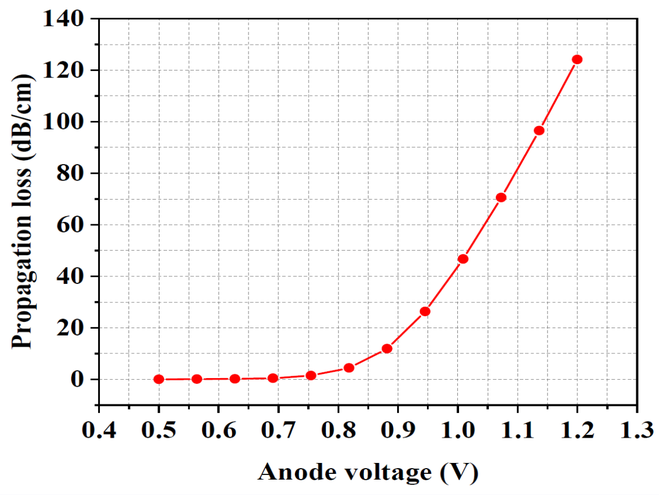


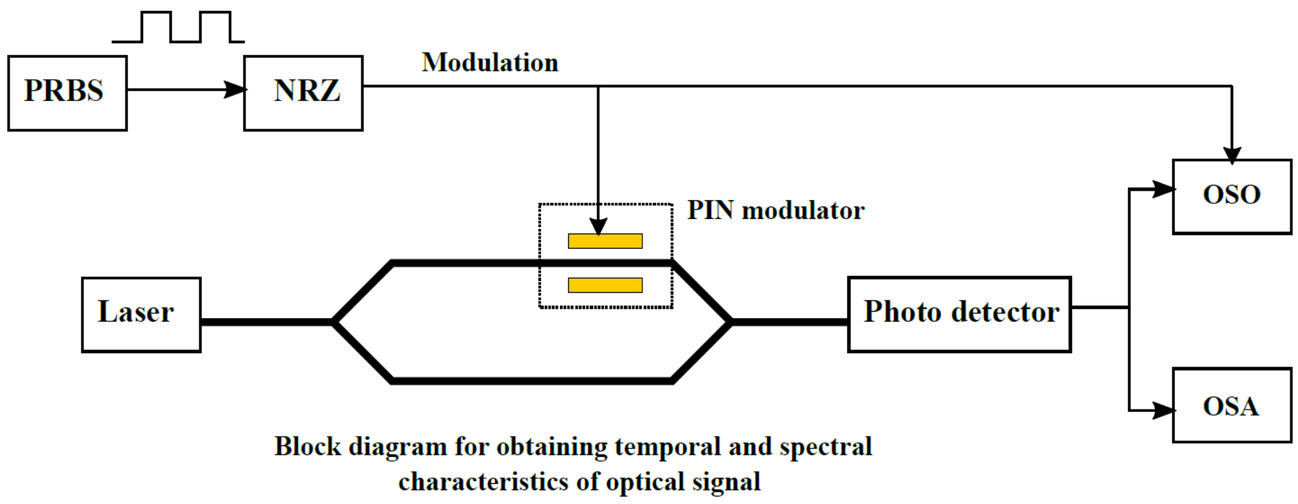


Optical characterization







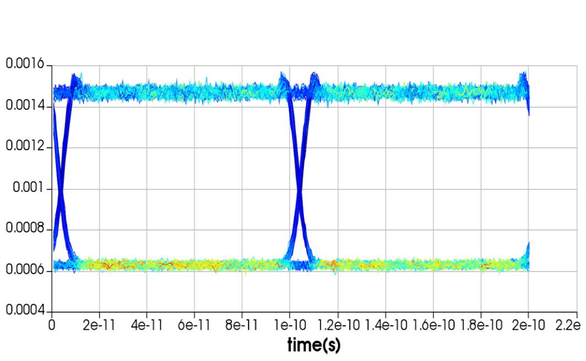


Block diagram for obtaining temporal and spectral characteristics of optical signal

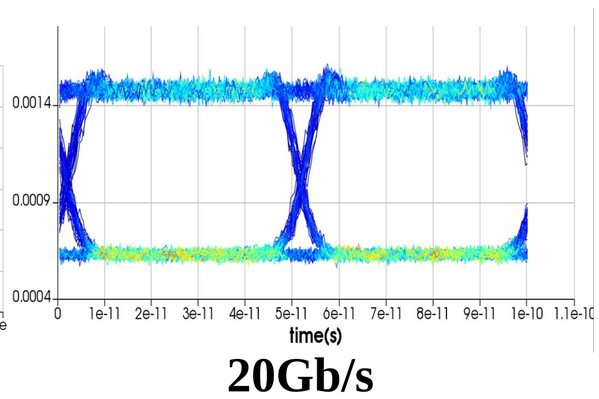
Results obtained

Parameter	Value
Effective refractive index change	-0.0054
L_π	144µm
Confinement factor	81%
Rise time	12.5ps
Fall time	12ps
Switching speed	40GHz
Data rate	38Gbps

Eye diagram analysis



10Gb/s



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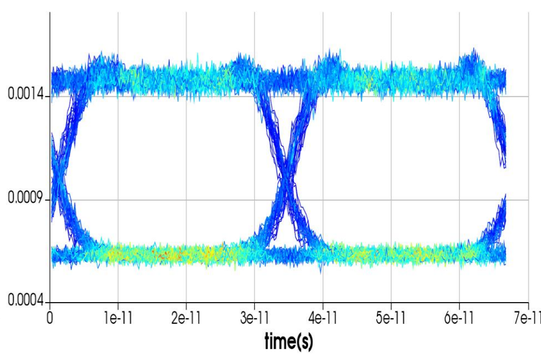
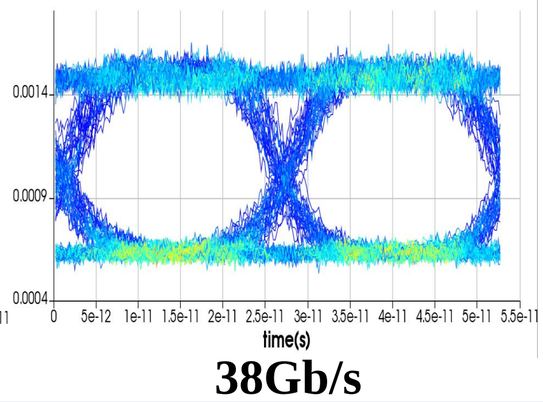


30Gb/s



38Gb/s

Conclusion

We have proposed a novel PIN modulator and optimized its optical properties. The modulator design was able to give an index change of -0.0054 and it can induce a phase shift of 'π' with a length of 144µm, which can be considered as a significant achievement when compared to the currently available PIN modulators. The device also exhibited an optical confinement of 81% and a clear eye opening up to 38 Gbps.

References

- R. Soref and B. Bennett, "Electrooptical effects in silicon," IEEE journal of quantum electronics, vol. 23, no. 1, pp. 123–129, 1987.
- G. Kang, S.-H. Kim, J.-B. You, D.-S. Lee, H. Yoon, Y.-G. Ha, J.-H. Kim, D.-E. Yoo, D.-W. Lee, C.-H. Youn et al., "Silicon-based optical phased array using electro-optic p-i-n phase shifters," IEEE Photonics Technology Letters, vol. 31, no. 21, pp. 1685–1688, 2019.

Acknowledgement

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