11D3-5

High-Speed (>55 GHz) Electro-Absorption Modulator Based on Two-Step Undercut Active Region Waveguide

T. H. Wu, F. Z. Lin, D.R. Lee and Y. J. Chiu

No 70, Lien Hai Rd., Kaohsiung, Taiwan R.O.C.
Institute of Electro-Optical Engineering, NSYSU
Email: d943050003@student.nsysu.edu.tw
Tel: +86-7-525-2000 ext 4472, Fax: +86-7-525-4499

Abstract

Higher than 55GHz electro-optical (EO) response was measured in electroabsorption modulator (EAM) fabricated by using the two-step-undercut-etching-active-region-waveguide (TSUEARM) method, It is shown that the high-speed EO performance can be obtained by simultaneously reducing cladding resistance, parasitic capacitance and the electrical insertion loss.

1. Introduction

High-speed electro-absorption modulators (EAM's) are getting more and more interest for use in both digital and analog high-speed fiber-optic links. A 50-GHz bandwidth lumped EAM (L-EAM) has been reported with the active waveguide length shortened to 63μm [2]. However, reducing the waveguide length results in smaller modulation efficiency due to both shorter modulation length and smaller power handling ability. To overcome the bandwidth limit without severely sacrificing modulation efficiency, the traveling-wave EAM (TW-EAM) has been proposed and experimentally investigated by several authors [3]. The TW-EAM speed is still restricted by the microwave properties inside the p-i-n waveguide, including of impedance mismatch, velocity mismatch and microwave propagation loss. We have previously proposed undercut-weting-acive-region (UEARW) structure to enhance the microwave propagation loss by reducing the cladding layer resistance to [1]. However, the capacitance is higher attributed to the parasitic capacitance of the undercut region between p- and n-type cladding layers (as shown in figure 1). In order to reduce this parasitic capacitance, two-step-undercut-etching method was performed to increase the gap between the cladding layers at the undercut region (as shown in figure 1). As compared with the UEARW structure, there is about 62.4% reduction in resistance-capacitance (RC) product leading to >55-GHz electro-optical (EO) response in TSUEARW EAM.

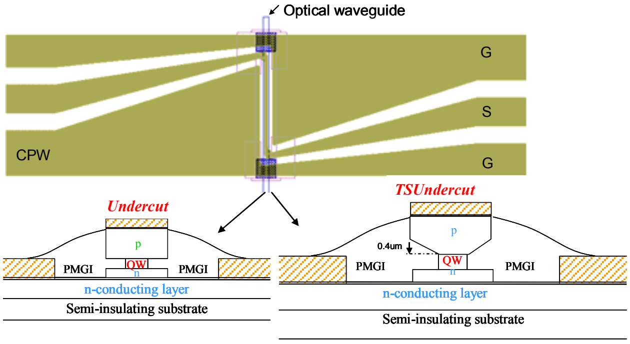

Fig. 1: Schematic structure of the device.

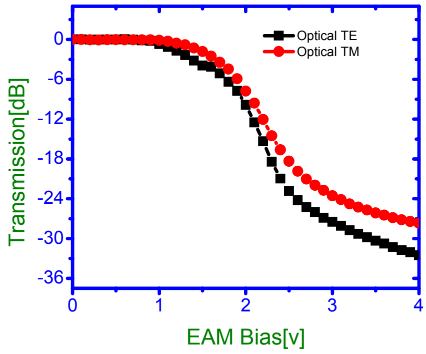

Fig. 2: The optical transmission against voltage for EAM.

2. Fabrication and Measurement

The semiconductor material is grown on semi-insulated InP by metal-organic chemical vapor deposition (MOCVD) method. The InGaAsP MQW consisted of ten tensile-strained QWs (10.4 nm) and barriers (7.6 nm). The tensile-strained QW was used to reduce the polarization dependence of the electroabsorption effect. The top p-cladding layer is 1.9 μm. A 6-μm wide, 1.5-μm deep (0.4 μm above

MQW) P-InP ridge was first defined by HBr based solution. After covering the ridge by photoresistor to protect the side wall, the HCl : H_3PO_4 solution was used to selectively undercut etch the InP. About 2.8-μm width of MQW was formed by using H_3PO_4:H_2O_2:H_2O solution. The p-type (Ti-Pt-Au) and n-type (Ni-AuGe-Ni-Au) metallization are deposited by an e-beam evaporator. PMGI (MicroChem Inc.) is used for waveguide passivation, planarization and bridging the coplanar waveguide (CPW) electrodes for the input and output microwave feed lines. The schematic plot of the device is also shown in Figure 1.

Light at wavelength 1550 nm was launched into the 300-μm-long EAM for the optical transmission against bias measurement. The coupling fibers are lensed fibers with 3-μm full-width-half-maximum (FWHM) mode size. The fiber-to-fiber insertion loss is 15 dB. As illustrated in Figure 2, over 20-dB/volt modulation efficiencies for both TE and TM polarization were obtained in this device. A high-speed vector network analyzer (Anritsu) is used to measure the device microwave S-parameters and EO response. Less than -7dB of S11 (<40GHz) and over 20 GHz 3-dB microwave transmission (S21) is obtained in TSUEARW EAM (Figure 3) showing the better microwave properties as compared with the UEARW EAM [6]. The measured EO response is given in Figure 4, which show the 3-dB response can exceed 55 GHz. The high-speed performance was analyzed by using the equivalent circuit for the TSUEARW EAM transmission line. It is found that the high EO response is due to the small cladding layer resistance associated with small intrinsic capacitance of the TSUEARW structure.

3. Conclusion

Further reduction in parasitic capacitance of UEARW EAM was achieved by using TSUEARW method. Over 55 GHz EO response was observed in TSUEARW EAM. Polarization insensitivity in optical transmission can be found resulting from the use of the tensile QWs. The modulation efficiency is 25dB/v.

4. Acknowledgements

The authors would like to thank the financial supports from the National Science Council, Taiwan (NSC 93-2215-E-110-018) and (NSC 93-2215-E-110-013), Technology Development Program for Academia (92-EC-17-A-07-S1-025) and “Aim for the Top University Plan Taiwan”

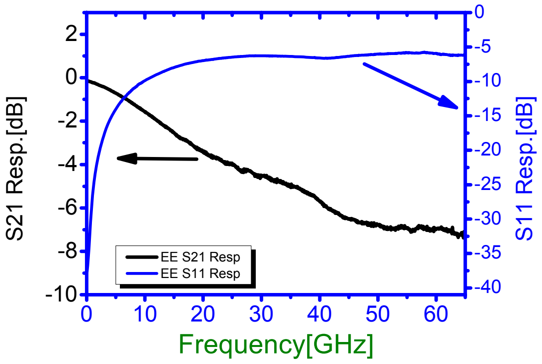

Fig.3: Elecrical transmission property.

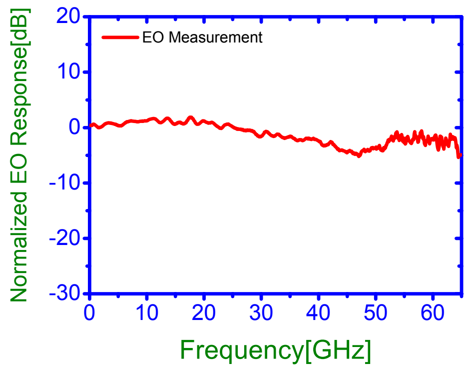

Fig.4: High-speed EO response of EAM.

5. References

[1] Yi-Jen Chiu, Tsu-Hsiu Wu, Wen-Chin Cheng, F. J. Lin, and John E. Bowers,” Enhanced Performance in Traveling-Wave Electroabsorption Modulators Based on Undercut-Etching the Active-Region,” IEEE P.T.L., vol. 17, no. 10, pp. 2065–2067, Oct. 2005

[2] T. Ido, S. Tanaka, M. Suzuki, M. Koizumi, H. Sano, and H. Inoue,“Ultra-high-speed multiple-quantum-well electro-absorption modulators with integrated waveguides,” J. Lightwave Technol., vol. 14, pp.2026–2034, 1996.

[3] S. Z. Zhang, Y. J. Chiu, P. Abraham, and J. E. Bowers, “25-GHz polarization-insensitive electroabsorption modulators with travelingwave electrodes,” IEEE Photon. Technol. Lett., vol. 11, pp. 191–193, 1999.

[4] Wu, Tsu-Hsiu, Lin, F.J.,Cheng, Wen-Chin,Lee, D.R.,Chiu, Yi-Jen,” High-speed undercut-wet-etching-active-region traveling-wave electroabsorption modulator,” Conference Proceedings - Lasers and Electro-Optics Society Annual Meeting-LEOS, v 2005, 18th Annual Meeting of the IEEE Lasers and Electro-Optics Society, LEOS 2005, 2005, p 410-411