

High Extinction Ratio Polarization Independent EA Modulator

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Abstract: An electro-absorption modulator is fabricated for optical network system. The strained InGaAs/InAlAs MQW shows improved modulation properties, including polarization independent, high extinction ratio ($> 40\text{dB}$) and low capacitance ($< 0.5\text{pF}$), with which, an ultra-high frequency ($> 10\text{GHz}$) can be obtained.

Key words: electro-absorption; modulator; polarization independence

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1 Introduction

Substantially increased transmission capacity is required by the long-haul trunk transmission systems. Much effort has been made to overcome the repeater's spacing limit during the development of a practical large capacity system^[1]. Because of the limit of chirp and chromatic dispersion when the laser emits an optical pulse with large signal amplitude, external modulator becomes essential in optical fiber communication systems.

Among the external modulators, electroabsorption modulators offer higher bandwidths with lower driving voltages^[2]. The highest figure of merit reported, to our knowledge, is 26GHz/V . Only the quantum confined stark effect in multiple quantum wells can provide simultaneously polarization independence and high modulation efficiency. The ultra-high speed is achieved up to 42GHz and the high extinction ratio up to 40dB ^[3]. Because of their high speed, low driving voltage, and integrability with lasers, electroabsorption modulators become essential in optical fiber communication systems, especially in the signal generating system and optical switching systems, such as $n \times n$

optical switch matrix, Optical Add/Drop Multiplexer (OADM) switching system, and Optical Time Division Multiplexer (OTDM)^[1].

Today in China, not much progress has been made with the single chip Electro-Absorption (EA) modulator. The integration of EA modulator and DFB laser^[4,5] is the focus of attention. However, sometimes the modulation properties of the integrated devices cannot be optimized, and cannot meet our requirements in the extinction ratio, polarization dependence insertion loss, and the modulation frequency, etc.

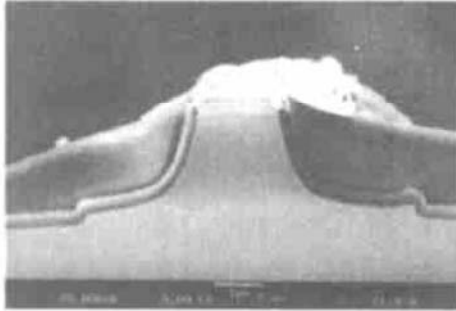
In this paper, we describe a high performance $1.55\mu\text{m}$ InGaAs-InAlAs MQW EA modulator grown with MOCVD, which can be used in high speed OTDM network as a signal generator and demultiplexer, and is supposed to apply to the ultra-fast switching systems, too.

2 Design and Fabrication

A deep ridge waveguide EA modulator buried with polyimide is designed for the purpose of obtaining a very low capacitance.

Figure 1 shows the schematic structure of the proposed strained InGaAs-InAlAs MQW EA mod-

ulator. An n-InAlAs buffer layer, an undoped strained MQW absorption layer, a $1.5\mu\text{m}$ thick p-InP cladding layer, and a p^+ -InGaAs contact layer are successively grown on an n-InP substrate by Metal Organic Chemical Vapor Deposit (MOCVD). The strained MQW absorption layer consists of twelve 9nm InGaAs wells (0.38% tensile strained) and 5nm InAlAs barriers (0.5% compressively strained). In addition to compensating for the well strain, the compressively strained barriers can reduce the band discontinuities, thereby increasing the optical saturation power^[6]. The width and length of the modulation region are



$1.7\mu\text{m}$ and $200\mu\text{m}$, respectively. We etch two different structures of a deep ridge (about $3\mu\text{m}$) using Br_2 and bury the deep ridge with polyimide. Figure 2 shows the SEM facet view of a cleaved device with the width of $1.7\mu\text{m}$ as well as the buried deep ridge.

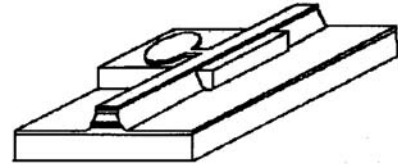


FIG. 1 Schematic Structure of InGaAs/InAlAs Strained MQW Electro-Absorption Modulator

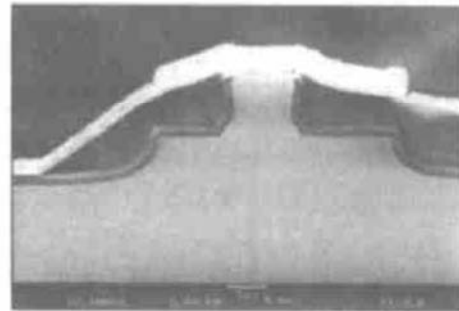


FIG. 2 SEM Facet View of a Structure

These two different deep ridge waveguide structures are fabricated to avoid the rupture when the ridge is too deep. The one showed in Fig. 2 can also prevent the InAlAs barrier and SCH layer from being oxidized. The thickness of polyimide is about $1.7\mu\text{m}$, the device contact resistor was 6.3Ω , and the capacitance was 0.5pF .

3 Characteristics

TE- or TM-polarized light from a tunable laser diode has been carried in and out of the EA facets through tapered-lens fibers, with the modulation characteristics been measured. A polarization controller is used to control the incident polarization. Figure 3 shows the normalized extinction ratio at the wavelength of 1540nm .

In order to compare the extinction ratios at

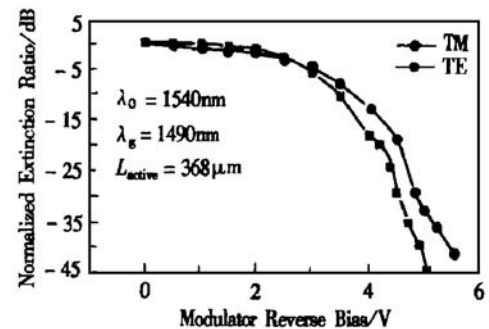


FIG. 3 Normalized Extinction Ratio at 1540nm Square and circle lines denote TE- and TM-polarized light, respectively.

different wavelength, we change the source light's wavelength from $1.50\mu\text{m}$ to $1.58\mu\text{m}$ while keeping the input power at 0dBm . The device shows a wavelength-dependence. The photo luminance peak of MQWs is at $1.49\mu\text{m}$. As the reverse bias increasing from 0 to 4V , the absorption peak of an

exciton changes to $1.54\mu\text{m}$. Measuring the modulation current at the same time, we find it increases following the increase of the reverse bias^[3].

The static capacitance of the device is measured at 1MHz by using an HP4284A, and found being reduced with the reverse bias increasing. Figure 4 shows the static capacitance at different reverse bias.

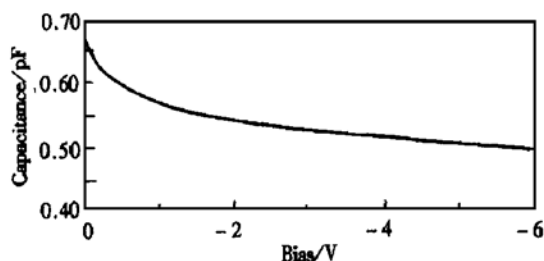


FIG. 4 Static Capacitance of EA Modulator

4 Conclusion

For the first time, an EA modulator over 10GHz is reported in China. The MQW EA modulator proposed is used as a signal generator and demultiplexer in OTDM systems. We have fabricated a MQW-EA modulator with high extinction ratio ($> 40\text{dB}$), low polarization-dependent loss, and low capacitance (0.5pF). It demonstrates that tensile strained MQW EA modulator is one of the most

promising optical switches for OTDM switching system.

References

- [1] Kazuhiko Shimomura and Shigehisa Arai, Semiconductor Waveguide Optical Switches and Modulators, *Fiber Integr. Opt.*, 1994, **13**: 65—100.
- [2] K. Wakita and I. Kotaka, Multiple-Quantum-Well Optical Modulators and Their Monolithic Integration with DFB Lasers for Optical Fiber Communications, *Microw. Opt. Technol. Lett.*, 1994, **7**: 120—128.
- [3] F. Devaux, S. Chelles, A. Ougazzaden *et al.*, Electro-absorption Modulators for High-Bit-Rate Optical Communications: A Comparison of Strained InGaAs/InAlAs and InGaAsP/InGaAsP MQW, *Semicond. Sci. Technol.*, 1995, **10**: 887—901.
- [4] Xu Guoyang, Wang Wei, Yan Xuejin *et al.*, Monolithic Integration of DFB Laser Diode and Electroabsorption Modulator by Selective Area Growth Technology, *Chinese Journal of Semiconductors*, 1999, **20**: 706(in English).
- [5] Luo Yi, Wen Guopeng, Sun Changzheng *et al.*, $1.55\mu\text{m}$ InGaAsP/InP Partially Gain-Coupled DFB Laser/Electroabsorption Modulator Integrated Device, *Chinese Journal of Semiconductors*, 1998, **19**: 557 [罗毅, 文国鹏, 孙长征, 等, $1.55\mu\text{m}$ InGaAsP/InP 部分增益耦合分布反馈式激光器/电吸收调制器集成器件, *半导体学报*, 1998, **19**: 557].
- [6] Yuichi Matsushima, Masatoshi Susuki, Hideaki Tanaka *et al.*, A High-Speed Electro-Absorption Semiconductor Light Modulator for Soliton Pulse Generators, *Optoelectron. Devices Technol.*, 1995, **10**(1): 75—88.

高消光比偏振不灵敏电吸收调制器

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摘要: 用一种新的方法制作出应用于光网络系统的电吸收调制器, 应用应变 InGaAs/InAlAs 材料做多量子阱, 实验测量的调制器调制性能显示出器件的偏振不相关性, 以及其高消光比($> 40\text{dB}$)和低电容($< 0.5\text{pF}$), 保证了器件可以应用于高速率的传输系统($> 10\text{GHz}$)。

关键词: 电吸收; 调制器; 偏振不灵敏

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