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1550nm Polarization-Insensitive Semiconductor Optical Amplifier Based on AlGaInAs-InP

Ma Hong[1,2], Zhu Guangxi[1] and Yi Xinjian[2]

(1 *Department of Electronics and Information Engineering, Huazhong University of Science and Technology, Wuhan* 430074, *China*)
(2 *Department of Optoelectronic Engineering, Huazhong University of Science and Technology, Wuhan* 430074, *China*)

Abstract: Polarization-insensitive AlGaInAs-InP semiconductor optical amplifier is realized at a wavelength of 1550nm. The active layer consists of three tensile strained wells with strain 0.40%. The amplifiers are fabricated to ridge waveguide structure with 7° tilted cavity. The two facets are coated with two layers of anti-reflection Ti_3O_5/Al_2O_3 films. Residual facet reflectivity is found to be less than 0.03%. The semiconductor optical amplifer exhibits 20dB of signal gain and 7.2dBm of saturation output power with an excellent polarization insensitivity (less than 0.8dB) at 200mA and 1540nm window.

Key words: polarization-insensitive; AlGaInAs-InP; optical amplifier; MOCVD
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1 Introduction

Semiconductor optical amplifiers (SOAs), in conjunction with fiber optical amplifiers, will likely be used in future optical network. For optical signal processing applications, SOAs have many advantages including high saturation output power, fast gain recovery time, wide gain bandwidth, and ease of integrability in photonic integrated circuits (PICs). However, a disadvantage of SOAs is the polarization sensitivity of the gain. This polarization dependence is not a limitation in cases where input polarization to the amplifiers is fixed, as for an integrated laser-amplifier. But it is unacceptable in cases where input polarization fluctuates, as for an optical receiver. A SOA with polarization-independent will make possible of a variety of useful PICs[1,2]. Previously, a number of study on 1550nm polarization independent SOAs using bulk material, tensile strained barriers, or both compressive and tensile wells based on InGaAsP-InP material system have been reported[3~5]. AlGaInAs-InP material system has shown an excellent material in building uncooled laser diodes due to their superior temperature characteristics over the conventional InGaAsP-InP system[6,7]. In the current study, AlGaInAs-InP was examined for its potential for high performance polarization insensitive optical amplifiers using tensile strain in the quantum wells for gain equalization. Koonath *et al*[8]. reported a 1310nm polarization-insensitive optical amplifier in AlGaInAs-InP material system. In this paper, we demonstrate a AlGaInAs-InP MQW amplifier employing tensile strained wells with nearly polarization-insensitive gain at 1550nm window.

2 Approach

In conventional SOAs which use bulk materi-

Ma Hong male, was born in 1971. He is engaged in research on semiconductor integrated optoelectronic devices and subsystems.

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als, optical gain in the TE mode is usually higher than that in the TM mode. This is mainly due to the different mode confinement factors for these modes even though conventional bulk materials exhibit polarization-insensitive optical gain. In multiple-quantum-well (MQW) SOAs, the optical gain is much larger for the TE mode than for the TM mode, so it seems difficult to achieve polarization insensitivity in MQW SOAs. Introducing tensile strain offers a promising way of achieving polarization-insensitive output power. As pointed out by several other papers published, under tensile strain, the energy level of the light holes (lh) band falls below that of the heavy holes (hh). This increases the recombination rate between the conduction band and the light hole, increasing the TM mode gain. The effectiveness of this approach derives from the fact that the TM mode gain can be enhanced, thus allowing a polarization-insensitive optical amplifier[9]. In conventional laser diodes based on GaInAsP-InP material system, a small conduction band offset ($\Delta E_c = 0.4\Delta E_g$) seems to be more responsible for the poor temperature characteristics because the confined electrons can readily overflow out of the quantum wells, and it has obscured the improvement expected by the strain effect. AlGaInAs-InP systems, in which the conduction band offset ($\Delta E_c = 0.72\Delta E_g$) is larger than that of conventional GaInAsP-InP systems, resulting in a smaller overflow of electrons, has been demonstrated. In this paper, the design and fabrication of 1550nm MQW AlGaInAs-InP polarization-insensitive SOA using tensile strain in the quantum wells for gain equalization are reported.

3 Device structure and fabrication

Figure 1 shows the structure of the 1550nm AlGaInAs optical amplifier that was fabricated. The structure was grown on 50mm n-type (100) InP substrate in a commercial Emcore low pressure metalorganic chemical vapor deposition (LP-MOCVD) system at 700℃ temperature and 9.33kPa pressure. The active layer comprised three tensile strained quantum wells having 10nm in width and 0.40% of tensile strain, each separated by lattice matched barrier regions of 14nm in width. This active layer was sandwiched between upper (0.1μm thick) and lower (0.15μm thick) AlGaInAs layers with 1.28μm of bandgap wavelength. Following these layers, a 1.5μm thick p-InP cladding layer and a 0.3μm p^+-InGaAs contact layer were grown. Moreover, 20nm thick p-InGaAsP etch-stop layer with peak photoluminescence wavelength for 1.24μm was inserted above the 100nm thick p-InP spacer on the top of the upper waveguide layer in order to avoid the oxidation of AlGaInAs material. The material then processed into 2.8μm wide ridge waveguide devices using standard fabrication techniques. These

p^+-InGaAs			Contact layer	0.3μm
p-InP			Cladding layer	1.5μm
p-InGaAsP	λ= 1.24μm		Etch-stop layer	20nm
p-InP			Spacer	0.10μm
p-AlGaInAs	λ= 1.28μm		Upper waveguide	0.1μm
AlGaInAs	λ= 1.6μm	ε= - 0.40%	Tensile strained well	10nm
AlGaInAs	λ= 1.28μm		Lattice matched barrier	14nm
AlGaInAs	λ= 1.6μm	ε= - 0.40%	Tensile strained well	10nm
AlGaInAs	λ= 1.28μm		Lattice matched barrier	14nm
AlGaInAs	λ= 1.6μm	ε= - 0.40%	Tensile strained well	10nm
AlGaInAs	λ= 1.28μm		Down waveguide	0.15μm
n-InP			Buffer layer	0.5μm
n-InP substrate				

Fig. 1 Schematic diagram of polarization insensitive 1550nm AlGaInAs/InP tensile strained quantum well optical amplifier structure

waveguides had a tilt angle of 7° with respect to crystallograghic axis for suppressing the residual reflection from the end of facets. To minimize reflections from the cleaved facets, the two facets were coated with anti-reflection (AR) Ti_3O_5/Al_2O_3 films, and residual facet reflectivity was found to be about 0.03%. To obtain a better performance at 1550nm wavelength, we adopted a longer device measuring for 650μm.

4 Experimental results

Figure 2 shows gain spectra for the amplifier at various bias levels for TE and TM polarized input. The gain measurement was performed by coupling tapered lensed single mode fibers to both facets of the device. Coupling losses between such tapered lensed fibers and the SOA were measured to be about − 4dB per facet. The data were taken

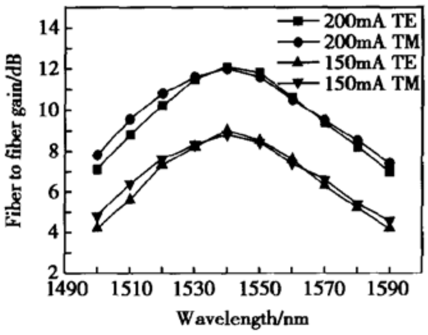

Fig. 2 SOA gain spectra (TE and TM polarization) at two bias levels (input power= − 25dBm)

using an Agilent tunable laser source module, and an Agilent 86142B optical spectrum analyzer (OSA). Input optical power was − 25dBm. The chip gain was as large as 20dB at 200mA and 1.54μm wavelength, and the polarization sensitivity remained less than 0.8dB over the entire range of wavelength (1500 ~ 1590nm). The 3dB bandwidth of the gain spectra was more than 55nm. The gain as a function of output power is shown in Fig. 3. The 3dB saturation output power was 7.2dBm at the output facet. Figure 4 shows the polarization resolved amplified spontaneous emission (ASE) spectra measured at 200mA. The 3dB optical bandwidth of the ASE spectrum was 56nm and the amplitude of the gain ripple was bellow 0.3dB.

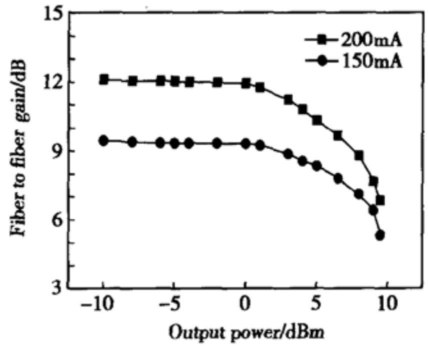

Fig. 3 SOA fiber to fiber gain as a function of output power at I = 200mA, 150mA, and λ = 1.54μm

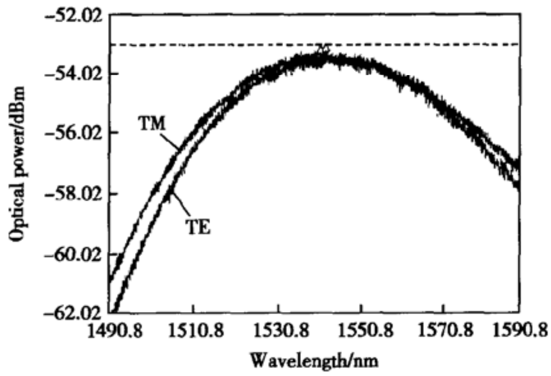

Fig. 4 Polarization resolved ASE spectra of SOA at 200mA

5 Conclusion

A polarization insensitive tensile strained well multiple quantum well optical amplifier at 1550nm wavelength in AlGaInAs-InP-based material system is realized. Gain equalization is achieved through introduction of 0.40% of tensile strain into the quantum wells. Optical amplifiers show excellent gain matching with 0.8dB of maximum gain difference with 20dB of chip gain at 200mA driving current and 1540nm wavelength.

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AlGaInAs-InP 材料系 1550nm 偏振无关半导体光放大器

马 宏[1,2] 朱光喜[1] 易新建[2]

(1 华中科技大学电子与信息工程系, 武汉 430074)
(2 华中科技大学光电子工程系, 武汉 430074)

摘要: 采用低压金属有机气相外延设备生长并制作了1550nm AlGaInAs-InP 偏振无关半导体光放大器, 有源区为3周期的张应变量子阱结构, 应变量为-0.40%. 器件制作成脊型波导结构, 并采用7°斜腔结构以有效抑制腔面反射. 经蒸镀减反膜后, 半导体光放大器的自发辐射功率的波动小于0.3dB, 3dB 带宽为56nm. 半导体光放大器小信号增益近20dB, 带宽大于55nm. 在1500~1590nm 波长范围内偏振灵敏度小于0.8dB, 峰值增益波长的饱和输出功率达7.2dBm.

关键词: 偏振无关; AlGaInAs-InP; 光放大器; MOCVD

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马 宏 男, 1971年出生, 主要研究领域为半导体集成光电子器件与子系统.

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