TUNABLE LASER DIODES ON THE BASIS OF III-V HETEROSTRUCTURES

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ABSTRACT

This paper describes the fabrication technique and operating characteristics of tunable sources on the basis of III-V with central emission wavelength 835nm and 980 nm. The laser diodes were realized using gain-guided AlGaAs/GaAs single quantum well and ridge-waveguide InGaAs/AlGaAs/GaAs multiquantum well heterostructures. Two type of design: two-section-single-cavity (TSSC) and cleaved-coupled-cavity (C3) tunable laser diodes were made.

The two sections of laser diode were obtained by photolithography and chemical etching frontal Au contact layer, width isolated stripe between sections is 4-5 μm. The coupled cavity was formed by cleaving the laser diode chips in two parts. The cleaved sections held together by the contact metals, were then indium soldered "p-side up" to a copper heat sink for CW operation. The emission spectra of 835 nm and 980 nm C3 laser diodes are presented.

Keywords: Tunable source, laser diode, cleaved-coupled-cavity.

1. INTRODUCTION

Currently wavelength tunable semiconductor laser diodes (LD) has very large application in different field such as wavelength division multiplexing (WDM) telecommunications systems, Raman spectroscopy, frequency doubling, material characterisations, remote sensing [1]. The distinguished characteristics of these optoelectronics devices and subsequently the main requirement, is a narrow spectral -linewidth and widely wavelength tunable range.

The low-cost tunable sources, emitting in the 800 - 1000 nm wavelength range are needed at special applications such as high resolution atomic microscopy, laser cooling of neutral atoms [2], new optoelectronics devices testing. The devices have proper advantages and disadvantages that consist in technical performances and fabrication abilities, but one the main requirement is technological simplicity and wide tunable performances.

2. EXPERIMENTAL

2.1. Basic laser diode structures

Two sets of heterostructure were used in this work - AlGaAs/GaAs single quantum well (SQW) and InGaAs/AlGaAs/GaAs multiquantum well (MQW) heterostructures. The AlGaAs/GaAs heterostructure with central emission wavelength 835 nm was grown using low temperature liquid phase epitaxy (LPE) technique in the temperature interval 600- 640 ^{0}C [3] and consists of a 2 μm n-GaAs buffer layer, a 0.9 μm n-$Al_{0,64}Ga_{0,36}As$ cladding , 0.15 μm n-$Al_{0,6-0,3}Ga_{0,4-0,7}As$ graded index (GRIN) waveguiding, 17 nm n-$Al_{0,08}Ga_{0,92}As$ active layer, 0.15 μm n-$Al_{0,6-0,3}Ga_{0,4-0,7}As$ GRIN waveguiding, 0.2 μm n-$Al_{0,66}Ga_{0,34}As$ cladding, 0.4 μm p-$Al_{0,66}Ga_{0,34}As$ cladding and a 0.2 μm p+ GaAs cap layer.

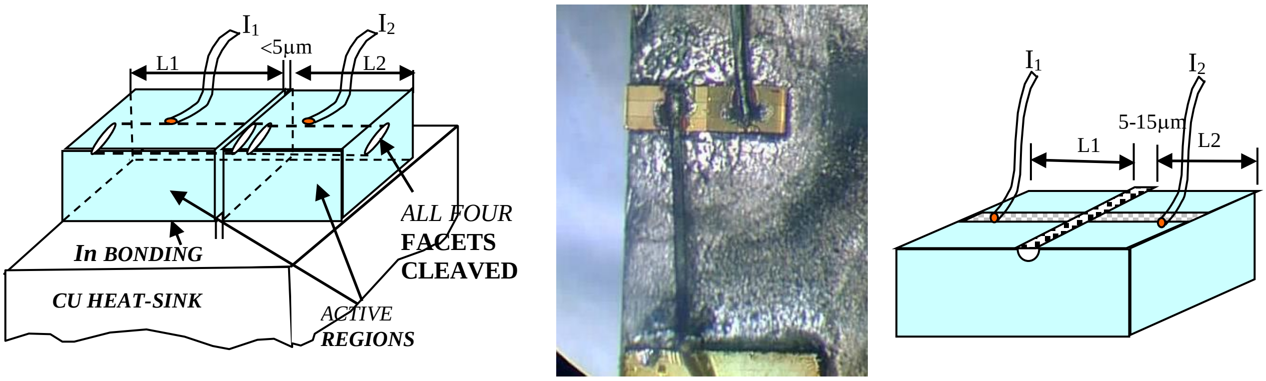
The second heterostructure was InGaAs/AlGaAs/GaAs strained multiquantum well (MQW) graded index separate confinement heterostructure (GRIN SCH) with central emission wavelength 980 nm and was grown by molecular beam epitaxy technique (MBE) on 3 ^{0} off (100) GaAs substrate. The structure consist of 0.5 μm - thick superlattice buffer n+ GaAs buffer layer, 0.1μm - thick superlattice buffer layer of five periods of 10 nm GaAs and 10 nm AlGaAs, a 2,0 μm thick n - $Al_{0,6}Ga_{0,4}As$ cladding layer, a 0.15 μm thick linearly graded index layer of n- $Al_xGa_{1-x}As$ with x and n decreasing from 0.6 to 0.15 and from $5{\cdot}10^{17}$ to $1{\cdot}10^{16}$ cm^{-3}, respectively, a 60 nm - thick undoped $Al_{0.15}Ga_{0.85}As$ layer, three 8 nm InGaAs/10 nm GaAs undoped QW active regions, a 60 nm thick undoped $Al_{0.15}Ga_{0.85}As$ layer, a linearly graded 0.15 μm thick p-$Al_xGa_{1-x}As$ layer with x and p increasing from 0.15 to 0.6 and 1 x10^{16} to 5 x 10^{17} cm^{-3}, respectively, a 2.0 μm thick p- $Al_{0.6}Ga_{0.4}As$ top cladding layer, and a 0.2 μm thick p+ GaAs contact layer.

2.2. Design of tuning laser diodes

The C3 scheme offers the possibility of electronic shifting since the current of two cavities can be independently controlled. If one of the cavities is operated below threshold, a change in its drive current significantly changes the carrier density inside the active region. Since the refractive index of a semiconductor laser changes along with the carrier density, the modes shift with a change in the drive current, and different FP modes of laser cavity can be selected.

In the design of a coupled-cavity lasers, the cavity length L1 and L2 are adjustable to some extent. The performances of such lasers depends on the relative optical length n_1L1 and n_2L2 of the two cavities, where n_1 and n_2 are the effective refractive indices. Another parameters of C3 laser is the intercavity gap width Lg between cavities, and of that depend the coupling efficiency. The air gap itself forms a third cavity, and the intercavity coupling is affected by the loss and phase shift experienced by the optical field while traversing the gap.

The AlGaAs/GaAs and InGaAs/AlGaAs/GaAs samples were processed into oxide stripe gain-guided (GG) and ridge waveguide (RW) lasers respectively. The LD bars with cavity length 240 μm, 260 μm (AlGaAs/GaAs) and 320 μm, 440 μm (InGaAs/AlGaAs/GaAs) were cleaved from the samples. For improving of reciprocal cavity coupling ratio of C3 devices, the antireflection coating (AR) of inside facets are needed. The AR coating (R =0.1) was deposed only on one facet of the (AlGaAs/GaAs) LD bars, after first λ/2 ZnSe deposition procedure [4]. So the LD bars with asymmetrical coating (R_1 =0.3, R_2 = 0.1) were prepared. The cleaved sections, held together by the contact metals, were then indium soldered p- side up to a Cu heatsink. The intercavity gap width Lg was for Al GaAs /GaAs about 5 μm and for InGaAs/AlGaAs/GaAs about 1 μm, fabricating the C3 with different values of intercavity gap allows vary the coupling constant **C** as well and so may vary the tuneable performances of devices. In Fig. 1 the schematic representation of C3 and TSSC are shown.

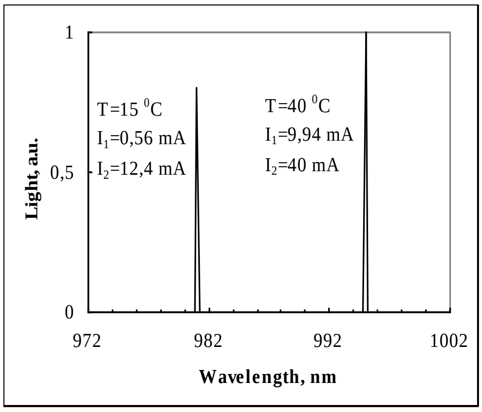


a) b) c)

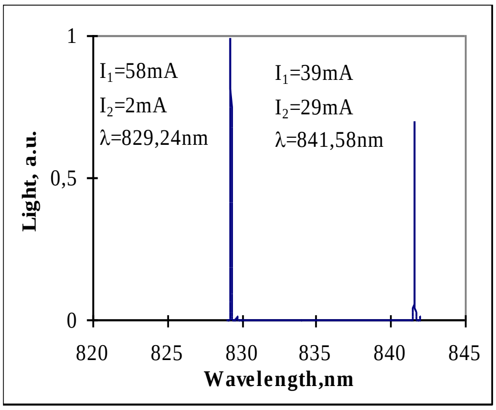
Fig.1. The schematic representation (a), picture (b) of C3 and TSSC (c).

For Al GaAs / GaAs C3 device the length of output cavity, section 1, was 240 μm, section 2 was 260 μm. The CW threshold current for laser section 1 was 21 mA with no current applied to the other cavity. For laser section 2 this parameter was 22 mA. For InGaAs/AlGaAs/GaAs C3 device the lengths of sections 1 and 2 was 320 and 440 μm, respectively. The CW threshold currents of sections 1 and 2 at room temperature was 15 mA and 18 mA, respectively. The spectral characteristics of the C3 lasers were measured under various operating conditions by changing the level of pumping current via sections and also the temperature of devices.

Fig.2 shows the optical spectra obtained for different currents applied to section 1 and 2 for InGaAs/AlGaAs/GaAs and AlGaAs/GaAs devices. The wavelength tunability range for Al GaAs/GaAs and InGaAs/AlGaAs/GaAs C3 was estimated 12.3 nm and 16 nm respectively.



a)



b)

Fig. 2. Emission spectra of 980 nm a) and 835 nm b) C3 laser under various pumping currents.

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