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EXPERIMENTAL CHARACTERIZATION OF INDEX-COUPLED AND GAIN-COUPLED DISTRIBUTED FEEDBACK (DFB) LASERS

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Abstract

For WDM or dense WDM communication systems, long FP lasers (cavity length> 200µm) are not useful because of their many-modes and strong thermal dependent system. The development of high-power, single mode lasers is needed. In this paper, we investigated the characteristics of the lasing mode spectra of the Index –Coupled and Gain-Coupled DFB lasers before and after AR coating.

Keywords : WDM (Wavelength-Division Multiplexing), FP (Febry-Perot) Laser, Gain-Coupled DFb Laser, Index-Coupled DFB Laser, DFB (Distributed Feedback) Laser, RW (Ridge Waveguide) DFB Laser .

Introduction

Wavelength Division Multiplexing (WDM) is quickly becoming a critical technology for many high speed communication systems. The operation of a WDM system begins with the conversion of each input data stream into separate wavelengths. In the case of optical communication, the wavelengths are grouped in transmission windows around 850, 1300 and 1500nm (the available hardware for optical communications is typically centered around these wavelengths). Each application creates a channel that operates at a separate wavelength. The WDM system then combines and simultaneously transmit the channels through the same optical fiber. Since each wavelength is completely isolated from the other, protocols can be mixed within the same link. The combined signals are then separated by the WDM at the other side and converted back to their original wavelength. Essentially, WDM systems create multiple virtual fiber pairs from one. Since light of different wavelengths do not interfere with each other, multiple wavelength signals can be transmitted through the same optical fiber without error. WDM begins to capture the true

Bandwidth potential of fiber optics by allowing multiple high speed communication applications to simultaneously share the same fiber.

Photonic Integrated Circuit (PICs) for WDM communication system require the integration of high performance 1.55µm DFB-Lasers : high single mode output power, small line widths and good high temperature behavior are demanded. Ridge-Waveguide (RW) type DFB-lasers are favorable compared with buried heterostructure (BH) lasers, because they show an unproblematic ageing behavior and only two epitaxial steps are needed for fabrication. However. High power performance of RW-laser is often limited by lateral mode instability leading to undesirable lasing action of a second lateral mode. So the hetero structure layout and stripe width has to be designed to provide lateral single mode emission particularly at high injection currents.

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Experimental Measurement On Index-Coupled DFB Laser

The Index-Coupled DFB laser is based on a ridge waveguide structure. The active region consists of an In_{1-x} Ga_x As_{1-y} P_y strained layer multi-quantum well (MQW) embedded between quaternary waveguides. A rectangular grating without a phase shift was etched into the upper waveguide layer before processing the p-InP ridge. The etch depth was calculated to achieve a coupling strength κ larger than $100cm^{-1}$.The length and the width of the laser ridge were 400 µm and 2.4 µm, respectively. The name of the laser structure is Clock 09 C 20.

First the pulsed light current characteristics of the Index-Coupled DFB laser with cleaved facets was measured. Figure-1 shows the typical light output power versus current characteristics under temperature 20°C pulsed operation.

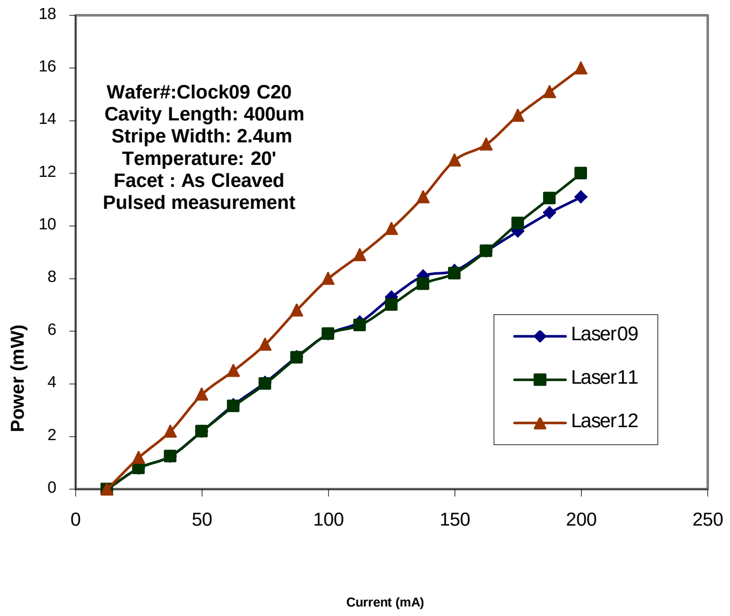

Figure 1 Light output versus current characteristics of Index-Coupled DFB laser with cleaved facets.

In these DFB lasers, low threshold current and high light output power have been achieved. The threshold current was about 10 mA. The corresponding lasin spectra of the Index-Coupled DFB laser under temperature 20°C CW operation at different currents was also measured. The lasing spectrum is changed depends on the injected current. Figure-2 shows the spectrum characteristics of the Index-Coupled DFB laser with cleaved facets.

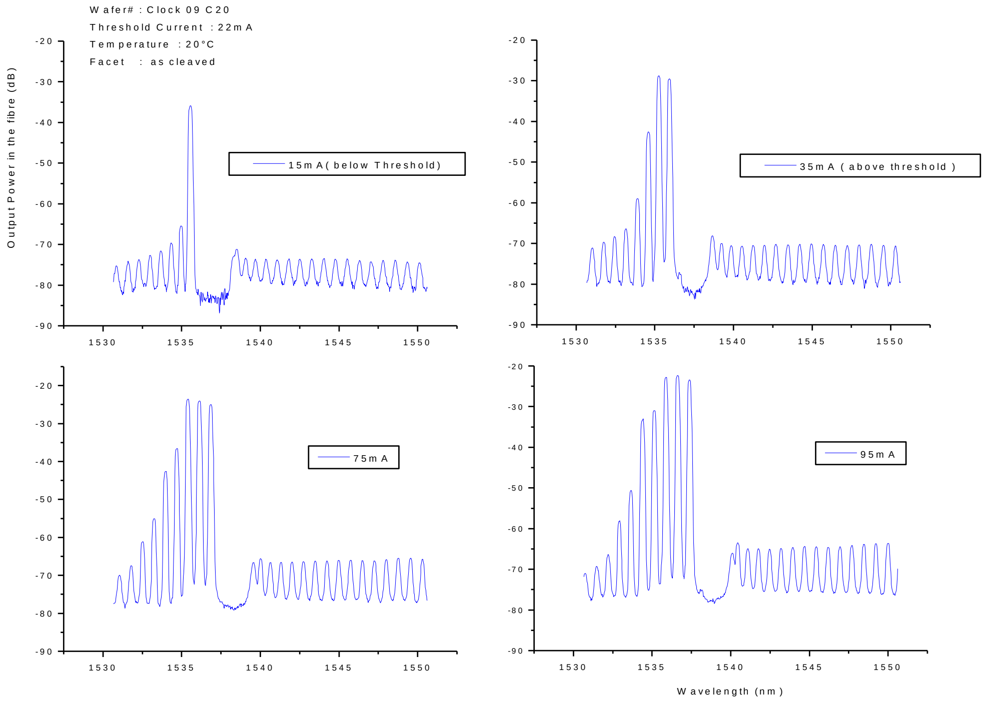

Figure-2 Lasing spectra of Index-Coupled DFB laser with cleaved facets.

In order to get the stable single- mode lasers, the facets of the laser have been AR coated. Anti-reflection (AR) films have been deposited on both facets so that their reflectivity was reduced to $\leq 1*10^{4}$. The light current characteristics and the corresponding lasing spectra of the Index-Coupled DFB laser with AR-coated facets at different currents were measured again.

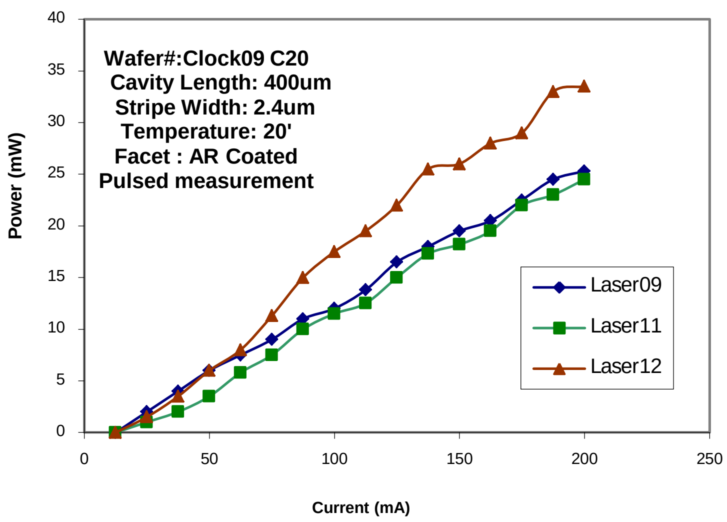

Figure 3 Light output versus current characteristic of Index-Coupled DFB laser with AR-coated facets.

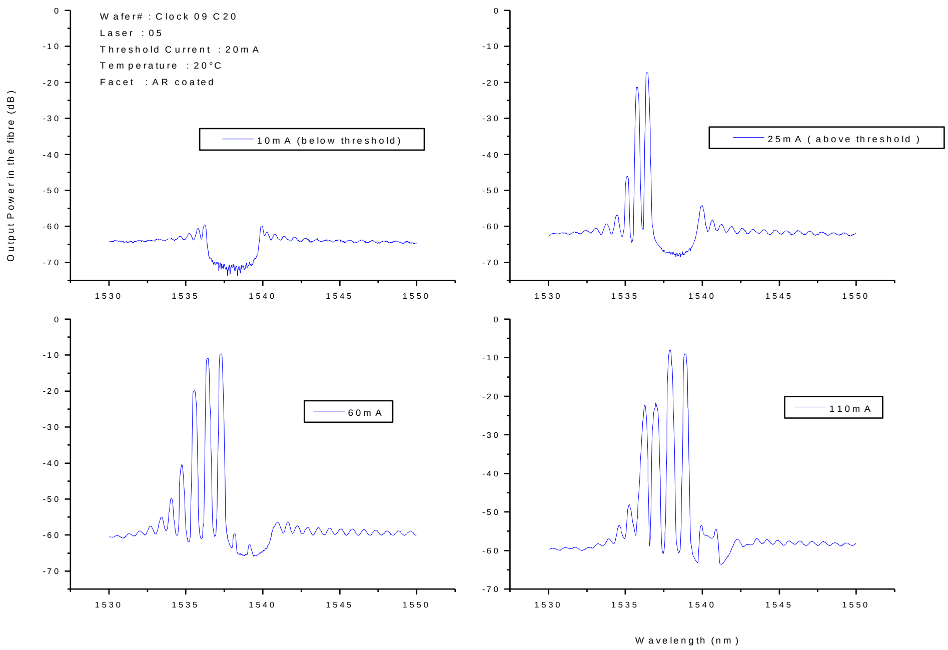

Figure 4 Lasing spectra of Index-Coupled DFB laser with AR-coated facets.

Results

Table 1 The results of the threshold current and output power before and after AR-coating.

Facet	I_{th} (Threshold Current)	Power at 100mA (Output Power)
As cleaved	10mA	17mW
AR coated	10mA	34 mW

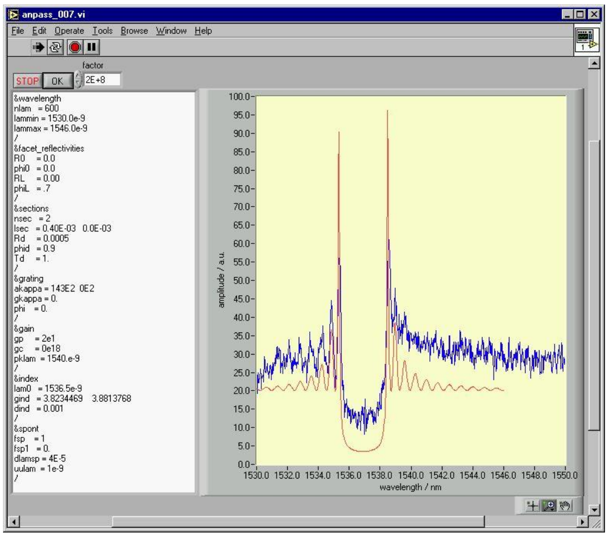

Figure 5 Theoretical curve fitting with the experimental result of the Index-Coupled DFB laser.

It can be seen that, there is no change of I_{th} after AR coating because of the large κ-value. K is about $143 cm^{-1}$. Spectra are characterized by the spatial hole burning effect. In large κ values spatial hole burning occurs and led to the dominant lasing of the mode at the low wavelength stop band side. In most of the cases no single mode behavior could be measured. Further studies are necessary to find the optimum coupling strength which is needed for mode selection of the one hand and prevailing many mode behavior of the other hand.

Experimental Measurement on Gain-Coupled DFB Laser

An alternative approach for feedback insensitive single mode lasers is the introduction of gain coupling. At least different principles of a complex-coupling are known : first the grating is etched in the active layer, second an absorption layer is structured as a grating, third the grating is build by inverse pn diode modulating the carrier concentration and fourth a modulated lattice damage by ion implantation in the active layer is realized. If the real part and the imaginary part of the refractive index are in phase, the stop band mode of the longer wavelength side is dominant in opposite to the antiphase case where the modes in the smaller wavelength side have low threshold values. Purely gain-coupled lasers were treated theoretically. They have a lasing mode exactly at the Bragg frequency. The example that should be discussed in the following is a complex coupled DFB laser realized by a loss grating. In that case real and imaginary part of the refractive index is in antiphase. The Gain-Coupled DFB laser is based on ridge waveguide lasers. The active region consists of an $In_{1-x} Ga_x As_{1-y} P_y$ strained layer multi-quantum well (MQW) embedded between quaternary waveguides. A rectangular grating was deeply etched into a In GaAs absorption layer placed above the quaternary waveguide before processing the p-InP ridge. The length and the width of the laser ridge were 400 µm and 2.4 µm, respectively. The name of the laser structure is gl02.

First the light current characteristics of the Gain-Coupled DFB laser with cleaved facets was measured. Figure-6 shows the typical light output power versus current characteristics under temperature 20°C pulsed operation.

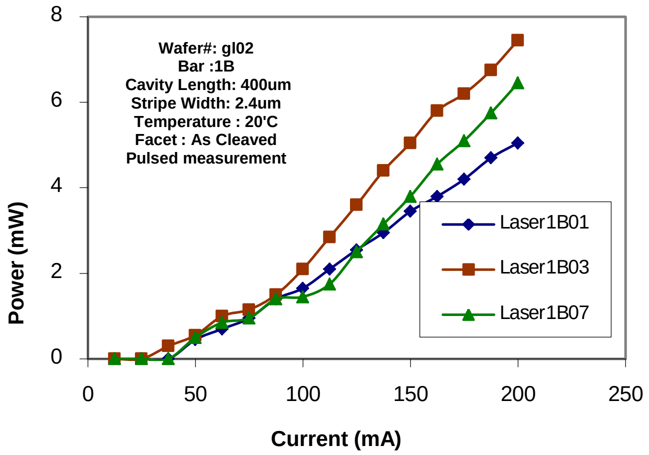

Figure 6 Light output versus current characteristic of Gain-Coupled DFB laser with cleaved facets.

The threshold current of the Gain-Coupled DFB laser is higher than that of the Index-Coupled DFB laser and the optical output power is lower than that of the Index-Coupled DFB laser.

The corresponding lasing spectra of the Gain-Coupled DFB laser under temperature 20°C CW operation at different currents was also measured. The lasing spectrum is changed depends on the injected current. Figure-7 shows the spectrum characteristics of the Gain-Coupled DFB laser with cleaved facets. For injection currents below and slightly above threshold the expected dominance of the smaller wavelength stop band mode could be observed.

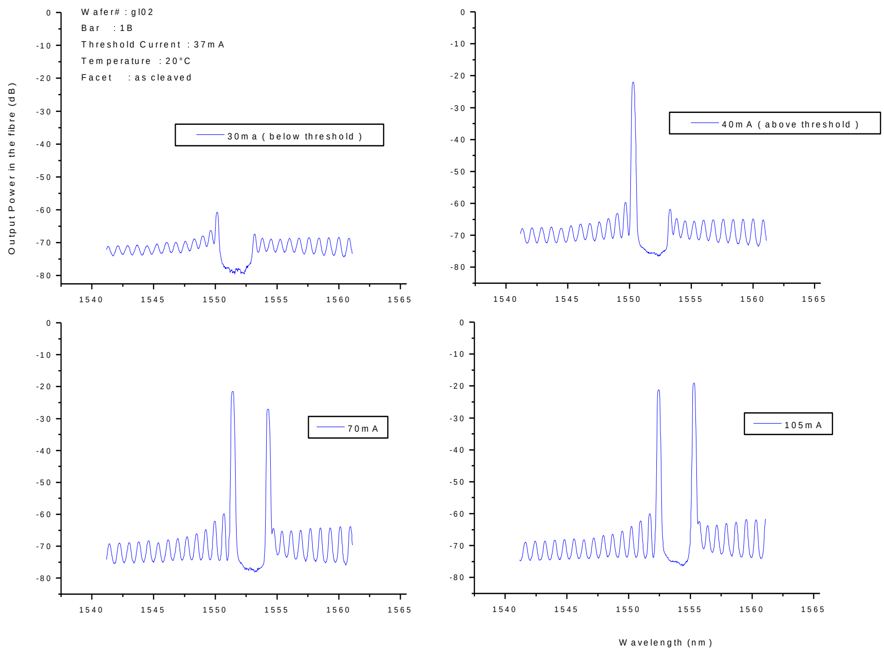

Figure 7 Lasing spectra of Gain-Coupled DFB laser with cleaved facets.

In order to get stable single- mode lasers, the facets of the laser have been AR coated. Anti-reflection (AR) films have been deposited on both facets so that their reflectivity was reduced to $\leq 1*10^4$. The light current characteristics and the corresponding lasing spectra of the Gain-Coupled DFB laser with AR-coated facets at different currents were measured again.

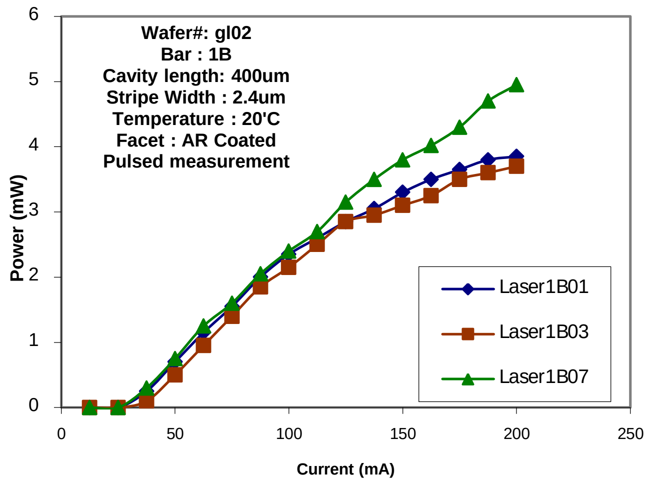

Figure 8 Light output versus current characteristics of Gain-Coupled DFB laser with AR-coated facets.

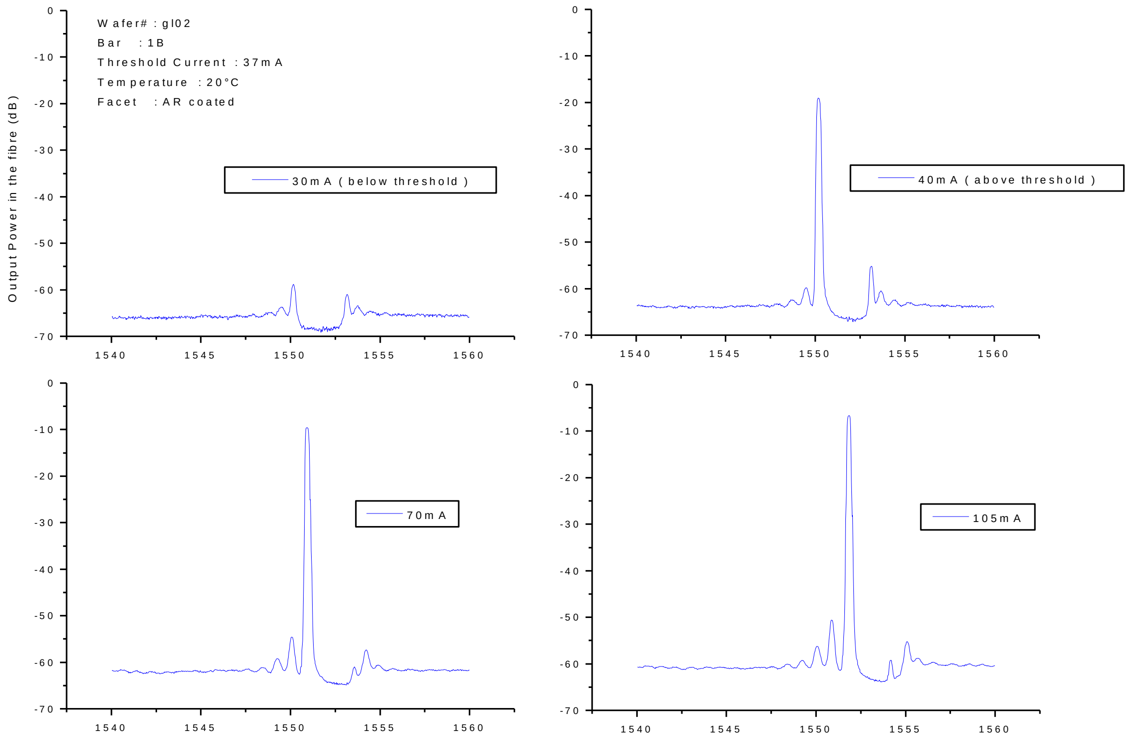

Figure 9 Lasing spectra of Gain-Coupled DFB laser with AR-coated facets.

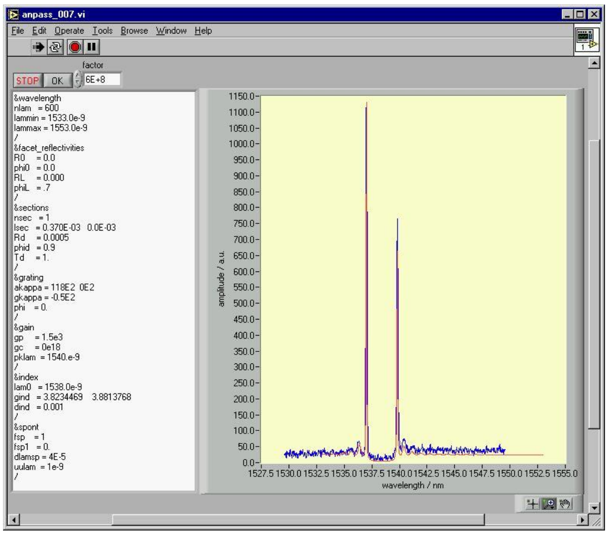

Figure 10 Theoretical curve fitting with the experimental result of the Gain-Coupled DFB laser.

Most of the lasers show single mode behavior over the whole current range (up to 100mA). In agreement with the theoretical predictions the smaller wavelength stop band mode dominates. The coupling parameters were determined using a fit program write by Hans Wenzel. For a spectrum below threshold we drive coupling strength values $\kappa_I = 118\text{cm}^{-1}$ and $\kappa_G = 0.5\text{cm}^{-1}$. The gain part of the coupling is rather small. This might be responsible to the double mode behaviour in the case of as cleaved lasers, that is very similar to pure Index-Coupled lasers.

Conclusion

In experiment on Index-Coupled DFB laser, firstly the light current characteristic and the lasing spectrum of the Index-Coupled DFB laser with cleaved facets have been measured. The mode spectrum of the laser is changed depending on the injected current. And then the facets of the Index-Coupled DFB laser are AR coated and the light current characteristic and the lasing spectrum have been measured again.

In experiment on Gain-Coupled DFB laser, by measuring the light current characteristic of the Gain-Coupled DFB laser, it can be seen that the threshold currents of the Gain-Coupled DFB lasers are higher than that of the Index-Coupled DFB laser and the output power is lower than that of the Index-Coupled DFB laser. By measuring the lasing spectrum of the Gain-Coupled DFB laser with cleaved facets and with AR coated facets, it can be seen the changes of the mode spectrum of the laser depending on the injected currents.

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