UNIVERSITI TEKNOLOGI MARA

THEORETICAL STUDIES OF HIGH POWER LONG WAVELENGTH InGaNAs QUANTUM WELL LASER DIODE FOR PUMPING RAMAN AMPLIFIER

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ABSTRACT

This thesis studies the effects of Nitrogen (N) fraction, quantum well (QW) number, presence and absence of $GaN_{0.01}As_{0.99}$ barrier and thicker GaAs waveguide layers based on three device designs (device A, B and C) of $In_{0.32}Ga_{0.68}N_{0.007}As_{0.993}$ QW laser diodes (QWLDs). These effects are theoretically studied using sophisticated simulator of RSoft LaserMOD in order to deliver a good quality long wavelength and high power $In_{0.32}Ga_{0.68}N_yAs_{1-y}$ QWLD suitable for pumping Raman amplifier (RA). N fraction is varied from 0.007 to 0.022 with a step of 0.003, number of QW is elevated from 1 to 3, conventional GaAs barriers are replaced with the $GaN_{0.01}As_{0.99}$ barriers, and the GaAs waveguide thickness is varied from 380 nm to 2000 nm. It was found that by increasing N fraction up to 0.022 the lasing wavelength λ_l is significantly elongated from 1.2400 µm to 1.6416 µm, 1.2378 µm to 1.5892 µm and 1.2127 µm to 1.2790 µm for device A, B and C respectively while the output power (P_{out}) is slightly degrades from 4.618 W to 3.103 W, 4.5609 W to 2.0093 W and 8.748 W to 8.975 W. The shifting of λ_l is caused by the reduction of the $In_{0.32}Ga_{0.68}N_yAs_{1-y}$ band-gap when higher N fraction is introduced into all devices. The best N fraction is then determined as 0.007 for all devices. Furthermore P_{out} degradation and shifting of λ_l is suggested to have strong relationship with the phenomenological relationship constant valued at 99.5 eV, 88 eV and 18 eV for device A, B and C respectively. Increasing the number of QW was found to prominently increased optical confinement factor (OCF) rather than increasing P_{out} in all devices. The best number of QW is determined as 2 for all devices which yields OCF of 1.8029 %, 1.84008 % and 1.58900 % for device A, B and C respectively with maximum P_{out} of 5.102 W, 2.281 W and 1.509 W taken at various current injection level. The used of $GaN_{0.01}As_{0.99}$ barrier and thicker GaAs waveguide was found to enhance P_{out} and λ_l. A maximum P_{out} of 5.454 W, 2.440 W and 2.286 W are recorded for device A, B and C respectively along with λ_l of 1.2404 µm, 1.2379 µm and 1.1538 µm. Also by using thicker GaAs waveguide layer, the internal loss (α_i) of the devices can possibly be reduced to amplify P_{out}. The optimum GaAs waveguide thickness for device A, B and C is then determined at 1600 nm, 800 nm, and 1100 nm respectively. Based from the simulated outputs, an appropriate correlation between N fraction, number of QW, $GaN_{0.01}As_{0.99}$ barriers and thicker GaAs waveguide layers of the $In_{0.32}Ga_{0.68}N_yAs_{1-y}$ QWLD towards the J_{th}, P_{out} and λ_l is proposed.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

Long haul communication has been made possible since the deployment of the first transatlantic fiber optics cables in 1988 [1] which connect United States to England and France (TAT-8), Hawaii (HAW-4), Japan and Guam (HAW-4 and TPC-3). Ever since, technological advancement has brought these communication networks into the new level when wavelength division multiplexing (WDM) and optical amplifiers are introduced and deployed to support the increase in traffic bandwidth and to compensate optical attenuation when signals travel over long distances.

In today's communication networks, doped fiber amplifier (DFA) [2-13], semiconductor optical amplifier (SOA) [14-17] and the Raman amplifier (RA) [18-20] are the examples of mostly deployed optical amplifiers. These optical amplifiers have their very own specific advantages and drawbacks upon deployment in the fiber optics communication networks. In the early stage of optical amplifiers deployment, DFA and SOA are much preferable to study compared to RA since SOA does not requires any additional pump laser to operate and DFA such as erbium doped fiber amplifier (EDFA) requires only conventional laser diode (LD) to excite Erbium ions (Er^{3+}) leaving behind RA which requires very high power LD to trigger stimulated Raman scattering (SRS) effect. Yet to best compensate optical attenuation in the long haul communication networks, the use of RA is much preferable as early experimental work demonstrated that RA performs better than EDFA on the long haul WDM communication network [21].

Such demonstration inspired the idea in deploying RA in the actual fields. However, this idea can only be realized when there is enough SRS in the RA system provided by the high power LD. In the early 1990s, the availability of high power LDs are still limited but nowadays they are commercially available. Nonetheless, the performance of these LDs are inconsistent due to some conditions such as catastrophic optical mirror damage (COMD) and thermal rollover when operated at high current