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R & D STATUS REPORT

DARPA Order No. : 6325

Contractor : Ortel Corporation

Contract No. : N00014-88-c-0483

Contract Amount : $708,516.-

Effective Date of Contract : 18 July 1988

Expiration Date of Contract : 17 July 1990

Principal Investigator : Dr. Nadav Bar-Chaim

Telephone No. : (818)281-3636

Title of Work : "Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well lasers for Optical Interconnect"

Reporting Period : July - January 1989

FISCAL STATUS

(1) Amount currently provided on contract: $458,707

(2) Expenditures and commitments to date : $ 89,556

(3) Funds required to complete work : $618,960

R & D STATUS REPORT (# 1)

February 18, 1989

The following constitutes the 1st progress report for work done on Contract No. N00014-88-C-0483 entitled "Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well Lasers for Optical Interconnect".

The main emphasis during this period has been placed on the following efforts: 1) establishing a system and a method to fabricate gratings; 2) growing and qualifying quantum well GaAs/GaAlAs material generated in our low pressure MOCVD reactor; 3) fabrication of ultra-low threshold buried heterostructure lasers using liquid-phase-epitaxy regrowth; 4) processing of standard double heterostructure ring lasers in order to determine the losses associated with curved structures.

was designed and set up

We have designed and set up a system for fabrication of submicron gratings in order to be able to generate gratings required for vertically emitting lasers. The system consists of a He-Cd laser which emits light in the 325 nm UV line. The light is spatially filtered and expanded and then split into a couple of beams that create an interference pattern. Using this system we have exposed GaAs wafers that were coated with positive photoresist to create gratings with periods in the range of 0.2-1.0 micron. (A typical second order grating for GaAlAs laser is 0.24 micron).

As mentioned earlier we have grown and characterized single quantum well material in order to fabricate ultra low-threshold lasers. The basic structure is a graded-index separate-confinement heterostructure (GRIN-SCH) single quantum well. The growth took place in our low-pressure metalo-organic chemical-vapor-deposition (MOCVD) reactor. The sources used were: Trimethyl Gallium, Trimethyl Aluminum, Diethyl Zinc and Hydrogen Selenide. The growth has been performed at a temperature of 750°C at a pressure of 80 torr with an average gas flow of 15 liters/minute. The following layers were grown on n^+ GaAs substrate: 0.5 micron n^+ - GaAs buffer layer, 1.5 micron n - $Al_{0.4}Ga_{0.6}As$ cladding layer, 0.2 micron graded n - $Al_xGa_{1-x}As$ layer ($x = 0.4$ to 0.2), 150 Å undoped GaAs quantum well, 0.2 micron undoped $Al_xGa_{1-x}As$ layer ($x = 0.2$ to 0.4) and p - $Al_{0.4}Ga_{0.6}As$ cladding layer.

At first, broad stripe lasers (~100 micron wide, 500 micron long) were fabricated from the grown material. Typical threshold current densities range from 250 A/cm^2 to 500 A/cm^2. An important step in material qualification was to anneal the material at elevated temperatures in the range of 700°C-800°C, for 2 hours in order to simulate the temperature cycle required for regrowth, which is the next step in fabricating buried-heterostructure lasers. It was found that the best results, i.e. threshold current densities change negligibly, were obtained for annealing temperatures in the range of 700-750°C. Material was also characterized by measuring room temperature photoluminescence as well as carrier concentrations and mobilities.

Following that we have fabricated buried heterostructure lasers as follows: 1.5 micron wide mesas along the $(1,\bar{1},0)$ crystal orientation were produced by etching through the MOCVD grown layers into the substrate. A 0.5 micron p-$Al_{0.5}Ga_{0.5}As$ followed by a 3.0 micron n-$Al_{0.5}Ga_{0.5}As$ layer were grown by liquid-phase-epitoxy (LPE) to provide electrical and optical lateral confinement. A shallow Zn diffusion was performed to facilitate the ohmic contact on the p-side metal contact (chromium-gold) of the device metallization: . The wafer was then lapped, backside metallized (gold-germanium, nickel, gold) and the contacts were alloyed.

A typical laser, with a cavity length of 250 microns, had a threshold current of 4 mA (with uncoated mirrors) and slope efficiency of 0.4-0.5 mW/mA (from one mirror). After coating the back side with high reflectivity (~70%) dielectric coating (quarter-wave aluminum oxide followed by quarter-wave silicon) the threshold current decreased to ~3 mA and the slope efficiency (from the front mirror) increased to ~0.75 mW/mA. An additional similar high-reflectivity coating on the front mirror resulted in further reduction of the threshold current to ~2 mA while restoring the slope efficiency to the original value of 0.4-0.5 mW/mA.

These results verify our original considerations that unlike conventional double-heterostructure lasers, enhancement of the facet reflectivity of quantum well structures lead to a substantial reduction of the threshold current, without paying any significant penalty in the quantum efficiency of the devices. This is basically due to the lower current density needed to make the transverse structure with the thin active layer transparent and the low distributed losses in the crystal.

We have also fabricated ring double-heterostructure lasers with both first and second growth performed by LPE. This was done as a preliminary step to fabricate such lasers using MOCVD quantum well material. The basic process is similar to the one outlined above, with the main difference (in addition to having a double heterostructure) being to use a curved lateral waveguide structure consisting of half a ring with a diameter of 150 microns. The advantage of such a structure is that both mirrors are cleaved at the same crystal facet, eliminating the necessity for two cleavages. This leaves room on the wafer for fabricating electronic components without being limited to small areas. The lasers we've fabricated have typical threshold currents of 40 mA and slope efficiency of 0.2-0.3 mW/mA (both facets). Straight reference lasers from the same wafer displayed threshold currents of 10-20 mA and slope efficiencies of 0.6-0.8 mW/mA (adding both facets). The difference in performance is due to the bending loss of the curved waveguide.

The next quarter will be dedicated to additional studies of the ultra-low threshold lasers especially regarding high-speed multi-gigahertz performance. We will also evaluate the lasers reliability as far as catastrophic optical damage (COD) and the necessity of non-absorbing mirrors. Further study of different coatings on the lasers characteristics will be carried out. We also plan to fabricate quantum well ring lasers for integrated optoelectronic application, and study their performance.