Simulation of a Double Ridge Edge Emitting InGaAsP/InP MQW Laser

Introduction

In order to investigate the influence of ridge separation on the transverse optical modes of a double ridge edge multiple quantum well (MQW) emitting laser, we have designed a generic device based on the InGaAsP/InP MQW 1.5µm wavelength emission. The aim of this study is to investigate power loading in the structure with increasing bias using the bottom layer as the reference plane.

To do this, the first three transverse modes were considered and the power associated with each mode was monitored as a function of the device design. Silvaco ***ATLAS LASER*** was used for this investigation.

Active Region

The active region of the chosen device was based on a publication by J. H. Song, et al. that appears in IEEE Photonics Technology Letters, Vol12, 7 July 2000. The Multiple Quantum Well region was specified with the MQW statement. The XMIN, XMAX, YMIN, and YMAX parameters define this region. The width of each well is defined by the (WW) parameter, the well separation is defined by the (WB) parameter, and the number of wells used is defined by the (NWELL) parameter.

Schrodinger's Equation is performed to extract bound state energies. The NX and NY parameters specify the quantum mesh that is required for the solution of Schrodinger's Equation. This will define a box of uniform mesh within the MQW region. We have also specified the YAN model in order to calculate the spontaneous recombination from a hole band.

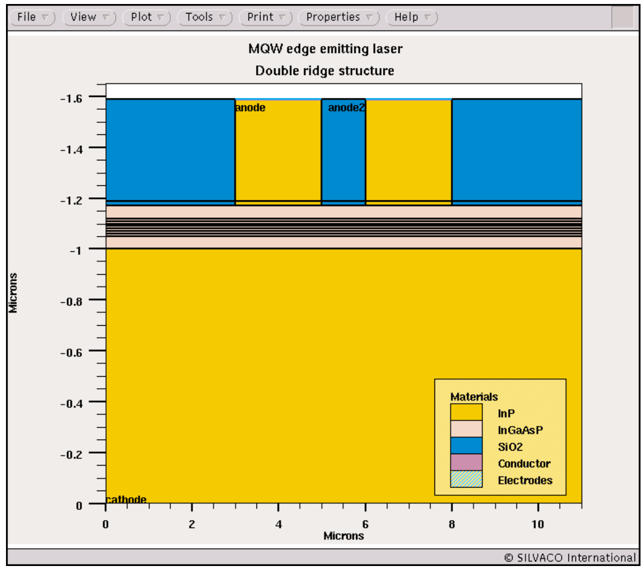

Figure1. the structure of the two laser devices used for this study. Note the laser ridges and their separation.

In order to take account of the strain in the MQW system, the Ishikawa model was invoked. The band edge parameter is modified for Schrodinger's Equation by defining the strain percentage. There are a number of tabulated, user-definable factors that modify the effect of the strain on the conduction and valance-band effective masses. These are found in Ishikawa's paper (Takuya Ishikawa and J.E. Brown, IEEE Journal of Quantum Electronics, Vol 30, No 2, Feb 1994 pp 562-570) and are reproduced in the *ATLAS User*'s manual (Quantum chapter).

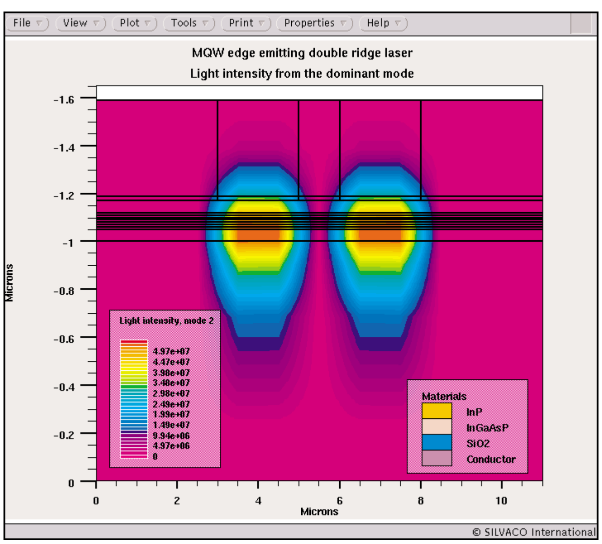

Figure 2a. Light intensity contour map from the dominant transverse mode in a structure with 1µm separation.

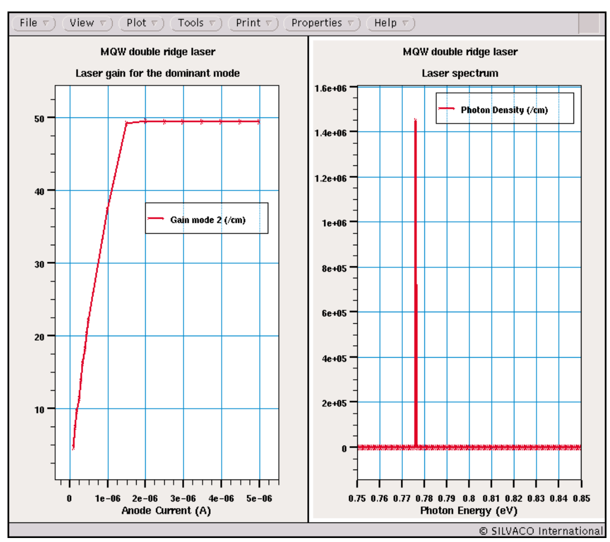

Figure2b. Laser gain and frequency spectrum for the 1µm structure at an anode current of 1e-5A.

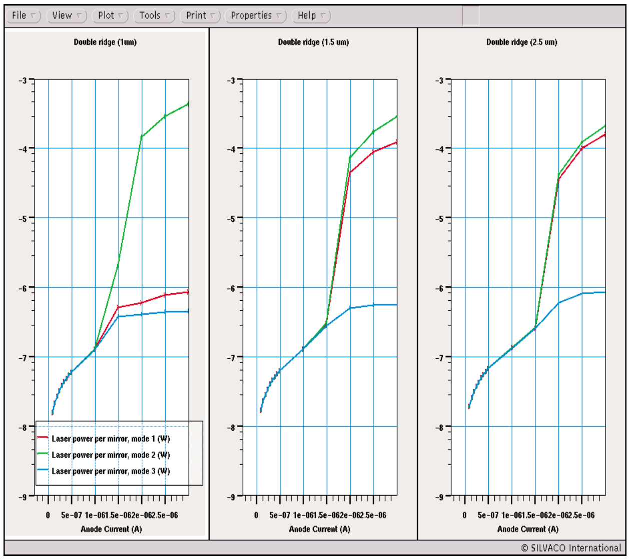

Figure 3. Laser power output from Three structures with ridge separation of 1 micron (left panel), 1.5 micron (middle panel) and .5 micron (right panel).

The materials used in this example were defined in the usual way: molar fractions were specified in the region statements, while the quantum wells molar fractions were defined in the MQW statement.

The Laser Structure

The structure was defined using the region statements in which several parameters were specified, including thickness, y mesh density, x position, material concentration, and doping concentration. This simplifies the definition of the y mesh point as the regions are stacked on top of each other. Here in order to define the five laterally stacked regions (oxide/ridge/oxide/ridge/oxide) the parameter STAY was utilized within the region statement (Figure 1).

Figure 2a shows a map of the light intensity for the dominant lateral mode of a structure with a 1um ridge separation at a current of 1e-5A. Figure 2b shows the laser gain and frequency spectrum under the same structure and bias conditions.

The Experiment

In order to obtain a structure with a single transverse mode, laser simulations were run with the first three principle transverse modes taken into account, up to a current of 1e-5A. The modes were monitored as a function of the ridge separation(s). For this work, the ridge width (r) was kept at a constant 2mm. In order to simplify this investigation, we used fixed statements for separation and other dimensions with algebraic expressions. These were defined in the beginning of the input deck in order to simplify the generation of data for various device dimensions.

Influence of the ridge separation on the modal laser power:

The results in Figure 3 show the output laser power as a function of current flowing through the structure. The results from the first three transverse modes show that when the ridge separation exceeds 1 micron, the laser shows a bi-modal operation, with the power of the first two modes being fairly similar. Under bias conditions where the anode current is 3e-6A, the first two modes are within the same order of magnitude. As the separation reduces to 1 micron, the laser operates with one dominant mode that generates power about 3 orders of magnitude greater than the other two modes at a bias of 3e-6A anode current.

Temperature Distribution in the Device

Figure 4 illustrates a 2D map of the lattice temperature contours in a device with a 2µm separation between the ridges. The bottom cathode plane was used as a reference temperature (300K) for these calculations. As expected, the areas of maximum temperature coincide with the active regions where most of the current passes and the recombination events take place. At a bias condition of 1e-5A anode current, the temperature rise is rather small. However, it is a good indicator of the trend in the device temperature with increasing bias.

Conclusions

In this study, we demonstrated the use of ***ATLAS LASER*** to fine-tune the design of a multiple quantum well (MQW) edge-emitting laser. For this typical 1.5µm wavelength InGaAsP/InP laser, the separation between the two light confining ridges must measure around 1µm to ensure a single mode operation.

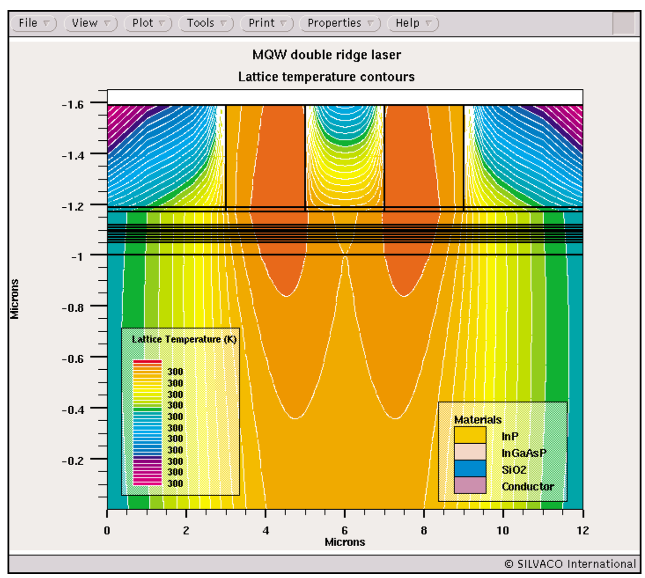

Figure 4 showing a typical lattice temperature contours in a device with 2mm ridge separation. Note the areas with maximum temperature coincide with areas of maximum lasing activity.