Investigating a Hypothetical Semiconductor Laser Bar with a Smile-Shaped Temperature Profile using a Laser Diode Simulation/Emulation Tool

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Abstract

In this paper, Barlase, a semiconductor laser diode emulation tool, is used to emulate the by-emitter degradation analysis of high power semiconductor laser diodes. Barlase is a software that uses a LabView control interface. We have already demonstrated how Barlaseworks using a hypothetical laser diode bar (multiple emitters) to validate the usefulness of the tool. It should however, be noted that, this scenario is valid for devices at the start of the aging process only. This scenario was investigated to demonstrate Barlase as follows: curved temperature (smile) profile with maximum temperature at the centre of the bar. The result of this simulation scenario shows the successful implementation of Barlase in the by-emitter analysis of laser diodes.

Index terms— by-emitter, emitter, defect, smile-shaped temperature profile, emitter power, quantum well, degradation, threshold current, slope efficiency, band gap

1 Introduction

esearch in the optoelectronic field has improved tremendously leading to the widespread use [1] of optoelectronic devices. As a consequence, progress in the development of high power laser bars has skyrocketed due to their high demand and their improved reliability and durability. Numerous applications of high power lasers have therefore emerged, including light detection and ranging and free space optical communications [2], apart from their traditional applications [3] in recent times. turn to emit more power and therefore are the hottest within a bar.

2 II.

3 Materials and Methods

Bars are made up of multiple emitters, and therefore there was a need to find an innovative way to include the interactions between individual emitters within the bar. This gave rise to the Barlase concept as indicated in Figure 1 as a flow chart showing the communication between emitters in a bar. A bar is considered as a monolithic block of multiple emitters connected in parallel with each other with a common voltage connected across them as shown in Figure ??.

4 III.

5 Results and Discussion

In this paper, the scenario investigated was the impact of a curved heatsink temperature profile across the bar, with a maximum temperature at the centre of the bar. The edges of the bar were held at 300 K. Temperature variations of this magnitude (up to 30 K) have been measured in high-power laser bars with 25 - Barlase therefore presents an attempt to understand further, the by-emitter degradation analysis technique developed over recent years [4][5][6][7][8]. This tool is also an addition to the by-emitter analysis technique where the effects of certain factors that affect the degradation of laser emitters/bars can be investigated. Barlase [9] in this book is used to perform a by-emitter analysis of a laser bar, when a smile-shaped temperature profile is used since it is well known that central emitters 50 emitters operating at high currents (e.g. 30 A -50 A). Comparing the average current per emitter in those cases with the hypothetical 8 emitter bar at a current of 10 A investigated here, we see that the assumed temperature distribution is realistic. Using these values, multi-emitter simulations were carried out in constant current mode for bar currents of 2, 4, 6, 8 and 10 A. Figure **??** show the heatsink temperature profile for the investigation, with Table 1 showing the table of values of the heatsink temperatures assigned to each emitter in the bar.

Figure **??** shows the P-I characteristic of the bar together with the P-I and P-V characteristics of each of the individual emitters. The threshold current and slope efficiency for the bar are also shown as legend in Figure **??**a. From the emitter P-I curves in Figure **??**b, the threshold current and slope efficiency have been calculated for each individual emitter. These quantities are plotted as a function of emitter number in Figure **??**. The results for the different emitters clearly show an increased threshold current, decreased slope efficiency and earlier onset of thermal roll-over for the hotter emitters (as expected). The threshold currents of the individual emitters vary by +/? 5% from the average value, whilst the slope efficiencies deviate by +3/?5% from the average value. Nevertheless, the hotter emitters draw more current and emit more power. This can be attributed to the fact that the temperature-induced changes in the "apparent" threshold current and the "apparent" slope efficiency are opposite to the changes in the actual threshold current and slope efficiency. This is due to the temperature induced band gap reduction, which lowers the turn-on voltage and strongly affects the current competition between emitters. Strain-induced changes in the band gap energy are expected to give similar behaviour of the apparent threshold current and slope efficiency, but this is not expected for increases in the defect or trap density (since it does not change the turn-on voltage of the diode). Finally, this example also shows temperature as a principal cause of emitter threshold current and slope efficiency variations. Figure 6 shows the distribution of current, power and maximum quantum well (QW) temperature across the bar for a total bar current of 2 A. Figure **??** shows the same quantities for a total bar current of 10 A. The horizontal broken lines in Figures 6 and 7 represent the ideal values of emitter current and power found by dividing the values from the total bar P-I characteristic by the number of emitters. In these graphs, the effects of current competition and the distribution of the power between emitters are made clear. The emitter currents vary by up to +/?10% from the average value, whilst the emitter output powers vary by up to +3/?5%. Barlase therefore has been again used in this scenario to gain more knowledge about the interaction between emitters in a laser bar when a curved temperature (smile) profile with maximum temperature at the centre of the bar is investigated. In fact, this is the practical outcome of most semiconductor laser bars as the central emitters emit more power and therefore degrade faster with aging [10].

IV.

6 Conclusion

The case investigated in this paper using multiemitter simulations show that variations in the operating conditions and environment of the individual emitters also affect the performance of other emitters and of the bar as a whole. The introduction of a non-uniform temperature profile caused the most significant change in the bar and emitter operating conditions and in its performance. However, it should be remembered that this scenario is for devices at the start of the aging process. When all of the relevant effects are combined and allowed to interact over time, high levels of defects are expected to play a more important role. This will be caused by current competition due to a reduction in the turn-on voltage as a result of local temperature and/or strain-induced changes in the band gap energy. Indeed, it is well known that the propagation and growth of defects increases with increasing temperature. Thus, the rate of defect generation and propagation within emitters are inextricably linked with the temperature profile of the bar.

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1

Figure 1: Figure 1 :

1

Emitter Number	Heatsink Temperature	(K)
1	300	
2	310	
3	320	
4	330	
5	330	
6	320	
7	310	
8	300	

Figure 2: Table 1 :

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