

## Research Article

### Investigating a Hypothetical Semiconductor Laser Bar with a Damaged Single Emitter Using a Laser Diode Simulation/Emulation Tool

<sup>1,2</sup>C.K. Amuzuvi and <sup>1</sup>J.C. Attachie

<sup>1</sup>Department of Electrical and Electronic Engineering, University of Mines and Technology, Tarkwa, Ghana

<sup>2</sup>Photonic and Radio Frequency Engineering Group (PRFEG), Electrical Systems and Optics Research Division, Faculty of Engineering, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

**Abstract:** This study demonstrates the use of *Barlase*, a semiconductor laser diode emulation tool, to emulate the by-emitter degradation of high power semiconductor laser diodes. *Barlase* is software that uses a LabView control interface. In this study, a hypothetical laser diode bar (multiple emitters) was used to investigate a damaged single emitter randomly located in the bar and its behavior analyzed within the bar. It should however, be noted that, this scenario is valid for devices at the start of the aging process only. When all other relevant effects that affect the performance of laser diodes bars are allowed to interact over time, high levels of defects can also play important role in the degradation process. The results of this simulation scenario show the successful implementation of *Barlase* in the by-emitter analysis of laser diodes.

**Keywords:** Band gap energy, by-emitter, defect, degradation, emitter, nonradiative recombination, quantum well, slope efficiency, temperature, threshold current

## INTRODUCTION

Due to several applications emerging in the use of high-power laser bars (Steel, 2008), there is a greater demand on their improved reliability and durability. Apart from their traditional applications such as pumping solid-state lasers, material processing (Schulz and Poprawe, 2000), printing, medicine and entertainment; they have found other uses in the light detection and ranging and free space optical communications (Chazan *et al.*, 1998).

*Barlase* presents an attempt to understand further, the by-emitter degradation analysis technique developed over recent years (Xia *et al.*, 2002; Tomm *et al.*, 2002; Bull *et al.*, 2005; Lim *et al.*, 2007, 2009, 2005; Bream *et al.*, 2006). The tool is 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.

In this study, *Barlase* (Amuzuvi and Attachie, 2013) is used to perform a by-emitter analysis of a laser bar when an emitter within the bar is damaged. The objective of this study is to investigate and analyze various scenarios of defects in the operation of a laser bar, especially if there is a localized defect like a defective emitter within the bar.

## 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 (Fig. 1), where a bar is considered as a monolithic block of multiple emitters connected in parallel with each other with a common voltage connected across them, Fig. 2 (Amuzuvi, 2013).

Each emitter is biased with a common voltage, but the emitter currents and powers change depending on the details of the individual emitters and their environment.

## RESULTS AND DISCUSSION

In Amuzuvi and Attachie (2013), *Barlase* was used to investigate a practical scenario, where a laser bar has a random low-level of defects distributed across the bar. In this study, another practical scenario is being investigated where one random emitter has a high level of defects. The bar being considered is the same as in Amuzuvi and Attachie (2013), an (8) emitter bar (Fig. 2). Emitter #3 was randomly selected to represent a “damaged” emitter. The level of defects introduced in

**Corresponding Author:** C.K. Amuzuvi, Department of Electrical and Electronic Engineering, University of Mines and Technology, Tarkwa, Ghana

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

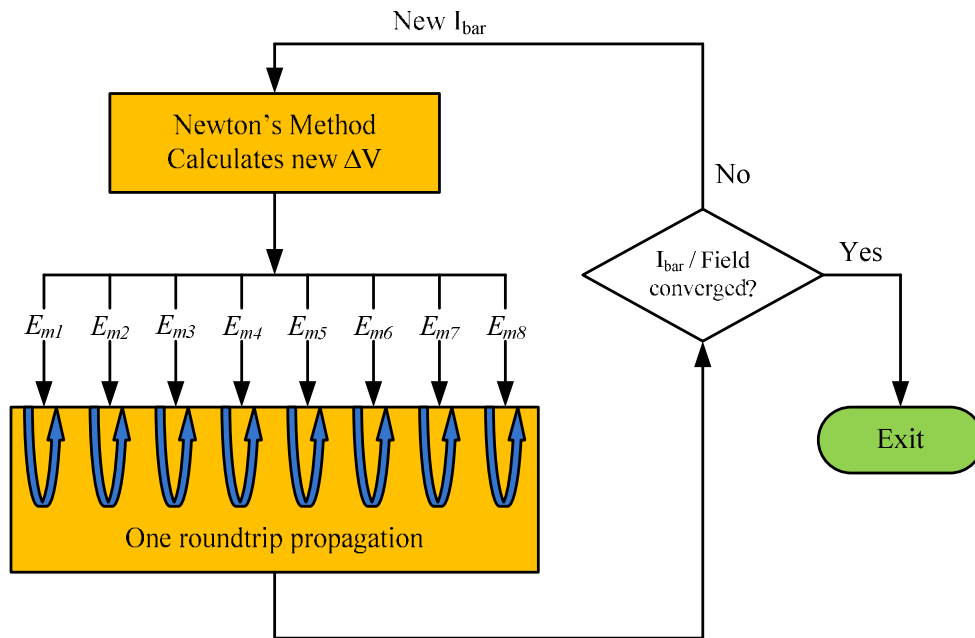


Fig. 1: Flow chart showing the communication between emitters in Barlase

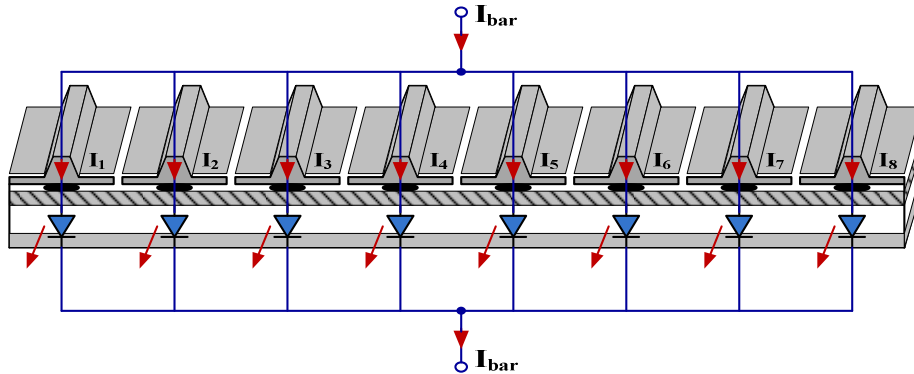


Fig. 2: The representation of an eight emitter laser bar

Table 1: Values of QW trap densities assigned to each emitter in the bar

Emitter number	Trap density (cm <sup>-3</sup> )
1	2.00×10 <sup>15</sup>
2	2.00×10 <sup>15</sup>
3	2.00×10 <sup>16</sup>
4	2.00×10 <sup>15</sup>
5	2.00×10 <sup>15</sup>
6	2.00×10 <sup>15</sup>
7	2.00×10 <sup>15</sup>
8	2.00×10 <sup>15</sup>

emitter #3 was chosen to be  $2 \times 10^{16} \text{ cm}^{-3}$  - an order of magnitude higher than that found in the other 7 emitters. Again, multi-emitter simulations were carried out in constant current mode for bar currents of 2, 4, 6, 8 and 10 A. Table 1 indicates the levels of QW trap densities assigned to each emitter in the bar.

Figure 3 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 Fig. 3a. The threshold current and slope efficiency have been calculated for each individual emitter from the emitter P-I curves in Fig. 3b. Figure 3c also shows the power versus individual emitter voltages. The variations of apparent threshold/threshold current and apparent slope/slope efficiency of individual emitters are plotted as a function of emitter number in Fig. 4. The P-I curve of the emitter with the high level of defects is lower than that of the other emitters, as expected. The threshold current in emitter number 3 is 16% higher, whilst the slope efficiency is only 0.25% lower compared to the other emitters.

Figure 5 shows the distribution of current, power and maximum QW temperature for each emitter across the bar for a total bar current of 2 A. Figure 6 shows the same quantities for a total bar current of 10 A. From

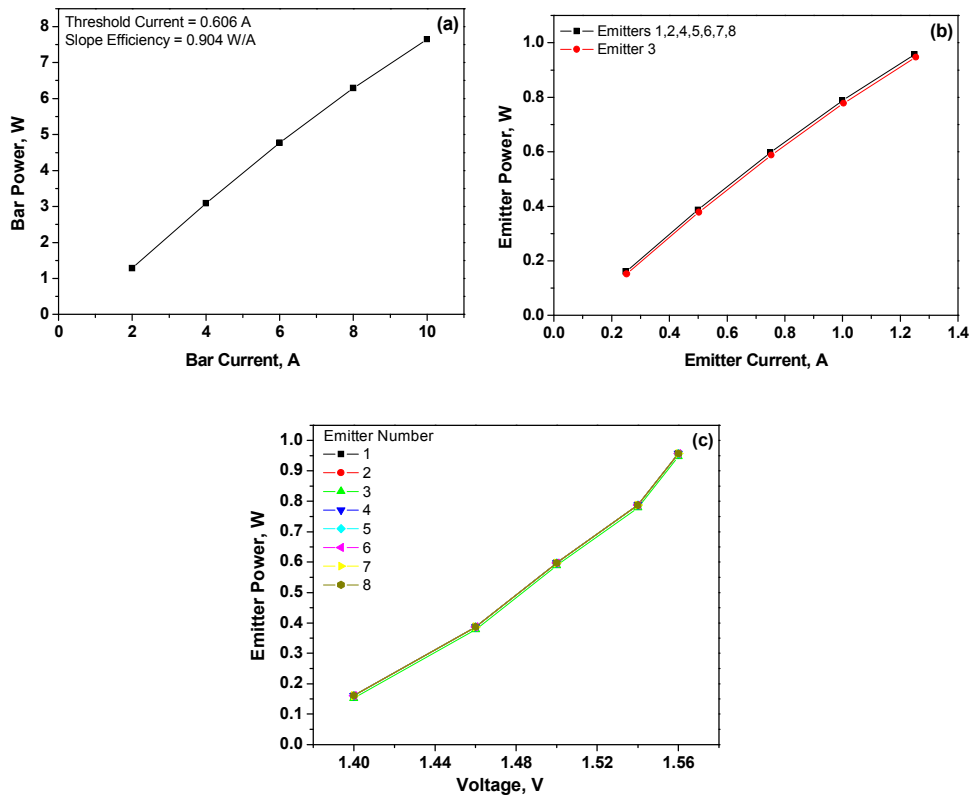


Fig. 3: (a) Bar power-current characteristics, (b) power-current characteristics of the individual emitters, (c) power versus individual emitter voltage

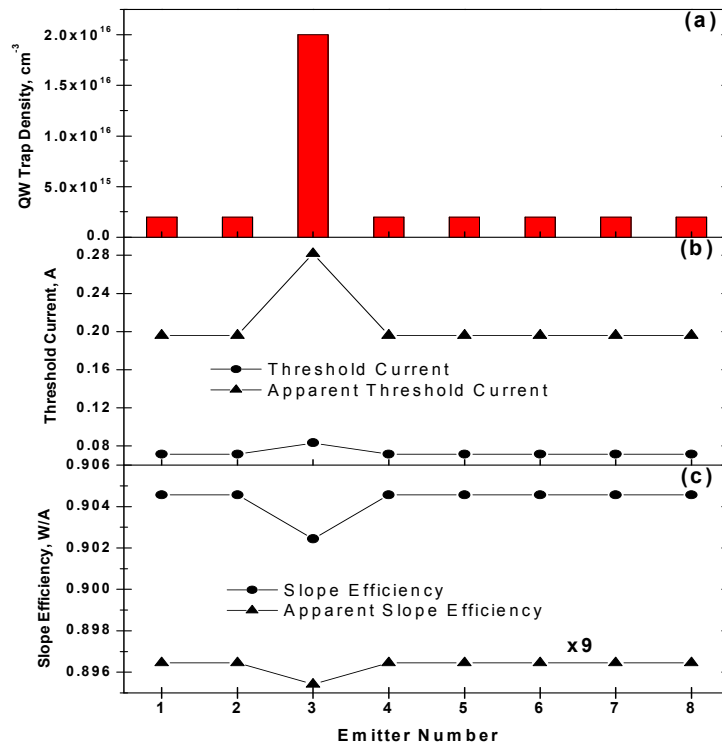


Fig. 4: (a) QW trap densities assigned to each emitter, (b) variation of apparent threshold/threshold current, (c) apparent slope/slope efficiency of individual emitters

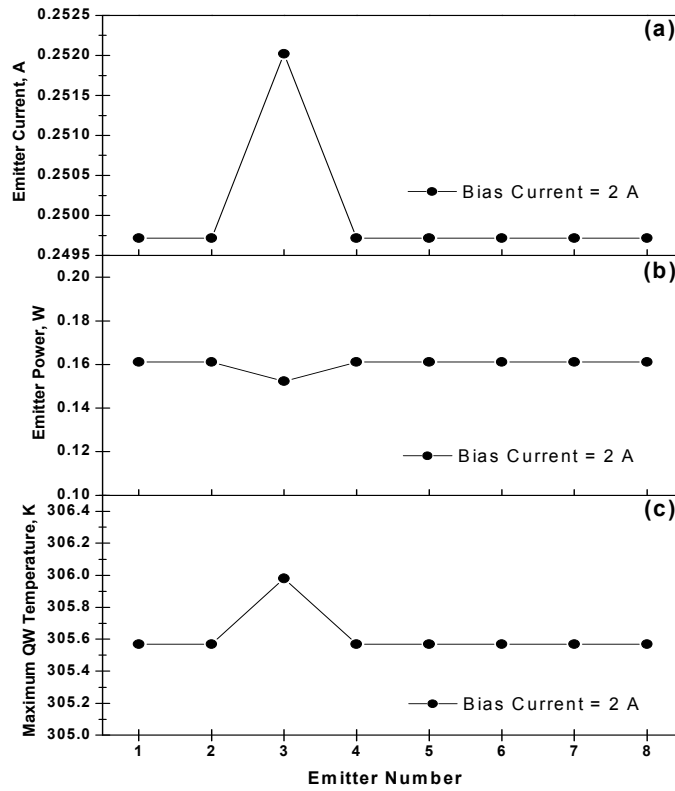


Fig. 5: (a) Distribution of the emitter currents, (b) emitter powers, (c) maximum emitter QW temperatures across the bar at a total bar bias current of 2 A

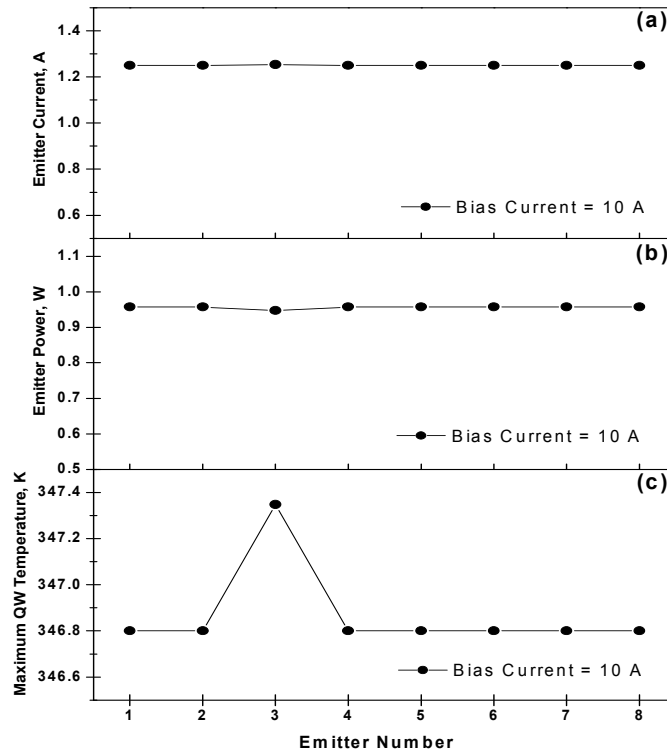


Fig. 6: (a) Distribution of the emitter currents, (b) emitter powers, (c) maximum emitter QW temperatures across the bar at a total bar bias current of 10 A

these graphs, the relationship between the current, power and maximum QW temperature of the emitter with the high level of defects can be seen to be different in comparison to the standard emitters. The higher level of defects in emitter number 3 causes its current to be 0.35% higher, its output power to be 1.0% lower and its maximum QW temperature to be just over 0.5 K greater than the other emitters.

*Barlase* has therefore been used in this scenario to gain more knowledge and insight into the interaction between emitters in a laser bar when defective emitters are present in the bar.

### CONCLUSION

The variations in the operating condition and environments of the individual emitters were seen to affect the performance of the other emitters and of the bar as a whole. This scenario investigated using *Barlase* demonstrates the effect that a damaged emitter will have on a laser bar via the distribution of power and current competition within the bar. From this scenario, the capabilities of *Barlase* has clearly been investigated and demonstrated, indicating the increase in temperature and the corresponding decrease in power when a damaged emitter is present in a bar.

### ACKNOWLEDGMENT

CKA thanks the University of Mines and Technology, Tarkwa, Ghana and the GetFund for their support.

### REFERENCES

- Amuzuvi, C.K., 2013. Emulation and By-Emitter Degradation Analysis of High Power Lasers. LAP LAMBERT Academic Publishing, Saarbrücken, Germany.
- Amuzuvi, C.K. and J.C. Attachie, 2013. Investigating a hypothetical semiconductor laser bar using a laser diode simulation/emulation tool using random levels of defects. Res. J. Appl. Sci. Eng. Technol., DOI: 10000-RJASET-DOI.
- Bream, P.J., J.J. Lim, S. Bull, A.V. Andrianov, S. Sujecki and E.C. Larkins, 2006. The impact of nonequilibrium gain in a spectral laser diode model. Opt. Quantum Electron., 38: 1019.
- Bull, S., J.W. Tomm, M. Oudart, J. Nagle, C. Scholz, K. Boucke, I. Harrison and E.C. Larkins, 2005. By-emitter degradation analysis of high-power laser bars. J. Appl. Phys., 98: 063101.
- Chazan, P.J., M. Mayor, S. Morgott, M. Mikulla, R. Kiefer, S. Muller, M. Walther, J. Braunstein and G. Weimann, 1998. High-power near-diffraction-limited tapered amplifiers at 1064 nm for optical intersatellite communications. IEEE Photonics Technol. Lett., 10: 1542-1544.
- Lim, J.J., T.M. Benson and E.C. Larkins, 2005. Design of wide-emitter single-mode laser diodes. IEEE J. Quantum Electron., 41: 506.
- Lim, J.J., R. MacKenzie, S. Sujecki, M. Sadeghi, S.M. Wang, Y.Q. Wei, J.S. Gustavsson, A. Larsson, P. Melanen, P. Sipila, P. Uusimaa, A.A. George, P.M. Smowton and E.C. Larkins, 2007. Simulation of double quantum well GaInNAs laser diodes. Proceeding of the 21st Conference on Semiconductor Integrated Optoelectronics (SIOE). Cardiff, WALES, pp: 259-265.
- Lim, J.J., S. Sujecki, L. Lang, Z.C. Zhang, D. Paboeuf, G. Pauliat, G. Lucas-Leclin, P. Georges, R.C.I. MacKenzie, P. Bream, S. Bull, K.H. Hasler, B. Sumpf, H. Wenzel, G. Erbert, B. Thestrup, P.M. Petersen, N. Michel, M. Krakowski and E.C. Larkins, 2009. Design and simulation of next-generation high-power, high-brightness laser diodes. IEEE J. Select. Topics Quantum Electr., 15: 993-1008.
- Schulz, W. and R. Poprawe, 2000. Manufacturing with novel high-power diode lasers. IEEE J. Select. Topics Quantum Electr., 6: 696-705.
- Steel, R., 2008. Laser Focus World. Retrieved from: <http://online.qmags.com/LFW1108/Default.aspx?sessionID=81697E67BEC59096E4AA81FC2&cid=798041&eid=10916>.
- Tomm, J.W., A. Gerhardt, T. Elsaesser, D. Lorenzen and P. Hennig, 2002. Simultaneous quantification of strain and defects in high-power diode laser devices. Appl. Phys. Lett., 81: 3269.
- Xia, R., E.C. Larkins, I. Harrison, S.R.A. Dods, A.V. Andrianov, J. Morgan and J.P. Landesman, 2002. Mounting-induced strain threshold for the degradation of high-power AlGaAs laser bars. IEEE Photon. Technol. Lett., 14: 893.