Journal of Electrical and Electronic Engineering
2013; 1(3): 55-60
Published online August 20, 2013 (http://www.sciencepublishinggroup.com/j/jeee)
doi: 10.11648/j.jeee.20130103.11

By-emitter emulation of the degradation of a calibrated 975 nm tapered laser bar using a laser diode simulation/emulation tool

Christian Kwaku Amuzuvi[1, 2, *], Seth Ofori[1]

[1]University of Mines and Technology, Department of Electrical and Electronic Engineering, Tarkwa, Ghana
[2]Photonic and Radio Frequency Engineering Group (PRFEG), Electrical Systems and Optics Research Division, Faculty of Engineering, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Email address:
ckamuzuvi2000@yahoo.com, ckamuzuvi@umat.edu.gh(C. K. Amuzuvi)

To cite this article:
Christian Kwaku Amuzuvi, Seth Ofori, By-Emitter Emulation of the Degradation of a Calibrated 975 nm Tapered Laser Bar Using a Laser Diode Simulation/Emulation Tool. *Journal of Electrical and Electronic Engineering.* Vol. 1, No. 3, 2013, pp. 55-60.
doi: 10.11648/j.jeee.20130103.11

Abstract: In this paper, *Barlase* has been taken a step further by emulating the degradation processes in high power semiconductor laser bars to further deepen the understanding of the behaviour of laser bars. In publications elsewhere where *Barlase* was used, investigations were done using hypothetical laser bars to emulate various degradation processes commonly found in the operations of lasers. In this paper however, the emulation of a real laser bar is being investigated to compare experimental results to the emulated results to establish a correlation between them. The results established show a close matching between the experimental and the emulated results but the levels of change were not similar. The reason for this can be attributed to the thermal properties used in *Barlase* and that the consideration of a global thermal solver will be necessary to improve upon the mismatch between the experimental and emulated results.

Keywords: By-Emitter, Calibration, Tapered Laser Bar, Heatsink Temperature, Electroluminescence, Emitter, Degradation, Near Infra-Red, Trap Density

1. Introduction

High power semiconductor laser diodes have occupied the minds of researchers in the last decade due to the emerging widespread usage in the fields of medicine, industry and in telecommunications [1-3].

The effectiveness of *Barlase* has already been demonstrated using hypothetical laser bars and published elsewhere [4]. *Barlase* is being used in this paper to simulate/emulate the degradation processes using a real single emitter high power laser bar and a multiple emitter bar. Experimental results of a real laser bar are compared with the emulated results to establish a correlation between them.

This paper gives a further credence to the by-emitter degradation analysis technique developed over recent years Xia *et al.*[5], [6-8] and Bream *et al.* [9]. 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. The objective of this study is to establish a correlation between experimental and emulated results to demonstrate the versatility of the emulation tool *Barlase*.

2. Materials and Methods

In a paper published elsewhere [4], hypothetical (uncalibrated) laser bars were used to demonstrate the operation of *Barlase* and to better understand the interactions of emitters within a bar. In this paper, a first attempt is made to emulate the degradation of real bars, whose performance and degradation was characterised in detail using by-emitter degradation analysis and published [10].

The structure of the real device used for the emulation (975 nm tapered bars from III-V LAB) is a 16 emitter tapered laser bar with 4 emitter mini-arrays. The measurements on the bar are performed on one emitter and then scaled up to 4 emitters. Data from experiments (temperature and near infra-red (NIR) electroluminescence (EL) from defects) extracted at the bar level were used to derive inputs for the simulations. Figure 1 shows details of the real laser bar being investigated in the emulation.

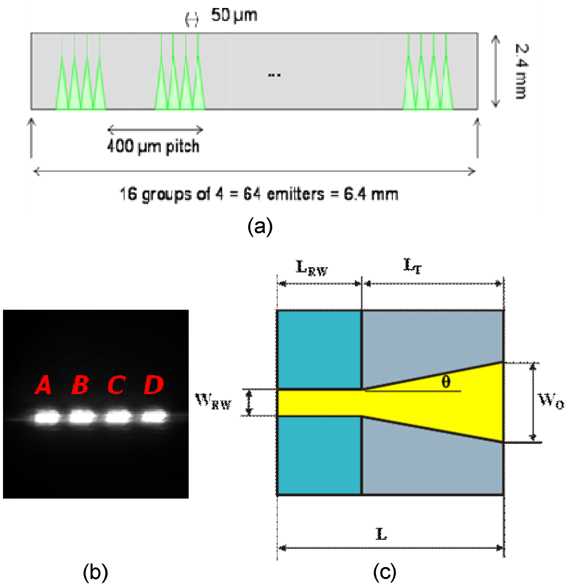


Figure1. *(a) Structure of the investigated laser bar: 16 emitter tapered laser bar with each group of 4 mini-array emitters, (b) near field (NF) image of 4 sub-emitter groups, (c) laser structure for a tapered mini array.*

In order to get a good match between the experimental and emulated results, a calibration procedure was undertaken to set up the initial conditions necessary for the emulation. The calibration of the 975 nm tapered laser bar was performed using several device parameters, including: (a) trap density N_T; (b) hole absorption cross section; and (c) QW/waveguide composition. Numerous simulations were performed using single emitter P-I curves, which were determined from bar P-I curves and the assumption made of identical emitters (975 nm bars, 0 hours, III-V LAB). The simulated P-I curves were compared with the experimental P-I curves of unaged emitters until a reasonable agreement was achieved (Figure 2). Two different 975 nm bars (Bar 16022 and 16024) were used to achieve the agreement between the experimental and emulated results.

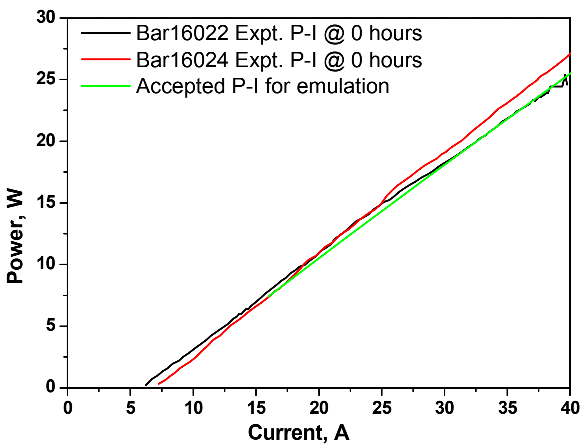


Figure2. *Graphs of the experimental and calibrated laser bar at 0 hours.*

3. Results and Discussion

3.1. Emulation of the Degradation of the Calibrated Single Emitter

Prior to the emulation of the real bar, single emitter (SE) simulations were performed using the calibrated version of the 975 nm tapered laser bar. Aging (degradation) of the SE was also performed for aging times of 0, 500, 1000, 2000, 5000 and 10000 hrs at temperatures of 300 K, 320 K and 340 K respectively. Figs. 3a and b show the graphs of emitter output power (W) against aging time (hrs) for the three temperatures and power loss versus aging time, respectively. The power loss increases with increasing aging time and temperature as expected.

The threshold currents and slope efficiencies for heatsink temperatures of 320 K and 340 K are compared at aging times of 0, 1000, 5000 and 10000 hrs, respectively. These are shown in Table 1. Significant changes occur in the threshold current, but much smaller changes are observed in the slope efficiency.

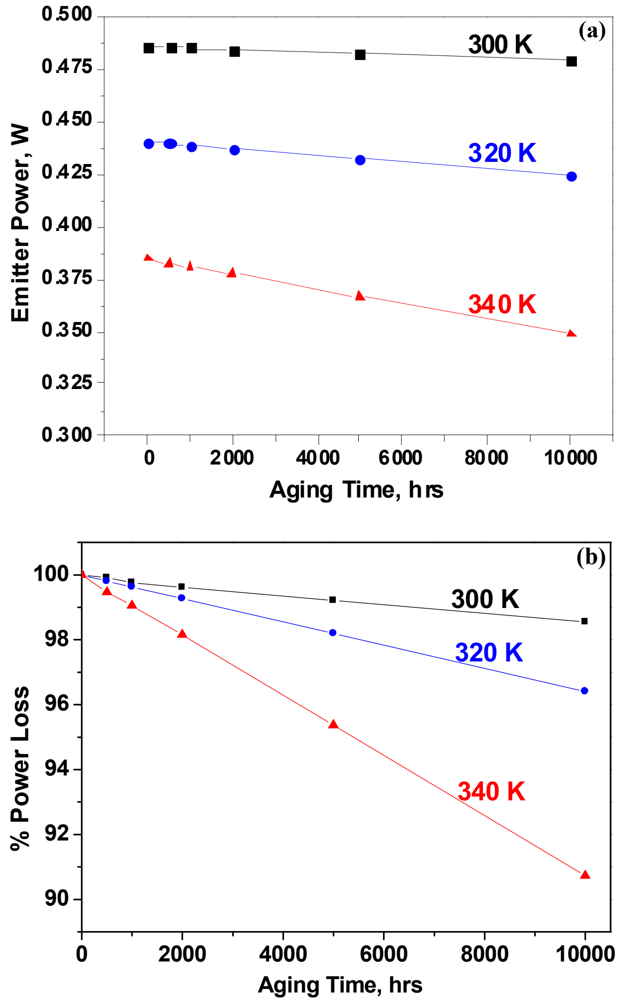


Figure3. *Graphs of (a) emitter output power and (b) % power loss against aging time.*

Table 1. *Comparison of apparent threshold and slope efficiency*

Aging Time (Hours)	$T_{Heatsink}$ = 320 K		$T_{Heatsink}$ = 340 K	
	Threshold Current	Slope Efficiency	Threshold Current	Slope Efficiency
0	0.082 A	0.66 W/A	0.10 A	0.59 W/A
1,000	+1.5%	-0.19%	+4.4%	-0.23%
5,000	+10%	-0.56%	+24%	-0.83%
10,000	+21%	-0.99%	+49%	-1.7%

3.2. Multiple Emitter Degradation Emulation of the Calibrated bar

Also prior to the emulation of the real bar, multiple emitter scenario using 8 (eight) emitters was also performed for the calibrated 975 nm tapered laser bar. This was done to demonstrate that the aging model will work for a real bar with interacting emitters. This demonstrates the role of current competition in bar degradation and the behaviour of the individual emitters during aging. The bar used in this scenario was an 8-emitter tapered 975 nm laser connected in parallel with individual emitters identical to those in the SE emulation scenario. In other words, this is a test scenario to demonstrate the workability of the calibrated 975 nm tapered laser bar.

The condition used for the emulation of this test scenario was non-uniform (frown shaped) packaging-induced strain profile with higher strain in the middle of the bar. Simulations were performed to verify the effect of strain on a bar under “isothermal”, “thermal” and “thermal + varied heatsink temperature” conditions. (Note: Under “thermal” conditions, self-heating effects are simulated within each emitter, but thermal cross-talk between emitters is not included. In order to approximately account for the thermal cross-talk effects, different heatsink temperatures are used for each emitter.)

The emulation was performed at a bar current of 6 A i.e. (I_{BAR} = 6 A) for an unaged bar. Figures 4a, 4b, and 4c show the output power, current and QW temperature distributions across the bar against the emitter group number. All the conditions used yielded different results as can be seen in the legends of the graphs. This shows that the effect of strain is important in the operation of a high power laser.

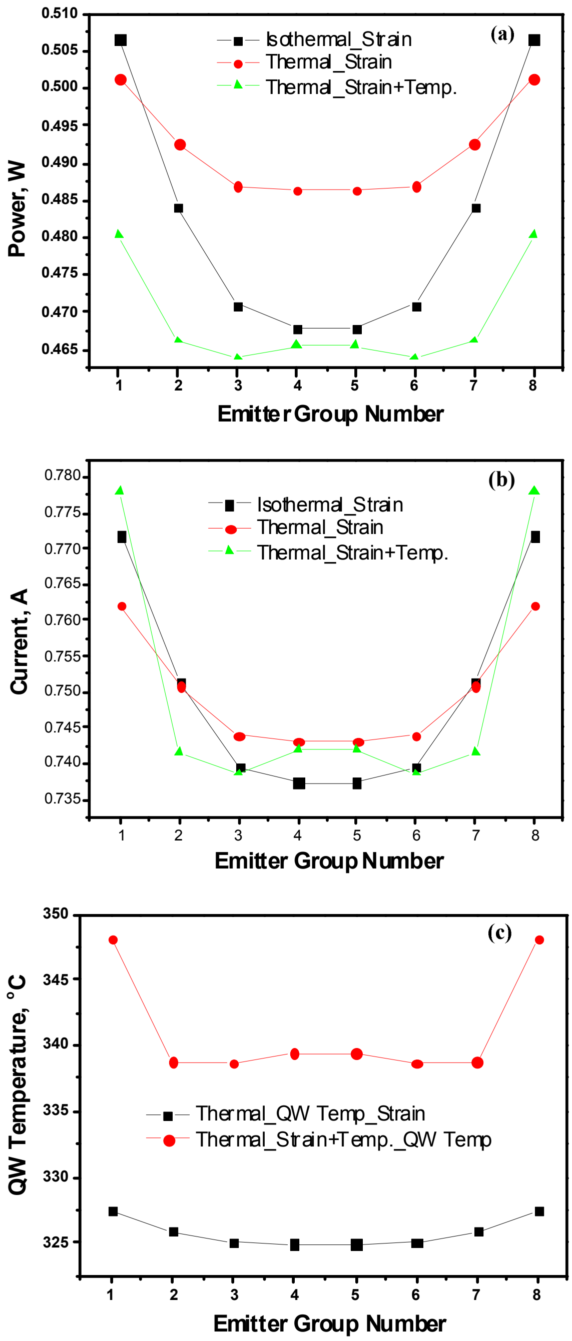


Figure4. *Graphs of: (a) output power, (b) current and (c) QW temperature versus emitter group number at zero aging time (view legends in the graphs for conditions simulated).*

3.3. By-Emitter Emulation of the Real Bar (975 nm Laser Bar with 16 Tapered Emitters)

In this part of the paper, a first attempt was made to emulate the observed degradation of the actual laser bar. Prior to attempting to emulate the degradation of the bar, cognisance was taken of the experimental results attained before and during the measurement of the device. For instance, microscopic photographs were taken before and after measurements to identify damaged emitters. Also, some measurement results were used to tailor the initial simulation parameters of the emitters for the emulation of the degradation process. The temperature and the NIR EL signal (defect) profiles for the bar at an aging time of 0 hrs (i.e. unaged) were used as initial input parameters, since they both play a significant role in the degradation of the laser bar.

Emulation Results (Unaged) – Bar 16022

Figure 5a and 5b show the temperature and NIR defect EL profiles across Bar 16022. The emulation results for the unaged bar (time = 0 hrs) are shown in Figure 6 below for comparison of the experimental and simulated results. The initial results yielded the distributions of output power and QW temperature shown in Figure 6a and 6b, respectively. The simulated output power in Figure 6a did not correspond well with the experimental results - perhaps due to the physical damage of the end emitters observed by optical microscopy. The correlation between the experimental and simulated temperature profiles (Figure 6b) is better (except for the edge emitters, which were known to be damaged). The temperature profiles are similar in shape, but the magnitudes differ. This discrepancy is due to the fact that the simulated temperature is the QW temperature, whereas the measured temperature is a spatial average (spatial resolution of camera ~30µm) of the bulk temperature.

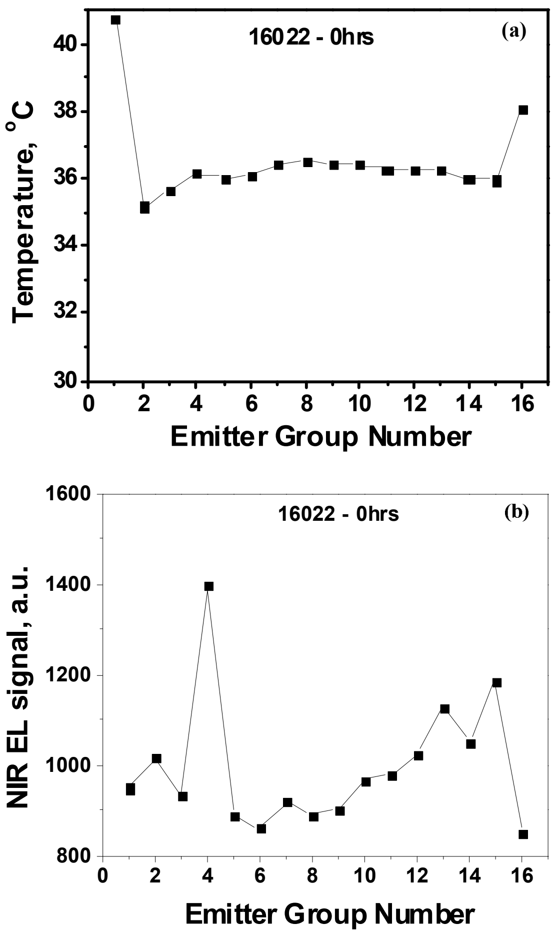


Figure5. *(a) Temperature and (b) NIR defect EL profiles of Bar 16022.*

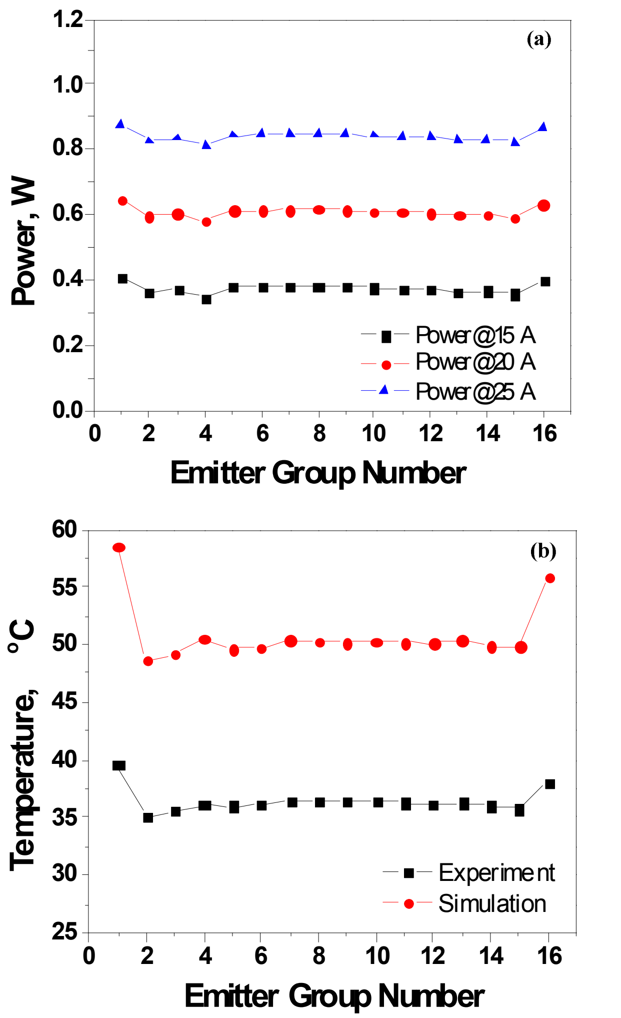


Figure6. *Simulated output power and temperature profiles of Bar 16022; (a) initial emulation and (b) QW temperature.*

The initial simulation result at time 0 for the output power distribution did not match the measured result - especially at the ends of the bar. More specifically, the simulated power levels at the ends of the bar increased despite the damage. In order to represent the defect levels of the edge emitters, (i.e. emitters 1 and 16) their defect levels were increased by a factor of 3 relative to the experimental defect values at time = 0. The result is a drop in the power of the edge emitters, giving a better qualitative agreement with the experimental results. Figure 7a shows the modified emulation results of power versus emitter group number for the unaged bar. Figure 7b shows the normalised temperature profile (without considering the edge emitters due to their higher temperatures as a result of their damage). However, there was a reasonable agreement between the normalised experimental and simulated temperature profiles for the other emitters.

Attempts were made to improve the emulation result of this bar by deliberately increasing the defect composition of the damaged edge emitters to reduce their output powers. Figure 7a shows the reduction in the output powers of the damaged edge emitters.

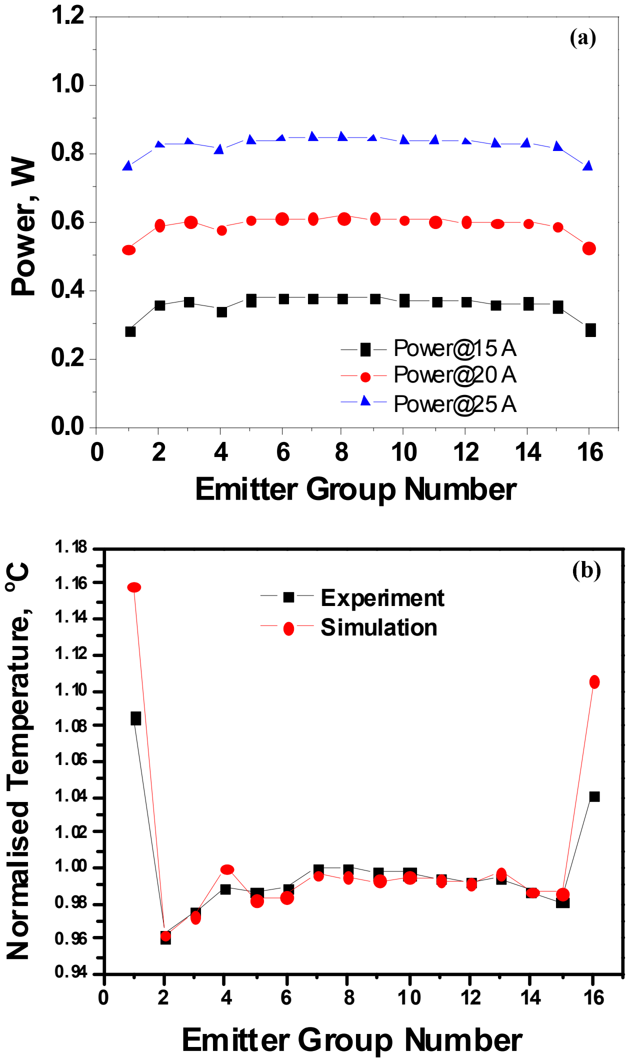
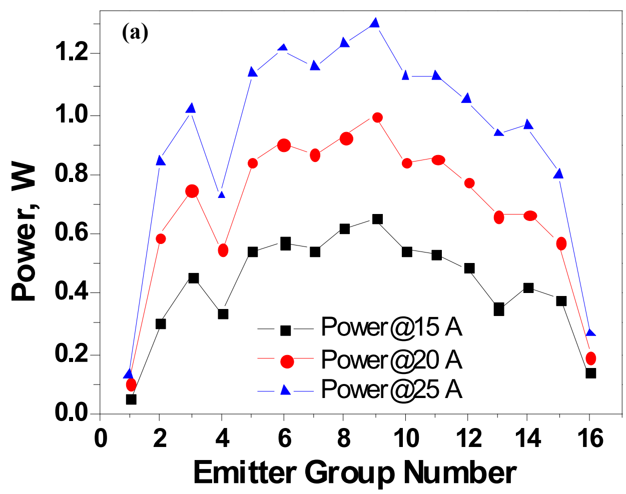


Figure7. Simulated output power and temperature profiles of Bar 16022; (a) modified defect levels at edge emitters by a factor of 3, (b) normalised temperature without edge emitters.



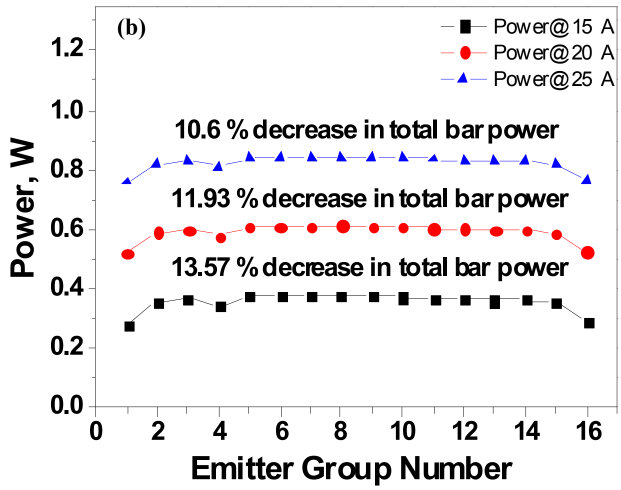


***Figure8.** Comparison of power distribution profiles of bar 16022: (a) experimental output power, (b) emulated output power.*

Strong disagreement is observed between the measured and the emulated power distribution profiles. However, the percentage error between the total bar output power of the measured result and the simulated result is 13.57% for 15 A, 11.93% for 20 A and 10.6% for 25 A (Figure 8b). This deviation may not be too large at this stage of the research. The strong disagreement may be attributed to the damage at the edges of the bar, affecting the emulated degradation behaviour. The power and temperature discrepancy of the damaged emitters suggests that a more complicated representation of the damage is required (e.g. the mirror facet reflectivity and absorption losses may need to be modified). Furthermore, the introduction of a global thermal solver will be needed to enhance the capability of *Barlase*.

4. Conclusion

In this paper, we have demonstrated how UNott's state-of-the-art simulation tool, *Barlase*, can be used to simulate both single emitter and multiple emitter laser bars under a wide range of operation conditions. To the best of our knowledge, this is the first time a laser bar has been simulated and its degradation behaviour emulated.

A general correlation was observed between the temperature and power distributions of the undegraded bars. The power distributions of the bars typically have frown-shaped profile, so that higher emission power is observed for the emitters at the centre of the bar. At the same time, the typical temperature profile of the bars is also frown-shaped. Emitters with poor performance in the unaged bar was often found to correlate with damage observed by optical microscopy and photoluminescence microscopy / electroluminescence microscopy at the facet.

Acknowledgment

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

References

[1] Schulz, W. and R. Poprawe, 2000. “Manufacturing with novel high-power diode lasers”, *IEEE Journal of Selected Topics in Quantum Electronics,* vol. 6, pp. 696-705.

[2] Gannot, I and R. W. Waynant, 2001. “Introduction to the issue on lasers in medicine and biology”, *IEEE Journal of Selected Topics in Quantum Electronics,* vol. 7, pp. 873-873.

[3] Rochat, E., K. Haroud, and R. Dandliker, 1999. “High-power Nd-doped fiber amplifier for coherent intersatellite links”, *IEEE Journal of Quantum Electronics,* vol. 35, pp. 1419-1423.

[4] Amuzuvi, C. K. and J. C. Attachie, 2013. “Describing a Laser Diode Emulation Tool Using Single Emitter Simulation Results”. *Research Journal of Applied Sciences, Engineering and Technology*, 5(04): 1358-1361.

[5] 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.

[6] 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”, *Applied Physics Letters,* vol. 81, pp. 3269-3271.

[7] 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”, *Journal of Applied Physics,* vol. 98, p. 063101.

[8] 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.

[9] 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.

[10] Amuzuvi, C. K., 2013. *Emulation and By-Emitter Degradation Analysis of High Power Lasers*: Lap Lambert Academic Publishing, Saarbrücken, Germany, ISBN 978-3-659-37035-9.