Optimizing Temperature Variation in Gallium-Nitride One-Dimensional Laser Array

Maciej Dems, Dominika Dąbrówka, Robert P. Sarzała
Institute of Physics, Lodz University of Technology, ul. Wólczańska 219, 90-924 Łódź, Poland

***Abstract*—We propose a novel approach to address the issue of uneven temperature distribution in laser arrays, specifically in gallium nitride edge-emitting lasers emitting green light of 540 nm. We can control thermal crosstalk by adjusting the placement of the emitters within the array and the size of the upper gold cap, without changing the overall dimensions of the device. The proposed design alterations facilitate heat dissipation from inner emitters, ensuring an even temperature distribution across the array without the need for an active control system. This method is significant for achieving cost-effective high-power devices, particularly beneficial for green lasers where heating effects are a major concern.**

I. Introduction

One of the main limitations of the performance of laser arrays is the uneven temperature distribution in its individual emitters (chips) and the varying temperature in their active areas. This effect is closely related to the self-heating effect (*thermal crosstalk*) [1], [2], [3], which becomes stronger as number of emitters in the array increases. In such a case, the necessity to maintain a reasonable dimensions of the whole device implies a decrease in the distance between emitters. In consequence, the emitters in the middle of the array have significantly larger temperature than the ones at the edges. Such unfavorable temperature distribution causes unequal operation of the individual chips. They not only switch on and off asynchronously, but they also emit different wavelengths, deteriorating the output beam quality.

The simplest solution to this problem is to strongly increase the distance between individual emitters. However, in this way the compactness of the array is lost. More complex approach involves individual driving of each chip with separate current sources. However, this strongly increases the complexity of the whole device and results with the nonuniform power emitted by the emitters.

We propose a much simpler solution to this problem. The undesired thermal crosstalk effect can be controlled by carefull selection of the chips placement. By decreasing the distance between the emitters located closer to the array edges, it is possible to increase their temperature and facilitate heat dissipation from the inner emitters. As shown later, such an operation does not increase the mean temperature of the device.

In the talk, we present such an optimization process for arrays comprising arbitrary number of gallium nitride edge-emitting lasers, emitting green light of 540 nm. They were chosen because solid-state green-light-emitting lasers based on InGaN/GaN have attracted, in recent years, interest in several fields. Among other things, they are used in laser displays, illumination systems, projection systems, telecommunication fibers. At the same time, there is a demand for compact green lasers that could be used in small (micro or pico scale) portable projectors, in medical equipment and for military applications, since the beam does not show dependence on external conditions [4], [5], [6].

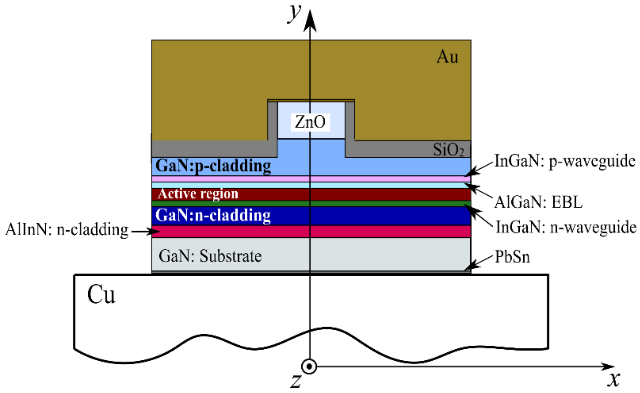

Figure 1: Schematic structure of a single emitter in the investigated layer array.

However, despite the great interest, the efficiency of these instruments, especially those emitting light above 530 nm, is still strongly limited. Particularly, at high supply voltages, this causes thermal problems, as most of the input power is converted to heat. This is another reason to carefully investigate thermal issues in green lasers.

II. Simulations

We investigate an array comprising a number (4–25) of 2-μm wide GaN emitters illustrated in Fig. 1. They are arranged in a line on a single epitaxial plate. Originally, the centers of the emitters are spaced 50 μm from each outer, which makes the total size of a 10-chip array 452 μm. For the purpose of our optimization we assume that the dissipated heat over a single emitter is 1 W. Because of a low quantum efficiency of 540 nm GaN active, this can be approximately considered as a total device power. Thus, the total power of the whole array varies between 4 – 25 W, depending on the number of chips.

For the unoptimized structures, there is a visible temperature difference between the inner and outer emitters, as seen in Fig. 2 (gray lines). In our computations, we have shifted the positions of individual emitters with an additional constraint that the outermost chips positions are fixed. This ensured the total size of the whole device unchanged. However, in order to regulate the temperature of these fixes emitters, we change the lateral dimensions of the gold layer covering the array. This layer serves two purposes: on the one hand it provides an electrical contact on the p-side and, on the other hand, it serves as a heatspreader enabling lateral flow of the heat in the array.

After optimization (the red lines in Fig. 2), the temperature becomes the same for each chip of the array. In fact, the standard deviation of the temperatures in the centers

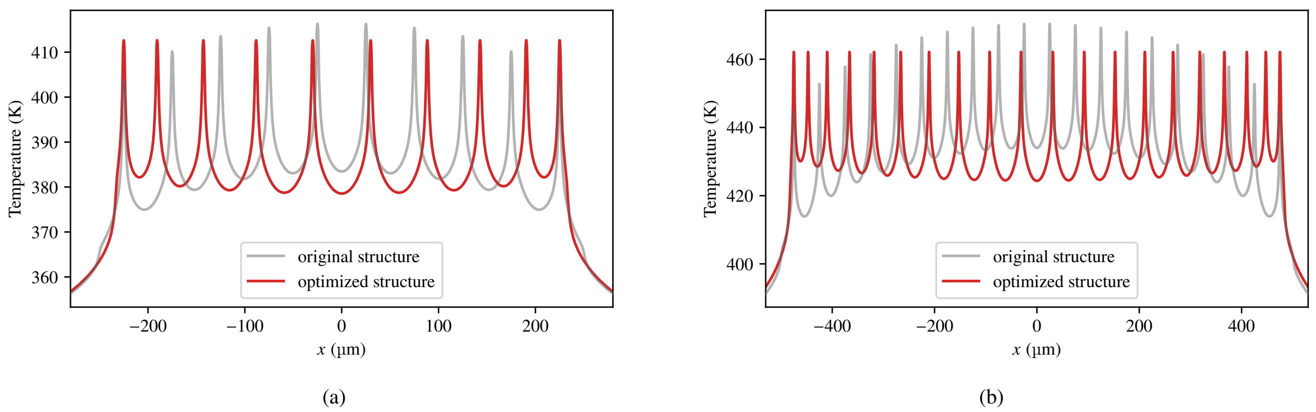

Figure 2: Temperature profile over the active region of one-dimensional array with 10 (a) and 20 (b) emitters prior to the device optimization (gray lines) and after it (red lines).

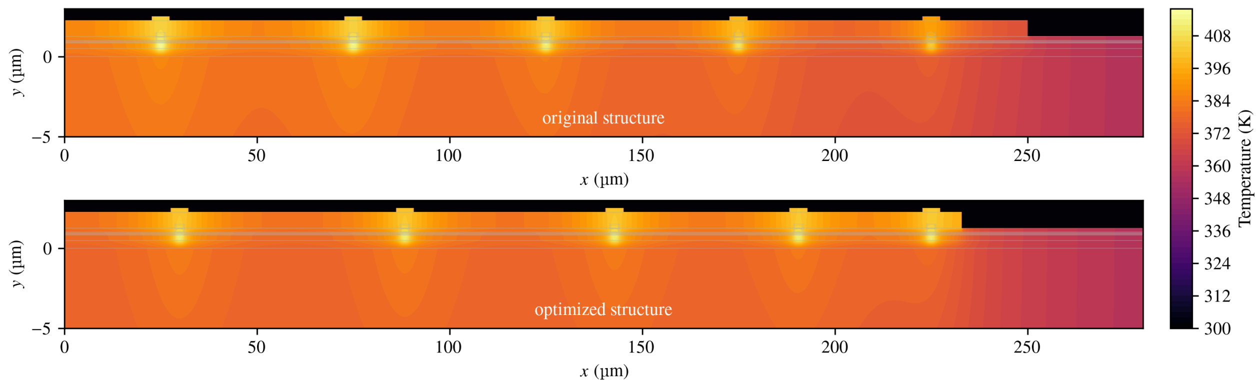

Figure 3: Temperature map of one-dimensional array with 10 emitters before and after optimization.

of emitters active regions (which was used as a figure of merit for the optimization process) does not exceed 0.01 K. Furthermore, the average temperature of the all devices does not change. The increased heading of the side emitters is compensated by the better heat dissipation of the central ones. The overall temperature distribution is shown in Fig. 3, which also indicates the positions of the emitters and the side of the p-side gold cap.

Although the optimization process is performed for a fixed input power, the modified structure shows robustness for large range of powering. In particular, if less heat is generated than assumed in the optimization, the chips temperature non-uniformity does not exceed 0.1 K and for higher power—up to 1.5 W / chip—it is still around 0.5 K (Fig. 4).

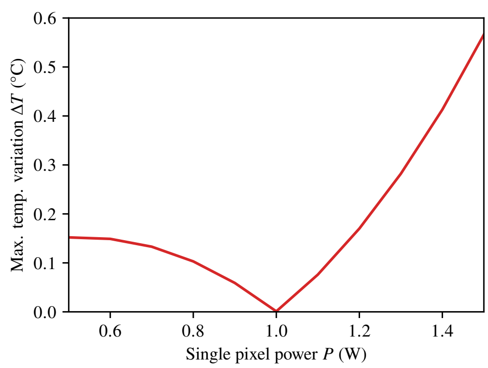

Figure 4: Maximum temperature difference between chips in the optimized 10-emitters array, a function of the input power.

III. Conclusions

We have shown a simple method to equalize temperatures in individual chips of a one-dimensional array of edge-emitting lasers, which is paramount in green lasers, in which the heating effects are still an important issue. We achieve this by distributing the internal emitters and adjusting the size of the upper gold cap, without changing the positions of the edge emitters in the array. Thus, an even temperature distribution across the individual emitters can be achieved without a special active control system, but only by design alternations, which is important to achieve inexpensive high-power devices.

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