

Simulation of an Index-Guided Tapered Laser

Introduction

Tools used: Tapered Laser Utility, BeamPROP, LaserMOD

Tapered laser diodes have emerged as a low-cost source for providing a high-output coherent beam, with applications including but not limited to telecommunication, printing and manufacturing, and medicine. The tapered geometry overcomes the poor beam quality issues that are faced by conventional high-power, broad-area laser diodes, while still maintaining compatibility with traditional fabrication processes. However, the tapered structure makes the design process significantly more complicated, necessitating the need for a full 3D simulation including the optical, electronic and thermal effects.

Traditional simulation techniques used to model such devices either oversimplify the problem and can't deal with detrimental effects like spatial hole burning, filamentation, self-focusing, etc.; or do a rigorous time domain analysis, which is highly computationally intensive both in time and memory. The Tapered Laser (TL) Utility provides an efficient and accurate design tool for analyzing and optimizing such tapered laser diodes. It essentially combines, in a self-consistent manner, two of RSoft's mature and powerful simulation tools, BeamPROP and LaserMOD, to provide a full 3D simulation of tapered laser diodes. The quasi-3D electrical, quantum mechanical gain and thermal calculations are performed via LaserMOD, whereas the optical field is propagated via BeamPROP.

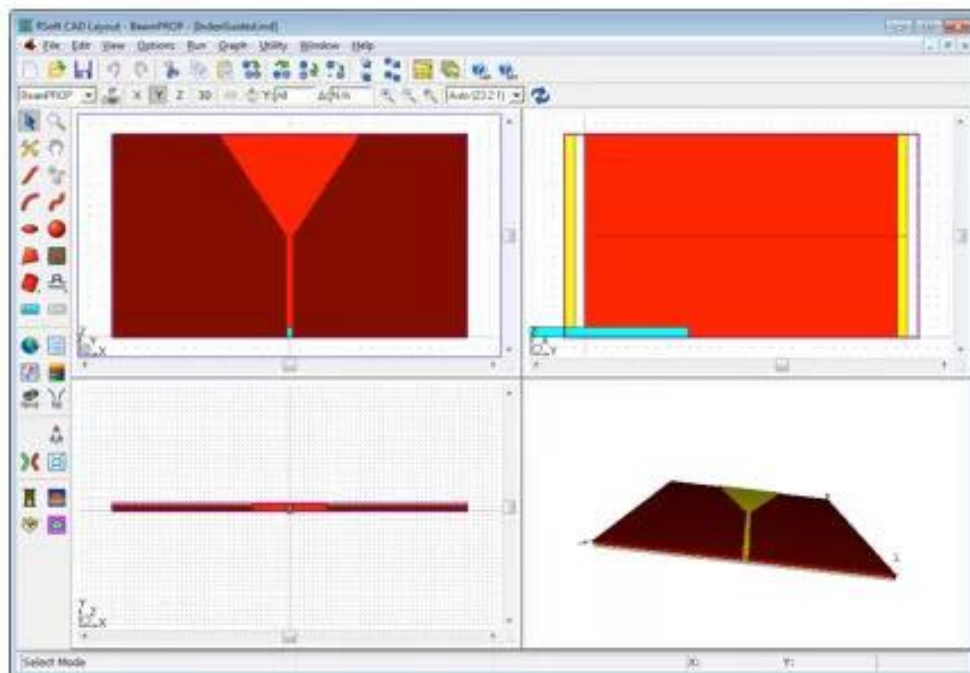


Figure 1. The Index Guided Tapered Laser Diode layout in RSoft CAD. The yellow regions depict the electrodes.

Structure Overview

Figure 1 shows the general structure of a tapered laser diode. The longitudinal structure is a straight waveguide section followed by a tapered waveguide section. The transverse cross-section consists of an arbitrary epitaxial-layered structure that may contain p / n cladding, p / n waveguide, and quantum well layer. The example models a tapered laser diode, with a 1,000-m-long straight section and a 1,000-m linear tapered section. This depicts a generic structure that can be easily modified to match the required specifications, in terms of the material systems, the multi-layered transverse cross-section, and the longitudinal characteristics like the length of the straight section and the tapered region. The TL utility simulation parameters have been set up to perform a voltage bias ramp from 1.3 V to 1.6 V with seven intermediate steps.

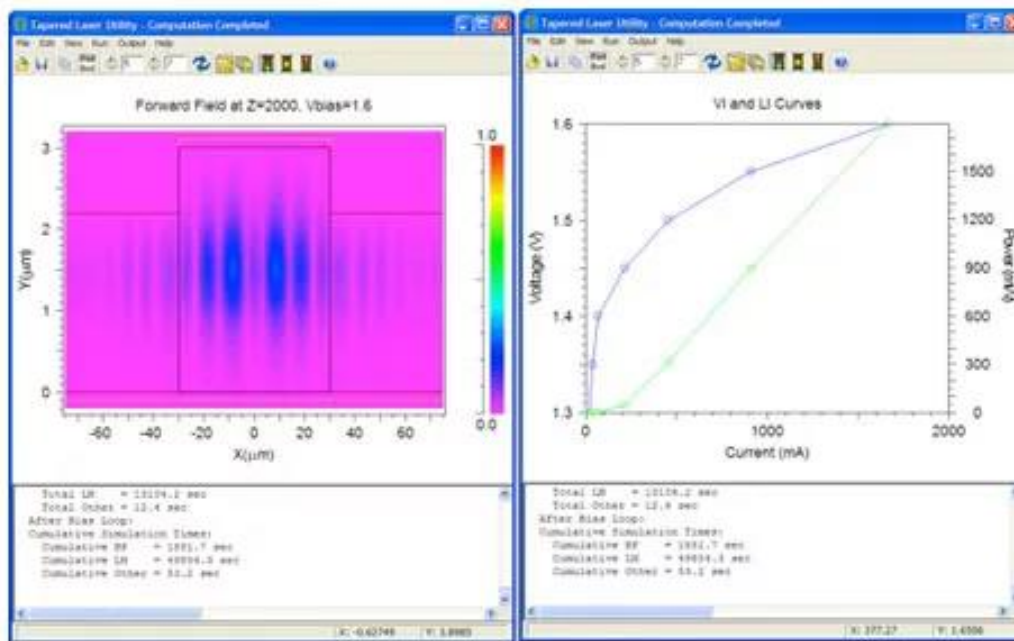


Figure 2. (a) The Tapered Laser Utility Simulation Window upon completion. (b) The final light-current-voltage (LIV) curve.

Simulation Results

Figure 2 shows the results for this structure. For the final bias point $V_{\text{bias}} = 1.6$ V, the result for the combined power exiting from both laser facets is ~1789 mW and the current is ~1670 mA. As can be seen from Figure 2, the field at the output facet at bias 1.6 V has a lot of characteristics. Moreover, the light-current (LI) curve follows very closely a straight line. Once the simulation is complete the user can also scroll through the forward and backward field profiles inside the laser cavity at each simulated bias above the threshold.

The stabilized field profiles, for $V_{\text{bias}} = 1.45$, at various z-slices along the laser cavity are shown in Figure 3. It is evident that even at the input facet the field profile deviates quite a bit from the fundamental mode.

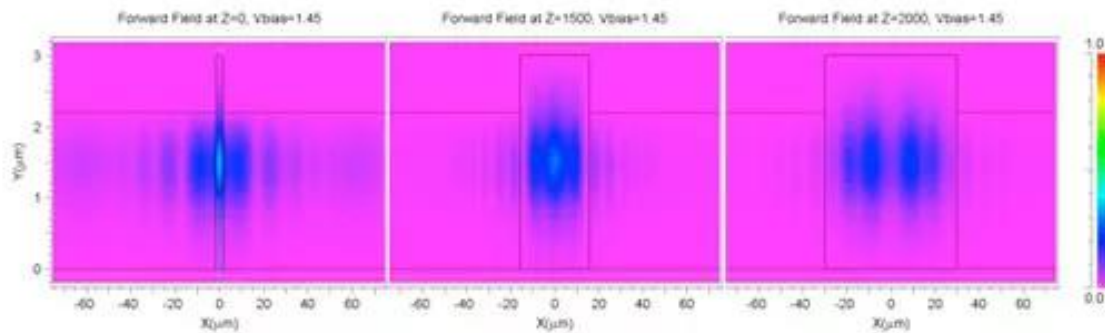


Figure 3. Field profile at $V_{\text{bias}} = 1.45\text{V}$

- (a) $Z = 0\ \mu\text{m}$ (input facet)
- (b) $Z = 1500\ \mu\text{m}$ (taper middle)
- (c) $Z = 2000\ \mu\text{m}$ (output facet).

Moreover, if we look at the stabilized field shapes at different biases (see Figure 4), it is clear that the characteristics of the field profile changes significantly, with effects like filamentation getting stronger at higher biases.

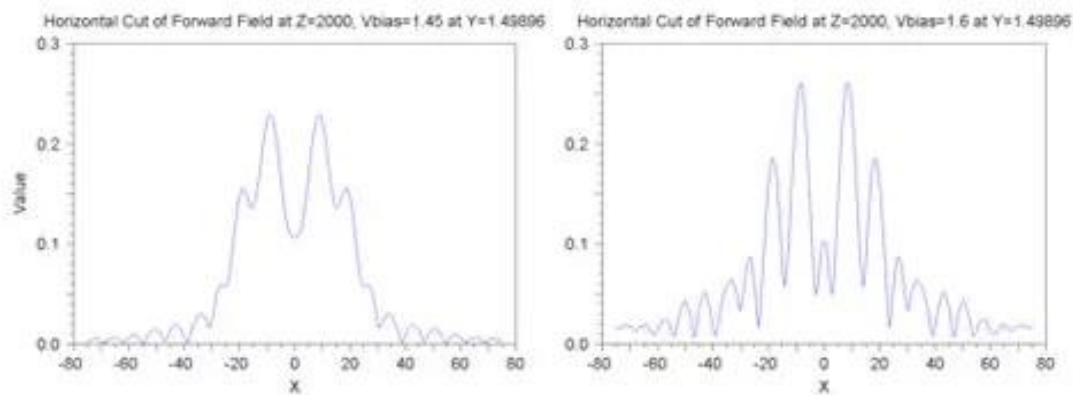


Figure 4. Horizontal cut of the field profiles at the output facet at

- (a) $V_{\text{bias}} = 1.45\ \text{V}$
- (b) $V_{\text{bias}} = 1.6\ \text{V}$

Summary

The need for high-power and high-beam-quality tapered laser diodes requires efficient and accurate simulation tools capable of accurately modeling the complex electro-thermal-optical interactions occurring inside such devices. RSoft's new Tapered Laser Utility provides an ideal package, accurate, efficient, and user friendly, for analyzing and optimizing such tapered laser diodes for a wide range of applications.