Numerical Simulation and Analysis of Optically Pumped Micro Disk Lasers for Photonic Integrated Circuits

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Abstract:
An optically pumped micro disk laser operating at $1.2\mu\mathrm{m}$ under three waveguide coupling schemes, were numerically simulated. The numerical analysis is done to characterize the device for photonic integrated circuit-based applications. The rate equations were solved under steady state and transient analysis to evaluate the output power characteristics. A turn-on delay of 0.184 ns is observed, as the device is switched from 0 to 1.5 times the threshold input pump power (Pth) and it decreases to 0.041 ns when switched to 5P th , for all the three coupling schemes. However, the rise time settles at a constant value of 0.0235 ns for the coupling schemes. Maximum modulation bandwidth of 9.5GHz is obtained for the coupling scheme employing optimal spiral waveguide and a slot waveguide, with efficiency of 67%, while it increases to 10.5 GHz for the coupling scheme employing optimized spiral waveguide alone, with efficiency of 88%.

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Contents

The efficiency of MDLs improved significantly by introducing a GaAsP strain compensation layer during the fabrication of multiple quantum wells from GaAs/InGaAs on a Silicon substrate. The MDLs fabricated using these techniques possessed very low lasing threshold [1]. Pulley-coupled design of MDLs also resulted in larger on chip output powers at very low threshold pump powers [2]. Also, by reducing the defect density, ten times lower lasing threshold was obtained when compared with devices having higher defective interfaces [3]. With the advent of micro-structured polymer assisted printing technique, very precise, low threshold MDLs have been fabricated [4]. The lasing characteristics of optically pumped, GaN MDLs change with different configurations, with undercuts, cladding layers and using thin film technology [5]. Mode competition exists in MDLs when the device is injected with various currents. Increasing the injection current also increases the temperature of the active region of the device [6]. Various active region designs of MDLs based on quantum dot structures have been proposed to operate the device at room temperature and at lower threshold pump powers [7]. MDLs emitting light laterally reduce the optical loss and facilitates integration of several devices [8]. Also, the line width of MDLs can be easily measured using interferometric techniques [9]. The coupling efficiency and Purcell factor techniques designed for MDLs were computed to adjudicate the device performance [10]. Various analysis pertaining to parametric variation to predict the device performance have been carried out in Vertical Cavity Surface Emitting Lasers (VCSELs) and Quantum Cascade Lasers (QCLs) [11]–[13]. Laser diodes can be either electrically or optically pumped, based on their structure and configuration, for various applications. Vertical cavity surface emitting lasers have been used for optical communication and sensing applications. Recently, Quantum Cascade lasers were investigated for Terahertz pulse transmitter applications. Modelling and simulation of laser diodes have aided tremendously for the development of optimized structures with increased efficiency [14]–[31]. This work presents a detailed analysis on the steady state, transient and modulation characteristics of MDLs for the three coupling schemes proposed by [10] which have not been carried out otherwise. This numerical investigation helps to predict the device parameters in time and frequency domain. This work is organized as follows. Section II describes the modelling of MDLs and the various coupling schemes employed. Section III provides the results on the characteristics of MDLs. Section IV concludes the findings.