Thermal Effects in InAs/GaAs Quantum Dot Vertical Cavity Surface Emitting Lasers

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Abstract

The performance of 1.3-µm InAs/GaAs quantum dot (QD) vertical cavity surface emitting lasers (VCSELs) is adversely affected by self-heating effect. In this talk, a self-consistent model comprising rate equations and thermal conduction equation will be presented to analyze the influence of self-heating on the carrier dynamics and output power of QD VCSELs. The simulation results indicate that the low output power is attributed to hole thermalization and escape due to the thin wetting layer. The hole confinement can be improved by increasing the number of QD layers and surface density, as well as adopting p-type modulation doping. The fabricated p-doped QD VCSELs exhibit high temperature stability in the threshold current. The highest output power of 0.435 mW and lowest threshold current of 1.2 mA under single-mode operation were achieved, with side mode suppression ratio (SMSR) of 34 dB at room temperature (RT). However, the output power is limited by the small-sized oxide apertures. To achieve both high output power and enhancement of the fundamental mode emission, a dielectric-free (DF) approach with surface-relief (SR) technique is applied in our device fabrication. Compared with the conventional dielectric-dependent (DD) method, the DF approach potentially reduces the fabrication cost and complexity. Moreover, with the same oxide aperture area, the differential resistance is reduced by 36.47% and output power is improved by 78.32% under continuous-wave (CW) operation. The output power increases up to 3.42 mW under pulsed operation with oxide aperture diameter of ~15 µm. The surface-relief technique effectively enhances the fundamental mode emission of the QD VCSEL

19th NOVEMBER 2012 (MONDAY)
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2.30 PM

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