Single Mode and High Power Lasers Based on (Ga)InAs Quantum Dots
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Within the last few years a rapid progress has been made in the fabrication of quantum dot structures based on self assembling techniques which allow the realization of high performance semiconductor lasers. Dot specific properties like ultra low threshold current densities and very high $T_0$ values below room temperature could be already demonstrated. But good laser performance well above room temperature is still a challenge which need an overall optimization of the laser design. In this talk an overview is given about the recent development of high performance quantum dot lasers for single mode, i.e. sensor and telecommunication, as well as for high power applications.
To improve the high temperature properties of quantum dot lasers the carrier confinement in the active region was improved by short period superlattices which work as electronic Bragg reflectors. With this technique operation temperatures of 980 nm quantum dot lasers well above 200 °C were achieved. This new type of devices are also very suitable for ultra stable single mode emitting distributed feedback (DFB) lasers. Due to the broad gain spectrum and reduced temperature shift of the gain maximum these DFB lasers can be operated over a temperature span of about 200 K without any mode jump.
By implementing large optical cavity designs for 980 nm emitting quantum dot lasers the devices can also be operated at high output power with a record cw output power of 4 W ($\approx 40$ mW/µm) for 100 µm wide and 2 mm long broad area lasers. For 1 mm long devices slope efficiencies of $> 1$ W/A and wall plug efficiencies $> 50 \%$ were achieved. Due to the improved carrier confinement the lasers are very temperature stable even at high operating temperatures. Only about 20 % current increasement is necessary to get 1 W output power at 80 °C.
For achieving device quality quantum dot structures for 1.3 µm emission the growth mode has to be modified and the InAs dots are embedded in GaInAs QWs ("D WELL"-concept). Threshold currents as low as 4.4 mA could be achieved by this technique for a 400 µm long ridge waveguide laser. Although the total gain is limited ($< 20$ cm$^{-1}$ for 6 stacked dot layers) short cavities can be realized by appropriate high reflection coating of the mirrors.
Due to the low internal absorption ($< 2$ cm$^{-1}$) a slope efficiency of $> 0.2$ W/A can be achieved. Laser operation can be observed (cf. Fig. 4) up to 85 °C/156 °C in cw/pulsed operation, respectively.
By using laterally complex coupled gratings in combination with a ridge waveguide geometry first distributed feedback lasers could be realized on 1.3 µm emitting quantum dot laser material. 6 800 µm long devices show a side mode suppression ratio of 48 dB, a cw output power of 8 mW and a threshold current of 20 mA.
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