High-power 980 nm quantum dot broad area lasers

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High-power quantum dot broad area lasers emitting at 980 nm are presented. Continuous-wave output powers of 4.3 W from a 50 µm stripe width laser and of 6.3 W from a 100 µm stripe width laser were achieved at 15°C.

Introduction: High-power diode lasers using a quantum well (QW) as active region are state-of-the-art. Output powers up to 12 W from 100 µm-wide broad area lasers were recently reported [1]. As an alternative, lasers with a quantum dot (QD) active region are currently being investigated intensively. State-of-the-art QD lasers have threshold current densities and efficiencies comparable to QW lasers emitting at the same wavelength. Owing to the QD gain medium, these devices exhibit a smaller shift of the lasing wavelength with increasing current and a smaller linewidth enhancement factor. However, the achievement of a high output power is an additional challenge. To date, high-power QD laser devices based on QD material have been reported by Sellin *et al.* [2] for $\lambda = 1140$ nm with a maximal output power P_{max} (pulsed) = 3.7 W, by Mikhrin *et al.* [3] for $\lambda = 940$ nm with P_{max} (CW) = 3.9 W, by Ustinov *et al.* [4] for $\lambda = 1.3$ µm with P_{max} (CW) = 2.7 W, and by Klopf *et al.* [5] for $\lambda = 980$ nm with P_{max} (CW) = 4 W. The highest output power for QD lasers was reported by Sellin *et al.* [6] for 1135 nm. They reached 4.7 W in CW operation and 11.7 W in quasi-CW operation at 20°C from a 150 µm stripe width laser, i.e. a facet load of up to 30 and 80 mW/µm, respectively.

In this Letter, results of high-power broad area lasers emitting near 980 nm are presented. They show a maximal facet load that is three times larger than the measured maximal facet load for QD broad area lasers to date. Results concerning the power-voltage–current characteristics, maximum CW output powers up to 6.3 W and quasi-CW powers up to 9.5 W are reported.

Laser structure: The expitaxial structure is similar to that described in [7]. The active region is formed by a single layer of self-assembled InAs/$In_{0.2}Ga_{0.8}As$ quantum dots embedded in a 370 nm-thick graded-index waveguide ($Al_{0.33}Ga_{0.67}As$) surrounded by 1400 nm-thick $Al_{0.4}Ga_{0.6}As$ cladding layers. A part of the 2 inch wafer was analysed concerning the electro-optical parameters. For 100 µm stripe width lasers a transparency current density of $j_{TR} = 123.3$ A/cm^2, a modal gain coefficient of $\Gamma_{g0} = 33.8$ cm^{-1}, an internal efficiency of $\eta_i = 0.93$ and internal losses of $\alpha_i = 3.3$ cm^{-1} were determined. The vertical far-field angle (full width at half maximum) was 40°. The characteristic temperature of the threshold current density, T_0, was determined to 118K for a 1 mm-long device and comparable to that of QW lasers emitting at the same wavelength.

Another part of this wafer was processed to broad area devices using a conventional technology as described in [8]. Lasers with stripe widths of 50, 70 and 100 µm and a cavity length of 2 mm were fabricated and their facets were coated. The front facet had a reflectivity $R_f = 3\%$ and the rear facet $R_r = 95\%$. Finally, the lasers were mounted *p*-side (epi-side) down on CuW submounts using standard soldering techniques [9] and attached to copper heatsinks. The *n*-side was contacted by wire bonding.

Results: Typical CW power-voltage–current characteristics of the 980 nm QD lasers are given in Fig. 1. The threshold current of the 50 µm stripe width devices is about 200 mA, for the 70 µm lasers 275 mA, and for the 100 µm lasers 375 mA. For all geometries the slope efficiency is about 0.75 W/A. A maximum wall-plug efficiency of 43% is obtained. At an injection current of 3 A an output power of typical 2 W was measured.

Fig. 2 shows the maximal output powers in CW operation at 15°C and 25°C heatsink temperatures. For the lasers with a stripe width of 100 µm no catastrophic optical mirror damage (COMD) was observed. The devices showed a thermal rollover with a maximum output power of $P_{max} = 6.3$ W at 15°C and $P_{max} = 5.9$ W at 25°C. The 50 µm stripe width lasers showed a COMD with $P_{max} = 4.3$ W at 15°C and 4.2 W at 25°C. At 15°C this leads to a maximal facet load of 86 mW per µm stripe width and extends the previously reported value in CW operation [6] by a factor of three. To our knowledge this is the highest CW facet load for QD lasers reported to date.

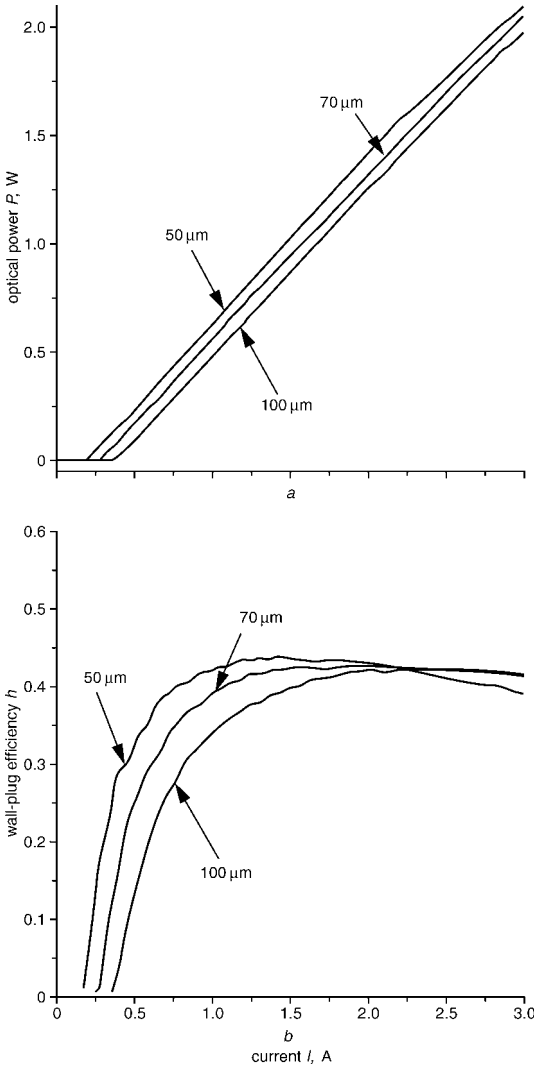

Fig. 1 *CW output power and wall-plug efficiency against injection current for broad area QD lasers having different stripe widths emitting at 980 nm (cavity length 2 mm, T = 25°C)*

a CW output power
b Wall-plug efficiency

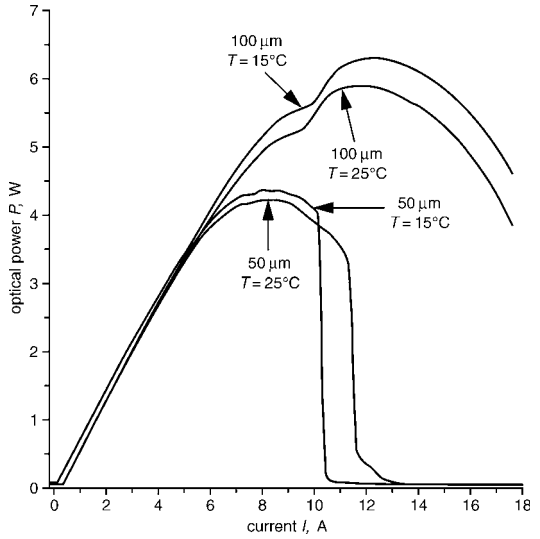

Fig. 2 *CW output power against injection current showing thermal roll-over and COMD (cavity length 2 mm)*

The same experiments were performed in quasi-CW operation. The pulse length was 100 µs and the interval between two pulses was 50 ms. The results are shown in Fig. 3. Here, for the 50 µm stripe width device a maximum output power of $P_{max} = 5.4$ W and for the 100 µm stripe width

device $P_{max} = 9.5$ W were measured limited by COMD and thermal rollover, respectively. This leads to a maximum facet load of 108 mW/μm.

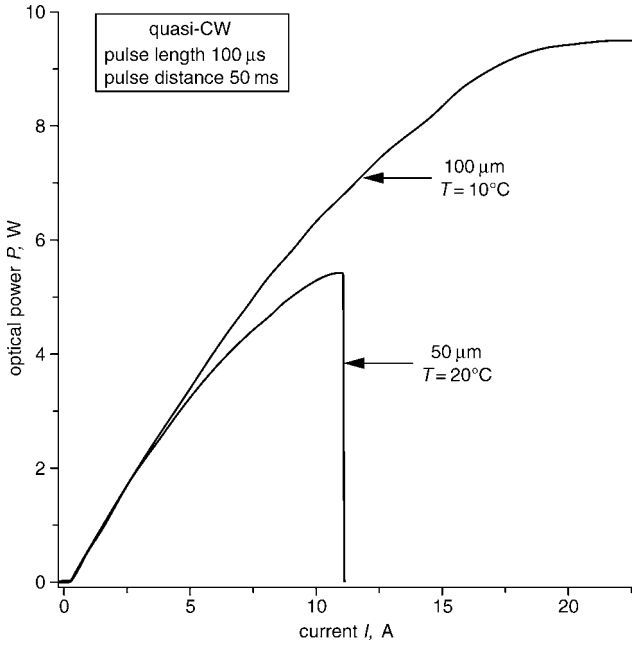

Fig. 3 *Quasi-CW output power against injection current showing thermal rollover and COMD (cavity length 2 mm)*

Conclusions: High-power broad area QD lasers emitting at 980 nm have been manufactured. Maximum CW output powers of 6.3 W and QCW output powers of 9.5 W were measured for 100 μm stripe width lasers. Maximal facet loads of 86 mW/μm in CW operation and 108 mW/μm in QCW operation were reported for 50 μm stripe width lasers. To the best of our knowledge these are the highest CW and QCW facet loads of QD lasers reported to date. Achieving this power level QD lasers also become an interesting light source for pumping of Yb-based solid-state lasers.

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