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Invited

Progress in Quantum Dot Lasers: 1100nm, 1300nm and High Power Application

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Quantum dot (QD) lasers have decisive advantages compared to quantum well (QW) lasers [1]. These have been predicted and analyzed in detail. The present technology of epitaxial growth of self-organized QDs allows to fabricate QD lasers that realize their theoretical benefits. Among those are very low threshold current density, operation in new wavelength ranges for a given substrate and high power operation. The historic development of quantum well and QD laser diode threshold current densities (as cleaved facets, room temperature) is shown in Fig. 1. Starting from first results in 1994 [2] the breakthrough occurred this year [3].

QDs offer potential advantages for high power lasers, hardly explored, due to the zero-dimensional charge carrier localization and reduction of charge carrier diffusion. Reduced non-radiative surface recombination decreases facet overheating and larger catastrophic optical mirror damage (COMD) threshold is expected. These advantages can be combined with the low threshold and the high temperature stability of QD lasers to create high power lasers with lower temperature sensitivty, slightly larger wall-plug efficiency, and an extended wavelength range compared to conventional QW lasers.

We present results on MOCVD and MBE grown high power QD lasers based on InGaAs QD's (Fig. 2) on GaAs substrate. In Fig. 3 a MOCVD laser emitting at 1100 nm with 3.5 W (Fig. 3) is shown. The threshold is 210 A/cm^2 and the differential efficiency 57 %. The saturation value of the spectral power density is 200 mW/nm. Therefore each QD produces about 12.5 nW of external optical power, corresponding to 7×10^{10} photons/s and an upper limit for the refill time of 14 ps. At 1280 nm high power operation is demonstrated by a MBE grown QD laser (Fig. 4). The measured output power from both facets and the lasing wavelength as a function of the drive current for a laser diode (L=1.9 mm, w=200 μm) under cw operation (at 17 ^{0}C) are depicted in Fig. 4. The threshold current density is 92 A/cm^2. The maximum output power of 2.8 W is limited by thermal rollover.

[1] D. Bimberg, M. Grundmann, N.N. Ledentsov, Quantum Dot Heterostructures (John Wiley, Chichester, 1998)
[2] N. Kirstaedter, N. N. Ledentsov, M. Grundmann, D. Bimberg et al., Electron. Lett. 30, 1416 (1994)
[3] G.T. Liu, A. Stintz, H. Li, K.J. Malloy, L.F. Lester, 1999 Digest of the IEEE LEOS Summer Topical Meetings, IEEE Catalog #99TH8455, ISBN: 0-7803-5633-0, p. 19

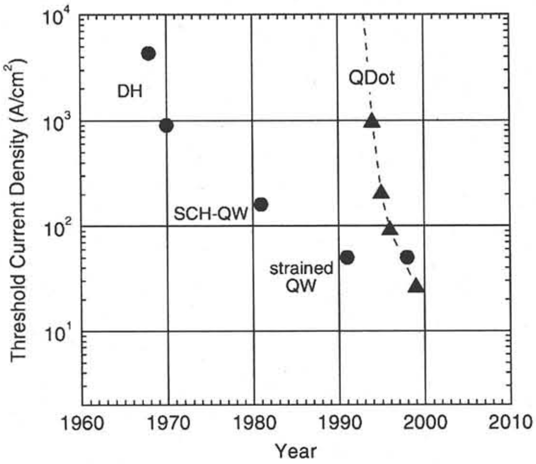

Fig. 1 Historic development of quantum well and QD diode laser threshold current density.

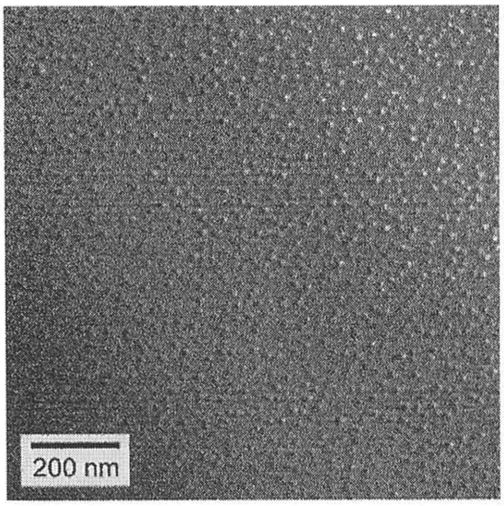

Fig. 2 Plan view TEM image of a MOCVD grown InGaAs/GaAs QD array (single sheet) for optimized conditions with a lateral QD density of 1.3×10^{11} cm^{-2}.

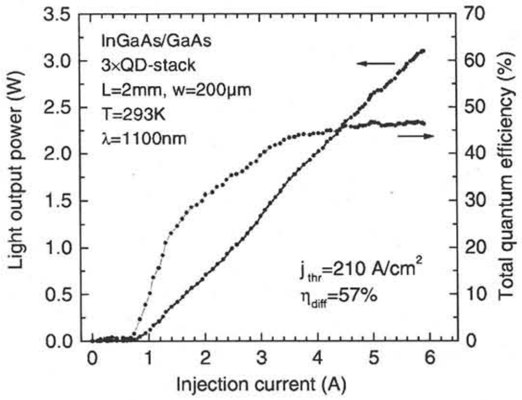

Fig. 3 Light output (front facet × 2) and total quantum efficiency vs. injection current for triple layer MOCVD QD laser. Injection conditions were 650 ns pulses and a duty cycle of 1/384.

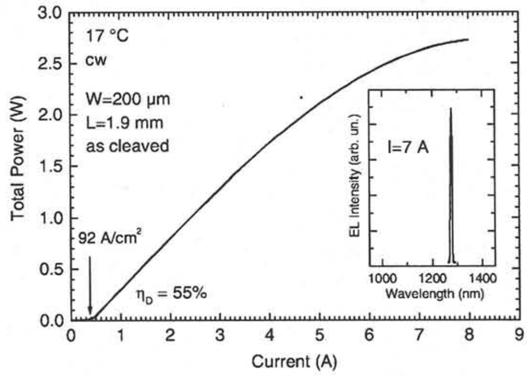

Fig. 4 Light output (front facet × 2) and lasing spectrum (inset) for MBE QD laser.