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Experimental investigations into the thermal properties of 1.5-1.8-μm InAs/InP quantum dash lasers

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We present what we believe to be the first ever high-pressure and spontaneous emission measurements on quantum dash lasers. The results show that temperature sensitivity of these lasers is caused by nonradiative processes, which depend on the lasing wavelength.

The deposition of InAs within AlGaInAs layers grown on conventional InP substrates can produce self-assembled, finite-length, quantum wire-like InAs structures (quantum dashes) with emission wavelengths longer than 1.5 μm. This makes these structures promising for near- and mid-infrared applications. Controlling the density of states in the active region of a semiconductor laser using quantum confinement makes it possible to restrict the injected electrons and holes to those levels where they can take part most efficiently in the stimulated emission process. This has been used effectively in quantum well lasers (2D) for many years and more recently self-assembled quantum dot (0D) structures have started to show promising characteristics. However, until very recently relatively little success could be achieved with quantum wire (1D) structures.

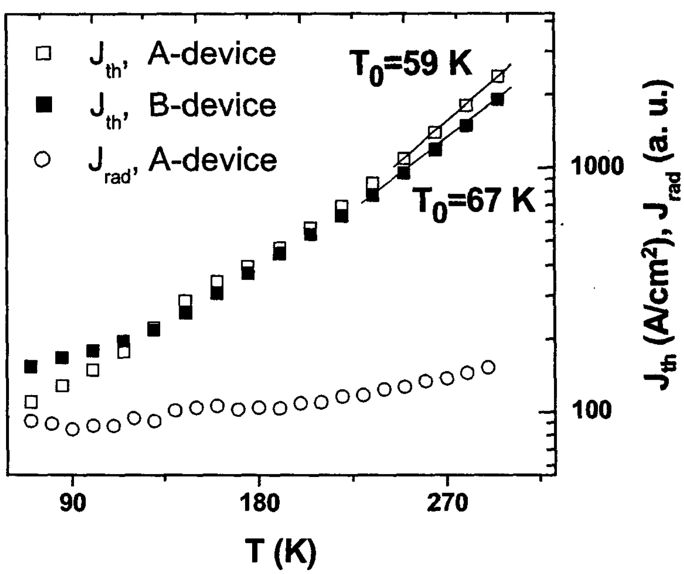

Fig. 1. Temperature dependence of the threshold current density, J_{th}, of the 1.76 μm- and 1.52-μm quantum dash lasers. Radiative current for the A-device was measured as integrated spontaneous emission at threshold current.

In this work we studied two types of quantum dash lasers operating at wavelengths of 1.52 μm (A) and 1.76 μm (B). The active region of the A-type devices consisted of 4 InAs (5MLs) quantum dash layers embedded in an InGaAlAs/InP GRINSCH structure. In B-type devices the active region was formed by 4 InAs (7.5MLs) quantum dash layers placed in an $In_{0.53}Ga_{0.23}Al_{0.24}As$ waveguide [1].

We studied the threshold current, stimulated emission from the facet and unamplified spontaneous emission from a window milled in a substrate contact as a function of temperature in the interval T=70-300 K. As shown in Fig. 1, in both laser types the threshold current density, J_{th}, was about 2 kA/cm^2 at room temperature and had a similar temperature sensitivity, characterised by a T_0 of about 80 K in the range T=120-250 K, and T_0=60-70 K from 250 to 300K. Measurements of the spontaneous emission showed that the radiative part, J_{rad}, of J_{th}, is less than 5% in type-A devices at room temperature, though the internal differential efficiency of these lasers was as high as 50%. Also J_{rad} is almost temperature independent as was observed previously in quantum dot lasers [2]. Therefore the relatively large value of J_{th} and its temperature sensitivity must be due to non-radiative recombination processes.

Applying hydrostatic pressure, p, we shifted the band gap and lasing photon energy, E_{las}, towards the higher energies (Fig. 2a). Both laser types showed a similar gradient dE_{las}/dp of 8.2 meV/kbar. In fig. 2 (b) we plot the normalised E_{las}^2, which is the expected approximate variation of the threshold current for the ideal case in absence of any nonradiative recombination by analogy with quantum dot and quantum well lasers [2]. However, in both lasers J_{th} decreased with increasing pressure (Fig. 2b), demonstrating that in both lasers at room temperature J_{th} is influenced by a nonradiative recombination process which is strongly dependent on the band gap. The decrease of J_{th} at p=10 kbar was about 5% and 25% in 1.52 μm and 1.76 μm quantum dash lasers, respectively. These dramatically different behaviours can be interpreted by assuming that in the 1.52 μm lasers, pressure independent defect related recombination outside the dashes due to thermal carrier spill-over or thermal leakage dominates, while in the 1.76 μm quantum dash laser 60% of J_{th} is due to Auger recombination. Such an interpretation is consistent with measurements on quantum well and quantum dot devices when the shape of the dashes is taken into account.

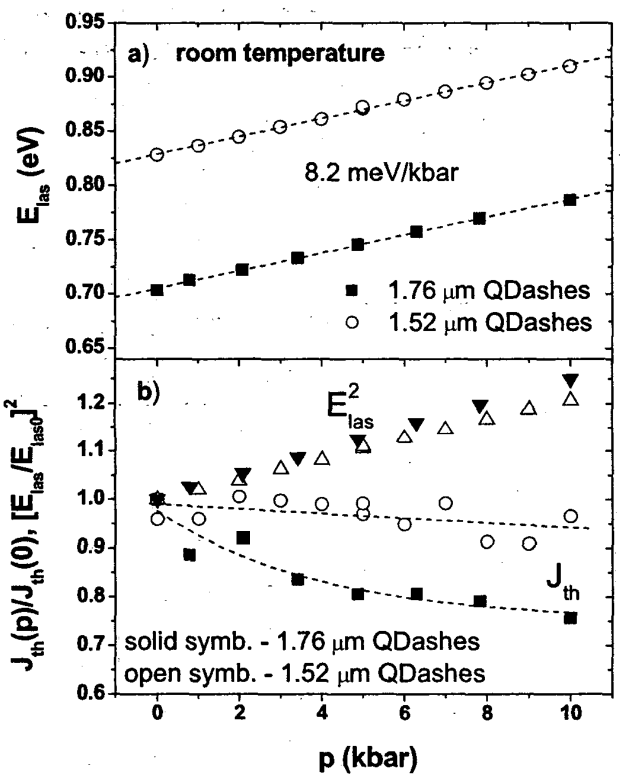

Fig. 2. (a) Lasing energy, E_{las}, (b) normalised threshold current $J_{th}(p)/J_{th}(0)$ and normalised square of the lasing photon energy $[E_{las}(p)/E_{las}(0)]^2$ vs pressure at room temperature for the 1.76 μm- and 1.52-μm quantum dash lasers

References

1. R. Schwertberger, D. Gold, J. P. Reithmaier, A. Forchel, IEEE Photon. Tech. Lett., Vol. 14, No. 6, 2002, pp. 735-737.
2. I. P. Marko, A. D. Andreev, A. R. Adams, R. Krebs, J. P. Reithmaier, A. Forchel, IEEE J. Select. Topics Quant. Electr., Vol. 9, No. 5, 2003, pp. 1300-1307.