1516 nm room temperature CW operation of quantum dot InAs/InP(311)B singlemode laser

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Reported is the first demonstration of the performance and properties of a singlemode Fabry-Pérot laser processed from InAs/InP(311)B quantum dot material, which gives emission at 1.516 μm under continuous-wave operation at room temperature.

Introduction: Quantum dot (QD)-based lasers have attracted a lot of interest in the last decade owing to their expected remarkable properties arising from charge carrier confinement in the three space dimensions [1]. Low threshold current densities [2], high material gain [2, 3], temperature insensitivity [4], and near zero linewidth enhancement factor at the lasing wavelength [5, 6] have been reported. This latter property combined with a high damping factor [7] is of utmost importance because it should increase the tolerance to optical feedback in these devices and may also offer potential advantages for direct modulation without transmission dispersion penalty. Directly modulated QD lasers may hence play a major role in next generation telecommunication links (local and metropolitan area network) for coolerless and isolator-free applications. Many efforts have been devoted to the GaAs-based QD material system for emission in the 1.3 μm band, owing to a better material maturity [2–6], which allowed the demonstration of temperature insensitive 10 Gbit/s transmission [8]. However, for the case of long-haul applications, QD lasers grown on InP substrate are required to cover the 1.55 μm window. Molecular beam epitaxy (MBE) on (100) InP substrates has already allowed the growth of quantum dots [9], or quantum dashes [10], which has led to the demonstration of high-performance lasers [10, 11]. On the other hand, the use of the specific InP(311)B orientation has already allowed the demonstration of 3D confined nanostructures with a QD density as high as 10^{11} cm^{-2} [12] as well as a low chirp of a 2.5 Gbits/s directly modulated singlemode waveguide laser emitting at 1.6 μm [13]. This Letter reports for the first time the realisation of a narrow ridge singlemode waveguide laser emitting on the ground state at 1516 nm on InAs/InP(311)B under continuous-wave operation at room temperature. The emission wavelength in the C-band is the closest ever reported in this material system.

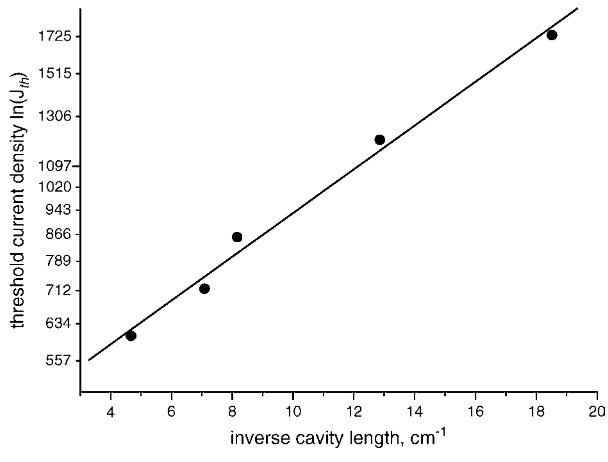

Fig. 1 *Jth (log sacle) against 1/L for InAs/InP broad-area lasers of 50 μm width and cavity lengths ranging from ~800 to 1800 μm*

Broad-area lasers: The laser heterostructure was grown by MBE on a (311)B InP substrate. The active region consists of five layers of QDs separated by 30 nm InGaAsP quaternary ($\lambda_g = 1.18$ μm) barriers (named Q1.18), located at the centre of a Q1.18 optical waveguide. The optical confinement layer corresponds to a laser cavity thickness of 435 nm. Structural analysis based on AFM has allowed the determination of quantum dot dimensions where a mean diameter and height of 25 and 5 nm have been deduced as well as a high QD density close to 10^{11} cm^{-2}. Photoluminescence (PL) measurements were performed on this laser structure at room temperature (RT) under continuous laser excitation at 647 nm. The PL peak is centred at 1.51 μm, with a full width at half maximum (FWHM) of 58 meV. This linewidth, which is comparable to the best values reported [14], reveals a very low size dispersion of the QDs. Room temperature GS lasing is observed under pulsed-excitation for as-cleaved broad area (BA) lasers of 50 μm width and cavity lengths ranging from ~800 to 1800 μm. For instance, a differential efficiency equal to 0.12 W/A per facet is demonstrated for a 1300 μm cavity length. Fig. 1, shows the threshold current density against the inverse of cavity length. The threshold current density at an infinite cavity length, often defined as the transparency current density, is 400 A/cm^2. Consequently, the current density per QD stack is 80 A/cm^2. The Γg_0 modal gain can be derived from the slope of Fig. 1 and is ~16 cm^{-1}.

Singlemode lasers: Singlemode ridge waveguide lasers structures have been processed by a combination of ion beam etching and specific reactive ion etching (RIE). Planarisation of the electrodes was ensured by standard BCB processing. The ridge waveguide width is 2.5 μm. Fig. 2 shows the light-current characteristics of an as-cleaved device of 1490 μm long cavity. The threshold current is equal to 60 mA under pulsed operation while it rises to 80 mA under CW operation owing to heating effects. The maximum output power and external efficiency are, equal to 11 mW and 0.12 W/A per facet, respectively, under pulsed excitation (4 mW and 0.11 sW/A per facet under CW operation). Fig. 3 shows the optical spectrum recorded at $I = 1.85 I_{th}$ (~111 mA). Transverse singlemode behaviour is demonstrated with a lasing wavelength of 1.51 μm. The net gain has also been investigated using the Hakki–Paoli method in CW regime. Fig. 4 shows the net gain ($\Gamma g - \alpha_i$) against injected current above threshold using a high resolution optical spectrum analyser (10 pm). Gain peak wavelength is located around 1512 nm at threshold and the FWHM of the spectral gain is close to 60 nm.

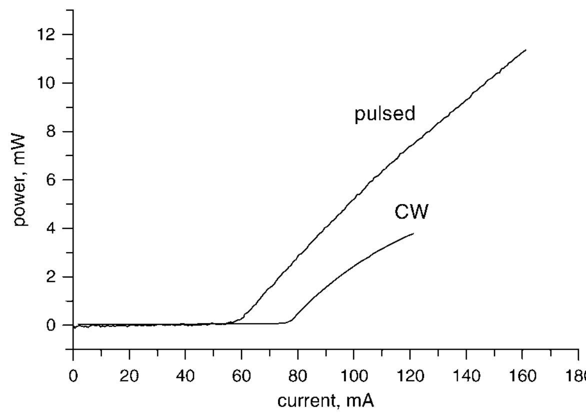

Fig. 2 *Light–current characteristic of 1490 × 2.5 μm ridge laser measured under pulsed and CW operations at room temperature*

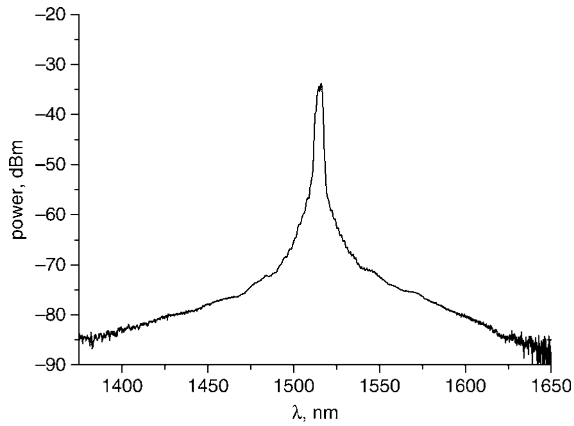

Fig. 3 *CW room temperature optical spectrum of 1490 × 2.5 μm ridge laser measured under CW operation at room temperature ($I = 1.85 I_{th} \simeq$ 111 mA)*

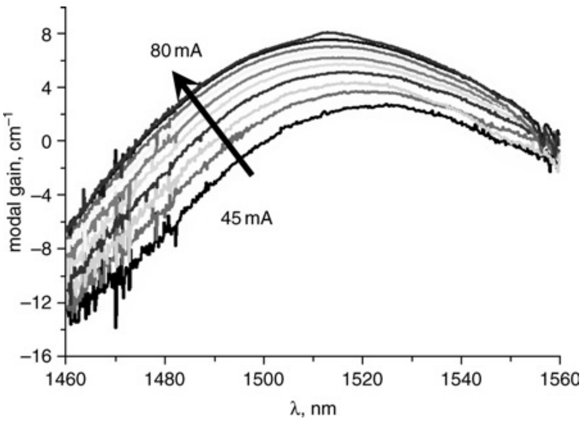

Fig. 4 *Net gain spectra in CW regime for current increasing from 45 to 80 mA (L = 1490 μm, threshold current 80 mA)*

Conclusions: A transverse singlemode InAs QD laser grown on InP(311)B substrate has been realised. The device, which contains five layers of QD, emits at 1516 nm close to the telecommunications C-band. It operates at room temperature and under continuous wave, with a threshold current of 80 mA. The maximum output power remains limited since it does not exceed 5 mW while the external efficiency is equal to 0.12 W/A. Although these performances must be improved, these results constitute, to our knowledge, the state-of-the-art on InP(311)B substrate. They also open the way to a further improvement of QD laser performances at 1.55 μm on InP substrate, as already demonstrated for InAs–GaAs QDs at 1.3 μm.

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