2 μm InAsSb quantum-dot lasers

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Abstract: InAsSb quantum-dot lasers near 2 μm were demonstrated in cw operation at room temperature with a threshold current density of 733 A/cm^2, output power of 3 mW/facet and a differential quantum efficiency of 13%.

There are growing interests in InAs quantum-dot (QD) lasers for long wavelength applications, however, the performance of the InAs QD lasers, especially in the wavelength region of 2 μm, is still limited [1]. Recently, we have achieved high density InAsSb QDs on (001) InP using metalorganic vapor-phase epitaxy (MOVPE) [2]. Compared with InAs QDs, much more efficient room temperature photoluminescence (PL) at the wavelength near 2 μm has been observed from the InAsSb QDs, as shown in Fig. 1, possibly due to the reduction of dislocations from the strain energy relaxation. In this paper, we report room temperature cw operation of InAsSb QD lasers based on InP substrate at wavelength near 2 μm.

The InAsSb QD laser was grown by MOVPE on an InP (001) substrate. The active region of the laser consists of a single-stack InAsSb QDs self-assembled in a slightly tensile-strained (less than −0.5% mismatch) InGaAs quantum well with thickness of 7 nm, which is further sandwiched between 150 nm InGaAsP (λg=1.35 μm). Growth temperatures were in the range of 500–550 °C for the InAsSb QD layers, and 625 °C for the rest of structures. The InAsSb dots have an average lateral size of around 35 and 4 nm in height with an area density of 4x10^{10} /cm^2. Room-temperature PL measurement showed a ground-state peak at 1.98 μm at the edge of a 2 inch wafer with a spectral full width at half maximum of 34 meV, indicating a good homogeneity of the QDs. The devices were fabricated using narrow ridge waveguide design with ridge width of 5 μm, and then cleaved with cavity lengths between 0.5 and 1.5 mm with both facets left uncoated. The lasers are tested in bar form using a temperature-controlled probe station with an epitaxial-side-up configuration.

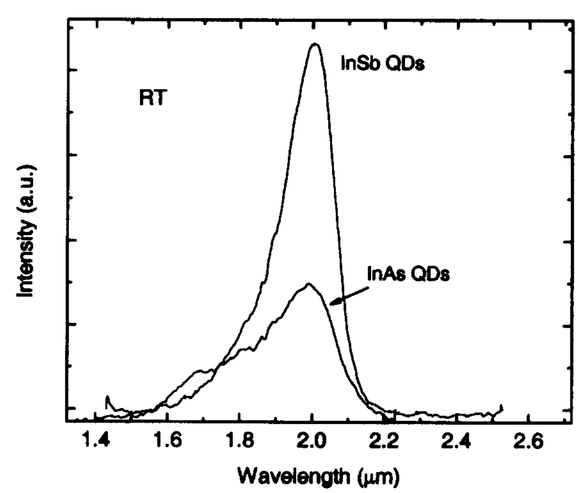

Fig. 1. Room temperature PL spectra of InAsSb and InAs QDs on InP substrates, indicating more efficient luminescence at 2 μm.

Ground-state cw lasing has been achieved at room temperature for cavity lengths of 1 and 1.5 mm, with the lasing wavelength between 1.95

and 1.96 μm. Shown in Fig. 2 the room-temperature cw lasing spectra of a 1.5-mm-cavity QD laser at different injection current, display some spectral features unique to QD lasers with three or four broadened longitudinal modes with spacing of 2.6 nm. Given an effective refractive index of 3.4, the Fabry-Perot longitudinal mode spacing should be about 0.37 nm at wavelength of 1.95 μm, there should be 6–7 Fabry-Perot longitudinal modes within each broadened longitudinal mode, which are not visible here due to the resolution of the monochrometer. From the spectra, the homogeneous and the inhomogeneous broadening are estimated to be 1 and 3–5 meV.

Figure 3 shows the single facet light output characteristics versus current of a 1.5-mm-cavity-length laser operating cw measured at different temperatures. At 10 °C, the threshold current and threshold current density are about 55 mA and 730 A/cm^{-2} respectively, the output power exceeds 3 mW/facet and the differential slope efficiency is about 13%, which is higher than that of InAs quantum-dash lasers at 2.03 μm [1] but still much lower than that at 1.66 μm [3]. The characteristic temperature T_0 is 35 K at temperatures below 15 °C and 20 K above 20 °C. With increasing temperature, the differential slope efficiency decreases gradually to 11% at 20 °C then drops abruptly to about 3% at 25 °C, suggesting a poor electron confinement as a result of Sb incorporation in the QDs. Further optimization is in process.

1. T. Rotter, A. Stintz, and K. J. Malloy , "Long wavelength quantum dash lasers grown on InP substrates", CThI6, CLEO'2003, Baltimore, Maryland 2003.
2. Y. Qiu and D. Uhl, "Self-assembled InAsSb quantum-dots on (001) InP substrate", (unpublished).
3. R. H. Wang, A. Stintz, P. M. Varangis, T. C. Newell, H. Li, K. J. Malloy, and L. F. Lester, IEEE Photonics. Technol. Lett. 13, 767 (2001).

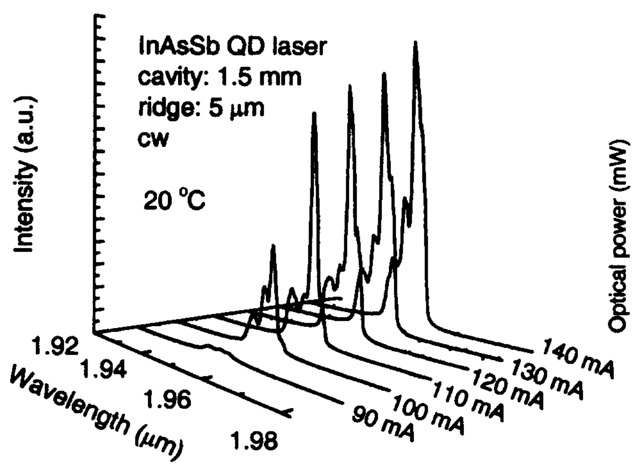

Fig. 2. Ground-state cw lasing spectra of a 1.5-mm-cavity-length laser measured at different currents at 20 °C.

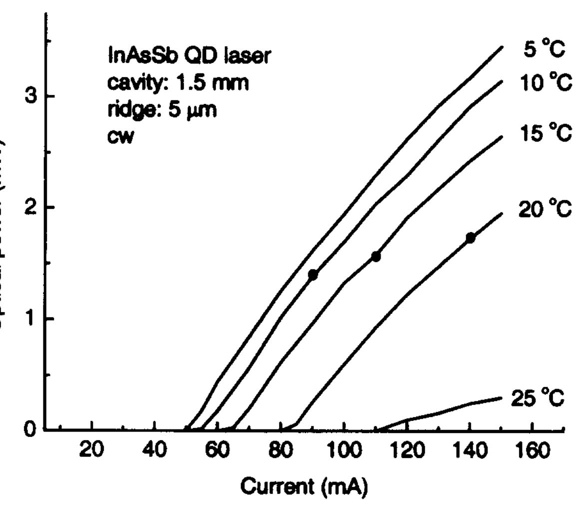

Fig. 3. Light vs current for a 1.5-mm-cavity-length laser without facet coating measured at different temperatures.