InAs quantum dot lasers on InP substrate

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Abstract: Single-stack InAs self-assembled quantum dots (QD) lasers based on InP substrate have been grown by metalorganic vapor phase epitaxy. The narrow ridge waveguide lasers lased up to 260 K in continuous wave operation, and near room temperature in pulsed mode, with emission wavelengths between 1.59 to 1.74 µm. Above 200 K, a very low wavelength temperature sensitivity of 0.09 nm/K was obtained, which is as low as that caused by the refractive index change.

InAs quantum dot (QD) lasers based on InP substrate are of considerable interest as they offer the potential for telecommunication and spectroscopic applications in long wavelength region of 1.8 to 2.3 µm. There are significant progresses in InAs quantum-dash lasers on InP [1], however InAs QD lasers on InP substrate remained low temperature operation [2]. Recently, we discovered that the InAs QD size non-uniformity caused by alloy phase separation is one of the major reasons for low temperature performance of InAs QD lasers at long wavelength. Improved dot size uniformity and luminescence efficiency have been achieved by inserting a thin GaAs interface layer between InAs QDs and the underlying InGaAs layer [3]. In this paper, we report characteristics of single-stack InAs QD lasers based on InP substrate.

The InAs QD lasers were grown on (001) InP substrates using metalorganic vapor phase epitaxy. The dots have an average lateral size around 60 nm and of 7 nm in height with area density of 3×10^{10} /cm^2. The laser structure consists of a single-stack InAs QDs self-assembled on a thin GaAs interface layer within an tensile-strained InGaAs quantum well with thickness of 7 nm, which is further sandwiched between 150 nm InGaAsP (λg=1.35 µm) and 1.5 µm InP cladding layers on both sides, and finally a 200 nm InGaAs cap layer. 8-µm ridge waveguide lasers were fabricated with cavity lengths between 0.5 to 2.0 mm and no facet coating. The laser bars were affixed with indium, epilayer side up, onto a copper heat-sink and then mounted on the temperature-controlled cold finger of an optical cryostat. The optical output power was measured with a cooled InSb detector calibrated by a thermopile power meter when the average power was high.

The lasers were operated in cw mode at heat-sink temperatures up to 260 K. At 80 K, its threshold current and threshold current density were about 10 mA and 125 A/cm^2, respectively. The single facet output power exceeds 25 mW and the differential slope efficiency is about 27%. With increasing temperature, the slope efficiency changed little until 160 K, then it became less that 8% between 180 and 260 K. Characteristic temperature T_0 was 220 K below 100 K and became 61 K to heat-sink temperature of 260 K. When the laser was operated under pulsed conditions (1µs, 1 kHz), it could operate at near room temperature of 280 K.

The lasing wavelengths were between 1.69 to 1.74 µm for 2 mm cavity, and 1.59 to 1.69 µm for 1 mm cavity. For lasers with 2 mm cavity, mode-switching behavior was not observed over the course of injection current and temperature. However, with increasing temperature, more longitudinal modes appeared at shorter wavelength side and diminished at longer wavelength side, resulting a noticeable blue shift for the overall lasing spectrum. This blue shift will partially compensate the red shift from the band gap shrinkage, and reduce the temperature sensitivity of the emission wavelength of QD lasers. Figure 1 shows pulsed lasing spectra of a 2-mm-cavity laser. Temperature induced wavelength shift is as low as 0.09 nm/K.

In summary, we have presented lasing characteristics of InAs QD lasers on InP substrate. These lasers operated at temperature up to 260 K in cw mode, and near room temperature in pulsed mode, with emission wavelengths between 1.59 to 1.74 µm, and a very low wavelength temperature sensitivity of 0.09 nm/K was obtained. The results will provide guidance for further development of long wavelength InAs QD lasers based on InP substrate.

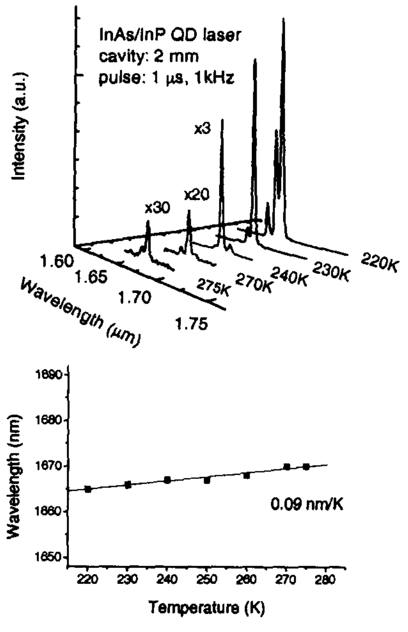

Figure 1: Pulsed lasing spectra of a 2-mm-cavity laser, showing a very low wavelength temperature sensitivity of 0.09 nm/K.

Reference

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