Laterally coupled InAs quantum dot distributed feedback lasers at 1.3 μm

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Abstract: InAs quantum dot (QD) distributed feedback lasers at 1.3 μm were fabricated using four stacks of InAs QD's embedded within strained InGaAs quantum wells as an active region. The lasers show stable single mode continuous wave operation at temperature of 90 °C with sidemode suppression ratios of above 30 dB, threshold currents as low as 20 mA and output power up to 4 mW.

Owing to significant radiation tolerance greater than quantum wells, quantum dot (QD) optoelectronics are of great interest for NASA's planetary and Earth-orbiting missions. Characteristics of InAs QD lasers at wavelength of 1.3 μm on GaAs substrates have been significantly improved over the last few years, even single mode distributed feedback (DFB) QD laser diodes operating continuous wave at room temperature have been realized using laterally coupled metal gratings [1]. In this paper, we report a continuous wave operation of uncoated single mode QD DFB lasers at 1.3 μm using laterally coupled etched gratings.

The QD laser structure was grown by solid source molecular beam epitaxy on a (001) GaAs substrate and similar growth conditions to those published previously were used [2]. The active region is formed by deposition of 2.3 monolayers of bulk InAs within 70 Å strained $In_{.15}Ga_{.85}As$ quantum wells separated by 29 nm GaAs barriers. Device fabrication began with the formation of 4-μm ridges, then the lateral grating with period of 200 nm was defined by electron beam lithography, both ridges and gratings were etched with plasma etching. Plasma enhanced chemical vapor deposition was then used to form a thin oxide layer, and windows are plasma etched in the oxide above the ridges to enable electrical contact. The Ti/Pt/Au p-type contacts are *e*-beam deposited. Finally, AuGe/Ni/Au n-type contacts were thermally deposited after the substrate had been lapped down to a thickness of ~ 125 μm. The wafer is then cleaved into laser bars with a cavity length ranging from 500 μm to 1.5 mm, with no facet coating.

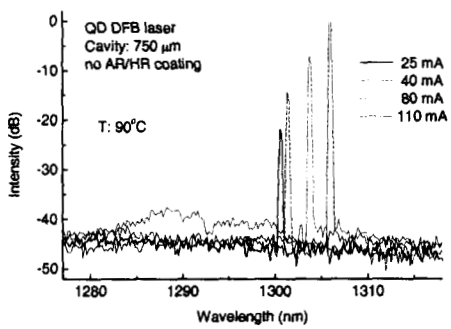

Fig. 1. Emission spectra of typical 750-μm-cavity-length uncoated QD DFB laser at 90°C under different bias current.

All lasers are tested in bar form using a temperature controlled probe station with an epitaxial-side up configuration under continuous wave operation. At temperature as high as 90 °C, the lasers show stable single mode emission at 1.3 μm with sidemode suppression ratios (SMSR) above 30 dB except at 25 mA and threshold currents of typically 20 mA. Fig. 1 plots spectra of a typical 750-μm-cavity-length uncoated QD DFB laser diode at different injection currents. At room temperature, however, the lasers show F-P modes at wavelength of 1.26 μm, with increasing injection current DFB modes appearing near 1.3 μm. It is believed that a large detuning contributed to the existence of both F-P and DFB modes. With increasing temperature, the gain peak moves faster towards longer wavelength than the DFB mode, the difference between the gain maximum and the DFB mode becomes smaller, leading to a stable single mode operation at high temperature.

Fig. 2 shows the output power and the SMSR as a function of the injection current for a typical laser diode at temperature of 90°C, with an emission wavelength of 1.30 μm near threshold. At a current of 110 mA, a single facet maximum output power of 4 mW and a SMSR of over 30 dB were obtained at a lasing wavelength of 1306 nm. For injection currents from 50 mA to about 90 mA, a decrease of SMSR and a hump on the L-I curve, corresponding to small bumps near 1.29 μm observed on emission spectra. This is believed from the competition between F-P modes and DFB mode. The slope efficiency of the laser is about 0.05 W/A, which is comparable to the result reported previously [1].

In conclusion, we have reported single mode QD DFB lasers at wavelength of 1.3 μm using laterally coupled etched grating. With further QD uniformity improvement and device design optimization, it is possible to realize 1.3 μm InAs QD DFB lasers for practical applications.

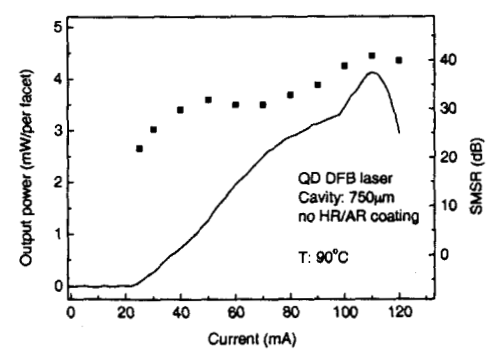

Fig. 2. Output power and SMSR of QD DFB laser with wavelength of 1.30 μm near threshold against injection current.

Reference

1. F. Klopf, R. Krebs, A. Wolf, M. Emmerling, J. P. Reithmaier and A. Forchel, "InAs/GaInAs quantum dot DFB lasers emitting at 1.3 μm", Electron. Lett. 37, 634-636 (2001).
2. Y. Qiu, P. Gogna, S. Forouhar, A. Stintz, and L. F. Lester, "High-performance InAs quantum-dot lasers near 1.3 μm", Appl. Phys. Lett. 79, 3570-3572 (2001).