1310 nm quantum dot DFB lasers with high dot density and ultra-low linewidth-power product

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Abstract: Laterally-coupled distributed feedback lasers using a high-density InAs quantum dots-in-a-well (DWELL) active region demonstrate a nominal wavelength of 1310 nm, a linewidth as small as 68 kHz, and a linewidth-power product of 100 kHz-mW.

Characteristics of InAs quantum dot (QD) lasers at wavelengths near 1.3 μm on GaAs substrates have significantly progressed over the last few years by using self-assembled InAs QDs embedded within strained InGaAs quantum wells, also known as the “dots-in-a-well” or DWELL structure [1]. This laser design has been vital towards realizing higher dot densities, and thereby larger optical gains, and validating the unique properties of QD lasers, especially the very low linewidth enhancement factor [2]. Key improvements in the total dot density have led to 4-stack 1260 nm Fabry-Perot QD lasers with practical cavity lengths of 500 micron that are suitable for data communications [3]. Separately, 6-stack 1279 nm distributed feedback (DFB) QD laser diodes have been realized using laterally coupled (LC) metal gratings [4]. However, there is a need to extend this performance into the 1290-1330 nm range associated with 10 Gigabit Ethernet and metro-SONET applications and to demonstrate such properties as low chirp, feedback insensitivity, and narrow linewidth at these wavelengths. For a GaAs-based QD laser, the LC-DFB structure has the advantages of a gain-coupled device without requiring regrowth or sacrificing crucial dot density. We have studied the properties of both the etched and metal grating versions of the LC-DFB, and in this presentation, we report the cw characteristics of lasers fabricated with the metal grating design.

The six-stack DWELL laser structure is grown by solid source molecular beam epitaxy on a (001) GaAs substrate using conditions similar to those published previously [1]. Room temperature photoluminescence (PL) measurements show a ground state peak at 1328 nm with a spectral FWHM of 74 nm, indicating good homogeneity of the QDs. As shown in fig. 1, the average dot density per layer of the six-stack DWELL active region is 1.3 x 10^11 cm^-2. This value is about 3-5 times higher than what has typically been achieved in the past for QDs emitting in this wavelength range and represents a significant advance in the field.

Device fabrication began with the formation of 3.5 to 4-μm ridges, followed by the e-beam lithographic patterning and metal liftoff of the lateral grating with a period of roughly 200 nm. After planarization of the front side, Ti/Pt/Au was deposited for the p-type contact. Finally, a Au/Ge/Ni/Au n-type contact was deposited after the substrate had been polished. The wafer was cleaved into laser bars with cavity lengths ranging from 300 μm to 800 μm and the facets were HR/HR coated to reinforce laser operation in the ground state of the QD. The DFB lasers emitted single mode in a wavelength range from 1277-1333 nm.
The DFB lasers were tested cw on a temperature-controlled heat sink. Single facet slope efficiencies were typically 0.08-0.1 mW/mA at 20°C with the 300-μm devices capable of 7 mA threshold current and a 45 dB side mode suppression ratio (SMSR) at bias currents greater than 10×Ith. Fig. 2 shows the single facet output power vs. current of one of the 800-micron devices that had a wavelength of emission of 1315 nm. This device had stable single-mode operation up to a 50 mA bias with an SMSR of at least 40 dB. Its static linewidth was measured using the self-homodyne technique by coupling the light into a fiber interferometer with a 3.5 μs time delay. Minimal effort was made to isolate the DWELL DFB laser from back reflections from the fiber, which was angle-cleaved at 2°. The results in Fig. 3 show a linewidth of 68 kHz at a current of 40 mA and an SMSR of about 40 dB. With the total power being about 1.5 mW at this bias, the linewidth-power product is 100 kHz-mW, which is among the lowest values ever reported and is a clear indication of a semiconductor laser with low linewidth enhancement factor [5-7]. At currents above 40 mA, the linewidth increases. Although not known at this point, this result could be due to the decrease in SMSR at higher currents, feedback from the fiber, or inhomogeneous broadening in the quantum dot ensemble.

In conclusion, we have reported single-mode DWELL DFB lasers at wavelengths near 1310 nm using laterally coupled metal gratings. Significant accomplishments include the extension of the wavelength to as long as 1333 nm in realistic cavity lengths by achieving high dot density, an ultra-low linewidth-power product, and a qualitative demonstration of the feedback insensitivity of the QD DFB device. The authors wish to acknowledge nanoplus GmbH for the DFB laser fabrication.

Reference