Narrow Linewidth Quantum Dot distributed Feedback Lasers

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A tunable local oscillator with a narrow linewidth is a pivotal component for the deployment of future coherent communication systems [1]. A coherent system restores both the amplitude and the phase information of optical signals. However, it is sensitive to the phase noise of both transmitters and local oscillators hence affecting the bit error rates at the receiver side. Quantum well (QW) semiconductor lasers usually exhibit spectral linewidths of a few MHz that can be further reduced down to a few kHz by using various techniques which require either more complex technologies or bulky configurations [2]. A simpler approach to narrow the spectral linewidth relies on the use of self-assembled quantum dot (QD) nanostructures. Owing to the tight carrier confinement and the lower population inversion factor, spectral linewidths of a few hundreds of kHz have been reported in InAs/GaAs and InAs/InP distributed feedback (DFB) QD lasers [3,4,5].

This paper aims at moving forward by investigating both theoretically [7] and experimentally the spectral linewidth properties of InAs/InP QD DFB lasers operating at 1520 nm. In this work, the QD active region grown by CBE on a n-type InP(100) substrate consisted of 5 InAs dot layers with 1.15Q InGaAsP barriers and cladding for a total core thickness of 350 nm. The dots are about 1.6 nm in height and 50 nm in lateral extension, with an areal density of approximately 4×10^{10} cm^{-2} per layer. Following the growth of the laser core the wafer was patterned to create a uniform index coupled grating without phase shifts before having the top p-type InP cladding and InGsAs contact overgrown by MOCVD. Figure 1 shows the cross-sectional scanning electron microscope image of completed laser structure and the floating grating. 3 μm wide ridge waveguide DFB lasers were then fabricated and cleaved to form 1 mm long cavities. Figure 2 depicts the light current characteristics of two QD DFB lasers: the former has an antireflection coating (AR) on both facets (a), the latter is AR/HR with HR the high reflection coating applied on the rear facet (b). The insets show the optical spectra measured at 100 mA (red markers).

The spectral linewidth is measured with a self-heterodyne interferometer and retrieved from a Voigt profile. Figure 3 unveils the linewidth dependence on the drive current normalized to the threshold. With the AR/HR DFB laser, a narrow spectral linewidth operation is achieved with a minimum value of 160 kHz (red). However, due to the non-uniformity of the optical field distribution (spatial hole burning) and the increased scattering rates with the drive current, a spectral rebroadening is observed [6,7]. Using AR coatings on both facets allows tailoring the field distribution hence the spectral linewidth remains rather flat below 400 kHz over a wider range of drive currents (blue). These results show the importance of controlling the gain nonlinearities for narrow linewidth operation at high drive currents and overall the potential of quantum dot technology for increasing the transmission capacity in coherent communication systems.

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Figures

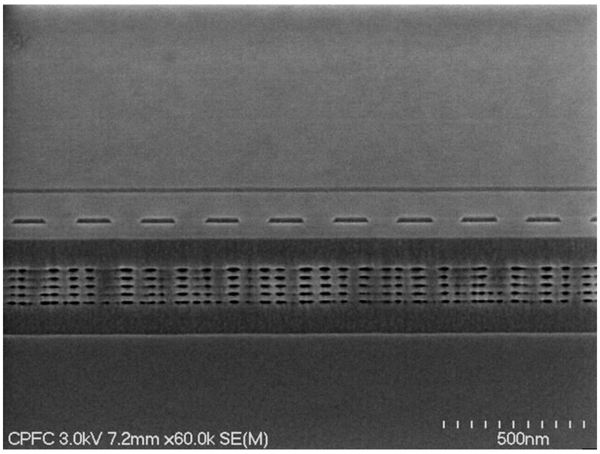

Fig. 1. Cross-sectional scanning electron microscope image of completed laser structure showing five-layer QD core and floating grating.

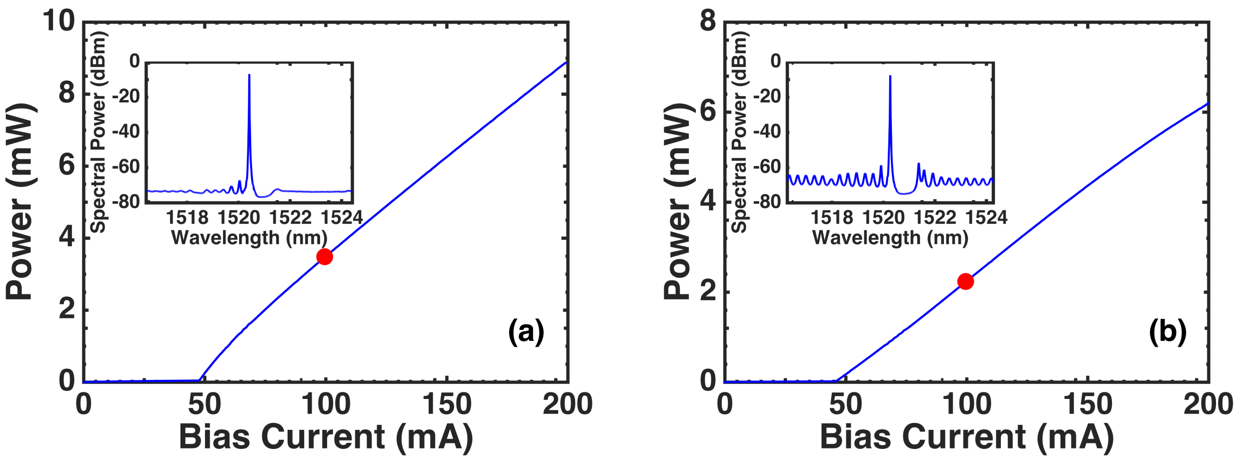

Fig. 2. Light current characteristics of (a) AR/AR DFB laser and (b) AR/HR DFB laser. The insets show corresponding optical spectra measured at 100 mA (red markers).

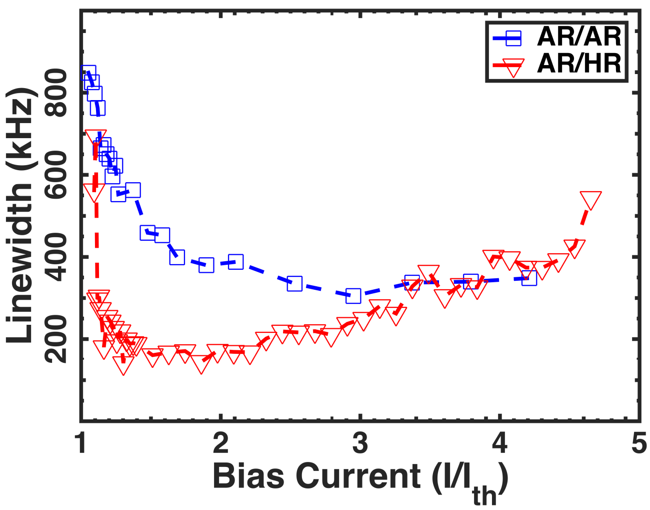

Fig. 3. Spectral linewidth fitted with Voigt profile as a function of bias current, normalized to the threshold value (I/I_{th}), for AR/AR DFB laser and AR/HR DFB laser.