Thermal dependence of the emission linewidth of 1.52-µm single mode InAs/InP quantum dot lasers

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***Abstract*—This paper experimentally investigates the thermal dependence of the emission linewidth of 1.52-µm single mode InAs/InP quantum dot lasers. Using a distributed feedback cavity made with symmetric antireflection coatings, a minimum linewidth of 300 kHz is unveiled. This narrow line is found rather constant with the injection current and the temperature range (293 K - 313 K). However, under certain operating conditions, a linewidth rebroadening is also observed, which may be attributed to the spectral hole burning and to the variations of the alpha-factor with the temperature and bias current. Nevertheless, these results confirm the potential of this technology for manufacturing low-phase noise oscillators for coherent optical communications.**

Keywords—Quantum dots; Distributed feedback lasers; spectral linewidth; rebroadening

Narrow spectral linewidth has become essential for local oscillators in future coherent communication systems, in which phase noise impacts the ratio of signal power to noise power hence determining the maximum achievable data rate [1]. Owing to their low inversion factor, quantum dots (QDs) lasers made without artificial solutions are straightforward to meet these goals exhibiting emission linewidths of a few hundreds of kHz at room temperature [2,3]. However, the control of the spatial nonlinearities (i.e., the longitudinal spatial hole burning) has been shown to be of vital importance to stabilize the linewidth with the injection current. In this paper, we aim at going a step forward by investigating its thermal stability.

The laser under study is a distributed feedback (DFB) laser. The active region consists of 5 InAs dot layers with 1.15Q InGaAsP barriers and cladding for a total core thickness of 350 nm, which is grown by chemical beam epitaxy (CBE) on a (100) oriented n-type InP substrate. Each layer contains QDs with 1.6 nm in height and 50 nm in lateral extension and the dot density of about 4×10^{10} cm^{-2}. 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 InGaAs contact overgrown by MOCVD. The grating period is 235 nm leading to a lasing wavelength of 1.52-µm. The laser has a cavity length of 1 mm and a stripe width of 3-µm with an antireflection coating on both facets. Fig.1 displays the light current characteristics of the QD DFB laser at different heat sink temperatures, from 293 K to 313 K. The threshold current I_{th} increases from 47 mA at 293 K to 63 mA at 313 K resulting in a characteristic temperature of 67 K (293 K-313 K), while the external efficiency is reduced from 10.2 % at 293 K to 9.5 % at 313 K. Fig. 2 shows the lasing spectra at $2 \times I_{th}$ for 293 K and 313 K. Single mode emission is successfully achieved with a constant side mode suppression ratio beyond 60 dB and a wavelength shift of 0.1 nm/K. The emission linewidth is then measured with a self-heterodyne interferometry [3]. Fig. 3(a) displays the experimental normalized radio-frequency (RF) spectrum (blue). The full width at half maximum extracted from the Voigt profile (red) leads to a minimum spectral line of 300 kHz which transforms into an intrinsic linewidth as low as 110 kHz with a Lorentzian fitting at $2.3 \times I_{th}$ and 293K. Fig. 3(b) shows the thermal dependence of the linewidth from 293 K to 313 K for pumping level of $2 \times I_{th}$ and $3.8 \times I_{th}$, respectively. At room temperature, the linewidth is not affected by increasing the injection current hence exhibiting a constant value of about 350 kHz. In addition, at $2 \times I_{th}$, the emission line shows a good thermal stability with an increase not exceeding 410 kHz at 313 K. However, when the injection current is raised to $3.8 \times I_{th}$, a spectral rebroadening is observed leading to a degradation of the emission line up to 850 kHz at 313 K. Although the origin of the rebroadening is still under investigation, it can be due to spectral hole burning (e.g. carrier heating) as well as to the variations of the alpha-factor (driving the linewidth) with the temperature and bias current. This last point will be discussed during the presentation. Despite that, we demonstrate a QD DFB with a stable narrow line between 293 K and 313 K up to 3 times the threshold and with about 10 mW total output power. Further work will also investigate QD lasers fabricated on native GaAs substrate as well as on silicon. Overall, these results show the potential of QDs as a straightforward solution for producing narrow line oscillators in compliance with coherent receivers requirements.

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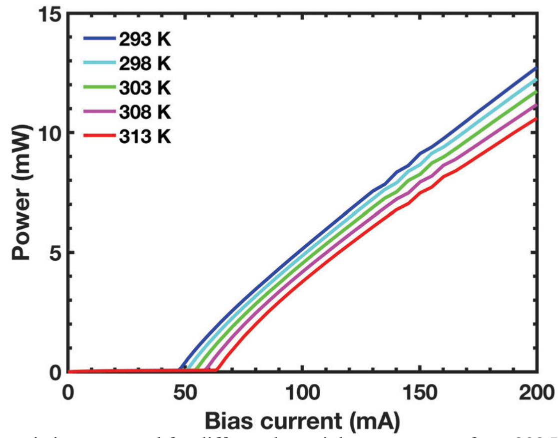

Fig. 1. Light-current characteristics measured for different heat sink temperatures from 293 K to 313 K with a step of 5 K.

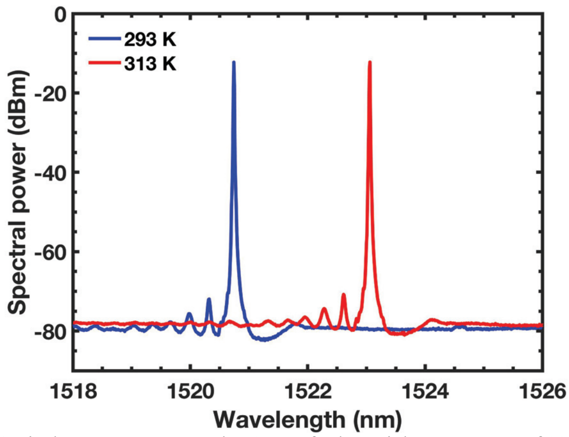

Fig. 2. Optical spectrum measured at 2 × I_{th} for heat sink temperature of 293 K and 313 K.

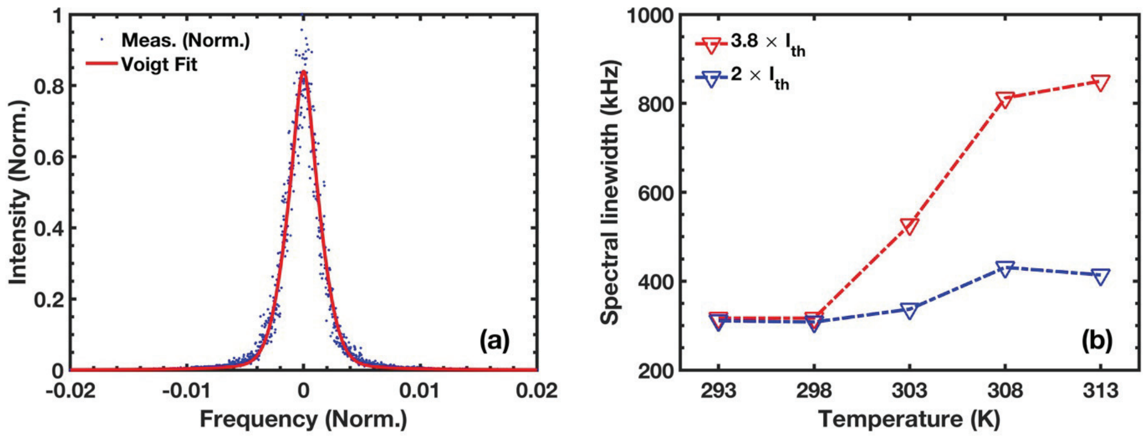

Fig. 3. (a) Normalized RF spectrum and the corresponding Voigt fitted spectrum. (b) Extracted emission linewidth as a function of the heat sink temperature ranging from 293 K to 313 K with a step of 5 K for the cases of 2 × I_{th} and 3.8 × I_{th} values.

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