Resonant optical feedback in epitaxial 1.3-μm passively mode-locked quantum dot lasers on silicon

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I. Abstract

Research on quantum dot mode-locked lasers (QD-MLL) directly grown on silicon substrates reveals that such light source is ideal candidate for the development of low-cost and energy-efficient integrated photonics components applied in Photonics Integrated Circuits (PICs) [1]. This paper reports on the influence of the α-factor as well as the optical feedback dynamics of InAs/InGaAs QD-MLL epitaxially grown on silicon. The laser structure under study is shown in Fig.1, where the saturable absorber (SA) is integrated at the edge of the cavity.

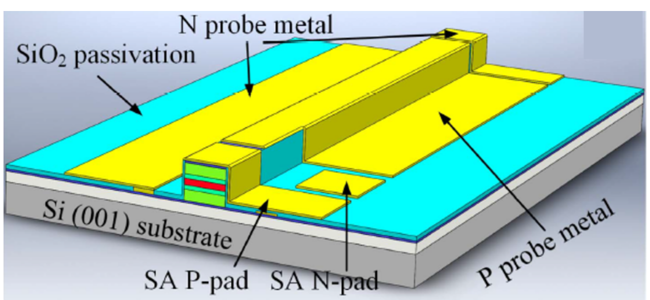

Fig. 1. Schematic of QD-MLL under study

Superior passive mode-locking may be expected at a higher reverse bias voltage on the SA [1]. The α-factor, which is a key parameter in semiconductor laser physics [2], is able to influence the dynamics of mode-locking. Indeed, Figure 2(a) revealed that the value of the effective α-factor at threshold, which includes both the contributions of the SA section and the gain section, increases with the reverse voltage; such an effect is caused by the decrease of the differential gain induced by the absorption from the SA section. For instance, when the reverse voltage on the SA is increased from -1V to -5V, the value of α-factor is enlarged from 3 to 12. We also investigate the optical feedback dynamics of such QD-MLL assuming an external cavity length L_{ext} of 7 meters. When the laser operates at twice the threshold under -35 dB optical feedback strength, with -1V biased on the SA, Fig.2(b) depicts that introducing a sub-picosecond delay line in the feedback loop influences both the repetition rate (blue) and the RF linewidth (red). In particular, when the optical length of the external cavity is a multiple of that of the free-running QD-MLL, a large reduction of the RF linewidth is anticipated, indicating that the device is in the integer resonant operation [3]. In such an operation, its RF linewidth is indeed reduced down to about 600 kHz against 2.7 MHz in free-running operation, by assuming -1V applied to the SA and a fine tuning of the external cavity length L_{ext} towards the optimum feedback resonant condition. Similar trends can also be observed for all bias voltages under study (eg., from 0V to -5V) as previously observed [4]. At this stage, it is worth stressing that both L_{ext} and the SA reverse bias voltage could be further optimized to approach the narrowest RF linewidth.

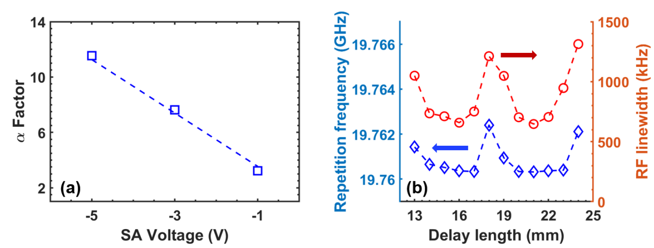

Fig. 2. (a) Effective α-factor under different voltages on the SA. (b) L_{ext} around 7 m, optical delay line dependence of the repetition rate (blue) and RF linewidth (red), when the laser operates at $2\times I_{th}$ under -35 dB optical feedback strength, with -1V biased on the SA.

To summarize, this work demonstrates that the reverse bias voltage on the SA section contributes to enlarge the α-factor thus influencing the mode-locking effect. In addition, we also show that the resonant optical feedback operation is beneficial to reduce the RF linewidth of the epitaxial QD-MLL on silicon.

References

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