Self-sustained pulse oscillations in a quantum dot laser monolithically grown on germanium

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InAs/GaAs quantum dot (QD) lasers monolithically grown on Ge or Si are a promising method to achieve low cost, large scale, and high yield optical sources for photonic integrated circuits [1]. This work shows that a free-running Ge-based QD laser can output periodic pulse oscillations with one, two and three periods, without incorporating saturable absorber or employing any external perturbations [2,3]. The QD laser under study was epitaxially grown on a 4-inch Ge-wafer by the gas-source molecular beam epitaxy, and the active region consists of five stacked dot-in-well layers [4]. The wafer was fabricated into a ridge-waveguide laser with a ridge width of 4.0 μm and a cavity length of 4.4 mm. The laser shows a lasing threshold of 60 mA at 20 °C, and the lasing peak is at 1213 nm. Figure 1(a) shows that the relative intensity noise (RIN) of the Ge-based laser pumped at 80 mA exhibits a common resonance with continuous-wave output. However, the resonance of the laser pumped at 160 mA does not become overdamped, but evolves into pulse oscillations with a high and sharp peak. Figure 1(b) shows the resonance frequency and the damping factor extracted from the RIN spectra. The resonance frequency increases with the pump current from 0.4 GHz at 80 mA up to 1.1 GHz at 170 mA, whereas the damping factor declines from 4.0 GHz down to 0.03 GHz. The damping reduction confirms the onset of peculiar pulsing dynamics for pump currents above 140 mA.

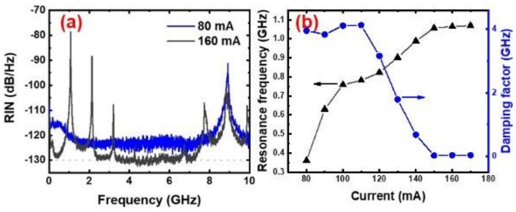

Fig. 1. (a) RIN spectra at 80 mA and at 160 mA. (b) Resonance frequency and damping factor versus pump currents.

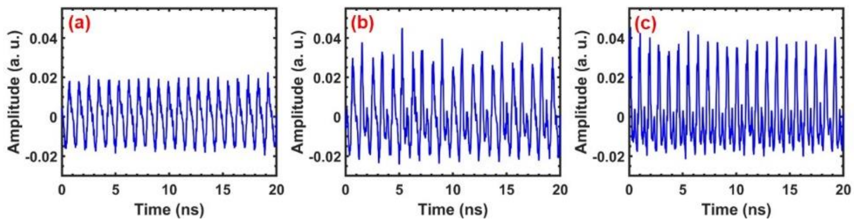

Fig. 2. Time series of (a) one-period oscillation at 180 mA, (b) three-period oscillation at 215 mA, and (c) two-period oscillation at 235 mA.

As shown in Fig. 2(a), the pulse oscillation has one period for pump currents in the range of 140-190 mA. The one-period oscillation can be used for photonic microwave generation (not shown). Beyond 190 mA, the free-running Ge-based laser exhibits three-period oscillations (Fig. 2(b)) and two-period oscillations (Fig. 2(c)). The self-sustained pulse oscillations of the free-running Ge-based QD laser can be attributed to the inhomogeneous nature of the QD active region, which provides a few confined QD states and hence results in the saturable absorption by energy states lower than the photon energy [2]. In summary, we demonstrate self-sustained pulse oscillations of one, two, and three periods in a free-running InAs/GaAs QD laser monolithically grown on Ge. The study unveils the potential of Ge-based QD lasers for the realization of photonic microwave oscillators. This work is supported by National Natural Science Foundation of China (NSFC, 61804095).

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