Traveling wave modeling of mode-locked quantum dot semiconductor lasers

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Semiconductor lasers based on self-assembled quantum dots (QD) attract significant attention due to improvement in lasing threshold, modulation bandwidth, relative intensity noise, as well as due to reduction of chirp, temperature sensitivity and sensitivity to optical feedback at telecom wavelengths. The advantages of QD material can be exploited in multisection mode-locked (ML) lasers which are able to generate high-intensity sub-picosecond pulses [1].

Adequate modeling of QD lasers should take into account carrier exchange processes between their wetting layer (WL) and quantum dots. Recently proposed relatively simple models based on rate equations for solitary QD lasers (see, e.g., [2]) and delay differential equations for ML-QD lasers [3] demonstrate qualitative agreement with some experimental observations. However, these models neglect spatial distributions of carriers and electric field envelopes, which should be taken into account in a comprehensive study of dynamics in ML-QD lasers. Therefore, in this presentation we apply the traveling wave modeling (partial differential equations) approach allowing to describe spatial nonuniformity of laser parameters and resolve spatial-temporal dynamics of carrier densities and optical fields counter-propagating along the laser cavity axis.

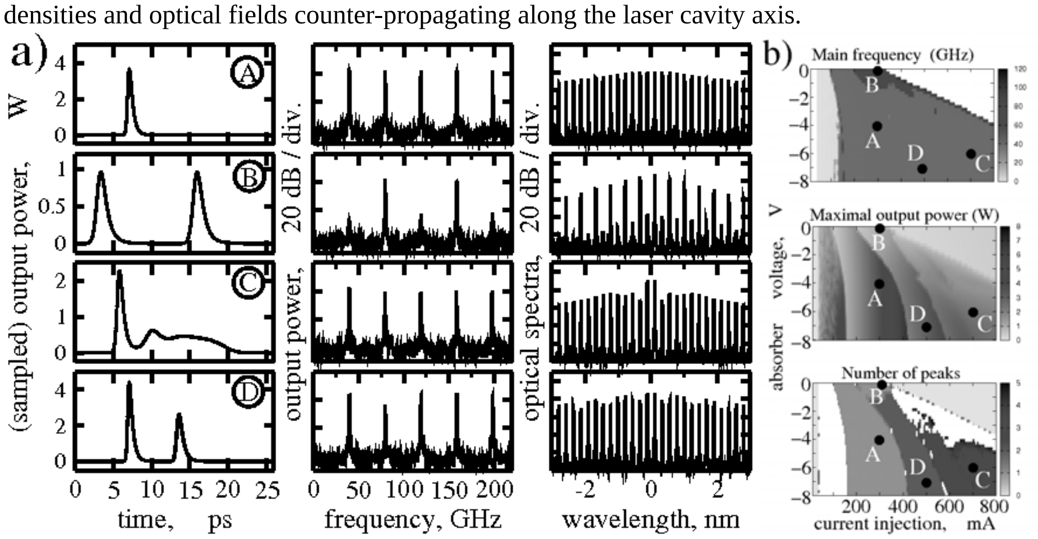

Fig. 1 (a): four simulated stable regimes with periodic laser intensity. Fundamental ML (A), 2nd harmonic ML (B), ML with an enhanced trailing edge (C), and double pulse within roundtrip time (D). Fist, second and third columns show periodically sampled intensity, radiofrequency and optical spectra of the emitted field, respectively. (b): two-parameter characterization of the dynamical states. Top, middle and bottom diagrams show main intensity oscillation frequency, maximal power, and number of distinguishable peaks of the emitted optical field. Black dots show parameter values corresponding to the computed regimes presented in part (a) of the figure.

We simulate and analyze a model of a ML-QD laser consisting of reversely biased saturable absorber and forward biased amplifying sections. We perform a comprehensive two-parameter study of the operation regimes in this laser by identifying type of the dynamical states as well as estimating different ML-state characteristics [4], such as pulse width, amplitude and phase jitter, signal to noise ratio, etc.. Some selected time traces of the laser intensity and spectra together with the location of corresponding regimes in two-parameter plane are shown in Figs. 1a) and 1b).

References

[1] E.U. Rafailov et al., “High-power picosecond and femtosecond pulse generation from a two-section mode-locked quantum-dot laser,” Appl. Phys. Lett. **87**, 081107 (2005).
[2] K. Lüdge et al., “Turn-on dynamics and modulation response in semiconductor quantum dot lasers,” Phys. Rev. B **78**, 035316 (2008).
[3] E. Viktorov et al., “A model for mode-locking in quantum dot lasers,” Appl. Phys. Lett. **88**, 201102 (2006).
[4] U. Bandelow et al., “Harmonic Mode-Locking in Monolithic Semiconductor Lasers: Theory, Simulations and Experiment,” Opt. Quant. Electron. **38**, pp. 495-512 (2006).

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