Introduction to the Issue on Physics and Applications of Laser Dynamics (IS-PALD 2017)

F. GRILLOT,1,2,* M. SCIAMANNA,3 AND S.-C. CHAN4,5

1Télécom ParisTech, Université Paris-Saclay, 46 rue Barrault, 75634 Paris Cedex 13, France
2Center for High Technology Materials, The University of New-Mexico, 1315 Goddard SE, Albuquerque, NM 87106, USA
3Chair in Photonics, LMOPS EA 4423 Laboratory, CentraleSupélec, Université Paris-Saclay, and Université Lorraine, 57070 Metz, France
4Department of Electronic Engineering, City University of Hong Kong, Hong Kong, China
5State Key Laboratory of Millimeter Waves, City University of Hong Kong, Hong Kong, China
*grillot@telecom-paristech.fr

Abstract: In this paper, we introduce the Optics Express feature issue of the 7th International Symposium on Physics and Applications of Laser Dynamics (IS-PALD). This issue consists of expanded papers related to oral and poster presentations. Selected papers represent the best of IS-PALD 2017.

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References and links

1. F. Grillot, M. Sciamanna, and Y.-F. Chen, “Introduction to the issue on Physics and Applications of Laser Dynamics (IS-PALD 2013),” Opt. Express 22(6), 7362–7363 (2014).
2. O. Graydon, “Embracing instability,” Nat. Photonics 12(2), 66–67 (2018).
3. K. Lüdge, Nonlinear laser dynamics: from quantum dot to cryptography, Wiley (2012).
4. A. Uchida, Optical communication with chaotic lasers: Applications of nonlinear dynamics and synchronization, Wiley, (2012).
5. J.-M. Liu, Semiconductor laser dynamics for novel applications, 341–354, Springer, (2009).
6. C.-H. Cheng, C.-Y. Chen, J.-D. Chen, D.-K. Pan, K.-T. Ting, and F.-Y. Lin, “3D pulsed chaos lidar system,” Opt. Express 26(9), 12230–12241 (2018).
7. C.-Y. Chen, C.-H. Cheng, D.-K. Pan, and F.-Y. Lin, “Experimental generations and analyses of chaos-modulated pulses for pulsed chaos lidar applications based on gain-switched semiconductor lasers subject to optical feedback,” Opt. Express 26(10), 20851–20860 (2018).
8. T. S. Rasmussen, Y. Yu, and J. Mork, “Modes, stability, and small-signal response of photonic crystal Fano lasers,” Opt. Express 26(13), 16365–16376 (2018).
9. H. Han and K. A. Shore, “Analysis of high-frequency oscillations in mutually-coupled nano-lasers,” Opt. Express 26(8), 10013–10022 (2018).
10. M. Tomiyama, K. Yamasaki, K. Arai, M. Inubushi, K. Yoshimura, and A. Uchida, “Effect of bandwidth limitation of optical noise injection on common-signal-induced synchronization in multi-mode semiconductor lasers,” Opt. Express 26(10), 13521–13535 (2018).
11. J. Tiana-Alsina, C. Quintero-Quiroz, M. Panizzo, M. C. Torrent, and C. Masoller, “Experimental study of modulation waveforms for entraining the spikes emitted by a semiconductor laser with optical feedback,” Opt. Express 26(7), 9298–9309 (2018).
12. C.-H. Uy, L. Weicker, D. Rontani, and M. Sciamanna, “Sustained oscillations accompanying polarization switching in laser dynamics,” Opt. Express 26(13), 16917–16924 (2018).
13. N. Li, H. Susanto, B. R. Cemlyn, I. D. Henning, and M. J. Adams, “Mapping bifurcation structure and parameter dependence in quantum dot spin-VECSELs,” Opt. Express 26(11), 14636–14649 (2018).
14. T. Malica, J. Lin, T. Ackemann, D. J. Little, J. P. Toomey, D. Pabreuf, W. Lubeigt, N. Hempler, G. Malcolm, G. T. Maker, and D. M. Kane, “Mapping the dynamical regimes of a SESAM mode-locked VECSEL with a long cavity using time series analysis,” Opt. Express 26(13), 16624–16638 (2018).
15. X.-G. Wang, B.-B. Zhao, F. Grillot, and C. Wang, “Frequency noise suppression of optical injection-locked quantum cascade lasers,” Opt. Express 26(12), 15167–15176 (2018).
16. T. C. Newell, F. Grillot, A. Gavrielides, R. Kaspi, C. Lu, C. Yang, T. Bate, and S. Luong, “Experimental Investigation of broad area quantum cascade lasers under external feedback,” Opt. Express 26(14), 17927–17935 (2018).
As Guest Editors, it a great pleasure to introduce this feature issue on Physics and Applications of Laser Dynamics. This issue collects the most original peer-reviewed papers related to oral or poster contributions of the International Symposium on Physics and Applications of Laser Dynamics (IS-PALD) held in Paris on November 15–17, 2017. This symposium is the seventh of a series of symposia on laser dynamics organized up to now in collaboration between France and Taiwan [1]. The symposium IS-PALD was born in 2010 under the impulsion of J. M. Liu, Professor at the University of California Los Angeles, USA [2]. The 2017 edition was co-chaired by F. Grillot, Professor at Télécom ParisTech (France) and M. Sciamanna, Professor and Head of the Chair in Photonics at CentraleSupélec (France). The 2018 edition will take place in Hong Kong on December 4-6 and will be chaired by our third guest editor S. C. Chan, Associate Professor at the City University of Hong Kong (China).

This special issue covers new research topics and state-of-the-art developments in the area of semiconductor lasers, nonlinear dynamics, ultrafast laser dynamics, and related photonic devices including quantum dot and dash semiconductor materials, vertical-cavity surface-emitting lasers (VCSELs), mode-locking, frequency combs, and quantum cascade lasers. Today, the rich physics behind the field of semiconductor lasers and nonlinear laser dynamics is of growing interests for plethora of applications including but not limited to optical communications, defense and security, optical computing, optics-based information security, and optical storage [3–5]. This special issue takes you through the most trendy topics of this exciting research field. The selected contributions to this featured issue are all written by international researchers who comprehensively treat various topics describing some of the most exciting work in the field and are a testament to the creativity and continuing vitality of the subject area.

Among the best contributions, we would like to emphasize an extensive paper on 3D chaotic lidar systems written by C.-H. Cheng et al [6]. This paper was also highlighted in the OSA’s “Spotlight on Optics”. Nowadays, the market for lidar is currently booming due to the development of self-driving cars that need a variety of low-cost sensors including lidar and cameras to help interrogate their surroundings and navigate. In this paper, authors show that the use of a chaotic light pulses makes the lidar much more secure and unhackable. In a second paper, the same group also experimentally investigated generations and analyses of chaos-modulated pulses for chaos lidar applications based on gain-switched semiconductor lasers subject to optical feedback [7].

Then the article written by Rasmussen et al. reported on self-pulsed Fano resonance nanolasers in a photonic crystal platform. The paper shows that such nanodevices have strong potential for ultrahigh modulation bandwidths beyond 1 THz, hence circumnavigating the limit of the intrinsic relaxation oscillations [8]. In a similar purpose but relying on a different approach, Han et al. discussed the dynamics of mutually coupled nano-lasers. Using rate equations incorporating the Purcell cavity-enhanced spontaneous emission factor as well as the spontaneous emission coupling factor, results unveiled that small-amplitude oscillations with frequencies of the order of 100 GHz are generated with a remarkable stability [9].

In this special issue, Tomiyama et al. investigated the synchronization of two multimode semiconductor lasers subject to a bandwidth-limited optical noise signal [10]. Synchronization is found to be degraded as the number of longitudinal modes of one of the lasers is decreased. However, large correlation can be obtained if the overlapped modes are selected and compared. The paper shows the difficulty to completely reproduce the synchronized waveforms using synchronization, when the bandwidth of the noise drive signal that can be recorded by the eavesdropper is limited.
It is also interesting to emphasize the paper from J. Tiana-Alsina et al., which focused on a semiconductor laser with optical feedback, and operating in the low-frequency fluctuations regime [11]. Authors revealed that the LFF regime, which displays abrupt spikes can be synchronized to a weak periodic signal that directly modulates the laser pump current. The role of the modulation features (amplitude and frequency) and the dc value related to the pump current controlling the natural spike frequency in the entrainment quality are discussed. Still on optical feedback dynamics, C.-H. Uy et al. showed the emergence of sustained oscillations over a slow and periodic polarization switching in a laser subjected to polarization rotated optical feedback [12]. Analytical study reveals also that the frequency of this new oscillatory dynamics is independent of the time delay, which can be meaningful for random number generation and all-optical flip-flop system.

At IS-PALD 2017, we also had various other talks describing dynamics of quantum dot and quantum cascade lasers, frequency combs, quantum dot spin-VCSELs, and semiconductor ring lasers. Some of them are available in this special issue. For instance, N. Li et al. investigated the mapping bifurcation structure and parameter dependence in quantum dot spin-VCSELs [13]. Detailed numerical simulations illustrate the role played by the quantum dot energy states, the gain parameter, and the amplitude-phase coupling. By tuning such parameters authors showed that the dynamical regions evolve as a function of the intensity and polarization of the optical pump, as well as in the plane of the spin relaxation and linear birefringence rates. Then, Malica et al. reported on a mapping of the dynamical regimes of a SESAM mode-locked VECSEL with long cavity using time series analysis [14]. The observed dynamical transitions from fundamental mode-locking provide insights into instability challenges in developing a stable, widely tunable, low repetition rate, turn-key system.

X.-G. Wan et al. discussed the suppression of frequency noise in injection-locked quantum cascade lasers [15] whereas Newell et al. reported on new dynamics in broad area quantum cascade lasers with external optical feedback for high-power applications [16]. In the former, it is shown that the low-frequency noise is completely suppressed by the optical injection and that the suppression bandwidth is enhanced with increasing the injection ratio. In addition, it is found that the optical injection invokes an additional peak in the frequency noise spectrum, which strongly depends on the linewidth broadening factor of the quantum cascade laser. In the latter article, authors unveiled that judicious angles of the feedback external mirror lead to a plethora of curious modes hence producing dynamics strongly dominated by transverse mode competition ranging for less than 20 MHz to greater than 100 MHz. Then, the paper written by T. T. M. van Schaijk et al. proposed a theoretical analysis of a feedback insensitive unidirectional semiconductor ring laser that can be of further interest for experimental verifications in photonics integrated circuits [17]. Last but not the least, Columbo et al. studied multimode dynamics in single section semiconductor ring lasers with quantum dots active region. In the particular case of the unidirectional ring configuration, their simulations unveil the occurrence of self-mode-locking leading to sub-picosecond ultra-short pulses with a terahertz repetition rate which is meaningful for high-data rate optical information encoding and transmission as well as the generation of terahertz or sub-terahertz signals [18].

To this end, we would like to stress that this feature issue would not have been possible without the professionalism, dedication, and expertise of all the members of the OSA publication team. In particular, the Guest Editors would like to express thanks to the authors, both invited and contributed, for submitting comprehensive and thought-provoking papers. Special thanks go out to the international peer reviewers who donated their time and skills to maintain the technical quality of this special edition while also staying within tight deadlines. Many thanks also to all our industrial sponsors as well as to the office of Naval Research Global (ONRG) and the European office of Aerospace Research and Development (EOARD) for their financial support, the members of the conference organizing committee, and the members of the international advisory committee for their great involvement in making this
conference successful. We would like to also specially thank the OSA staff for their assistance and support. Finally, the Editors would like to thank Professor A. Weiner from Purdue University (USA), Editor-in-Chief of Optics Express, for inviting us to serve the semiconductor laser community and for helping us complete this challenging, yet enjoyable task. We wish everyone very good reading and hope that this IS-PALD special issue will be a source of inspiration for many scientists working in the semiconductor laser community.