

PROCEEDINGS OF SPIE

**Novel In-Plane
Semiconductor Lasers IX**

Alexey A. Belyanin

Peter M. Smowton

Editors

25–28 January 2010

San Francisco, California, United States

Sponsored and Published by

SPIE

Volume 7616

Proceedings of SPIE, 0277-786X, v. 7616

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Novel In-Plane Semiconductor Lasers IX*, edited by Alexey A. Belyanin, Peter M. Smowton, Proceedings of SPIE Vol. 7616 (SPIE, Bellingham, WA, 2010) Article CID Number.

ISSN 0277-786X
ISBN 9780819480125

Published by

SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Copyright © 2010, Society of Photo-Optical Instrumentation Engineers

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/10/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

ix Conference Committee

SESSION 1 LOW DIMENSIONAL MATERIAL

- 7616 02 **Unique lasing mechanism of localized dispersive nanostructures in InAs/InGaAlAs quantum dash broad interband laser** [7616-01]
C. L. Tan, Lehigh Univ. (United States); H. S. Djie, JDS Uniphase Corp. (United States); C. K. Tan, The Univ. of Sheffield (United Kingdom); B. S. Ooi, Lehigh Univ. (United States) and KAUST (Saudi Arabia)
- 7616 05 **Random population of InAs-GaAs quantum dots** [7616-04]
I. O'Driscoll, M. Hutchings, P. M. Smowton, P. Blood, Cardiff Univ. (United Kingdom)
- 7616 06 **Dual-state lasing and the case against the phonon bottleneck** [7616-05]
P. Spencer, J. Shi, E. Clarke, R. Murray, Imperial College London (United Kingdom); M. Majid, D. Childs, R. Alexander, K. Groom, R. Hogg, The Univ. of Sheffield (United Kingdom)

SESSION 2 MATERIALS + MODE-LOCKING

- 7616 07 **Pulse characteristics of passively mode-locked quantum dot lasers (Invited Paper)** [7616-06]
L. F. Lester, The Univ. of New Mexico (United States); D. J. Kane, Mesa Photonics (United States); N. G. Usechak, Air Force Research Lab. (United States); C.-Y. Lin, Y. Li, The Univ. of New Mexico (United States); Y.-C. Xin, IBM Systems and Technology Group (United States); V. Kovanic, Air Force Research Lab. (United States)
- 7616 08 **Improved performance of GaAsSb/GaAs SQW lasers** [7616-07]
N. Hossain, S. R. Jin, S. J. Sweeney, Univ. of Surrey (United Kingdom); S.-Q. Yu, S. R. Johnson, D. Ding, Y.-H. Zhang, Arizona State Univ. (United States)
- 7616 0A **A platform for GaAs opto-electronic integrated circuits based on GaAs/AlGaAs regrowth upon patterned InGaP** [7616-10]
K. M. Groom, B. J. Stevens, P. D. L. Greenwood, D. T. D. Childs, J. S. Roberts, M. Lomas, M. Hugues, H. Shahid, R. Hogg, The Univ. of Sheffield (United Kingdom)

SESSION 3 MODE-LOCKING AND DYNAMICS

- 7616 0C **Progress on compact ultrafast quantum dot based lasers (Invited Paper)** [7616-12]
E. U. Rafailov, M. A. Cataluna, Univ. of Dundee (United Kingdom)

| | |
|---------|---|
| 7616 0D | Double-interval harmonic mode-locking technique for diverse waveform generation [7616-13] Y. Li, F. L. Chiragh, The Univ. of New Mexico (United States); Y.-C. Xin, IBM Systems and Technology Group (United States); C.-Y. Lin, L. F. Lester, The Univ. of New Mexico (United States) |
| 7616 0F | Linewidth enhancement factor and dynamical response of an injection-locked quantum-dot Fabry-Perot laser at 1310nm [7616-15] M. Pochet, N. A. Naderi, The Univ. of New Mexico (United States); N. Terry, V. Kovanis, Air Force Research Lab. (United States); L. F. Lester, The Univ. of New Mexico (United States) |

SESSION 4 NITRIDES

| | |
|---------|---|
| 7616 0G | Progress of blue and green InGaN laser diodes (Invited Paper) [7616-16] S. Lutgen, A. Avramescu, T. Lermer, M. Schillgalies, D. Queren, J. Müller, D. Dini, A. Breidenassel, U. Strauss, OSRAM Opto Semiconductors GmbH (Germany) |
| 7616 0H | Lasing of semi-polar InGaN/GaN(1122) heterostructures grown on m-plane sapphire substrates [7616-17] A. Strittmatter, M. Teepe, C. Knollenberg, Z. Yang, C. Chua, N. M. Johnson, Palo Alto Research Ctr., Inc. (United States); P. Spiberg, Ostendo Technologies, Inc. (United States); V. Ivantsov, A. Syrkin, L. Shapovalov, A. Usikov, TDI, Inc. (United States) |

SESSION 5 QCLS I

| | |
|---------|---|
| 7616 0M | An aluminum-free mid-infrared quantum cascade laser [7616-22] M. Nobile, H. Detz, A. M. Andrews, P. Klang, W. Schrenk, Vienna Univ. of Technology (Austria); G. Strasser, Vienna Univ. of Technology (Austria) and Univ. at Buffalo, The State Univ. of New York (United States) |
| 7616 0N | Suppression of carrier leakage in 4.8 μm - emitting quantum cascade lasers [7616-23] D. Botez, J. C. Shin, L. J. Mawst, Univ. of Wisconsin-Madison (United States); I. Vurgaftman, J. R. Meyer, U.S. Naval Research Lab. (United States); S. Kumar, Massachusetts Institute of Technology (United States) |

SESSION 6 QCLS II (THZ QCLS)

| | |
|---------|---|
| 7616 0R | Surface-emitting THz sources based on difference-frequency generation in mid-infrared quantum cascade lasers [7616-27] M. Geiser, Harvard Univ. (United States) and ETH Zürich (Switzerland); C. Pfügl, Harvard Univ. (United States); A. Belyanin, Texas A&M Univ. (United States); Q. J. Wang, N. Yu, M. A. Belkin, Harvard Univ. (United States); T. Edamura, H. Kan, Hamamatsu Photonics K.K. (Japan); M. Fischer, A. Wittmann, J. Faist, ETH Zürich (Switzerland); F. Capasso, Harvard Univ. (United States) |
|---------|---|

SESSION 7 SILICON PHOTONICS: JOINT SESSION WITH CONFERENCE 7606

- 7616 OS **Thin film edge emitting lasers integrated onto silicon (Invited Paper)** [7616-28]
N. M. Jokerst, S. Palit, Duke Univ. (United States); J. Kirch, G. Tsvid, L. Mawst, T. Kuech, Univ. of Wisconsin-Madison (United States)
- 7616 OT **Compact hybrid Si microring lasers (Invited Paper)** [7616-29]
D. Liang, J. E. Bowers, Univ. of California, Santa Barbara (United States); M. Fiorentino, R. G. Beausoleil, Hewlett-Packard Labs. (United States)
- 7616 OV **Sb-based laser sources grown by molecular beam epitaxy on silicon substrates (Invited Paper)** [7616-31]
J. B. Rodriguez, L. Cerutti, P. Grech, G. Boissier, G. Narcy, E. Tournie, Institut d'Electronique du Sud, CNRS, Univ. Montpellier 2 (France)

SESSION 8 HIGH POWER / HIGH STABILITY

- 7616 0W **High-power spectrally-stable DBR semiconductor lasers designed for pulsing in the nanosecond regime** [7616-32]
J. K. O'Daniel, M. Achtenhagen, Photodigm, Inc. (United States)
- 7616 0X **High-power ultralow-noise semiconductor external cavity lasers based on low-confinement optical waveguide gain media (Invited Paper)** [7616-33]
P. W. Juodawlkis, W. Loh, F. J. O'Donnell, M. A. Brattain, J. J. Plant, MIT Lincoln Lab. (United States)
- 7616 0Y **Ultra high power, ultra low RIN up to 20 GHz 1.55 µm DFB AlGaInAsP laser for analog applications** [7616-34]
J.-R. Burie, G. Beuchet, M. Mimoun, P. Pagnod-Rossiaux, B. Ligat, J. C. Bertreux, J.-M. Rousselet, J. Dufour, P. Rougeolle, F. Laruelle, 3S Photonics (France)
- 7616 0Z **High-power, high-reliability, and narrow linewidth, Al-free DFB laser diode for Cs pumping (852nm)** [7616-35]
C. Cayron, V. Ligeret, P. Resneau, Y. Robert, O. Parillaud, M. Lecomte, M. Calligaro, Alcatel-Thales III-V Lab. (France); S. Bansropun, J. Nagle, Thales Research & Technology (France); M. Krakowski, Alcatel-Thales III-V Lab. (France)
- 7616 10 **High-power ridge waveguide DFB and DFB-MOPA lasers at 1064 nm with a vertical farfield angle of 15°** [7616-36]
O. Brox, F. Bugge, A. Ginolas, A. Klehr, P. Ressel, H. Wenzel, G. Erbert, G. Tränkle, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)

SESSION 9 QCLS III

- 7616 12 **High performance short wavelength InP-based quantum cascade lasers (Invited Paper)** [7616-38]
D. G. Revin, J. P. Commin, S. Y. Zhang, A. B. Krysa, K. Kennedy, J. W. Cockburn, The Univ. of Sheffield (United Kingdom)

- 7616 14 **Coherent transport in QCLs: a new theoretical approach** [7616-40]
A. Gordon, D. Majer, Optigo Systems Ltd. (Israel)
- 7616 15 **Room-temperature edge and surface-emitting distributed-feedback quantum cascade lasers without top cladding layers** [7616-41]
A. Bousseksou, J.-R. Coudeville, G. Xu, R. Colombelli, Institut d'Électronique Fondamentale, CNRS, Univ. Paris-Sud (France); C. Sirtori, Lab. MPQ, CNRS, Univ. Paris Diderot (France); G. Beaudoin, I. Sagnes, Lab. de Photonique et de Nanostructures, CNRS/LPN (France)

SESSION 10 QCLS IV

- 7616 17 **Heat transfer speed and phonon related phenomena in terahertz quantum cascade lasers (Invited Paper)** [7616-43]
G. Scamarcio, M. S. Vitiello, CNR-INFM Regional Lab. LIT, Univ. degli Studi di Bari (Italy)
- 7616 18 **Integrated tunable DBR quantum cascade lasers with 30 cm^{-1} tuning range at $4.7 \mu\text{m}$** [7616-44]
L. Cheng, X. Chen, F.-S. Choa, T. Worchesky, Univ. of Maryland, Baltimore County (United States)

SESSION 11 NOVEL MIR LASERS

- 7616 19 **Challenges for mid-IR interband cascade lasers (Invited Paper)** [7616-45]
I. Vurgaftman, M. Kim, C. S. Kim, W. W. Bewley, C. L. Canedy, J. R. Lindle, J. Abell, J. R. Meyer, U.S. Naval Research Lab. (United States)
- 7616 1A **Mid-infrared emitters utilizing intersublevel transitions in self assembled InAs quantum dots (Invited Paper)** [7616-46]
T. Ribaldo, Univ. of Massachusetts Lowell (United States); B. S. Passmore, Sandia National Labs. (United States); D. C. Adams, X. Qian, S. Vangala, W. D. Goodhue, Univ. of Massachusetts Lowell (United States); E. A. Shaner, Sandia National Labs. (United States); S. A. Lyon, Princeton Univ. (United States); D. Wasserman, Univ. of Massachusetts Lowell (United States)
- 7616 1B **InAs-based plasmon-waveguide interband cascade lasers** [7616-47]
Z. Tian, C. Chen, R. Q. Yang, T. D. Mishima, M. B. Santos, J. C. Keay, M. B. Johnson, The Univ. of Oklahoma (United States); J. F. Klem, Sandia National Labs. (United States)

SESSION 12 HIGH POWER I

- 7616 1E **Simulation of high brightness tapered lasers (Invited Paper)** [7616-50]
I. Esquivias, H. Odriozola, J. M. G. Tijero, L. Borruel, A. M. Mínguez, Univ. Politécnica de Madrid (Spain); N. Michel, M. Calligaro, M. Lecomte, O. Parillaud, M. Krakowski, Alcatel-Thales III-V Lab. (France)

- 7616 1F **Two-sections tapered diode lasers for 1 Gbps free-space optical communications with high modulation efficiency** [7616-51]
 N. Michel, M. Ruiz, M. Calligaro, Y. Robert, M. Lecomte, O. Parillaud, M. Krakowski, Alcatel-Thales III-V Lab. (France); I. Esquivias, H. Odriozala, J. M. G. Tijero, Univ. Politécnica de Madrid (Spain); C. H. Kwok, R. V. Penty, I. H. White, Univ. of Cambridge (United Kingdom)
- 7616 1G **Catastrophic optical mirror damage in diode lasers monitored during single pulse operation** [7616-52]
 J. W. Tomm, M. Ziegler, T. Elsaesser, Max-Born-Institut (Germany); H. E. Larsen, P. M. Petersen, P. E. Andersen, DTU Fotonik (Denmark) and Technical Univ. of Denmark (Denmark); S. Clausen, Risø-DTU (Denmark) and Technical Univ. of Denmark (Denmark); U. Zeimer, D. Fendler, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)
- 7616 1H **Comparison of 650 nm tapered lasers with different lateral geometries at output powers up to 1 W** [7616-53]
 B. Sumpf, P. Adamiec, J. Fricke, P. Ressel, H. Wenzel, G. Erbert, G. Tränkle, Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (Germany)

SESSION 13
HIGH POWER II

- 7616 1I **High-power high-brightness semiconductor lasers based on novel waveguide concepts (Invited Paper)** [7616-54]
 D. Bimberg, K. Posilovic, V. Kalosha, T. Kettler, D. Seidlitz, V. A. Shchukin, N. N. Ledentsov, Technische Univ. Berlin (Germany); N. Y. Gordeev, L. Y. Karachinsky, I. I. Novikov, M. V. Maximov, Y. M. Shernyakov, A. V. Chunareva, A.F. Ioffe Physical-Technical Institute (Russian Federation); F. Bugge, M. Weyers, Ferdinand-Braun-Institut (Germany)
- 7616 1J **High-peak-power pulse generation with GHz repetition rate using a Q-switched 1060nm DBR tapered laser** [7616-55]
 A. Klehr, B. Sumpf, K. H. Hasler, J. Fricke, A. Liero, T. Hoffmann, G. Erbert, G. Tränkle, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)
- 7616 1K **Novel single-mode fiber coupled broadband seed source for pulsed fiber laser systems** [7616-56]
 E. A. Zibik, B. Sverdlov, S. Mohrdiek, J. Troger, S. Pawlik, H.-U. Pfeiffer, N. Lichtenstein, Oclaro (Switzerland) AG (Switzerland)
- 7616 1L **High-power high-brightness semiconductor tapered diode lasers for the red and near infrared spectral range (Invited Paper)** [7616-57]
 B. Sumpf, H. Wenzel, G. Erbert, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)

SESSION 14 QCLS V

- 7616 1Q **Ring resonator-based surface emitting quantum cascade lasers (LASE Best Student Paper Award) [7616-62]**
E. Mujagić, C. Schwarzer, M. Nobile, H. Detz, S. Ahn, P. Klang, A. M. Andrews, W. Schrenk, C. Deutsch, K. Unterrainer, Technische Univ. Wien (Austria); J. Chen, Princeton Univ. (United States) and Shanghai Institute of Technical Physics (China); C. Gmachl, Princeton Univ. (United States); G. Strasser, Technische Univ. Wien (Austria) and SUNY at Buffalo (United States)
- 7616 1R **Near-infrared quenching effects on mid-infrared quantum cascade lasers [7616-63]**
D. Guo, F.-S. Choa, L. Cheng, X. Chen, Univ. of Maryland, Baltimore County (United States)

POSTER SESSION

- 7616 1T **Manipulation of optical modes in quantum dot laser diodes by selective oxidation of high aluminum content AlGaAs layers [7616-65]**
G. J. Michell, P. M. Smowton, Cardiff Univ. (United Kingdom); H. D. Summers, Swansea Univ. (United Kingdom)

Author Index

Conference Committee

Symposium Chair

E. Fred Schubert, Rensselaer Polytechnic Institute (United States)

Symposium Cochairs

Liang-Chy Chien, Kent State University (United States)

James G. Grote, Air Force Research Laboratory (United States)

Program Track Chair

Klaus P. Streubel, OSRAM Opto Semiconductors GmbH (Germany)

Conference Chairs

Alexey A. Belyanin, Texas A&M University (United States)

Peter M. Smowton, Cardiff University (United Kingdom)

Program Committee

Martin Achtenhagen, Photodigm, Inc. (United States)

Yasuhiko Arakawa, The University of Tokyo (Japan)

Dan Botez, University of Wisconsin-Madison (United States)

David Bour, Palo Alto Research Center, Inc. (United States)

Federico Capasso, Harvard University (United States)

Claire F. Gmachl, Princeton University (United States)

Michael Kneissl, Technische Universität Berlin (Germany)

Hui Chun Liu, National Research Council Canada (Canada)

Luke J. Mawst, University of Wisconsin-Madison (United States)

Jerry R. Meyer, U. S. Naval Research Laboratory (United States)

Jesper Mørk, Technical University of Denmark (Denmark)

Mario J. Paniccia, Intel Corporation (United States)

Richard V. Penty, University of Cambridge (United Kingdom)

Johann P. Reithmaier, Universität Kassel (Germany)

Nelson Tansu, Lehigh University (United States)

Session Chairs

1 Low Dimensional Material

Luke F. Lester, The University of New Mexico (United States)

2 Materials + Mode-Locking

Nelson Tansu, Lehigh University (United States)

- 3 Mode-Locking and Dynamics
Johann P. Reithmaier, Universität Kassel (Germany)
- 4 Nitrides
Michael Kneissl, Technische Universität Berlin (Germany)
- 5 QCLs I
Hui Chun Liu, National Research Council Canada (Canada)
- 6 QCLs II (THz QCLs)
Gottfried Strasser, Technische Universität Wien (Austria)
- 7 Silicon Photonics: Joint Session with Conference 7606
Mario J. Paniccia, Intel Corporation (United States)
- 8 High Power / High Stability
Martin Achtenhagen, Photodigm, Inc. (United States)
- 9 QCLs III
Jerry R. Meyer, U.S. Naval Research Laboratory (United States)
- 10 QCLs IV
Daniel M. Wasserman, University of Massachusetts Lowell
(United States)
- 11 Novel MIR lasers
Dan Botez, University of Wisconsin-Madison (United States)
- 12 High Power I
Luke J. Mawst, University of Wisconsin-Madison (United States)
- 13 High Power II
Walter Duncan, The University of Texas at Dallas (United States)
- 14 QCLs V
Christian J. Pflügl, Harvard University (United States)