

PROCEEDINGS OF SPIE

Novel In-Plane Semiconductor Lasers VIII

**Alexey A. Belyanin
Peter M. Smowton**
Editors

**26–29 January 2009
San Jose, California, United States**

Sponsored and Published by
SPIE

Volume 7230

Proceedings of SPIE, 0277-786X, v. 7230

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 VIII*, edited by Alexey A. Belyanin, Peter M. Smowton, Proceedings of SPIE Vol. 7230 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X

ISBN 9780819474766

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 © 2009, 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/09/\$18.00.

Printed in the United States of America.

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



SPIDigitalLibrary.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 NOVEL MATERIALS I

- 7230 03 **Metamorphic InGaAs telecom lasers on GaAs** [7230-02]
I. Tångring, Y. X. Song, Chalmers Univ. of Technology (Sweden); D. H. Wu, Z. C. Niu, Institute of Semiconductors (China); S. M. Wang, A. Larsson, Chalmers Univ. of Technology (Sweden)

SESSION 2 NOVEL MATERIALS II

- 7230 0A **Self pulsing quantum dot lasers for optical coherence tomography** [7230-09]
H. Liu, P. Smowton, G. Edwards, W. Drexler, Cardiff Univ. (United Kingdom); H. Summers, Swansea Univ. (United Kingdom)
- 7230 0B **Coherence length characteristics from broadband semiconductor emitters: superluminescent diodes versus broadband laser diodes** [7230-10]
C. E. Dimas, C. L. Tan, Lehigh Univ. (United States); H. S. Djie, JDS Uniphase Corp. (United States); B. S. Ooi, Lehigh Univ. (United States)
- 7230 0C **Multi-contact quantum dot superluminescent diodes for optical coherence tomography** [7230-11]
P. D. L. Greenwood, K. V. Patel, D. T. D. Childs, K. M. Groom, B. J. Stevens, M. Hopkinson, R. A. Hogg, The Univ. of Sheffield (United Kingdom)

SESSION 3 NITRIDES

- 7230 0E **Ultraviolet laser diodes on sapphire and AlN substrates (Invited Paper)** [7230-13]
M. Kneissl, Z. Yang, M. Teepe, N. M. Johnson, Palo Alto Research Center, Inc. (United States)
- 7230 0F **Impact of filamentation on the far-field of high power broad ridge (Al,In)GaN laser diodes** [7230-14]
H. Braun, S. Rogowsky, U. T. Schwarz, Univ. of Regensburg (Germany); S. Brüningshof, A. Lell, U. Strauß, OSRAM Opto Semiconductors GmbH (Germany)
- 7230 0G **Staggered InGaN quantum well diode lasers emitting at 500 nm** [7230-15]
H. Zhao, R. A. Arif, N. Tansu, Lehigh Univ. (United States)

SESSION 4 RING LASERS AND INTEGRATION

- 7230 0I **Semiconductor micro-ring and micro-disk lasers for all-optical switching (Invited Paper)** [7230-17]
M. Sorel, G. Mezösi, M. J. Strain, Univ. of Glasgow (United Kingdom)

- 7230 0J **Loss characterization of high-index-contrast ridge waveguide oxide-confined InAlGaAs quantum well racetrack ring-resonator lasers** [7230-18]
J. Wang, W. Yuan, C. S. Seibert, D. C. Hall, Univ. of Notre Dame (United States)

SESSION 5 INTEGRATION AND DEVICES FOR COMMs

- 7230 0M **A single comb laser source for short reach WDM interconnects** [7230-21]
G. L. Wojcik, D. Yin, A. R. Kovsh, Innolume, Inc. (United States); A. E. Gubenko, I. L. Krestnikov, S. S. Mikhlin, D. A. Livshits, Innolume GmbH (Germany); D. A. Fattal, M. Fiorentino, R. G. Beausoleil, Hewlett-Packard Labs. (United States)
- 7230 0N **Discrete mode lasers for communications applications (Invited Paper)** [7230-22]
L. P. Barry, Dublin City Univ. (Ireland); C. Herbert, D. Jones, Eblana Photonics, Ltd. (Ireland); A. Kaszubowska-Anandarajah, Dublin City Univ. (Ireland); B. Kelly, Eblana Photonics, Ltd. (Ireland); J. O'Carroll, Dublin City Univ. (Ireland) and Eblana Photonics, Ltd. (Ireland); R. Phelan, Eblana Photonics, Ltd. (Ireland); P. Anandarajah, K. Shi, Dublin City Univ. (Ireland); J. O'Gorman, Eblana Photonics, Ltd. (Ireland)
- 7230 0O **Multi-purpose InGaAsP buried heterostructure laser diodes for uncooled digital, analog, and wireless applications grown by molecular beam epitaxy and metal-organic chemical-vapor deposition** [7230-23]
G. W. Pickrell, H. L. Zhang, H. W. Ren, D. Zhang, Q. Xue, J. Um, H. C. Lin, K. A. Anselm, T. Makino, W. Y. Hwang, Applied Optoelectronics, Inc. (United States)

SESSION 6 MID-IR LASERS

- 7230 0R **High-performance interband cascade lasers emitting in the 2.9–4.2 μm wavelength range** [7230-26]
J. R. Lindle, C. S. Kim, M. Kim, W. W. Bewley, C. L. Canedy, I. Vurgaftman, J. R. Meyer, Naval Research Lab. (United States)
- 7230 0S **Recent progress in interband cascade lasers with separate confinement layers** [7230-27]
R. Q. Yang, Z. Tian, R. T. Hinkey, F. Zhao, Univ. of Oklahoma (United States); K. Mansour, C. J. Hill, Y. Qiu, Jet Propulsion Lab. (United States)
- 7230 0T **Rapid and minimally invasive quantum cascade wafer testing** [7230-28]
E. N. Bentil, F. Toor, A. J. Hoffman, M. D. Escarra, C. F. Gmachl, Princeton Univ. (United States)

SESSION 7 SILICON PHOTONICS: JOINT SESSION WITH CONFERENCE 7220

- 7230 0U **Grating based hybrid silicon lasers (Invited Paper)** [7230-29]
R. Jones, Intel Corp. (United States); A. W. Fang, Univ. of California, Santa Barbara (United States); M. N. Sysak, B. R. Koch, Intel Corp. (United States); E. Lively, H. Park, D. Liang, Univ. of California, Santa Barbara (United States); O. Raday, Intel Corp. (United States); J. E. Bowers, Univ. of California, Santa Barbara (United States)

SESSION 8 COMD

- 7230 0V **New approaches towards the understanding of the catastrophic optical damage process in in-plane diode lasers (Invited Paper)** [7230-30]
J. W. Tomm, M. Ziegler, V. Talalaev, C. Matthiesen, T. Elsaesser, Max-Born-Institut (Germany); M. Bou Sanayeh, P. Brick, M. Reufer, OSRAM Opto Semiconductors GmbH (Germany)
- 7230 0W **Bulk temperature mapping of broad area quantum dot lasers: modeling and micro-thermographic analysis** [7230-31]
J. Mukherjee, Univ. College Cork (Ireland); M. Ziegler, J. LeClech, J. W. Tomm, Max-Born-Institut (Germany); B. Corbett, J. G. McInerney, Univ. College Cork (Ireland); J. P. Reithmaier, Univ. Kassel (Germany); S. Deubert, A. Forchel, Univ. Würzburg (Germany)
- 7230 0X **Higher power density limit at COMD in GaInP/AlGaInP in quantum dots than in wells** [7230-32]
S. N. Elliott, P. M. Smowton, G. T. Edwards, Cardiff Univ. (United Kingdom); G. Berry, IQE, Ltd. (United Kingdom); A. B. Krysa, The Univ. of Sheffield (United Kingdom)
- 7230 0Y **Degradation processes in high power multi-mode InGaAs strained quantum well lasers** [7230-33]
Y. Sin, N. Presser, B. Foran, S. C. Moss, The Aerospace Corp. (United States)

SESSION 9 QUANTUM CASCADE LASERS I

- 7230 11 **High-power high-wall plug efficiency mid-infrared quantum cascade lasers based on InP/GaInAs/InAlAs material system (Invited Paper)** [7230-36]
M. Razeghi, Northwestern Univ. (United States)
- 7230 12 **Voltage tuning of gain spectra in quantum cascade lasers** [7230-46]
Y. Yao, K. J. Franz, Princeton Univ. (United States); Z. Liu, Princeton Univ. (United States) and Brown Univ. (United States); A. J. Hoffman, C. F. Gmachl, Princeton Univ. (United States)
- 7230 13 **Characteristics of deep-well 4.8- μ m emitting quantum-cascade lasers grown by MOCVD** [7230-38]
J. C. Shin, M. D'Souza, D. Xu, J. Kirch, L. J. Mawst, D. Botez, Univ. of Wisconsin-Madison (United States); I. Vurgaftman, J. R. Meyer, Naval Research Lab. (United States)

SESSION 10 QUANTUM CASCADE LASERS II

- 7230 15 **Coherence and beam shaping in quantum cascade lasers (Invited Paper)** [7230-40]
E. Mujagić, L. K. Hoffmann, S. Scharfner, M. Nobile, H. Detz, D. Andrijasevic, M. Austerer, W. Schrenk, A. M. Andrews, P. Klang, Technical Univ. of Vienna (Austria); M. P. Semtsiv, W. T. Masselink, Humboldt Univ. Berlin (Germany); G. Strasser, Technical Univ. of Vienna (Austria) and SUNY at Buffalo (United States)
- 7230 16 **Quantum cascade lasers based on single phonon-continuum depopulation structures** [7230-41]
K. Fujita, T. Edamura, N. Akikusa, A. Sugiyama, T. Ochiai, S. Furuta, A. Ito, M. Yamanishi, H. Kan, Hamamatsu Photonics K.K. (Japan)

- 7230 17 **Intracavity second harmonic generation in quantum cascade lasers in the telecommunication range** [7230-42]
Y.-H. Cho, A. Belyanin, Texas A&M Univ. (United States)

SESSION 11 QUANTUM CASCADE LASER PHYSICS

- 7230 19 **Predictive quantum theory of current and optical emission in quantum cascade lasers (Invited Paper)** [7230-44]
T. Kubis, P. Vogl, Technische Univ. München (Germany)
- 7230 1A **Simulation of gain in quantum cascade lasers (Invited Paper)** [7230-45]
A. Wacker, R. Nelandar, C. Weber, Lund Univ. (Sweden)

SESSION 12 HIGH POWER I

- 7230 1B **External-to-cavity lateral-mode harnessing devices for high-brightness broad-area laser diodes: concept, realizations, and perspectives (Invited Paper)** [7230-47]
N. Stelmakh, Univ. of Texas, Arlington (United States)
- 7230 1D **High-brightness tapered lasers with an Al-free active region at 1060 nm** [7230-49]
M. Ruiz, Alcatel-Thales III-V Lab. (France); H. Odriozola, Univ. Politécnica de Madrid (Spain); C. H. Kwok, Univ. of Cambridge (United Kingdom); N. Michel, M. Calligaro, M. Lecomte, O. Parillaud, M. Krakowski, Alcatel-Thales III-V Lab. (France); J. M. G. Tijero, I. Esquivias, Univ. Politécnica de Madrid (Spain); R. V. Penty, I. H. White, Univ. of Cambridge (United Kingdom)
- 7230 1E **1060 nm DBR tapered lasers with 12 W output power and a nearly diffraction limited beam quality** [7230-50]
B. Sumpf, K.-H. Hasler, P. Adamiec, F. Bugge, J. Fricke, P. Ressel, H. Wenzel, G. Erbert, G. Tränkle, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)
- 7230 1F **High-power DBR laser diodes grown in a single epitaxial step** [7230-51]
L. Jiang, M. Achtenhagen, N. V. Amarasinghe, P. Young, G. Evans, Photodigm, Inc. (United States)

SESSION 13 HIGH POWER II

- 7230 1G **Coherent combination of slab-coupled optical waveguide lasers (Invited Paper)** [7230-52]
R. K. Huang, B. Chann, L. J. Missaggia, S. J. Augst, M. K. Connors, G. W. Turner, A. Sanchez-Rubio, J. P. Donnelly, MIT Lincoln Lab. (United States); J. L. Hostetler, C. Miester, F. Dorsch, TRUMPF Photonics (United States)
- 7230 1H **High-power high-reliability narrow-linewidth Al-free DFB laser diode for Cs pumping (852 nm)** [7230-53]
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)

- 7230 1I **High power DFB lasers for D1 and D2 rubidium absorption spectroscopy and atomic clocks** [7230-54]
A. Klehr, H. Wenzel, O. Brox, F. Bugge, G. Erbert, T.-P. Nguyen, G. Tränkle, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)
- 7230 1J **Ultra-fine pitch individually addressable visible laser arrays for high speed digital printing applications** [7230-55]
O. P. Kowalski, S. D. McDougall, B. C. Qiu, G. H. Masterton, M. L. Armstrong, S. Robertson, S. Caldecott, J. H. Marsh, Intense, Ltd. (United Kingdom)
- 7230 1K **Diode laser arrays for 1.8 to 2.3 μm wavelength range** [7230-56]
M. T. Kelemen, J. Gilly, m2k-laser GmbH (Germany); M. Haag, J. Biesenbach, DILAS Diodenlaser GmbH (Germany); M. Rattunde, J. Wagner, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany)
- 7230 1L **Control of slow axis mode behavior with waveguide phase structures in semiconductor broad-area lasers** [7230-61]
H.-C. Eckstein, U. D. Zeitner, Fraunhofer Institute for Applied Optics and Precision Engineering (Germany); W. Schmid, U. Strauss, OSRAM Opto Semiconductors (Germany)

SESSION 14 MID-IR APPLICATIONS

- 7230 1M **High performance results and applications of miniaturized external-cavity quantum cascade lasers (ECqCL) (Invited Paper)** [7230-57]
T. Day, M. Weida, D. Arnone, M. Pushkarsky, R. Pritchett, D. Caffey, Daylight Solutions, Inc. (United States)
- 7230 1O **Native-oxide-confined mid-IR quantum cascade lasers via non-selective oxygen-enhanced wet oxidation** [7230-59]
C. S. Seibert, Univ. of Notre Dame (United States); M. D'Souza, J. C. Shin, L. J. Mawst, D. Botez, Univ. of Wisconsin, Madison (United States); D. C. Hall, Univ. of Notre Dame (United States)
- 7230 1P **Effect of waveguide side-wall roughness on the performance of quantum cascade lasers** [7230-60]
F. Toor, Princeton Univ. (United States); D. L. Sivco, Alcatel-Lucent (United States); C. F. Gmachl, Princeton Univ. (United States)

Author Index

Conference Committee

Symposium Chair

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

Symposium Cochair

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

Program Track Chair

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

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)

Gary A. Evans, Southern Methodist 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, Naval Research Laboratory (United States)

Jesper Mørk, Danmarks Tekniske Universitet (Denmark)

Mario J. Paniccia, Intel Corporation (United States)

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

Johann Peter Reithmaier, Universität Kassel (Germany)

Nelson Tansu, Lehigh University (United States)

Session Chairs

1 Novel Materials I

Nelson Tansu, Lehigh University (United States)

- 2 Novel Materials II
Richard V. Penty, University of Cambridge (United Kingdom)
- 3 Nitrides
Ulrich Schwarz, Universität Regensburg (Germany)
Michael Uneissl, Technische Universität Berlin (Germany)
- 4 Ring Lasers and Integration
Johann Peter Reithmaier, Universität Kassel (Germany)
- 5 Integration and Devices for Comms
Gadi Eisenstein, Technion-Israel Institute of Technology (Israel)
- 6 Mid-IR Lasers
Alexey A. Belyanin, Texas A&M University (United States)
- 7 Silicon Photonics: Joint Session with Conference 7220
Mario J. Paniccia, Intel Corporation (United States)
- 8 COMD
Paul Crump, Ferdinand-Braun-Institut für Höchstfrequenztechnik (Germany)
- 9 Quantum Cascade Lasers I
W. Ted Masselink, Humboldt- Universität zu Berlin (Germany)
- 10 Quantum Cascade Lasers II
Rui Q. Yang, University of Oklahoma (United States)
- 11 Quantum Cascade Laser Physics
Jerry R. Meyer, Naval Research Laboratory (United States)
- 12 High Power I
Luke J. Mawst, University of Wisconsin, Madison (United States)
- 13 High Power II
Martin Achtenhagen, Photodigm, Inc. (United States)
- 14 Mid-IR Applications
Christian J. Pflügl, Harvard University (United States)