

PROCEEDINGS OF SPIE

Vertical-Cavity Surface-Emitting Lasers XXII

Chun Lei
Kent D. Choquette
Editors

31 January – 1 February 2018
San Francisco, California, United States

Sponsored and Published by
SPIE

Volume 10552

Proceedings of SPIE 0277-786X, V. 10552

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

Vertical-Cavity Surface-Emitting Lasers XXII, edited by Chun Lei, Kent D. Choquette, Proc. of SPIE
Vol. 10552, 1055201 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2323069

Proc. of SPIE Vol. 10552 1055201-1

The papers 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. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers 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 these proceedings:

Author(s), "Title of Paper," in *Vertical-Cavity Surface-Emitting Lasers XXII*, edited by Chun Lei, Kent D. Choquette, Proceedings of SPIE Vol. 10552 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510615892
ISBN: 9781510615908 (electronic)

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 © 2018, 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/18/\$18.00.

Printed in the United States of America.

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

**SPIE. DIGITAL
LIBRARY**

SPIEDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five 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.

Contents

- v *Authors*
- vii *Conference Committee*
- ix *Introduction*

SESSION 1 DATA COMM VCSELS

- 10552 02 **50 Gb/s NRZ and 4-PAM data transmission over OM5 fiber in the SWDM wavelength range (Invited Paper)** [10552-1]
- 10552 04 **Behavioral modeling of VCSELS for high-speed optical interconnects (Invited Paper)** [10552-3]
- 10552 05 **VCSEL noise characterization for data rates beyond 25Gb/s** [10552-4]

SESSION 2 NEW VCSEL PHENOMENA

- 10552 06 **Mode selection and tuning of single-frequency short-cavity VCSELS (Invited Paper)** [10552-5]
- 10552 07 **Thermally stable surface-emitting tilted wave laser** [10552-6]
- 10552 08 **Quantum-cascade vertical-cavity surface-emitting laser integrated with monolithic high-contrast grating** [10552-7]
- 10552 09 **Demonstrating ultrafast polarization dynamics in spin-VCSELS** [10552-8]
- 10552 0A **Electrical birefringence tuning of VCSELS** [10552-9]

SESSION 3 PUSHING THE WAVELENGTH AND OUTPUT POWER

- 10552 0B **Room temperature continuous wave mid-infrared VCSEL operating at 3.35 μ m** [10552-10]
- 10552 0E **Low-divergence high-power VCSEL arrays for lidar application (Invited Paper)** [10552-14]

SESSION 4 NEW VCSEL APPLICATIONS

- 10552 0G **VCSELS in short-pulse operation for time-of-flight applications (Invited Paper)** [10552-15]
- 10552 0I **Wavelength tunable MEMS VCSELS for OCT imaging** [10552-17]

1055 0J **The vertical-cavity surface-emitting laser incorporating a high contrast grating mirror as a sensing device** [10552-18]

SESSION 5 MODULATION PROPERTIES

10552 0L **Integration of electro-absorption modulator in a vertical-cavity surface-emitting laser** [10552-20]

10552 0M **The influence of the VCSEL design on its electrical modulation properties** [10552-21]

10552 0N **Simplicity VCSELs** [10552-22]

10552 0O **Impact of the top DBR in GaAs-based VCSELs on the threshold current and the cavity photon lifetime** [10552-23]

10552 0P **Temperature stable oxide-confined 850nm VCSELs operating at bit rates up to 25Gbit/s at 150°C** [10552-24]

Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Agustin, M., 02, 07, 0P
Almuneau, G., 0L
Ansbæk, Thor, 0I
Arnoult, A., 0L
Block, Matthew K., 0E
Burgner, C., 0B
Calvez, S., 0L
Carson, Richard F., 0E
Cazabat, A., 0B
Cheng, An-Nien, 05
Chi, K. L., 02, 0P
Chu, Jason, 05
Cole, G. D., 0B
Czyszanowski, Tomasz, 08, 0J, 0M, 0N
Dacha, Preethi, 0E
Dems, Maciej, 08, 0J
Deutsch, C., 0B
Feng, Zheng-Wen, 05
Follman, D., 0B
Frasunkiewicz, Leszek, 0N
Gębski, Marcin, 0J, 0M, 0N, 0O
Geib, Kent M., 06
Gerhardt, Nils C., 09, 0A
Giovane, Laura M., 05
Gordeev, N. Yu, 07
Grine, Alejandro J., 06
Gronenborn, Stephan, 0G
Grzempa, Sandra, 08
Gu, Xi, 0G
Gudde, Ralph, 0G
Haghighi, Nasibeh, 0N, 0O
Hains, Christopher P., 06
Hansen, Ole, 0I
Harren, Ann L., 05
Helms, Christopher J., 0E
Herper, Markus, 0G
Heu, P., 0B
Hofmann, Martin R., 09, 0A
Jayaraman, V., 0B
Kalosha, V. P., 02, 07, 0P
Keeler, Gordon A., 06
Khan, Z., 02, 0P
Kocot, Chris, 04
Kolb, Johanna, 0G
Komar, Paulina, 0M, 0O
Kropp, J.-R., 02, 07, 0P
Kulagina, M. M., 07
Larisch, Gunter, 0N
Lascola, K., 0B
Ledentsov, Jr., N., 02, 07, 0P
Ledentsov, N. N., 02, 07, 0P
Lindemann, Markus, 09, 0A
Lott, James A., 0J, 0M, 0N, 0O
Marciniak, Magdalena, 0J, 0M
Marigo-Lombart, L., 0L
Maximov, M. V., 07
Maynard, John, 0E
Michalzik, Rainer, 09, 0A
Miller, Michael, 0G
Moench, Holger, 0G
Murty, M. V. Ramana, 05
Nakwaski, Włodzimierz, 08
Ottaviano, Luisa, 0I
Panajotov, Krassimir, 0J, 0L
Payusov, A. S., 07
Peake, Gregory M., 06
Piskorski, Łukasz, 0J
Podva, David, 0E
Pusch, Tobias, 09, 0A
Rosales, Ricardo, 0M, 0N, 0O
Rumeau, A., 0L
Sahoo, Hitesh Kumar, 0I
Sarzała, Robert P., 0O
Segal, S., 0B
Semenova, Elizaveta, 0I
Serkland, Darwin K., 06
Shchukin, V. A., 02, 07, 0P
Shernyakov, Yu. M., 07
Shi, J. W., 02, 0P
Smeets, Michael, 0G
So, Haley M., 06
Śpiewak, Patrycja, 0M, 0O
Sulmoni, Luca, 0M
Szczerba, Krzysztof, 04
Thienpont, H., 0L
Towner, F., 0B
Viallon, C., 0L
Walczak, Jarosław, 0O
Wang, Jingyi, 05
Warren, Mial E., 0E
Wasiak, Michał, 0J, 0M, 0O
Weigl, Alexander, 0G
Więckowska, Marta, 0O
Wood, Michael G., 06
Yvind, Kresten, 0I
Zhukov, A. E., 07
Zubov, F. I., 07

Conference Committee

Symposium Chairs

Connie J. Chang-Hasnain, University of California, Berkeley
(United States)

Graham T. Reed, Optoelectronics Research Centre, University of
Southampton (United Kingdom)

Symposium Co-chairs

Jean Emmanuel Broquin, IMEP-LAHC (France)

Shibin Jiang, AdValue Photonics, Inc. (United States)

Program Track Chair

Klaus P. Streubel, OSRAM AG (Germany)

Conference Chairs

Chun Lei, Lumentum (United States)

Kent D. Choquette, University of Illinois (United States)

Conference Program Committee

Nicolae Chitica, Finisar Corporation (Sweden)

Aaron James Danner, National University of Singapore (Singapore)

Martin Grabherr, Philips Technologie GmbH U-L-M Photonics
(Germany)

James K. Guenter, Finisar Corporation (United States)

Anders Larsson, Chalmers University of Technology (Sweden)

James A. Lott, Technische Universität Berlin (Germany)

M. V. Ramana Murty, Avago Technologies Ltd. (United States)

Krassimir Panajotov, Vrije Universiteit Brussel (Belgium)

Darwin K. Serkland, Sandia National Laboratories (United States)

Jean-Francois Seurin, Princeton Optronics, Inc. (United States)

Noriyuki Yokouchi, Furukawa Electric Company, Ltd. (Japan)

Jongseung Yoon, The University of Southern California (United States)

Mial E. Warren, TriLumina Corporation (United States)

Session Chairs

1 Data Comm VCSELS

Kent D. Choquette, University of Illinois (United States)

- 2 New VCSEL Phenomena
Chun Lei, Lumentum (United States)
- 3 Pushing the Wavelength and Output Power
James A. Lott, Technische Universität Berlin (Germany)
- 4 New VCSEL Applications
Darwin K. Serkland, Sandia National Laboratories (United States)
- 5 Modulation Properties
James Guenter, Finisar Corporation (United States)