

PROCEEDINGS OF SPIE

Silicon Photonics XIII

Graham T. Reed
Andrew P. Knights
Editors

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

Sponsored and Published by
SPIE

Volume 10537

Proceedings of SPIE 0277-786X, V. 10537

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

Silicon Photonics XIII, edited by Graham T. Reed, Andrew P. Knights, Proc. of SPIE
Vol. 10537, 1053701 · © 2018 SPIE · CCC code: 0277-786X/18/\$18
doi: 10.1117/12.2322595

Proc. of SPIE Vol. 10537 1053701-1

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 SPIDigitalLibrary.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 *Silicon Photonics XIII*, edited by Graham T. Reed, Andrew P. Knights, Proceedings of SPIE Vol. 10537 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510615595
ISBN: 9781510615601 (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**

SPIDigitalLibrary.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

vii	<i>Authors</i>
ix	<i>Conference Committee</i>

FABRICATION AND MANUFACTURING

10537 03	Challenges and solutions for high-volume testing of silicon photonics (Invited Paper) [10537-1]
10537 04	A self-aligned dry etching method for mechanical strain enhancement of germanium and its uniformity improvement for photonic applications [10537-2]
10537 06	Optimization of H₂ thermal annealing process for the fabrication of ultra-low loss sub-micron silicon-on-insulator rib waveguides [10537-4]

WAVEGUIDES

10537 09	A hybrid SOI/SiN photonic platform for high-speed and temperature-insensitive CWDM optical transceivers [10537-7]
10537 0A	2D materials integrated in Si₃N₄ photonics platform [10537-8]
10537 0B	Silicon nitride photonics: from visible to mid-infrared wavelengths [10537-9]

MODULATORS II: JOINT SESSION WITH CONFERENCES 10536 AND 10537

10537 0H	Silicon modulators with optimized vertical PN junctions for high-modulation-efficiency and low-loss in the O-band (Invited Paper) [10537-15]
----------	---

SILICON PHOTONIC SYSTEMS

10537 0K	Application of quantum-dot multi-wavelength lasers and silicon photonic ring resonators to data-center optical interconnects (Invited Paper) [10537-19]
10537 0L	Packaging of silicon photonic devices: from prototypes to production (Invited Paper) [10537-20]
10537 0N	Hybrid integrated single-wavelength laser with silicon micro-ring reflector [10537-22]

GERMANIUM INTEGRATION

10537 OR **Ge-rich graded-index $\text{Si}_{1-x}\text{Ge}_x$ devices for MID-IR integrated photonics** [10537-26]

LIGHT-EMITTING STRUCTURES

10537 OV **3D hybrid integrated lasers for silicon photonics** [10537-30]

**HYBRID SILICON OPTICAL SYSTEMS AND DEVICES I: JOINT SESSION WITH CONFERENCES
10537 AND 10538**

10537 OX **Defect-related degradation of III-V/Silicon 1.55 μm DBR laser diodes** [10537-32]

**HYBRID SILICON OPTICAL SYSTEMS AND DEVICES II: JOINT SESSION WITH CONFERENCES
10537 AND 10538**

10537 OZ **Design of phase change $\text{Ge}_2\text{Sb}_2\text{Te}_5$ based on-off electro-optic switch** [10537-34]

ADVANCED COMMUNICATION

10537 11 **New dynamic silicon photonic components enabled by MEMS technology (Invited Paper)**
[10537-36]

10537 12 **Ultra-narrow-linewidth erbium-doped lasers on a silicon photonics platform** [10537-37]

NOVEL APPLICATIONS AND PROCESSES II

10537 14 **Silicon photonic integrated devices for mode-/polarization-manipulations (Invited Paper)**
[10537-39]

10537 17 **Compact silicon photonics-based multi laser module for sensing** [10537-42]

POSTER SESSION

10537 18 **Silicon single mode waveguide modulator based upon switchable Bragg reflector**
[10537-43]

10537 1A **Boolean processing by cascaded all-optical devices via intra-bit phase encoding**
[10537-45]

10537 1B **Photonic molecules for application in silicon-on-insulator optical sensors** [10537-46]

- 10537 1C **Silicon-nitride/oxynitride wavelength demultiplexer and resonators for quantum photonics**
[10537-47]
- 10537 1D **Development of silicon hybrid SPAD 1D arrays for lidar and spectrometer applications**
[10537-48]
- 10537 1E **Strain analysis of SiGe microbridges** [10537-50]
- 10537 1F **Ring-patterned plasmonic photonic crystal thermal light source for miniaturized near-infrared spectrometers** [10537-51]
- 10537 1G **Silicon slot waveguide dispersion analysis and engineering through dynamic excess carrier generation** [10537-52]
- 10537 1I **Design of hybrid laser structures with QD-RSOA and silicon photonic mirrors** [10537-54]
- 10537 1L **Optimized optical devices for edge-coupling-enabled silicon photonics platform**
[10537-57]
- 10537 1M **Monolithic integration of SOI waveguide photodetectors and transimpedance amplifiers**
[10537-58]
- 10537 1N **Waveguide integrated graphene mid-infrared photodetector** [10537-59]
- 10537 1O **Experimental verification of layout physical verification of silicon photonics** [10537-60]
- 10537 1Q **A parametric approach for exploring grating coupler design space** [10537-62]
- 10537 1S **Broadband athermal waveguides and devices for datacom and telecom applications**
[10537-64]

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.

Adachi, Shunsuke, 1D
Adam, Thomas N., 12
Adelmini, L., 09
Agarwal, Anuradha M., 1S
Ahmed, Samy, 1I
Alonso-Ramos, C., 0R
Ang, Norman Soo Seng, 1C
Ang, Thomas Y. L., 0H, 1C, 1L
Anthony, Ross, 1E
Aspiotis, N. K., 1N
Ayotte, S., 17
Azogui, Jonathan, 18
Baba, Takashi, 1D
Babin, A., 17
Baldycheva, Anna, 0A, 12
Ballabio, A., 0R
Bardella, Paolo, 1I
Barea, Luis A. M., 1B
Bassani, Jose W. M., 1B
Beckett, Douglas J. S., 0K
Bédard, K., 17
Bellegarde, Cyril, 06
Benedetti, Alessio, 1I
Benedikovic, D., 0R
Bergman, Keren, 03
Bilodeau, G., 17
Björk, Joel, 1I
Blanchet-Létoir, J., 17
Bovington, Jock, 1I
Bowers, John E., 0X
Bradley, Jonathan D. B., 12
Bravo, T., 1Q
Bru, Luis A., 0B
Buffolo, Matteo, 0X
Businaro, Luca, 18
Cao, Bin, 0K
Cao, W., 1N
Carroll, Lee, 0L
Catellan, Alvaro R. G., 1B
Chen, G. F. R., 1L
Chen, Rong, 0K
Cheng, Qixiang, 03
Chrétien, P., 17
Ciasca, Gabriele, 18
Cirera, Josep M., 0B
Cirino, Giuseppe A., 1B
Colangelo, Marco, 1I
Coolbaugh, Douglas, 12
Costin, F., 17
Craciun, Monica, 0A
Crowe, Iain, 1E
Dai, D., 14
Dai, Liang Yuan, 03
D'Amato, D., 17
Davenport, Michael L., 0X
Davidson, C.-A., 17
De Santi, Carlo, 0X
Dhingra, Nikhil, 0Z
Doménech, David, 0B
Domínguez, Carlos, 0B
Edinger, Pierre, 1I
El Shamy, Raghi S., 1O
Elsayed, Ahmed A., 1F
Errando-Herranz, Carlos, 1I
Faneca, Joaquin, 0A
Fernández, Juan, 0B
Filion, B., 17
Fowler, D., 09
Frateschi, Newton C., 1B
Frigerio, J., 0R
Gandhi, Alagappan, 1C
Garcia, S., 09
Gerardino, Annamaria, 18
Ghosh, Souvik, 0Z
Gilbank, Ashley, 1E
Gioannini, Mariangela, 1I
Girard-Deschênes, E., 17
Gonzaga, Leonard, 0N
Gothoskar, Prakash, 1I
Gradkowski, Kamil, 0L
Guo, Tina X., 1L
Guo, Yuhao, 1S
Gylfason, Kristinn B., 1I
Han, Zhaohong, 1S
Hartmann, Jean-Michel, 06
Hassan, K., 09
He, Liuqing, 1S
Hickey, Ryan, 0K
Hogan, Benjamin T., 0A
Hosseini, Ehsan S., 12
Huang, C. C., 1N
Isella, G., 0R
Ismail, Yehea, 1G
Jiang, Xiaohui, 14
Khalil, Diaa, 1F
Khokhar, A. Z., 1N
Kimerling, Lionel C., 1S
Klamkin, J., 0V

Knights, Andrew P., 0K, 1E
 Krishnamurthy, Vivek, 0N
 Labib, Shady R., 1F
 Laplante, M., 17
 Le Roux, X., 0R
 Leake, Gerald, 12
 Lee, Chee-Wei, 0N
 Lee, Kwang Hong, 04
 Lemonnier, Olivier, 06
 Li, Chenlei, 14
 Li, Dongdong, 0N
 Li, Guifang, 1S
 Li, Nanxi, 12
 Li, Shuxia, 1M
 Lim, Soon Thor, 0H, 1C, 1L
 Lin, Yiding, 04
 Liu, Erhu, 14
 Liu, Q., 0R
 Liu, Y., 0V
 Logan, Dylan F., 0K
 Lu, Ding, 1C
 Lyan, Philippe, 06
 Ma, Danhao, 04
 Madsen, C. K., 1Q
 Magden, E. Salih, 12
 Malhouitre, S., 09
 Marris-Morini, D., 0R
 Mashanovich, G. Z., 1N
 Megalini, L., 0V
 Meiri, Amihai, 1A
 Mekawey, Hosam I., 1G
 Meneghesso, Gaudenzio, 0X
 Meneghini, Matteo, 0X
 Michel, Jurgen, 04, 1S
 Micó, Gloria, 0B
 Moras, Andre L., 1B
 Moresco, Michele, 12
 Morgan, K. A., 1N
 Morin, M., 17
 Morrissey, Pdraic E., 0L
 Muñoz, Pascual, 0B
 Nagano, Terumasa, 1D
 Nakamura, Shigeyuki, 1D
 Nedeljkovic, M., 1N
 Niklaus, Frank, 11
 O'Brien, Peter, 0L
 Oikonomou, Michail, 03
 Olivier, S., 09
 Ong, Jun Rong, 0H, 1C, 1L
 Osman, A. M., 1N
 Paré-Olivier, G., 17
 Pargon, Erwine, 06
 Pastor, Daniel, 0B
 Perron, L.-P., 17
 Petit-Etienne, Camille, 06
 Pinna, S., 0V
 Plantier, S., 09
 Png, Ching Eng, 0H, 1C, 1L
 Polster, Robert, 03
 Pu, Jing, 0N
 Purnawirman, Purnawirman, 12
 Qi, Y., 1N
 Qu, Z., 1N
 Rahman, B. M. A., 0Z
 Ramirez, J. M., 0R
 Ramon, Yonathan, 18
 Ren, Min, 0N
 Ribaud, Karen, 06
 Robin-Brosse, D., 09
 Rumley, Sebastien, 03
 Sabry, Yasser M., 1F
 Sahin, Ezgi, 1L
 Sánchez, Ana, 0B
 Sciancalepore, Corrado, 06, 09
 Singh, Gurpreet, 12
 Singh, Neetesh, 12
 Siriani, Dominic, 11
 Soler Penades, J., 1N
 Song, B., 0V
 Song, Junchao, 0Z
 Souza, Mario C. M. M., 1B
 Stemme, Göran, 11
 Sun, Jie, 12
 Swillam, Mohamed A., 1G, 1O
 Tan, Chuan Seng, 04
 Tan, D. T. H., 1L
 Tan, Ying, 14
 Tarr, N. Garry, 1M
 Teng, Jinghua, 1C
 Teo, Ee Jin, 1C
 Tjiptoharsono, Febi, 0N
 Toh, Yeow T., 0N
 Torres Alonso, E., 0A
 Traverso, Matt, 11
 Trivellin, Nicola, 0X
 Vakarin, V., 0R
 Vivien, L., 0R
 Von Zuben, Antonio A. G., 1B
 Wada, Kazumi, 1S
 Wang, Hong, 1L
 Wang, Qian, 0N
 Watts, Michael R., 12
 Wheeldon, Jeffery F., 0K
 Wilmart, Q., 09
 Wu, Hao, 14
 Wu, Y., 1N
 Xu, Zhengji, 0N
 Yamamoto, Koei, 1D
 Ye, Winnie N., 1M
 Zalevsky, Zeev, 18, 1A
 Zanoni, Enrico, 0X
 Zhang, Lin, 1S
 Zhou, Linjie, 0Z

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 Chairs

Yakov Sidorin, Quarles & Brady LLP (United States)

Benjamin Dingel, Nasfine Photonics, Inc. (United States)

Conference Chairs

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

Andrew P. Knights, McMaster University (Canada)

Conference Program Committee

Martijn J. R. Heck, Aarhus University (Denmark)

Siegfried Janz, National Research Council Canada (Canada)

Goran Z. Mashanovich, University of Southampton (United Kingdom)

Jurgen Michel, Massachusetts Institute of Technology (United States)

Ching Eng Jason Png, A*STAR Institute of High Performance
Computing (Singapore)

Andrew W. Poon, Hong Kong University of Science and Technology
(Hong Kong, China)

Haisheng Rong, Intel Corporation (United States)

Dries Van Thourhout, University Gent (Belgium)

Laurent Vivien, Institut d'Électronique Fondamentale (France)

William Whelan-Curtin, Tyndall National Institute (Ireland)

Jeremy Witzens, RWTH Aachen Universität (Germany)

Shui-Qing Yu, University of Arkansas (United States)

Zhiping Zhou, Peking University (China)

Aaron J. Zilkie, Rockley Photonics (United States)

Session Chairs

- 1 Fabrication and Manufacturing
Andrew P. Knights, McMaster University (Canada)
- 2 Waveguides
Jason Ching Eng Png, A*STAR Institute of High Performance Computing (Singapore)
- 3 Novel Applications and Processes I
Pavel Cheben, National Research Council Canada (Canada)
- 4 Modulators I: Joint Session with Conferences 10536 and 10537
Andrew P. Knights, McMaster University (Canada)
- 5 Modulators II: Joint Session with Conferences 10536 and 10537
Sailing He, KTH Royal Institute of Technology (Sweden)
- 6 Silicon Photonic Systems
Andrew P. Knights, McMaster University (Canada)
- 7 Germanium Integration
Graham T. Reed, Optoelectronics Research Centre, University of Southampton (United Kingdom)
- 8 Light-Emitting Structures
Joan Manel Ramírez, Centre de Nanosciences et de Nanotechnologies (France)
- 9 Hybrid Silicon Optical Systems and Devices I: Joint Session with Conferences 10537 and 10538
Alan X. Wang, Oregon State University (United States)
- 10 Hybrid Silicon Optical Systems and Devices II: Joint Session with Conferences 10537 and 10538
Andrew P. Knights, McMaster University (Canada)
- 11 Advanced Communication
Graham T. Reed, Optoelectronics Research Centre, University of Southampton (United Kingdom)
- 12 Novel Applications and Processes II
Callum G. Littlejohns, Nanyang Technological University (Singapore)