

# PROCEEDINGS OF SPIE

## ***Silicon Photonics XIV***

**Graham T. Reed**  
**Andrew P. Knights**  
Editors

**4–6 February 2019**  
**San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 10923**

Proceedings of SPIE 0277-786X, V. 10923

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

Silicon Photonics XIV, edited by Graham T. Reed, Andrew P. Knights, Proc. of SPIE Vol. 10923  
1092301 · © 2019 SPIE · CCC code: 0277-786X/19/\$18 · doi: 10.1117/12.2531300

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](http://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 *Silicon Photonics XIV*, edited by Graham T. Reed, Andrew P. Knights, Proceedings of SPIE Vol. 10923 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510624887

ISBN: 9781510624894 (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 © 2019, 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](http://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/19/\$18.00.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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



---

**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 | Authors              |
| ix  | Conference Committee |

---

## SESSION 1 FABRICATION TECHNOLOGY

---

- 10923 04 **Alignment-tolerant interfacing of a photonic integrated circuit using back side etched silicon microlenses** [10923-3]
- 10923 05 **High-yield parallel transfer print integration of III-V substrate-illuminated C-band photodiodes on silicon photonic integrated circuits** [10923-4]
- 10923 06 **Challenges and solutions for high-speed integrated silicon photonics** [10923-5]

---

## SESSION 2 SILICON WAVEGUIDES I

---

- 10923 08 **Suspended low-loss germanium waveguides for the longwave-infrared** [10923-7]

---

## SESSION 3 AMPLIFIED SILICON PHOTONICS

---

- 10923 0E **1.3 $\mu$ m U-bend traveling wave SOA devices for high efficiency coupling to silicon photonics** [10923-13]

---

## SESSION 4 SILICON PHOTONIC SENSORS

---

- 10923 0G **Silicon photonic integrated circuit for on-chip spectroscopic gas sensing (Invited Paper)** [10923-15]

- 10923 0H **Miniaturization of mid-IR sensors on Si: challenges and perspectives (Invited Paper)** [10923-16]

- 10923 0I **Integration of mid-infrared SOI photonics with microfluidics** [10923-18]

---

**SESSION 5 NEW APPLICATIONS OF SILICON PHOTONICS**

---

- 10923 0L **Photonic thermometry: upending 100 year-old paradigm in temperature metrology (Invited Paper)** [10923-19]
- 10923 0M **Astrophotonics: a promising arena for silicon photonics (Invited Paper)** [10923-20]
- 10923 0N **Sub-wavelength grating cavity optomechanics** [10923-21]

---

**SESSION 6 SILICON WAVEGUIDES II**

---

- 10923 0P **Wide spectral range operational and fabrication tolerant Si-wire WDM (de)multiplexers for optical interconnects** [10923-23]
- 10923 0Q **Temperature-insensitive echelle wavelength demultiplexer on standard silicon-on-insulator platform** [10923-24]
- 10923 0R **Germanium ion implantation for trimming the coupling efficiency of silicon racetrack resonators** [10923-25]
- 10923 0S **Low loss germanium-on-silicon waveguides for integrated mid-infrared photonics** [10923-26]

---

**SESSION 7 NONLINEAR SILICON PHOTONICS**

---

- 10923 0W **Spectral engineering of photonic filters using mode splitting in silicon nanowire integrated standing-wave resonators** [10923-30]

---

**SESSION 8 SILICON/GERMANIUM INTEGRATION**

---

- 10923 0Y **Ge-rich SiGe-based wideband polarization insensitive photonic platform for mid-infrared free-space communications** [10923-32]

---

**SESSION 9 INTEGRATED OPTICAL EMISSION**

---

- 10923 13 **Enhanced light emission from a Si photonics beam steering device consisting of asymmetric photonic crystal waveguide** [10923-37]

---

**SESSION 10 DEVICE TECHNOLOGY**

---

- 10923 17 **Generation of O-band PAM-4 signal using a silicon modulator driven by two binary sequences** [10923-40]
- 10923 18 **Model and design of silicon photonic carrier-depletion Mach-Zehnder modulators for 400Gb/s and beyond PAM and QAM applications** [10923-41]
- 10923 1A **50Gbps Si photonic crystal slow light modulator by the electro-optic phase matching** [10923-43]

---

**POSTER SESSION**

---

- 10923 1C **Two-dimensional subwavelength grating-based waveguide-to-fiber coupler** [10923-45]
- 10923 1E **Nested silicon-on-insulator Vernier effect microring resonators** [10923-47]
- 10923 1F **Compound period grating coupler for double beam generation and steering** [10923-48]
- 10923 1G **Parametric analysis of silicon nanowire based ring resonator** [10923-49]
- 10923 1H **Optimization of silicon on silica waveguides for mid-infrared applications at 4.28 μm** [10923-50]
- 10923 1I **A novel 350nm CMOS optical receiver based on a current-assisted photodiode detector** [10923-51]
- 10923 1J **Low-loss coupling interfaces between InP-based emitters and Si<sub>3</sub>N<sub>4</sub> photonic integrated circuits** [10923-52]
- 10923 1K **Novel silicon-on-insulator Michelson interferometer for optical filtering and wavelength demultiplexing applications** [10923-53]
- 10923 1M **A compact silicon-on-insulator gas sensor** [10923-55]
- 10923 1N **Silicon-based plasmonic nanoantennas** [10923-56]
- 10923 1O **Electro-optical modulator using silicon on insulator Michelson interferometer with electro-optical polymer** [10923-57]
- 10923 1P **Silicon photonics dual-coupler nested coupled cavities** [10923-58]
- 10923 1R **Tunable integrated optical modulator with dynamical photonic band transition of photonic crystals** [10923-61]
- 10923 1S **Novel spot-size converter for broadband and polarization insensitive coupling to conventional single-mode fiber** [10923-62]

10923 1U **Slotted electro-optic ring resonator as a tunable optical power splitter** [10923-64]

10923 1V **Broadband electro-optic modulator based on a phase-change material embedded in silicon photonic crystal slab waveguide** [10923-65]

# 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.

- |                                |                                 |
|--------------------------------|---------------------------------|
| Aalto, Timo, 0E                | Gautam, Abhinav, 1G             |
| Abe, Hiroshi, 13               | Gay, M., 17                     |
| Adib, George A., 1P            | Ghosh, Rajib R., 1U, 1V         |
| Afifi, Abdelrahman E., 1K, 1O  | Glière, Alain, 0H               |
| Ahmed, Zeeshan, 0L             | Glodde, Martin, 0G              |
| Akiyama, Daichi, 13            | Govdeli, Alperen, 1R            |
| Aktas, Ozan, 0R                | Goyvaerts, Jeroen, 05           |
| Alonso-Ramos, Carlos, 0Y       | Green, William M. J., 0G        |
| Ang, Thomas Y. L., 06          | Griskeviciute, U., 0S           |
| Arai, Hiroyuki, 1A             | Guina, Mircea, 0E               |
| Baba, Toshihiko, 13, 1A        | Guo, Wei, 1F                    |
| Badr, Mohamed, 1K              | Gupta, Nitin, 1V                |
| Baldassarre, L., 0S            | Hamood, Mustafa, 1E             |
| Ballabio, Andrea, 0Y           | Herman, Tobias, 0L              |
| Banakar, Mehdi, 0I             | Hinakura, Yosuke, 1A            |
| Barritault, Pierre, 0H         | Hong, Jin, 18                   |
| Barwicz, Tymon, 0G             | Ingelberts, Hans, 1I            |
| Bashir, Janib, 1U              | Isella, Giovanni, 0Y            |
| Baudot, C., 17                 | Ismail, Yehea, 1N               |
| Bhardwaj, Priyanka, 1V         | Ito, Hiroyuki, 13               |
| Bland-Hawthorn, J., 0M         | Jaeger, Nicolas A. F., 1E       |
| Boeuf, F., 17                  | Janz, Siegfried, 0Q             |
| Boulanger, Sven, 1I            | Jeong, Seok-Hwan, 0P            |
| Bramerie, L., 17               | Ketzaki, D., 1J                 |
| Chatzitheocharis, D., 1J       | Khalil, Diaa, 1H, 1P            |
| Cheben, Pavel, 0Q, 0Y          | Khokhar, Ali Z., 08, 0R         |
| Chen, Xia, 0R                  | Klimov, Nikolai, 0L             |
| Cherchi, Matteo, 0E            | Kocaman, Serdar, 1R             |
| Chong, Harold M. H., 0R        | Kohli, Niharika, 1S             |
| Chrostowski, Lukas, 1E         | Kuijk, Maarten, 1I              |
| Corbett, Brian, 05             | Kumari, Sulakshna, 05           |
| Coutard, Jean-Guillaume, 0H    | Kundagrami, Raunak, 0L          |
| Dabos, G., 1J                  | Kusunoki, Yuma, 13              |
| Das, Abhijit, 1U               | Labeye, Pierre, 0H, 0N          |
| Delâge, André, 0Q              | Leon-Saval, S. G., 0M           |
| Deniel, L., 17                 | Le Roux, Xavier, 0Y             |
| Dhawan, Anuj, 1U, 1V           | Lim, Soon Thor, 06              |
| Douglass, Kevin, 0L            | Liu, Qiankun, 0Y                |
| Duraffourg, Laurent, 0H, 0N    | Mangal, N., 04                  |
| El Shamy, Raghi S., 1K, 1M, 1O | Marchant, Adrien, 0H            |
| Ellis, S. C., 0M               | Marris-Morini, Delphine, 0Y, 17 |
| El-Rayany, Mohamed M., 1K, 1M  | Martin, Yves, 0G                |
| Fédéli, Jean-Marc, 0H, 0N      | Mashanovich, Goran Z., 08, 0I   |
| Fitzgerald, Ryan, 0L           | Mekawey, Hosam I., 1N           |
| Fournier, Maryse, 0H           | Melati, Daniele, 0Q             |
| Frigerio, Jacopo, 0Y           | Millar, R. W., 0S               |
| Gad, Michael, 1H, 1P           | Milosevic, Milan M., 0R         |
| Gallacher, K., 0S              | Missinne, J., 04                |
| Gasser, Anas, 1I               | Mistry, Ajay, 1E                |

- Mittal, Vinita, 0I  
 Moein, Tania, 0W  
 Moss, David J., 0W  
 Muliuk, Grigorij, 05  
 Nedeljkovic, Milos, 08, 0I  
 Nicoletti, Sergio, 0H  
 Ong, Jun Rong, 06  
 Oo, Swe Zin, 0R  
 Orcutt, Jason S., 0G  
 Ortolani, M., 0S  
 Osama, Aya A., 1O  
 Osman, A., 08  
 Ozolins, O., 17  
 Paul, D. J., 0S  
 Peacock, Anna C., 0R  
 Pérez-Galacho, D., 17  
 Peucheret, C., 17  
 Png, Ching Eng, 06  
 Priye, Vishnu, 1G  
 Purdy, Thomas P., 0L  
 Qi, Yanli, 0I  
 Qu, Z., 08  
 Ramírez, Joan Manel, 0Y  
 Reed, Graham T., 0R  
 Roelkens, Günther, 04, 05  
 Rowe, David J., 0I  
 Sabry, Yasser M., 1H, 1P  
 Saito, Shinichi, 0R  
 Sarangi, Smruti R., 1U  
 Schares, Laurent, 0G  
 Schmid, Jens H., 0Q  
 Selim, Mahmoud A., 1P  
 Shalaby, Rabab A., 1P  
 Singh, Anamika, 1C  
 Singh, Ritu Raj, 1C, 1G  
 Snyder, B., 04  
 Sobhy, Mina, 1H  
 Soler Penades, J., 08  
 Sorel, M., 0S  
 Subramanian , Senthil, 1V  
 Swillam, Mohamed A., 1K, 1M, 1N, 1O  
 Taurel, Boris, 0N  
 Teigell Benéitez, N., 04  
 Teng, Chu C., 0G  
 Tetsuya, Ryo, 13  
 Teulle, Alexandre, 0H  
 Thomson, David J., 0R  
 Tuorila, Heidi, 0E  
 Vakarin, Vladyslav, 0Y  
 Van Campenhout, J., 04  
 Van den Dries, Thomas, 1I  
 Van Steenberge, G., 04  
 Van Thourhout, Dries, 05  
 Vasiliev, A., 04  
 Verly, Pierre G., 0Q  
 Viheriälä, Jukka, 0E  
 Vivien, Laurent, 0Y, 17  
 Vrysokinos, K., 1J  
 Wang, Jian, 18  
 Wilkinson, James S., 0I  
 Wu, Dachuan, 1F  
 Wu, Jiayang, 0W  
 Wu, Yangbo, 08, 0I  
 Wysocki, Gerard, 0G  
 Xiong, Chi, 0G  
 Xu, Dan-Xia, 0Q  
 Xu, Xingyuan, 0W  
 Ye, Winnie N., 0Y, 1S  
 Yi, Yasha, 1F  
 Yu, Xingshi, 0R  
 Zhang, Eric J., 0G  
 Zhang, Jing, 04, 05  
 Zhang, Qun, 18  
 Zhang, Yuning, 0W  
 Zhou, Jianying, 18  
 Zhu, Likai, 18  
 Zia, Nouman, 0E

# 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

- Sailing He**, KTH Royal Institute of Technology (Sweden) and Zhejiang University (China)  
**Yasuhiro Koike**, Keio University (Japan)

## Program Track Chairs

- Yakov Sidorin**, Quarles & Brady LLP (United States)  
**Jean-Emmanuel Broquin**, IMEP-LAHC (France)

## 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)  
**Delphine Marris-Morini**, Centre de Nanosciences et de Nanotechnologies (France)  
**Goran Z. Mashanovich**, University of Southampton (United Kingdom)  
**Jurgen Michel**, Massachusetts Institute of Technology (United States)  
**Liam O'Faolain**, Tyndall National Institute (Ireland)  
**Jason Ching Eng 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**, Universiteit Gent (Belgium)  
**Laurent Vivien**, Centre de Nanosciences et de Nanotechnologies (France)  
**Jeremy Witzens**, RWTH Aachen University (Germany)

**Winnie N. Ye**, Carleton University (Canada)  
**Shui-Qing Yu**, University of Arkansas (United States)  
**Zhiping Zhou**, Peking University (China)  
**Aaron J. Zilkie**, Rockley Photonics (United States)

Session Chairs

- 1 Fabrication Technology  
**Graham T. Reed**, Optoelectronics Research Centre, University of Southampton (United Kingdom)
- 2 Silicon Waveguides I  
**Jonathan D. B. Bradley**, McMaster University (Canada)
- 3 Amplified Silicon Photonics  
**Andrew P. Knights**, McMaster University (Canada)
- 4 Silicon Photonic Sensors  
**Delphine Marris-Morini**, Centre de Nanosciences et de Nanotechnologies (France)
- 5 New Applications of Silicon Photonics  
**Graham T. Reed**, Optoelectronics Research Centre, University of Southampton (United Kingdom)
- 6 Silicon Waveguides II  
**Callum G. Littlejohns**, University of Southampton (United Kingdom)
- 7 Nonlinear Silicon Photonics  
**Andrew P. Knights**, McMaster University (Canada)
- 8 Silicon/Germanium Integration  
**Andrew P. Knights**, McMaster University (Canada)
- 9 Integrated Optical Emission  
**Iain F. Crowe**, The University of Manchester (United Kingdom)
- 10 Device Technology  
**Graham T. Reed**, Optoelectronics Research Centre, University of Southampton (United Kingdom)