

PROCEEDINGS OF SPIE

# ***Smart Photonic and Optoelectronic Integrated Circuits XVI***

**Louay A. Eldada**  
**El-Hang Lee**  
**Sailing He**  
*Editors*

**5–6 February 2014**  
**San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 8989**

Proceedings of SPIE 0277-786X, V. 8989

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

Smart Photonic and Optoelectronic Integrated Circuits XVI, edited by Louay A. Eldada, El-Hang Lee,  
Sailing He, Proc. of SPIE Vol. 8989, 898901 · © 2014 SPIE · CCC code: 0277-786X/14/\$18  
doi: 10.1117/12.2063959

Proc. of SPIE Vol. 8989 898901-1

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 *Smart Photonic and Optoelectronic Integrated Circuits XVI*, edited by Louay A. Eldada, El-Hang Lee, Sailing He, Proceedings of SPIE Vol. 8989 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819499028

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 © 2014, 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/14/\$18.00.

Printed in the United States of America.

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



[SPIDigitalLibrary.org](http://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 as 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

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

---

## SESSION 1    **ADVANCED ACTIVE OEICs**

---

- 8989 04    **High quality large area ELOG InP on silicon for photonic integration using conventional optical lithography (Invited Paper) [8989-3]**  
H. Kataria, W. T. Metaferia, C. Junesand, KTH Royal Institute of Technology (Sweden);  
C. Zhang, J. E. Bowers, Univ. of California, Santa Barbara (United States); S. Lourduoss,  
KTH Royal Institute of Technology (Sweden)
- 8989 05    **Photonic Mach-Zehnder modulators driven by surface acoustic waves in AlGaAs technology [8989-4]**  
A. Crespo-Poveda, Univ. de València (Spain); B. Gargallo, Univ. Politècnica de València  
(Spain); I. Artundo, J. D. Doménech, VLC Photonics S.L. (Spain); P. Muñoz, Univ. Politècnica  
de València (Spain) and VLC Photonics S.L. (Spain); R. Hey, K. Biermann, A. Tahraoui,  
P. V. Santos, Paul-Drude-Institut für Festkörperelektronik (Germany); A. Cantarero,  
M. M. de Lima Jr., Univ. de València (Spain)

---

## SESSION 2    **OPTICAL PHASED ARRAY OEICs**

---

- 8989 07    **Fully integrated hybrid silicon free-space beam steering source with 32-channel phased array (Invited Paper) [8989-6]**  
J. C. Hulme, J. K. Doyle, M. J. R. Heck, J. D. Peters, M. L. Davenport, J. T. Bovington,  
L. A. Coldren, J. E. Bowers, Univ. of California, Santa Barbara (United States)

---

## SESSION 3    **PICs FOR OPTICAL INTERCONNECTS: JOINT SESSION WITH CONFERENCES 8989 AND 8991**

---

- 8989 08    **Silicon nanophotonics integration for chip-scale optical communication (Invited Paper) [8989-7]**  
A. Grieco, Univ. of California, San Diego (United States); D. T. H. Tan, Singapore Univ. of  
Technology and Design (Singapore); K. Ikeda, Nara Institute of Science and Technology  
(Japan); M. P. Nezhad, Univ. of California, San Diego (United States) and RWTH Aachen  
(Germany); M. Puckett, Y. Fainman, Univ. of California, San Diego (United States)
- 8989 09    **Optical transceiver ICs based on 3D die-stacking of optoelectronic devices (Invited Paper) [8989-8]**  
H. J. S. Dorren, P. Duan, O. Raz, Technische Univ. Eindhoven (Netherlands)

---

**SESSION 4    ADVANCED HYBRID PICs**

---

- 8989 0A    **2D and 3D heterogeneous photonic integrated circuits (Invited Paper)** [8989-9]  
S. J. B. Yoo, Univ. of California, Davis (United States)
- 8989 0C    **Observation of optically induced transparency effect in silicon nanophotonic wires with graphene** [8989-11]  
L. Yu, J. Zheng, D. Dai, Zhejiang Univ. (China); S. He, Zhejiang Univ. (China) and KTH Royal Institute of Technology (Sweden)

---

**SESSION 5    ADVANCES IN SILICON PHOTONICS AND OPTOELECTRONICS**

---

- 8989 0D    **Recent results in silicon photonics at the University of Southampton (Invited Paper)** [8989-12]  
G. T. Reed, G. Z. Mashanovich, F. Y. Gardes, D. J. Thomson, Y. Hu, J. Soler-Penades, M. Nedeljkovic, A. Z. Khokhar, P. Thomas, C. Littlejohns, A. Ahmad, S. Reynolds, R. Topley, C. Mitchell, S. Stankovic, N. Owens, X. Chen, P. R. Wilson, L. Ke, T. M. Ben Masaud, A. Tarazona, H. Chong, Univ. of Southampton (United Kingdom)
- 8989 0F    **Electronic interfaces to silicon photonics (Invited Paper)** [8989-14]  
A. L. Lentine, J. A. Cox, W. A. Zortman, D. J. Savignou, Sandia National Labs. (United States)
- 8989 0G    **Design methodologies for silicon photonic integrated circuits (Invited Paper)** [8989-15]  
L. Chrostowski, J. Flueckiger, The Univ. of British Columbia (Canada); C. Lin, Univ. of Delaware (United States); M. Hochberg, Univ. of Delaware (United States), National Univ. of Singapore (Singapore), and Agency for Science, Technology and Research (A\*STAR) (Singapore); J. Pond, J. Klein, Lumerical Solutions, Inc. (Canada); J. Ferguson, C. Cone, Mentor Graphics Corp. (United States)
- 8989 0H    **Traveling wave electrode design for ultra compact carrier-injection HBT-based electroabsorption modulator in a 130nm BiCMOS process** [8989-16]  
E. Fu, V. Joyner Koomson, Tufts Univ. (United States); P. Wu, Z. R. Huang, Rensselaer Polytechnic Institute (United States)
- 8989 0I    **An integrated CMOS detection system for optical short-pulse** [8989-17]  
C.-G. Kim, N.-P. Hong, Y.-W. Choi, Chung-Ang Univ. (Korea, Republic of)

---

**SESSION 6    SMART PHOTON MANIPULATION SYSTEMS**

---

- 8989 0J    **Local slow-light engineering: Correlating out-of-plane phenomena with in-plane optical processing (Invited Paper)** [8989-18]  
K. Mnaymneh, Univ. of Michigan (United States)
- 8989 0K    **Towards optoelectronic architectures for integrated neuromorphic computers** [8989-19]  
R. Martinenghi, A. Baylon Fuentes, M. Jacquot, Y. K. Chembo, L. Larger, FEMTO-ST Institute, CNRS (France)

- 8989 OL **Precision alignment of integrated optics in surface electrode ion traps for quantum information processing** [8989-20]  
A. L. Young, J. D. Hunker, A. R. Ellis, S. Samora, J. R. Wendt, D. L. Stick, Sandia National Labs. (United States)

---

**SESSION 7 SMART OPTOELECTRONIC SENSING SYSTEMS**

---

- 8989 ON **Monolithic device for on-chip fast optical phase conjugation integrating an image sensor and a spatial light modulator** [8989-22]  
T. Laforest, A. Verdant, A. Dupret, CEA-LETI (France); S. Gigan, F. Ramaz, Institut Langevin, ESPCI Paris Tech, CNRS (France); G. Tessier, Neurophysiology and New Microscopies Lab., INSERM, CNRS, Univ. Paris Descartes (France); É. Benoit à la Guillaume, Institut Langevin, ESPCI Paris Tech, CNRS (France)
- 8989 OP **Glucose sensing by means of silicon photonics (Invited Paper)** [8989-24]  
R. Bockstaele, E. Ryckeboer, N. Hattasan, Y. De Koninck, M. Muneeb, S. Verstuyft, D. Delbeke, W. Bogaerts, G. Roelkens, R. Baets, Univ. Gent (Belgium)
- 8989 OQ **A novel phase-sensitive SPR biosensor array based on prism phase modulator** [8989-25]  
G. Ye, W. Yang, L. Jiang, J. Qian, S. He, KTH Royal Institute of Technology (Sweden), Lund Univ. (Sweden), and Zhejiang Univ. (China)

---

**SESSION 8 MODE CONVERSION AND POLARIZATION CONTROL STRUCTURES**

---

- 8989 OS **Mode conversion/coupling in submicron silicon-on-insulator optical waveguides and the applications (Invited Paper)** [8989-27]  
D. Dai, Zhejiang Univ. (China)
- 8989 OT **Metal membrane with dimer slots as a universal polarizer** [8989-28]  
S. Zhukovsky, M. Zalkovskij, R. Malureanu, Technical Univ. of Denmark (Denmark); C. Kremers, Bergische Univ. Wuppertal (Germany); D. Chigrin, Bergische Univ. Wuppertal (Germany) and RWTH Aachen (Germany); P. T. Tang, IPU (Denmark); P. U. Jepsen, A. V. Lavrinenko, Technical Univ. of Denmark (Denmark)

---

**POSTER SESSION**

---

- 8989 OV **Low-loss and low-crosstalk graded-index polymer optical waveguide circuit fabricated using an imprint method** [8989-30]  
Y. Yamashita, T. Ishigure, Keio Univ. (Japan)
- 8989 OW **Inter-channel crosstalk in densely aligned multimode polymer parallel optical waveguides** [8989-31]  
T. Kudo, T. Ishigure, Keio Univ. (Japan)

*Author Index*

# Conference Committee

## *Symposium Chairs*

**David L. Andrews**, University of East Anglia Norwich (United Kingdom)  
**Alexei L. Glebov**, OptiGrate Corporation (United States)

## *Symposium Co-chairs*

**Jean Emmanuel Broquin**, IMEP-LAHC (France)  
**Shibin Jiang**, AdValue Photonics, Inc. (United States)

## *Program Track Chair*

**Yakov Sidorin**, Quarles & Brady LLP (United States)

## *Conference Chairs*

**Louay A. Eldada**, Quanergy, Inc. (United States)  
**El-Hang Lee**, Inha University (Korea, Republic of)  
**Sailing He**, KTH Royal Institute of Technology (Sweden)

## *Conference Program Committee*

**Ray T. Chen**, The University of Texas at Austin (United States)  
**Shanhui Fan**, Stanford University (United States)  
**Chennupati Jagadish**, The Australian National University (Australia)  
**Jürgen Jahns**, FernUniversität Hagen (Germany)  
**David V. Plant**, McGill University (Canada)  
**Andrew W. Poon**, Hong Kong University of Science and Technology  
(Hong Kong, China)  
**Ali Serpengüzel**, Koç University (Turkey)  
**Michael Watts**, Massachusetts Institute of Technology (United States)  
**Dan-Xia Xu**, National Research Council Canada (Canada)

## *Session Chairs*

- 1 Advanced Active OEICs  
**Sailing He**, KTH Royal Institute of Technology (Sweden)
- 2 Optical Phased Array OEICs  
**Louay A. Eldada**, Quanergy, Inc. (United States)

- 3 PICs for Optical Interconnects: Joint Session with Conferences 8989 and 8991  
**Louay A. Eldada**, Quanergy, Inc. (United States)
- 4 Advanced Hybrid PICs  
**Sailing He**, KTH Royal Institute of Technology (Sweden)
- 5 Advances in Silicon Photonics and Optoelectronics  
**El-Hang Lee**, Inha University (Korea, Republic of)
- 6 Smart Photon Manipulation Systems  
**Louay A. Eldada**, Quanergy, Inc. (United States)
- 7 Smart Optoelectronic Sensing Systems  
**El-Hang Lee**, Inha University (Korea, Republic of)
- 8 Mode Conversion and Polarization Control Structures  
**El-Hang Lee**, Inha University (Korea, Republic of)

## Introduction

This volume features contributions from scientists and engineers in the areas of smart photonic integrated circuits (PIC) and optoelectronic integrated circuits (OEIC), together referred to as smart photonic and optoelectronic integrated circuits (SPOEIC). Photonic, optical, electronic, optoelectronic, photovoltaic, microwave, biological, and fluidic devices are integrated monolithically or using hybrid solutions to address the need for rapid progress in cost, space, performance, and reliability in an increasingly complex and connected world with dynamic environments that can benefit from smart solutions comprising integrated micro- and nano-scale circuits with artificial intelligence.

Demands for greater bandwidths have driven the telecom and datacom research and development communities to realize complex optoelectronic integrated circuits such as transceivers, switching systems, low chirp optical sources, and multichannel optical distribution systems. The integration of multi-wavelength laser arrays, monitoring photodiodes, and drivers is becoming a reality in the communications arena. Other emerging fields include 3D time of flight (TOF) sensing/scanning, real-time 3D imaging/mapping, 3D printing, holographic displays, smart pixel arrays, neural networks, optical computing, optical data storage, medical diagnostics, chemical/biological sensing, and object detection, tracking, identification, and classification.

The increased level of integration in recent years has resulted in an increased level of miniaturization, so we covered in this volume the emerging field of smart VLSI PICs, nanoscale and quantum OEICs, systems on a chip, as well as electronics and photonics convergence on a silicon CMOS platform.

The scientific and technological issues and challenges concerning the micro/nano/quantum-scale integration of optoelectronic devices, circuits, components, modules, subsystems and systems include the size effect, proximity effect, energy confinement effect, microcavity effect, single photon effect, optical interference effect, high field effect, noise effect, quantum optical effect, nonlinear effects, and chaotic noise effects. Optical alignment between miniature devices, minimizing interconnection and coupling losses, maintaining optical modes between devices, and maintaining the stability of optical interfaces, are some of the important issues that are receiving careful consideration.

Papers in these proceedings include discussions of the physics, theory, design, modeling, simulation, and scaling of a wide range of smart PICs and OEICs with regard to their optical, electrical, thermal and mechanical properties; the integration of different optoelectronic structure types including dots, wires, rings, disks, spheres, cavities, wells, planar, free space, one-dimensional, two-dimensional and three-dimensional photonics crystals, plasmonics and

metamaterials; the integration of different functions including lasers, amplifiers, detectors, sensors, solar cells, modulators, isolators, circulators, electrically-actuated/all-optical switches, attenuators, phased arrays, couplers, multi/demultiplexers, filters, wavelength converters, polarization controllers, chromatic/polarization mode dispersion compensators, intra-chip/chip-to-board/board-level optical interconnects, and control electronics; the fabrication, processing, and manufacturing techniques (UV/deep UV/X-ray/e-beam lithography, casting, molding, embossing, etching, passivation, etc.) as well as the packaging, assembly, reliability, qualification and certification of monolithic and hybrid OEICs and PICs in a variety of materials (semiconductors, glasses, polymers, ferroelectrics, magnetics, metals, biomaterials, etc.).

Applications include communications, quantum information services, computing, data storage, sensing, scanning, imaging, mapping, displays, printing, industrial automation, and robotization. Smart systems include nodes in self-healing optical communication networks, as well as light detection and ranging (LiDAR) sensing systems with object detection, tracking, identification, and classification capability for autonomous vehicles.

Some papers describe the refinement of existing schemes and processes, while others introduce novel concepts and new designs. Papers from academic and research institutions push the state of the art in miniaturization, level of integration, and performance figures of merit, and papers from the industry emphasize design criteria and manufacturing methods that result in practical OEICs and PICs that can be deployed commercially today or in the near future.

Although this volume cannot include all the recent important work in the vast field comprising OEICs and PICs, it does cover a significant cross-section of the advances happening globally in areas where these components are making an impact, and it provides a roadmap to the future of OEICs and PICs by presenting the cutting-edge work and the visions of leading experts who are actively inventing the future.

**Louay A. Eldada**  
**El-Hang Lee**  
**Sailing He**