

PROCEEDINGS OF SPIE

# ***Optoelectronic Integrated Circuits XIII***

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

**26–27 January 2011  
San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 7942**

Proceedings of SPIE, 0277-786X, v. 7942

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 *Optoelectronic Integrated Circuits XIII*, edited by Louay A. Eldada, El-Hang Lee, Proceedings of SPIE Vol. 7942 (SPIE, Bellingham, WA, 2011) Article CID Number.

ISSN 0277-786X

ISBN 9780819484796

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 © 2011, 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/11/\$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](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 OPTOELECTRONIC DEVICES FOR OPTICAL INTERCONNECTS: JOINT SESSION WITH CONFERENCE 7944**

---

- 7942 02 **Free-space-wave add/drop multiplexing for WDM optical interconnect system in package (Invited Paper) [7942-01]**  
S. Ura, Kyoto Institute of Technology (Japan); K. Kintaka, National Institute of Advanced Industrial Science and Technology (Japan)
- 7942 03 **Three-dimensional crossbar interconnection using planar-integrated free-space optics and digital mirror-device (Invited Paper) [7942-02]**  
U. Lohmann, J. Jahns, Univ. of Hagen (Germany); S. Limmer, D. Fey, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany)

---

## **SESSION 2 SI PHOTONICS FOR OPTICAL INTERCONNECTS: JOINT SESSION WITH CONFERENCE 7944**

---

- 7942 04 **Devices and architectures for large-scale integrated silicon photonics circuits (Invited Paper) [7942-03]**  
R. G. Beausoleil, A. Faraon, D. Fattal, M. Fiorentino, Z. Peng, C. Santori, Hewlett-Packard Labs. (United States)
- 7942 05 **CMOS compatible waveguides for all-optical signal processing (Invited Paper) [7942-04]**  
D. J. Moss, The Univ. of Sydney (Australia); A. Pasquazi, M. Peccianti, L. Razzari, D. Duchesne, M. Ferrera, Institut National de la Recherche Scientifique (Canada); S. Chu, B. E. Little, Infinera Corp. (United States); R. Morandotti, Institut National de la Recherche Scientifique (Canada)

---

## **SESSION 3 TRENDS IN OEICs**

---

- 7942 06 **Scaling technologies for terabit fiber optic transmission systems (Invited Paper) [7942-05]**  
B. J. Shastri, D. V. Plant, McGill Univ. (Canada)
- 7942 08 **Integration of RF-optical upconversion modules for millimeter-wave sensing and imaging systems (Invited Paper) [7942-07]**  
P. Yao, Phase Sensitive Innovations, Inc. (United States); R. Shrieen, J. Macario, Univ. of Delaware (United States); C. A. Schuetz, Phase Sensitive Innovations, Inc. (United States); D. W. Prather, Univ. of Delaware (United States)

---

**SESSION 4 VLSI PHOTONIC ICs**

---

- 7942 0A **Nanophotonic devices and circuits (Invited Paper)** [7942-09]  
M. P. Nezhad, A. Simic, O. Bondarenko, B. A. Slutsky, A. Mizrahi, Y. Fainman, Univ. of California, San Diego (United States)

---

**SESSION 5 SILICON OEICs**

---

- 7942 0D **Hybrid silicon lasers (Invited Paper)** [7942-12]  
G. Roelkens, Y. De Koninck, S. Keyvaninia, S. Stankovic, M. Tassaert, Univ. Gent (Belgium); M. Lamponi, G. Duan, Alcatel-Thales III-V Lab. (France); D. Van Thourhout, R. Baets, Univ. Gent (Belgium)
- 7942 0E **Silicon photonic integrated circuits: from devices to integration (Invited Paper)** [7942-13]  
T.-Y. Liow, Q. Fang, A. E.-J. Lim, L. Ding, Q. X. Zhang, J. Zhang, N. Duan, J. Song, F.-F. Ren, H. Cai, S. T. H. Silalahi, M. Yu, G.-Q. Lo, D.-L. Kwong, A\*STAR Institute of Microelectronics (Singapore)

---

**SESSION 6 GREEN OEIC TECHNOLOGIES**

---

- 7942 0F **Thin film CIGS photovoltaic modules: monolithic integration and advanced packaging for high performance, high reliability and low cost (Invited Paper)** [7942-14]  
L. Eldada, HelioVolt Corp. (United States)

---

**SESSION 7 NANOSCALE AND QUANTUM OEICs**

---

- 7942 0K **Towards arrays of smart-pixels for time-correlated single photon counting and time of flight application** [7942-19]  
B. Markovic, Politecnico di Milano (Italy); S. Tisa, Micro Photon Devices S.r.l. (Italy); A. Tosi, F. Zappa, Politecnico di Milano (Italy)
- 7942 0L **1024 pixels single photon imaging array for 3D ranging** [7942-20]  
S. Bellisai, F. Guerrieri, Politecnico di Milano (Italy); S. Tisa, Micro Photon Devices S.r.l. (Italy); F. Zappa, Politecnico di Milano (Italy) and Micro Photon Devices S.r.l. (Italy); A. Tosi, Politecnico di Milano (Italy); A. Giudice, Micro Photon Devices S.r.l. (Italy)

---

**SESSION 8 HYBRID OEICs**

---

- 7942 0M **Photonic network-on-chip architecture using 3D integration (Invited Paper)** [7942-21]  
A. Biberman, Columbia Univ. (United States); N. Sherwood-Droz, Cornell Univ. (United States); X. Zhu, Columbia Univ. (United States); K. Preston, Cornell Univ. (United States); G. Hendry, Columbia Univ. (United States); J. S. Levy, Cornell Univ. (United States); J. Chan, H. Wang, Columbia Univ. (United States); M. Lipson, Cornell Univ. (United States); K. Bergman, Columbia Univ. (United States)
- 7942 0N **The integration of silica and polymer waveguide devices for ROADMs applications (Invited Paper)** [7942-22]  
J. Fujita, R. Gerhardt, T. Izuhara, W. Lin, H. Wei, B. Grek, Enablence (United States)

- 7942 0O **InP on SOI devices for optical communication and optical network on chip (Invited Paper)**  
[7942-23]  
J.-M. Fedeli, B. Ben Bakir, N. Olivier, Ph. Grosse, L. Grenouillet, E. Augendre, P. Phillippe,  
K. Gilbert, D. Bordel, J. Harduin, Lab. d'Electronique de Technologie de l'Information  
(France)
- 7942 0P **Optical signal processing with a network of semiconductor optical amplifiers in the context  
of photonic reservoir computing** [7942-24]  
K. Vandoorne, M. Fiers, D. Verstraeten, B. Schrauwen, J. Dambre, P. Bienstman, Univ. Gent  
(Belgium)
- 7942 0Q **Nd-doped waveguide amplifiers for heterogeneous integration in optical backplanes**  
[7942-25]  
F. Ay, J. Yang, Univ. Twente (Netherlands); T. Lamprecht, IBM Research GmbH (Switzerland);  
K. Wörhoff, S. M. García-Blanco, A. Driessen, Univ. Twente (Netherlands); F. Horst, B. J. Offrein,  
IBM Research GmbH (Switzerland); M. Pollnau, Univ. Twente (Netherlands)

---

#### POSTER SESSION

- 7942 0R **Chromatic dispersion measurement of nano-silicon waveguides using a white-light  
interferometry method** [7942-26]  
S. H. Kim, S. H. Lee, D. W. Kim, K. H. Kim, E.-H. Lee, Inha Univ. (Korea, Republic of); J.-M. Lee,  
Electronics and Telecommunications Research Institute (Korea, Republic of)

*Author Index*



# Conference Committee

## *Symposium Chair*

**Liang-Chy Chien**, Kent State University (United States)

## *Symposium Cochairs*

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

**Klaus P. Streubel**, OSRAM GmbH (Germany)

## *Program Track Chair*

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

## *Conference Chairs*

**Louay A. Eldada**, HelioVolt Corporation (United States)

**El-Hang Lee**, Inha University (Korea, Republic of)

## *Program Committee*

**Yung-Jui Chen**, University of Maryland, Baltimore County (United States)

**Larry A. Coldren**, University of California, Santa Barbara (United States)

**Mario Dagenais**, University of Maryland, College Park (United States)

**P. Daniel Dapkus**, The University of Southern California (United States)

**Yeshaiahu Fainman**, University of California, San Diego (United States)

**Chennupati Jagadish**, The Australian National University (Australia)

**Richard M. Osgood, Jr.**, Columbia University (United States)

**Manijeh Razeghi**, Northwestern University (United States)

**Giancarlo Cesare Righini**, Istituto di Fisica Applicata Nello Carrara (Italy)

## *Session Chairs*

- 1 Optoelectronic Devices for Optical Interconnects: Joint Session with Conference 7944

**Louay A. Eldada**, HelioVolt Corporation (United States)

- 2 Si Photonics for Optical Interconnects: Joint Session with Conference 7944

**Ray T. Chen**, The University of Texas at Austin (United States)

- 3 Trends in OEICs  
**El-Hang Lee**, Inha University (Korea, Republic of)
- 4 VLSI Photonic ICs  
**Louay A. Eldada**, HelioVolt Corporation (United States)
- 5 Silicon OEICs  
**Louay A. Eldada**, HelioVolt Corporation (United States)
- 6 Green OEIC Technologies  
**Richard M. Osgood, Jr.**, Columbia University (United States)
- 7 Nanoscale and Quantum OEICs  
**El-Hang Lee**, Inha University (Korea, Republic of)
- 8 Hybrid OEICs  
**Chee Wei Wong**, Columbia University (United States)



## Introduction

This volume features contributions from scientists and engineers in the general area of optoelectronic integrated circuits (OEIC). Optical, electronic, photovoltaic, microwave, biological, and fluidic devices are integrated to address the issues of cost, space, performance, and reliability. Demands for greater bandwidths have driven the telecom and datacom research communities to realize complex OEICs such as transceivers, low chirp optical sources, switching systems, and multi-channel optical distribution systems. The integration of multi-wavelength laser arrays, monitoring photodiodes, and drivers is becoming a reality in the communications arena. Other emerging OEIC application areas include all-optical packet switching, neural systems, optical computing, optical storage, smart pixel arrays, projection displays, imaging, scanning, printing, medical diagnosis, and chemical/biological sensing.

In keeping with the latest global economic demands for the use of integration to achieve low cost solutions in critical areas, we covered in this volume the field of Green OEICs that are used in solar modules addressing the need for renewable energy that is cost competitive with fossil-fuel-based energy.

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 VLSI Photonic ICs, as well as Nanoscale and Quantum OEICs. 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, nonlinear effect, noise effect, quantum optical effect, and chaotic noise effects. Optical alignment between miniature devices, minimizing interconnection and coupling losses, 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 OEICs with regard to their optical, electrical, thermal and mechanical properties; the integration of different optoelectronic structure types including dots, wells, planar, free-space, one-dimensional, two-dimensional and three-dimensional photonics crystals; the integration of different functions including lasers, amplifiers, detectors, sensors, solar cells, modulators, isolators, circulators, electrically-actuated/all-optical switches, attenuators, 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 and qualification of monolithic and hybrid OEICs in a variety of materials (semiconductors, silica, polymers, ferroelectrics, magnetics, metals, biomaterials, etc.). 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 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 of OEICs, it does cover a significant cross-section of the advances happening globally in areas where OEICs are making an impact, and it provides a roadmap to the future of OEICs by presenting the cutting-edge work and the visions of leading experts who are actively inventing the future.

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