

PROCEEDINGS OF SPIE

***Nanophotonics and
Macrophotonics for
Space Environments III***

**Edward W. Taylor
David A. Cardimona**
Editors

**3–4 August 2009
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 7467

Proceedings of SPIE, 0277-786X, v. 7467

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 *Nanophotonics and Macrophotonics for Space Environments III*, edited by Edward W. Taylor, David A. Cardimona, Proceedings of SPIE Vol. 7467 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X
ISBN 9780819477576

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 © 2009, 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/09/\$18.00.

Printed in the United States of America.

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

The logo for SPIE Digital Library features the word "SPIE" in a bold, sans-serif font above the words "Digital Library" in a smaller, lighter font. To the right of the text is a stylized graphic consisting of three vertical bars of increasing height, resembling a bar chart or a signal waveform.

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 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 MATERIALS AND COMPONENTS FOR SPACE ENVIRONMENTS I

- 7467 02 **Topographic mapping from space** [7467-01]
A. W. Yu, M. A. Krainak, D. J. Harding, J. B. Abshire, X. Sun, NASA Goddard Space Flight Ctr. (United States)
- 7467 03 **Development of a low SWaP laser transmitter** [7467-02]
A. Rosiewicz, S. Coleman, EM4, Inc. (United States)
- 7467 04 **The effects of ionizing radiation, temperature, and space contamination effects on photonic coatings (Invited Paper)** [7467-03]
R. Pirich, J. Weir, D. Leyble, M. DiGiuseppe, Northrop Grumman Aerospace Systems (United States)
- 7467 05 **Space radiation effects modeling and analysis of quantum dot based photovoltaic cells** [7467-04]
A. I. Fedoseyev, M. Turowski, A. Raman, CFD Research Corp. (United States); E. W. Taylor, International Photonics Consultants, Inc. (United States); S. Hubbard, S. Polly, Rochester Institute of Technology (United States); Q. Shao, A. A. Balandin, Univ. of California, Riverside (United States)

SESSION 2 MATERIALS AND COMPONENTS FOR SPACE ENVIRONMENTS II

- 7467 07 **The effects of gamma-ray irradiation on organic materials of different conjugation lengths (Invited Paper)** [7467-06]
C. Zhang, Norfolk State Univ. (United States); E. W. Taylor, International Photonics Consultants, Inc. (United States)
- 7467 08 **Optical switching materials with high damage threshold for space environments (Invited Paper)** [7467-07]
A. Sarkar, S. Rahman, S. Mirza, P. R. Dvornic, Michigan Molecular Institute (United States); G. R. Rayfield, Univ. of Oregon (United States); E. W. Taylor, International Photonics Consultants, Inc. (United States)

SESSION 3 KEYNOTE ADDRESS

- 7467 OA **Layered polymeric optical systems using continuous coextrusion (Keynote Paper)** [7467-09]
H. Song, K. Singer, Y. Wu, J. Zhou, J. Lott, Case Western Reserve Univ. (United States);
J. Andrews, Youngstown State Univ. (United States); A. Hiltner, E. Baer, Case Western Reserve
Univ. (United States); C. Weder, Case Western Reserve Univ. (United States) and Univ. of
Fribourg (Switzerland); R. Bunch, R. Lepkowicz, Rose-Hulman Univ. (United States); G. Beadie,
Naval Research Lab. (United States)

SESSION 4 INNOVATIVE ORGANIC/POLYMER MATERIALS I

- 7467 OB **Magnetic field sensing based on Faraday rotation in inorganic/polymer hybrid materials (Invited Paper)** [7467-10]
T. Verbiest, J. Wouters, Katholieke Univ. Leuven (Belgium)
- 7467 OC **Faraday rotation in magnetic colloidal photonic crystals (Invited Paper)** [7467-11]
W. Libaers, Katholieke Univ. Leuven (Belgium); B. Kolaric, Katholieke Univ. Leuven (Belgium)
and Univ. de Mons-Hainaut (Belgium); R. A. L. Vallée, Katholieke Univ. Leuven (Belgium) and
Ctr. de Recherche Paul Pascal, CNRS (France); J. E. Wong, RWTH Aachen Univ. (Germany);
J. Wouters, V. K. Valev, T. Verbiest, K. Clays, Katholieke Univ. Leuven (Belgium)

SESSION 5 INNOVATIVE ORGANIC/POLYMER MATERIALS II

- 7467 OE **Testing of NASA LaRC materials under MISSE 6 and MISSE 7 missions** [7467-13]
N. S. Prasad, NASA Langley Research Ctr. (United States)
- 7467 OF **Nanoscope control to achieve radiation hardened materials** [7467-15]
J. Lichtenhan, Hybrid Plastics Inc. (United States); J. Spratt, Full Circle Research Inc. (United
States); E. Taylor, International Photonics Consultants, Inc. (United States)

SESSION 6 KEYNOTE ADDRESS

- 7467 OH **Surface plasmon polariton analogues of volume electromagnetic wave effects (Keynote Paper)** [7467-16]
F. Huerkamp, T. A. Leskova, A. A. Maradudin, Univ. of California, Irvine (United States)

SESSION 7 DEVICES FOR SPACE APPLICATIONS

- 7467 OK **Multi-spectral image analysis for improved space object characterization** [7467-19]
W. Glass, M. J. Duggin, R. A. Motes, Air Force Research Lab. (United States); K. A. Bush,
Schafer Corp. (United States); M. Klein, Northrop Grumman Corp. (United States)
- 7467 OL **Hyperspectral pixels in 2D imaging FPAs?** [7467-20]
P. D. LeVan, Air Force Research Lab. (United States); B. P. Beecken, Bethel Univ. (United
States)
- 7467 OM **Interference effects in a cavity for optical amplification** [7467-21]
D. A. Cardimona, P. M. Alsing, Air Force Research Lab. (United States)

SESSION 8 THZ FOR SPACE COMMUNICATIONS I

- 7467 0O **Current-driven plasma instabilities for a bilayer two-dimensional electron system** [7467-23]
A. Balassis, Fordham Univ. (United States); G. Gumbs, Hunter College (United States);
D. Huang, Air Force Research Lab. (United States)

SESSION 9 THZ FOR SPACE COMMUNICATIONS II

- 7467 0P **Terahertz quantum well devices and their potential for free space communication (Invited Paper)** [7467-24]
P. D. Grant, S. R. Laframboise, R. Dudek, M. Graf, A. Bezinger, H. C. Liu, National Research Council Canada (Canada)

- 7467 0Q **Grating-gate tunable plasmon absorption in InP and GaN based HEMTs (Invited Paper)** [7467-25]
R. E. Peale, H. Saxena, Univ. of Central Florida (United States); W. R. Buchwald, Air Force Research Lab. (United States); G. Aizin, Kingsborough College (United States);
A. V. Muravjov, Rensselaer Polytechnic Institute (United States) and Institute for Physics of Microstructures (Russian Federation); D. B. Veksler, Rensselaer Polytechnic Institute (United States); N. Pala, Florida International Univ. (United States); X. Hu, R. Gaska, Sensor Electronic Technology, Inc. (United States); M. S. Shur, Rensselaer Polytechnic Institute (United States)

SESSION 10 DETECTORS FOR SPACE SITUATIONAL AWARENESS

- 7467 0R **III-V infrared research at the Jet Propulsion Laboratory (Invited Paper)** [7467-26]
S. D. Gunapala, D. Z. Ting, C. J. Hill, A. Soibel, J. Liu, J. K. Liu, J. M. Mumolo, S. A. Keo, J. Nguyen, Jet Propulsion Lab. (United States); S. V. Bandara, U.S. Army Night Vision & Electronic Sensors Directorate (United States); M. Z. Tidrow, Missile Defense Agency (United States)

- 7467 0T **State-of-the-art Type II antimonide-based superlattice photodiodes for infrared detection and imaging (Invited Paper)** [7467-28]
M. Razeghi, B.-M. Nguyen, P.-Y. Delaunay, E. K. Huang, S. Abdollahi Pour, P. Manukar, S. Bogdanov, Northwestern Univ. (United States)

- 7467 0U **Improved performance of InAs/GaSb strained layer superlattice detectors with SU-8 passivation** [7467-29]
H. S. Kim, E. Plis, S. Myers, A. Khoshakhlagh, N. Gautam, M. N. Kutty, Y. D. Sharma, L. R. Dawson, S. Krishna, The Univ. of New Mexico (United States)

- 7467 0V **Investigation of multi-stack quantum dots-in-double-well infrared detectors** [7467-30]
M. N. Kutty, Y. D. Sharma, A. Barve, J. Shao, E. Plis, R. V. Shenoj, S. Krishna, The Univ. of New Mexico (United States); S. J. Lee, S. K. Noh, Korea Research Institute of Standards and Science (Korea, Republic of)

7467 0W

Al fraction induced effects on the capacitance characteristics of n⁺-GaN/Al_xGa_{1-x}N IR detectors [7467-31]

L. E. Byrum, G. Ariyawansa, R. Jayasinghe, N. Dietz, A. G. U. Perera, Georgia State Univ. (United States); S. G. Matsik, NDP Optronics LLC (United States); I. T. Ferguson, Georgia Institute of Technology (United States); A. Bezinger, H. C. Liu, National Research Council Canada (Canada)

Author Index

Conference Committee

Program Track Chairs

Stephen M. Hammel, Space and Naval Warfare Systems Center, San Diego (United States)

Alexander M. J. van Eijk, TNO Defense, Security and Safety (Netherlands)

Conference Chairs

Edward W. Taylor, International Photonics Consultants, Inc. (United States)

David A. Cardimona, Air Force Research Laboratory (United States)

Program Committee

Mansoor Alam, Nufern (United States)

Koen J. Clays, Katholieke Universiteit Leuven (Belgium)

Douglas M. Craig, Air Force Research Laboratory (United States)

Raluca Dinu, Lumera Corporation (United States)

Alexandre I. Fedoseyev, CFD Research Corporation (United States)

Allan Hahn, Air Force Research Laboratory (United States)

Michael J. Hayduk, Air Force Research Laboratory (United States)

Danhong Huang, Air Force Research Laboratory (United States)

Mark G. Kuzyk, Washington State University (United States)

Narasimha S. Prasad, NASA Langley Research Center (United States)

Kelly Simmons-Potter, The University of Arizona (United States)

Session Chairs

Materials and Components for Space Environments I

Narasimha S. Prasad, NASA Langley Research Center (United States)

Materials and Components for Space Environments II

Koen J. Clays, Katholieke Universiteit Leuven (Belgium)

Innovative Organic/Polymer Materials I

Mark G. Kuzyk, Washington State University (United States)

Innovative Organic/Polymer Materials II

Douglas M. Craig, Air Force Research Laboratory (United States)

Devices for Space Applications

David A. Cardimona, Air Force Research Laboratory (United States)

THz for Space Communications I

Danhong Huang, Air Force Research Laboratory (United States)

THz for Space Communications II

Danhong Huang, Air Force Research Laboratory (United States)

Detectors for Space Situational Awareness

David A. Cardimona, Air Force Research Laboratory (United States)

Introduction

The third SPIE conference on Nanophotonics and Macrophotonics for Space Environments (NMSE III) proved to be a highly diversified and interesting conference since, in part, it was an outgrowth from the previous SPIE Photonics for Space Environments I-XI conferences with the infusion of new nanotechnology topics. The synergism of nanotechnology and photonics for addressing and advancing space applications was clearly evident and has proven to be an excellent choice for this conference, providing a unique and useful forum.

Many invited papers were presented as well as two excellent keynote presentations, one by Dr. Kenneth Singer of Case Western Reserve University and the other by Dr. Alexei Maradudin of the University of California, Irvine. Dr. Singer's talk dealt with his research in manufacturing and processing layered polymeric optical systems, such as gradient index lenses, lasers, and photonic crystals, and Dr. Maradudin described some very exciting new research in plasmonic analogues to several effects known in regular optics, such as double-slit interference.

The conference covered a wide range of topics which indicates the steady diffusion of nano and plasmonic technology toward space systems and related applications. As in the first two NMSE conferences, papers were presented regarding NASA photonic technologies and missions, ionizing radiation effects in quantum dot based solar cells, and new topics dealing with the use of optical limiting materials for protecting space components. Presentations on the use of self-cleaning photonic coatings for lunar operations and applications of commercial, off-the-shelf devices and circuits provided a stark comparison between differences in required Earth and lunar technologies. Related papers on radiation-induced effects and radiation hardening of organic photonic materials and devices indicated that organic-polymer issues were being addressed and progress made for applying the technologies. Different from past years, several interesting papers reporting advances in magnetic sensing in organic devices for application to satellite attitude sensing, as well as papers on novel nanostructures for lasers or optical amplifiers, were presented. A paper on layered polymer structures for photonic devices addressing reduced size and weight for launch considerations as well as radiation hardness for use in space was well received. Papers on photonic requirements for space object characterization and a presentation describing a new concept for a hyperspectral detector for space object identification were also well received. Two related sessions on THz sources and/or detectors for satellite communication and a large session on new research for improving the performance of strained-layer superlattice and quantum dot IR detectors for space situational awareness and space object detection and identification were well attended.

We look forward to the next convening of the SPIE NMSE conference and expect that additional and advanced nano-, micro-, and macrophotonic areas of research and development will be presented and continue to expand and improve the conference objectives.

The chairs wish to thank the program committee, speakers, session chairs, and especially the SPIE staff for their many contributions to making the NMSE III conference a success.

Edward W. Taylor
David A. Cardimona