

PROCEEDINGS OF SPIE

Active Photonic Platforms IX

Ganapathi S. Subramania
Stavroula Foteinopoulou
Editors

6–10 August 2017
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 10345

Proceedings of SPIE 0277-786X, V. 10345

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

Active Photonic Platforms IX, edited by Ganapathi S. Subramania, Stavroula Foteinopoulou, Proc. of SPIE Vol. 10345, 1034501 · © 2017 SPIE · CCC code: 0277-786X/17/\$18 · doi: 10.1117/12.2286377

Proc. of SPIE Vol. 10345 1034501-1

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 *Active Photonic Platforms IX*, edited by Ganapathi S. Subramania, Stavroula Foteinopoulou, Proceedings of SPIE Vol. 10345 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

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

ISBN: 9781510611474
ISBN: 9781510611481 (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 © 2017, 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/17/\$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 *Authors*
- ix *Conference Committee*
- xiii *Introduction*

ACTIVE PHOTONIC DEVICES I: SOURCES AND MODULATORS

- 10345 04 **Quantum well intermixed tunable wavelength single stripe laser diode** [10345-84]

ACTIVE PHOTONIC DEVICES II: DETECTORS, SENSORS, AND MICROSCOPY SYSTEMS

- 10345 08 **Magnetic response of parallel slabs metamaterials at THz frequencies** [10345-7]

NANOSTRUCTURES FOR HARNESSING LIGHT-MATTER INTERACTION AND LASING II

- 10345 0J **Coherence and dynamics of a high- β metallo-dielectric nanolasers (Best Student Paper: Second Place)** [10345-18]

CARBON-BASED AND 2D MATERIAL PHOTONICS I

- 10345 0V **Role of defect states in functionalized graphene photodetectors** [10345-29]
- 10345 0Y **Electrical properties of SiO₂-based graphene under monochromatic visible light irradiation** [10345-32]

EXTRAORDINARY NON-LINEAR PHOTONIC PLATFORMS I

- 10345 12 **Enhanced optical nonlinearities in 2D-3D heteromaterials (Invited Paper)** [10345-36]

CARBON-BASED AND 2D MATERIAL PHOTONICS II

- 10345 18 **Modeling and simulation analysis of graphene integrated silicon waveguides** [10345-86]

DYNAMIC PHOTONICS WITH PHASE-CHANGE MATERIALS I

- 10345 19 **On-chip phase-change photonic memory and computing (Invited Paper)** [10345-42]

10345 1B **Chalcogenide active photonics (Invited Paper)** [10345-44]

DYNAMIC PHOTONICS WITH PHASE-CHANGE MATERIALS II

10345 1D **Optical modulation in silicon-vanadium dioxide photonic structures (Invited Paper)**
[10345-46]

10345 1F **Photoinduced optical dynamics of phase-change vanadium oxides** [10345-48]

10345 1G **Electrically driven hybrid photonic metamaterials for multifunctional control (Invited Paper)**
[10345-49]

TOPOLOGICAL PHOTONIC SYSTEMS II

10345 1N **Topological edge states of distorted photonic Kagome lattices** [10345-56]

TOPOLOGICAL PHOTONIC SYSTEMS III

10345 1U **Entangled photons in 2D topological photonic systems (Invited Paper)** [10345-64]

HIGHLY ASYMMETRIC AND NON-RECIPROCAL PHOTONIC PLATFORMS

10345 1V **Photonic crystal Fano resonances for realizing optical switches, lasers, and non-reciprocal elements (Invited Paper)** [10345-65]

10345 1Z **Non-PT-symmetric plasmonic waveguide-cavity systems: unidirectional reflectionlessness and broadband near total light absorption (Invited Paper)** [10345-69]

10345 20 **Structure-induced asymmetry between counterpropagating modes and the reciprocity principle in whistle-geometry ring lasers (Invited Paper)** [10345-70]

PT-SYMMETRY IN NON-HERMITIAN PHOTONIC SYSTEMS

10345 24 **PT-symmetry in kagome photonic lattices (Invited Paper)** [10345-75]

PLATFORMS FOR NON-CLASSICAL LIGHT CONTROL I

10345 26 **Quantum dots in photonic crystals for integrated quantum photonics (Invited Paper)**
[10345-77]

PLATFORMS FOR NON-CLASSICAL LIGHT CONTROL II

10345 2A **Photonic band control in a quantum metamaterial (Invited Paper)** [10345-81]

POSTER SESSION

- 10345 2C **Incident femtosecond pulse chirp influence on nonlinear localization of laser energy in layered photonic crystal** [10345-82]
- 10345 2D **Self-similar chirped laser pulse propagation in a medium with TOD and non-resonant TPA** [10345-83]

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.

Alsaleh, Mona H., 08
Alu, Andrea, 1N
Ayala, Brian, 1F
Barnes, Matthew D., 0V
Behera, Jitendra, 1B
Bekele, Dagmawi A., 1V
Bhaskaran, Harish, 19
Campbell, Sawyer D., 1G
Cao, Tun, 1B
Cao, Xueying, 0Y
Chen, Weimin, 0Y
Cheng, Zengguang, 19
Chern, Gia-Wei, 24
Chevres, Lee R., 1F
Chew, Li Tian, 1B
Craciun, Monica F., 0V
Ding, Yunhong, 1V
Dong, Weiling, 1B
Dubois, Marc, 0V
El Amili, Abdelkrim, 0J
Fainman, Yeshaiahu, 0J
Felbacq, Didier, 2A
Fernández, Félix E., 1F
Genov, Dentcho A., 08
Gu, Qing, 0J
Hafezi, Mohammad, 1U
Haglund, Richard F., 1D
Hallman, Kent A., 1D
Hu, Hao, 1V
Huang, Y., 1Z
Joshi, Swati, 18
Kalagara, Hemashilpa, 20
Kalinovich, Aleksey A., 2D
Kang, Lei, 1G
Kaushik, Brajesh Kumar, 18
Khanikaev, Alexander B., 1N
Kim, Je-Hyung, 26
Kumar, Nardeep, 1F
Leavitt, Richard P., 26
Lee, Hosuk, 20
Lei, Xiaohua, 0Y
Li, Xiangdi, 0Y
LiKamWa, Patrick, 04
Liu, Hailong, 1B
Liu, Li, 1B
Liu, Liu, 1G
Liu, Xianming, 0Y
Lysak, Tatiana M., 2C
Lysenko, Sergiy, 1F
Mao, Libang, 1B
Mayer, Theresa S., 1G
Mehew, Jake D., 0V
Miller, Kevin J., 1D
Min, C., 1Z
Mittal, Sunil, 1U
Mork, Jesper, 1V
Nehra, Vikas, 18
Ni, Xiang, 1N
Orre, Venkata Vikram, 1U
Osiński, Marek, 20
Ottaviano, Luisa, 1V
Oxenløwe, Leif K., 1V
Pan, Si Hui, 0J
Panoiu, Nicolae C., 12
Pernice, Wolfram H. P., 19
Ren, Qiang, 1G
Richardson, Christopher J. K., 26
Ríos, Carlos, 19
Rousseau, Emmanuel, 2A
Rúa, Armando, 1F
Russo, Saverio, 0V
Sakanas, Aurimas, 1V
Saxena, Avadh, 24
Semenova, Elizaveta, 1V
Simpson, Robert E., 1B
Smolyakov, Gennady A., 20
Sreekanth, Kandammathe V., 1B
Tabbakh, Thamer, 04
Theran, Larry, 1F
Trofimov, Vyacheslav A., 2C, 2D
Trykin, Evgenii M., 2C
Vallini, Felipe, 0J
Veronis, G., 1Z
Vinnakota, Raj K., 08
Waks, Edo, 26
Weiss, Sharon M., 1D
Werner, Douglas H., 1G
Wright, C. David, 19
Yang, Joel, 1B
You, Jian Wei, 12
Youngblood, Nathan, 19
Yu, Yi, 1V
Yue, Taiwei, 1G
Yvind, Kresten, 1V
Zakharova, Irina G., 2D
Zhang, Peng, 0Y
Zhou, Xilin, 1B

Conference Committee

Symposium Chairs

Harry A. Atwater Jr., California Institute of Technology (United States)
Nikolay I. Zheludev, Optoelectronics Research Centre
(United Kingdom) and Nanyang Technological University
(Singapore)

Symposium Co-chairs

James G. Grote, Air Force Research Laboratory (United States)
David L. Andrews, University of East Anglia (United Kingdom)

Conference Chairs

Ganapathi S. Subramania, Sandia National Laboratories
(United States)
Stavroula Foteinopoulou, The University of New Mexico (United States)

Conference Program Committee

Andrea Alù, The University of Texas at Austin (United States)
Paul V. Braun, University of Illinois at Urbana-Champaign
(United States)
Che Ting Chan, Hong Kong University of Science and Technology
(Hong Kong, China)
Zhigang Chen, San Francisco State University (United States)
Dmitry N. Chigrin, Rheinisch-Westfälische Technische Hochschule
Aachen (Germany)
Shanhui Fan, Stanford University (United States)
Didier Felbacq, Université Montpellier 2 (France)
Joseph W. Haus, University of Dayton (United States)
Stephen Hughes, Queen's University (Canada)
Boubacar Kante, University of California, San Diego (United States)
A. Femius Koenderink, FOM Institute for Atomic and Molecular Physics
(Netherlands)
Alexander V. Kildishev, Purdue University (United States)
Yuri S. Kivshar, The Australian National University (Australia)
Cefe López, Consejo Superior de Investigaciones Científicas (Spain)
Nicolae-Coriolan Panoiu, University College London
(United Kingdom)
Michelle L. Povinelli, The University of Southern California
(United States)

Christophe Sauvan, Laboratoire Charles Fabry (France)
Jörg Schilling, Martin-Luther-Universität Halle-Wittenberg (Germany)
Gennady B. Shvets, The University of Texas at Austin (United States)
Volker J. Sorger, The George Washington University (United States)
Andrey A. Sukhorukov, The Australian National University (Australia)
Kosmas L. Tsakmakidis, University of Ottawa (United States)
Georgios Veronis, Louisiana State University (United States)
Daniel M. Wasserman, University of Illinois at Urbana-Champaign
(United States)
Ralf B. Wehrspohn, Fraunhofer-Institut für Werkstoffmechanik
(Germany)
Sharon M. Weiss, Vanderbilt University (United States)
William Whelan-Curtin, University of St. Andrews (United Kingdom)

Session Chairs

- 1 Active Photonic Devices I: Sources and Modulators
Sanjay Krishna, The Ohio State University (United States)
- 2 Active Photonic Devices II: Detectors, Sensors, and Microscopy Systems
Soham Saha, Purdue University (United States)
- 3 Nanostructures for Harnessing Light-Matter Interaction and Lasing I
Liam O'Faolain, Cork Institute of Technology (Ireland)
- 4 Nanostructures for Harnessing Light-Matter Interaction and Lasing II
Pablo A. Postigo, Instituto de Microelectrónica de Madrid (Spain)
- 5 Platforms for Extreme Absorption and Thermal Management
Volker J. Sorger, The George Washington University (United States)
- 6 Carbon-Based and 2D Material Photonics I
Philippe Tassin, Chalmers University of Technology (Sweden)
- 7 Extraordinary Non-Linear Photonic Platforms I
Michelle L. Povinelli, The University of Southern California (United States)
- 8 Carbon-Based and 2D Material Photonics II
Ertugrul Cubukcu, University of California, San Diego (United States)
- 9 Dynamic Photonics with Phase-Change Materials I
Kevin J. Miller, Vanderbilt University (United States)
- 10 Dynamic Photonics with Phase-Change Materials II
Harish Bhaskaran, University of Oxford (United Kingdom)

- 11 Topological Photonic Systems I
Ganapathi S. Subramania, Sandia National Laboratories
(United States)
- 12 Topological Photonic Systems II
Yidong Chong, Nanyang Technological University (Singapore)
- 13 Extraordinary Non-Linear Photonic Platforms II
Nicolae Coriolan Panoiu, University College London (United Kingdom)
- 14 Topological Photonic Systems III
Ganapathi S. Subramania, Sandia National Laboratories
(United States)
- 15 Highly Asymmetric and Non-Reciprocal Photonic Platforms
Stavroula Foteinopoulou, The University of New Mexico (United States)
- 16 PT-Symmetry in Non-Hermitian Photonic Systems
Georgios Veronis, Louisiana State University (United States)
- 17 Platforms for Non-Classical Light Control I
Kosmas L. Tsakmakidis, University of Ottawa (Canada)
- 18 Platforms for Non-Classical Light Control II
Glenn S. Solomon, National Institute of Standards and Technology
(United States)

Introduction

Sculpting the behavior of light in space and time into unprecedented capabilities is essential to current photonic technologies that impact our everyday lives by pushing forward the speed of information transfer and computing, or enabling new means for medical diagnostics, and sustainable energy. The advancement of nanofabrication methods enabled the realization of sophisticated structured material platforms. These platforms can facilitate the required synergy between material photonic properties and form for controlling light in ways that would have been unimaginable some decades ago. While tremendous progress has been made with passive materials, such as metals and dielectrics, the potential of photonic platforms transcends into new unexplored domains when active material and/or material with tunable or dynamic photonic properties are incorporated. Examples of such material are gain or non-linear media, phase-change materials, magneto-photonic material, as well as quantum emitters.

The Active Photonic Platforms IX conference brought together the newest developments in the fundamentals and applications of structured-material platforms for active, dynamic, and tunable control of light. New exotic types of light propagation, which could open entirely new direction in active photonics have also been featured. Several keynote, invited, and contributed talks highlighted one class of such extra-ordinary light propagation, unveiled by the growing field of topological photonics. Judicious photonic designs were reported that interfaced systems of different topological phases demonstrating unidirectional and scatter-free properties. These properties can be in some cases controllable by the light's angular momentum; so these topological photonic systems are highly promising for applications in photonic circuitry and quantum information platforms.

A new exciting emerging topic, discussed in the opening keynote presentation [paper 10345-1], is non-linear photonic platforms for neuromorphic computing. Non-linear material platforms have also been featured with two separate sessions that have reported exciting new capabilities such as order-of-magnitude non-linear enhancement with 2D materials and transition-metal dichalcogenide nanomaterials and epsilon-near-zero (ENZ) enabled enhancement of non-linearities in aluminum-doped zinc oxide (AZO).

In addition, a number of fascinating talks focused on non-Hermitian photonic systems, where a balanced interplay between gain and loss manifests itself in parity-time (PT) symmetry, and can be exploited for unidirectional propagation and lasing. For context and contrast to asymmetric propagation properties in these active systems, a few talks discussed also paradigm systems where a strong asymmetry in coupling, or reflection can be effected in an entirely passive system.

Moreover, non-classical light generation as well as lasing phenomena at the nanoscale were also a central theme of the conference. Furthermore, interesting topics presented in the conference included platforms for extra-ordinary absorption management, harnessing near-field heat transfer, as well as tunable or dynamically controlled photonics with atomically thin materials such as graphene or monolayer MoS₂.

Last but not least, for the first time we featured in the conference an emergent and rapidly growing area, that of phase-change-material Nanophotonics. There were several invited talks reporting on photonic platforms with phase-change materials, such as chalcogenides, vanadium dioxide, samarium nickelate, or Ge₂Sb₂Te₅. These fascinating presentations in these topics demonstrated dynamically controlled and/or tunable absorption, thermal emission, or radiative fluorescent decay as well as a platform for thermal homeostasis, a non-volatile type of photonic memory and a bio-inspired photonic synapse.

Our conference also ran a *Best Student Paper* competition, recognizing the best contributed presentations that were presented by a student author. We would like to thank all student contributors for their enthusiasm with which they participated in this competition presenting outstanding and interesting research! The finalist winners of this competition, were recognized with an SPIE award certificate at the "Best Student Paper Award Announcement," session on the last day of the conference. We enlist below the winners of the *Best Student Paper* competition.

First place: Paper 10345-74 "*Higher-order exceptional points in photonic systems*," by **Hossein Hodaiei**, CREOL, The College of Optics and Photonics, Univ. of Central Florida (United States)

Co-authors: Absar U. Hassan, Steffen Wittek, Midya Parto, Hipolito Garcia-Gracia, CREOL, The College of Optics and Photonics, Univ. of Central Florida (United States); Ramy A. H. El-Ganainy, Michigan Technological Univ. (United States); Demetrios N. Christodoulides, Mercedeh Khajavikhan, CREOL, The College of Optics and Photonics, Univ. of Central Florida (United States)

Second place: Paper 10345-18 "*Coherence and dynamics of a high- β metallo-dielectric nanolasers*,"

by **Si Hui Pan**, Univ. of California, San Diego (United States)

Co-authors: Qing Gu, The Univ. of Texas at Dallas (United States); Abdelkrim El Amili, Felipe Vallini, Univ. of California, San Diego (United States); Yeshaiahu Fainman, Univ. of California (United States)

(See also paper annotated as best student paper: second place in this volume).

Third place: Paper 10345-35 "*Tunable chiral metasurfaces based on the transfer of electromagnetic angular momentum*,"

by **Sophie Viaene**, Vrije Univ. Brussel (Belgium), Chalmers Univ. of Technology (Sweden)

Co-authors: Vincent Ginis, Jan Danckaert, Vrije Univ. Brussel (Belgium); Philippe Tassin, Chalmers Univ. of Technology (Sweden)

Active Photonic Platforms IX has brought together theorists and experimentalists to exchange state-of-the art results in this rapidly evolving area of research. As conference chairs, we would like to express our sincere thanks to all the participants of the 10345 conference who contributed with their presentations as well as manuscripts to make this conference a stimulating and vibrant event.

Ganapathi S. Subramania
Stavroula Foteinopoulou

