PROCEEDINGS OF SPIE

Active Photonic Platforms XI

Ganapathi S. Subramania
Stavroula Foteinopoulou
Editors

11–15 August 2019
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 11081

Proceedings of SPIE 0277-786X, V. 11081

Active Photonic Platforms XI, edited by Ganapathi S. Subramania, Stavroula Foteinopoulou,
Proc. of SPIE Vol. 11081, 1108101 · © 2019 SPIE · CCC code: 0277-786X/19/$21
doi: 10.1117/12.2551009

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.

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 XI*, edited by Ganapathi S. Subramania, Stavroula Foteinopoulou, Proceedings of SPIE Vol. 11081 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

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

ISBN: 9781510628557
ISBN: 9781510628564 (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

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.

SPIE. DIGITAL LIBRARY
SPIEDigitalLibrary.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

POSTER SESSION

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.

Conference Committee

Symposium Chairs

Halina Rubinsztein-Dunlop, The University of Queensland (Australia)
Mark L. Brongersma, Geballe Laboratory for Advanced Materials (GLAM), Stanford University (United States)

Symposium Co-chairs

Reuven Gordon, University of Victoria (Canada)
Natalia M. Litchinitser, Duke University (United States)

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 City University of New York (United States)
Koray Aydin, Northwestern University (United States)
Harish Bhaskaran, University of Oxford (United Kingdom)
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, Nankai University (China), and San Francisco State University (United States)
Dmitry N. Chigrin, RWTH Aachen Universität (Germany)
Shanhui Fan, Stanford University (United States)
Didier Felbacq, Université Montpellier (France)
Joseph W. Haus, University of Dayton (United States)
Stephen Hughes, Queen's University (Canada)
Boubacar Kante, University of California, San Diego (United States)
Mercedeh Khajavikhan, CREOL, The College of Optics and Photonics, University of Central Florida (United States)
Alexander V. Kildishev, Purdue University (United States)
Nathaniel Kinsey, Virginia Commonwealth University (United States)
Yuri S. Kivshar, The Australian National University (Australia)
A. Femius Koenderink, AMOLF (Netherlands)
Aude L. Lereu, Institut Fresnel (France)
Cefe López, Consejo Superior de Investigaciones Científicas (Spain)

Liam O'Faolain, Cork Institute of Technology (Ireland) and Tyndall National Institute (Ireland)
Rupert F. Oulton, Imperial College London (United Kingdom)
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, Cornell University (United States)
Volker J. Sorger, The George Washington University (United States)
Isabelle Staude, Friedrich-Schiller-Universität Jena (Germany)
Andrey A. Sukhorukov, The Australian National University (Australia)
Philippe Tassin, Chalmers University of Technology (Sweden)
Kosmas L. Tsakmakidis, National and Kapodistrian University of Athens (Greece)
Georgios Veronis, Louisiana State University (United States)
Daniel M. Wasserman, The University of Texas at Arlington (United States)
Sharon M. Weiss, Vanderbilt University (United States)

Session Chairs

1 Special Session: In Memoriam of Joseph (Joe) Wendel Haus
Michael Scalora, U.S. Army Aviation and Missile Command (United States)

2 Topology and Symmetry in Photonics I
Ekaterina Poutrina, Air Force Research Laboratory (United States)

3 Topology and Symmetry in Photonics II
Ganapathi S. Subramania, Sandia National Laboratories (United States)

4 Topology and Symmetry in Photonics III
Ganapathi S. Subramania, Sandia National Laboratories (United States)

5 New Materials for Active Photonics: Theory, Design, and Characterization
Ruwen Peng, Nanjing University (China)

6 Topology and Symmetry in Photonics IV
Francesco Monticone, Cornell University (United States)

7 Photonics with Atomically Thin Materials I
Aude L. Lereu, Institut Fresnel (France)

Introduction

The Active Photonic Platforms XI conference took place in San Diego, California, between August the 11th and 15th 2019. This was another most exciting event of this conference series with more than 100 keynote, invited and contributed presentations and many lively discussions focusing on the most recent developments on active or dynamic light manipulation with natural and structured photonic materials. We hope the brief conference overview we give below will provide the reader with a flavor of the fascinating research that was presented in the conference and a useful navigation guide for the associated papers and presentation recordings enclosed in this proceedings volume.

Before we discuss the conference outline, with great sadness we note that in January 2019, Prof. Joseph (Joe) Haus, a program committee member of the conference, passed away. Dr. Haus was a Professor in the Electro-Optics and Photonics department at the University of Dayton, Dayton, Ohio (United States) and also a fellow of SPIE, APS and OSA. The conference started with a special session dedicated to his memory, which was organized and chaired by one of his long-time collaborators, Dr. Michael Scalora. We sincerely thank all collaborators and friends of Prof. Haus, Dr. Michael Scalora from US Army in Redstone Arsenal, Prof. Paras Prasad from University of Buffalo (United States), and Profs. Partha Banerjee and Andrew Sarangan from University of Dayton (United States), who made it possible to celebrate Prof. Haus's life and achievements. The special session paid tribute not only to Prof. Haus's exceptional body of work in non-linear and structured-material photonics but also to his tremendous service to the photonics discipline and his exemplary and inspiring dedication as a Professor and teacher. Prof. Haus was an incredible scientist and an incredible person. His bright example will most certainly be missed by everyone who knew him!

One of the central themes of this conference involved the role of symmetry in photonics, how it emerges in real space or phase (wavevector) space and how it guides the design of new unprecedented paradigms for nanolasers and non-linear systems. Specifically, there were four sessions dedicated to topology and symmetry in photonics,– sessions 2, 3, 4 and 6[1]–, showcasing different unconventional light control effects with topological photonic states, non-reciprocal responses as well as conserved or broken parity-time (PT) symmetry in gain-loss non-Hermitian photonic platforms. A notable keynote presentation in session 4, inspired by

[1] One of the presentations (110811L) originally scheduled for session 2 [Topology and Symmetry in Photonics I] had to unexpectedly be moved to session 13 [Exploring the Photonic-Computing Interface II]. The associated presentation recording is enlisted under the latter session.

counterpart systems in quantum mechanics, introduced a newfound route to photonic mode design: that of supersymmetry. Seemingly different photonic systems can be designed to be "twins", in some respects, with completely aligned eigen-spectra, but with strategically engineered differences that can enable monomodal lasing operation via dissipation of parasitic modes.

It is amazing that quantum mechanics has been a source of inspiration for photonic design since the advent of photonic crystals in the late 1980's and apparently continues to be so to this date. Apart from photonic supersymmetry and PT symmetry, quantum mechanics spurred research in photonic bound states in continuum (BIC). These BICs look like optical trapped modes inaccessible by external light excitations either because of the symmetry or because of accidental destructive interference of any outgoing radiation channels. New extraordinary BIC-related phenomena, such as BIC for enhanced second harmonic generation (SHG), single-sided BIC, merged symmetry-protected and accidental BIC were discussed in couple of fascinating keynote presentations in sessions 12 and 15 but also an exciting invited presentation in session 6. Moreover, an interesting poster presentation explored a semi-analytical tool for the study of BIC phenomena based on Bloch-wave interference that permits an easier sweeping of the parameter space to identify accidental BICs.

Tunable and dynamic photonic effects with structured photonic platforms are built upon the tunable and dynamic photonic responses of their material constituents. Atomically thin materials such as graphene, transition metal dichalcogenides (TMDs) as well as hBN are most promising for tunable and dynamic photonic responses due to their inherent sensitivity to external stimuli or optomechanical responses. Furthermore, metal oxides, metal nitrides and metal hydrides can have tunable permittivity responses that in some cases can be potentially dynamically controlled.

A number of interesting keynote, invited and contributed presentations in sessions 5, 7 and 8 discussed such exciting capabilities for tunability and dynamic photonic effects with these material. Specifically, the presentations in these sessions reported on theoretical and experimental studies that further our understanding of the photonic responses of these materials as well as advance the know-hows for the practical realization of relevant photonic platforms that integrate these materials. Additionally, achievement of new or enhanced photonic functionalities with traditional platforms that integrate quasi-2D material were discussed. Other promising structuring routes to achieve enhanced tunable responses with photonic platforms that includes also systems with active semiconductor constituents and optomechanical tunability was explored by a diverse set of presentations in session 9.

Furthermore, the conference featured two sessions (sessions 11 and 14) on photonics with phase-change materials (PCMs) which are materials that can change their structural and electronic properties with heating/cooling. These changes in structure and electronic properties may be volatile or non-volatile, depending on the particular material, affecting the respective photonic responses. The engaging keynote, invited, and contributed talks of these two sessions reported how to utilize PCMs for reconfigurable and switchable platforms including memories and infrared absorbers. In addition to such type of applications, one invited presentation also reported very promising research on how to improve the photonic responses of PCMs in the sense of improving the tunability of the refractive index without the adverse cost of simultaneously introducing a stronger extinction, i.e. higher photonic losses. Couple of presentations presented also results of electrically switchable PCM platforms, even with VO_2 which is typically switched between its phases optically. This electrical phase control offers versatility and is promising for PCM-based integrated photonics.

Emitters in complex photonic environments is an essential component to engineering nanoscale sources as well as for optical-based quantum computing applications. Several fascinating presentations in sessions 10, 15 and 18 focused both on advancing knowledge and theoretical tools to shed light on the intricate interactions between emitters and diverse photonic environments including 2D/quasi-2D materials as well as proposed platforms for room temperature quantum nanophotonics, helical-wave sources and nanolasing. Furthermore, nanolasing, non-linear and gain-material photonics were the overarching theme of sessions 16 and 18 that included amongst other topics intriguing reports on gain metamirrors and directional lasing. On the other hand, electromagnetic enhancement was discussed by presentations in session 17 within the context of applications for sensing, imaging and energy.

The recent rapid pace of progress in machine and deep learning spurred explorations of related operations and neuromorphic signal processing with photonic platforms. Cross-cutting keynote and invited talks in sessions 12 and 13 discussed analog optical computing with nanophotonic platforms, advances in neuromorphic photonics including non-linear electro-optic activation functions and silicon photonics reservoir computing as well as plasmonic-nanoantennae-based encoding for high-density data storage. A fascinating keynote presentation also reported on 3D printed diffractive optical element network designed based on the principles of deep-learning computing platforms that could perform image classification of handwritten digits and fashion products.

Along with the presentations discussed above, our conference also included a bustling poster session reporting advances in a variety of topics including dynamic signal control in waveguides as well as slow light waveguides, topological

photonics, bound states in continuum, dynamic photopolymer material and magnetically-doped photopolymers for holographic sensors/actuators, perfect, spectrally selective or wideband absorbers, elastic nanophotonic material for dynamic tunability, exceptional points for design of lasing platforms, optomechanical sensors, new material with controlled losses, vortex solitons, microdisk lasers, dynamic nanophotonics with microfluidic cavities, methods for nanophotonic design optimization, thermal emitter design based on phonon polaritons, non-resonant photonic platforms, as well as deterministic fabrication of quantum emitter sources.

For the past 5 years this conference runs a best student presentation competition which recognizes the best contributed orals presentations that were presented by a student author. The winners of the student award competition in 2019 were selected in a two-phase process. In the first phase of the competition the contributions are judged by the program committee of the Active Photonic Platforms conference, based on the submitted abstracts. Six contributions progressed to the second phase, which competed further on-site based on the oral presentation and were judged by a jury comprising expert attendees in the conference. This year we had three finalist winners that have tied in first place, enlisted below (the student presenter name is shown with bold font):

11081-21 [*110810L*]: Carrier kinetic models for intensity dependent refractive index in near-zero-index media
Author(s): **Ray Secondo**, Nathaniel Kinsey, Virginia Commonwealth Univ. (United States)

11081-63 [*110811S*]: Designing nonvolatile integrated photonics with low-loss optical phase change materials
Author(s): **Yifei Zhang**, Qihang Zhang, Massachusetts Institute of Technology (United States); Richard Soref, Univ. of Massachusetts Boston (United States); Tian Gu, Juejun Hu, Massachusetts Institute of Technology (United States)

11081-64 [*110811T*]: Electrical tuning of optical antenna resonance based on phase change material
Author(s): **Yifei Wang**, Patrick Landreman, Kye Okabe, H.-S. Philip Wong, Mark Brongersma, Stanford Univ. (United States)

We are delighted to congratulate the best student presentation winners and thank them for contributing these most amazing talks! The three winners enlisted above received an official SPIE certificate at the awards announcement session of the conference. See also coverage by SPIE in the awards and memberships photos section in the url below:

https://spie.org/conferences-and-exhibitions/optics-and-photonics/highlights-photos-and-more

With this opportunity we would like to also thank all student presenters for their enthusiastic participation in this competition contributing incredibly interesting research!

Active Photonic Platforms XI covered a vast topical range involving active, dynamic, and tunable control of light with structured-material platforms as well as systems involving atomically thin and phase-change materials. Novel behaviors for light waves in passive platforms that would enable new research directions in active photonics have also been featured. Theorists and experimentalists exchanged ideas, state-of-the art results and lively discussions in a rapidly evolving area of research.

As conference chairs, we would like to thank the program committee members of the conference, the session chairs as well as members of the best student presentation award jury for contributing in numerous ways to the success of this conference. We also sincerely thank all the authors of the 11081 conference who made this conference an interesting and stimulating event by engaging with their attendance and questions, presentations as well as manuscript contributions. Last but not least, we would like to thank all SPIE staff for their continuing and incredible support that made this event possible.

Ganapathi S. Subramania
Stavroula Foteinopoulou