PROCEEDINGS OF SPIE

Metamaterials, Metadevices, and Metasystems 2018

Nader Engheta Mikhail A. Noginov Nikolay I. Zheludev Editors

19–23 August 2018 San Diego, California, United States

Sponsored and Published by SPIE

Volume 10719

Proceedings of SPIE 0277-786X, V. 10719

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

Metamaterials, Metadevices, and Metasystems 2018, edited by Nader Engheta, Mikhail A. Noginov, Nikolay I. Zheludev, Proc. of SPIE Vol. 10719, 1071901 © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2515523

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 *Metamaterials, Metadevices, and Metasystems 2018*, edited by Nader Engheta, Mikhail A. Noginov, Nikolay I. Zheludev, Proceedings of SPIE Vol. 10719 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510620094

ISBN: 9781510620100 (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 © 2018, 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/18/\$18.00.

Printed in the United States of America.

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



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 ix	Authors Conference Committee
	METASURFACE OPTICS
10719 07	Huygens' metasurface made of core-shell spherical nanoparticles [10719-4]
	METADEVICES AND METASYSTEMS I
10719 OF	Reconfigurable passband filter using a controllable variable inductance [10719-13]
	STRONG COUPLING
10719 OK	Spontaneous emission of light by a dipole coupled to a plasmonic nanoresonator [10719-18]
10719 OL	Coupling effects in dense arrays of 3D optical metamaterials [10719-19]
	TOPOLOGICAL METAMATERIALS AND METASURFACES
10719 OS	Topologically protected embedded eigenstates, leaky modes, and Jordan modes (Invited Paper) [10719-26]
10719 OU	Advanced multi-objective and surrogate-assisted optimization of topologically diverse metasurface architectures [10719-28]
	DIELECTRIC NANO-OPTICS
10719 15	All-dielectric metasurface lenses for focal plane arrays operating in mid-wave infrared spectrum [10719-39]
	MID-IR TO THZ
10719 1H	Confined terahertz surface waves on meta-surfaces and Goubau lines [10719-50]

	PLASMONIC METAMATERIALS AND PHENOMENA
10719 1Q	Accumulation layer surface plasmons (Invited Paper) [10719-59]
	DIELECTRIC META-OPTICS
10719 IV	Dielectric zero-index metamaterial filled photonic crystal defect waveguide: design and analysis [10719-64]
	MATERIAL COMPONENTS
10719 23	Finite-difference time-domain numerical study of ultrashort pulse propagation across submicron scale distances in Al:ZnO/ZnO at the epsilon near-zero spectral point [10719-72]
	FUNDAMENTAL PHENOMENA II
10719 29	Coupled mode formulation by reciprocity in waveguides based on double and single negative metamaterial media [10719-77]
	METADEVICES AND METASYSTEMS II
10719 2D	Coupling between metallic structure and phonon polaritons for sensing applications [10719-82]
10719 2E	Determining attenuation and propagation constants of microstrip line in long-wave infrared [10719-83]
10719 2F	High efficient metasurface for broadband achromatic focusing in visible spectrum [10719-84]
	HYPERBOLIC METAMATERIALS
10719 2K	Large-area outcoupling of quantum dot emission on multilayer hyperbolic metamaterials [10719-88]
10719 2L	Mode coupling in graphene-based hyperbolic metamaterial waveguides [10719-90]
	STRUCTURED LIGHT
10719 2P	Vortex beam generation using all dielectric metasurface [10719-93]

POSTER SESSION

10719 2V	A hybrid method for scattering by multiple bodies [10719-98]
10719 2W	Dynamic coherent light scattering by the cement with carbon nanotubes during hydration process [10719-99]
10719 2Y	Reconfigurable dual-band to single-band filter based on a composite right/left-handed resonator [10719-101]
10719 33	Propagation properties of Fibonacci hypercrystal based on metamaterials [10719-106]
10719 34	Study of conductivity of the poly(3-hexylthiophene-2, 5-diyl) polymer (P3HT) in resonant Fabry-Perot cavities [10719-107]
10719 35	Toward plasmonic control of light propagation in an optical fiber [10719-108]
10719 38	Time resolved terahertz spectroscopy of optically pumped multilayered graphene on silicon substrate [10719-111]
10719 39	Epsilon-near-zero copper-dielectric composite for terahertz frequency range [10719-112]
10719 3C	Fractal plasmonic metamaterial with tunable properties in the near-infrared [10719-117]

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.

Abraha, A. J., 0K Adomanis, Bryan M., 0L Ahmed, Shahid, 35 Alexander, R., 34

Alsalhin, Abdelgader A., 2D Andrade-Ambriz, Yair A., 2Y Asane, J. K., 34

Bagci, Fehim T., 15
Baldycheva, Anna V., 38
Becker, Sven, 1H
Burckel, D. Bruce, 0L
Calandrini, Eugenio, 3C
Campbell, Sawyer D., 0U
Campione, Salvatore, 0L
Cattarin, Sandro, 3C
Chang, Shengqian, 2F
Chen, Xiaolin, 07
Cheng, L.-J., 2K

Demchenko, Petr S., 38, 39 Drachenberg, Reggie, 35 Estudillo-Ayala, Julián M., 2Y

Faruk, Md Omar, 35 Feigenbaum, Eyal, 35 Felbacq, Didier, 2V Finch, Michael F., 2D Fip, Tassilo, 1H Garoli, Denis, 3C Genevet, Patrice, 2V Gorsky, M. P., 2W Gourdin, Anthony, 2V

Grebenchukov, Alexandr N., 38

Isidio de Lima, J. J., 33 Janaszek, B., 29, 2L

Jáuregui-Vázquez, Daniel, 0F

Kalra, Yogita, 1V Kannegulla, A., 2K Kataria, Tejinder K., 0F Kelly, Priscilla, 23

Khodzitsky, Mikhail K., 38, 39

Kieliszczyk, M., 29, 2L Kocer, Hasan, 2P Kornilov, Egor V., 38 Kovalska, Evgeniya O., 38 Kurt, Hamza, 15, 2P Kuznetsova, Lyuba, 23 Lail, Brian A., 2D, 2E Litvinov, Egor A., 39

Liu, Siqi, 2F Liu, Xu, 2F Liu, Y., 2K

Maksimyak, P. P., 2W Miao, Shenjie, 2E Monticone, Francesco, 0S Nagar, Jogender, 0U Noginov, Mikhail A., 34, 35 Novoselov, Mikhail G., 38 Ortolani, Michele, 3C Ozdemir, Aytekin, 15 Ozer, Ahmet, 2P Paim, Miriele C., 33 Perotto, Sara, 3C

Peters, D. A., 34 Peters, V. N., 34 Ponzellini, Paolo, 3C Rahm, Marco, 1H Ramos, E. Alexander, 1Q

Reyes-Ayona, Jose R., 0F, 2Y Rodriguez-Esquerre, V. F., 33 Rojas-Laguna, Roberto, 0F Salandrino, Alessandro, 1Q Shahbazyan, T. V., 0K Shankhwar, Nishant, 1V Sheklanova, Elizaveta B., 39 Shemelya, Corey, 1H Sierra-Hernandez, Juan M., 2Y

Sinclair, Michael B., OL Sinha, Ravindra Kumar, 1V Sun, Pena, 2F

Sun, Peng, 2F Szczepański, P., 29, 2L Takashima, Yuzuru, 15 Tao, Chenning, 2F Tao, Xiao, 2F Toma, Andrea, 3C Tyszka-Zawadzka, A., 29, 2L

Uzodinma, J. A., 0K

Vargas-López, Evelyn L., 0F, 2Y Vozianova, Anna V., 39

Wallace, T., 34 Wang, Chang, 2F Wang, Y.-C., 2K Werner, Douglas H., 0U Werner, Pingjuan L., 0U Whiting, Eric B., 0U

Wu, B., 2K Wu, Rengmao, 2F Yao, Peijun, 07 Yilmaz, Nazmi, 15, 2P Zaitsev, Anton D., 38 Zhang, Wentao, 2F Zheng, Zhenrong, 2F Zhu, Danny Z., 0U

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

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

Conference Chairs

 Nader Engheta, University of Pennsylvania (United States)
 Mikhail A. Noginov, Norfolk State University (United States)
 Nikolay I. Zheludev, Optoelectronics Research Centre (United Kingdom) and Nanyang Technological University (Singapore)

Conference Program Committee

Andrea Alù, The University of Texas at Austin (United States)
Pierre Berini, University of Ottawa (Canada)
Alexandra Boltasseva, Purdue University (United States)
Igal Brener, Sandia National Laboratories (United States)
Mark Brongersma, Standford University (United States)
Joshua D. Caldwell, United States Naval Research Laboratory (United States)

Luca Dal Negro, Boston University (United States)

Jennifer A. Dionne, Stanford University (United States)

Javier García de Abajo, ICFO - Institut de Ciències Fotòniques (Spain)

Harald W. Giessen, Universität Stuttgart (Germany)

Yuri S. Kivshar, The Australian National University (Australia)

Jacob B. Khurgin, Johns Hopkins University (United States)

Uriel Levy, The Hebrew University of Jerusalem (Israel)

Natalia M. Litchinitser, University at Buffalo (United States)

Peter Nordlander, Rice University (United States)

Alessandro Salandrino, The University of Kansas (United States)

Gennady B. Shvets, The University of Texas at Austin (United States)

David R. Smith, Duke University (United States)

Mark I. Stockman, Georgia State University (United States)

Philippe Tassin, Chalmers Universitet of Technology (Sweden)
 Päivi Törmä, Aalto University School of Science (Finland)
 Sergei Tretyakov, Aalto University School of Science and Technology (Finland)

Din Ping Tsai, National Taiwan University (Taiwan)

Augustine M. Urbas, Air Force Research Laboratory (United States)

Martin Wegener, Karlsruher Institut für Technologie (Germany)

Jeong Weon Wu, Ewha Womans University (Korea, Republic of)

Xiang Zhang, University of California, Berkeley (United States)

Session Chairs

1 Metasurface Optics
Jacob B. Khurgin, Johns Hopkins University (United States)

2 Fundamental Phenomena I Mark Lawrence, Stanford University (United States)

- Metadevices and Metasystems I
 Ortwin Hess, Imperial College London (United Kingdom)
- 4 Strong Coupling Sander A. Mann, CUNY Advanced Science Research Center (United States)
- Special Session: Engineered Materials for EXTREME Optics and Imaging I
 Douglas H. Werner, The Pennsylvania State University (United States)
- 6 Topological Metamaterials and Metasurfaces
 Stavroula Foteinopoulou, The University of New Mexico (United States)
- 7 Special Session: Engineered Materials for EXTREME Optics and Imaging II

Douglas H. Werner, The Pennsylvania State University (United States)

- 8 Dielectric Nano-OpticsAndrei Faraon, Caltech (United States)
- 9 Metafilms and Metasurfaces Joshua D. Caldwell, Vanderbilt University (United States)
- 10 Mid-IR to THz Isabelle Staude, Friedrich-Schiller- Universität Jena (Germany)
- Nonlinear PhenomenaWiktor T. Walasik, Duke University (United States)

- 12 Plasmonic Metamaterials and Phenomena
 Nikolay I. Zheludev, Optoelectronics Research Centre (United Kingdom)
- Dielectric Meta-OpticsPrineha Narang, Harvard University (United States)
- 14 Material ComponentsBabak Bahari, University of California, San Diego (United States)
- 15 Fundamental Phenomena IISophie Viaene, Vrije Universiteit Brussel (Belgium)
- 16 Metadevices and Metasystems II
 Nathaniel Kinsey, Virginia Commonwealth University (United States)
- 17 Hyperbolic MetamaterialsDavid J. Bergman, Tel Aviv University (Israel)
- 18 Structured Light **Hui-Hsin Hsiao**, National Taiwan Normal University (Taiwan)
- 19 Mechanical and Acoustical Metamaterials Srujana Prayakarao, Norfolk State University (United States)