PROCEEDINGS OF SPIE

Terahertz Physics, Devices, and Systems X: Advanced Applications in Industry and Defense

Mehdi F. Anwar
Thomas W. Crowe
Tariq Manzur
Editors

17–19 April 2016
Baltimore, Maryland, United States

Sponsored and Published by
SPIE

Volume 9856

Proceedings of SPIE 0277-786X, V. 9856

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

Terahertz Physics, Devices, and Systems X: Advanced Applications in Industry and Defense, edited by Mehdi F. Anwar, Thomas W. Crowe, Tariq Manzur, Proc. of SPIE Vol. 9856, 985601 · © 2016 SPIE · CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2231212

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 *Terahertz Physics, Devices, and Systems X: Advanced Applications in Industry and Defense*, edited by Mehdi F. Anwar, Thomas W. Crowe, Tariq Manzur, Proceedings of SPIE Vol. 9856 (SPIE, Bellingham, WA, 2016) Six-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)
ISBN: 9781510600973

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.

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 six-digit CID article numbering system structured as follows:

- 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.

Contents

v *Authors*
vii *Conference Committee*

SESSION 1 KEYNOTE SESSION

9856 03 **Graphene-based van der Waals heterostructures for emission and detection of terahertz radiation (Invited Paper)** [9856-5]

SESSION 2 THZ SPECTROSCOPY I

9856 05 **Parallel plate waveguide time domain spectroscopy to study terahertz conductivity of utltrathin materials (Invited Paper)** [9856-1]

SESSION 3 THZ: ADVANCED CONCEPTS I

9856 0B **Terahertz metamaterials: design, implementation, modeling and applications (Invited Paper)** [9856-7]

9856 0F **Cooperative promotion of plasma instabilities for emission of terahertz radiation in an asymmetric dual-grating-gate graphene-channel FET** [9856-11]

9856 0G **Advanced terahertz techniques for quality control and counterfeit detection** [9856-12]

9856 0H **Detection of small metal particles by a quasi-optical system at sub-millimeter wavelength** [9856-13]

SESSION 4 THZ IMAGING

9856 0I **Externally triggered imaging technique for microbolometer-type terahertz imager (Invited Paper)** [9856-14]

9856 0M **New algorithm for the passive THz image quality enhancement** [9856-18]

9856 0N **Developing terahertz imaging equation and enhancement of the resolution of terahertz images using deconvolution** [9856-19]

SESSION 5 THZ: ADVANCED CONCEPTS II

9856 0O **Terahertz oscillators using resonant tunneling diodes and their functions for various applications (Invited Paper)** [9856-20]

9856 0P **Photonic crystal technology for terahertz system integration (Invited Paper)** [9856-21]

9856 0R **Quasioptical devices based on extraordinary transmission at THz (Invited Paper)** [9856-23]

SESSION 6 THZ DETECTION

9856 0S **Broadband and high-sensitivity terahertz-wave detection using Fermi-level managed barrier diode (Invited Paper)** [9856-24]

9856 0U **A terahertz monolithic integrated resonant tunneling diode oscillator and mixer circuit** [9856-26]

SESSION 7 THZ SPECTROSCOPY II

9856 0W **Temperature dependent terahertz properties of energetic materials (Invited Paper)** [9856-28]

9856 0Y **Probing charge transfer and hot carrier dynamics in organic solar cells with terahertz spectroscopy (Invited Paper)** [9856-30]

9856 0Z **The terahertz spectroscopic investigation and vibration analysis of triadimefon** [9856-31]

POSTER SESSION

9856 10 **Modeling of terahertz images based on x-ray images: a novel approach for verification of terahertz images and identification of objects with fine details beyond terahertz resolution** [9856-32]

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

Ahi, Kiarash, 0G, 0N, 10
Ahmed, Towfiq, 0W
Ajayan, Pulickel M., 05
Aleshkin, Vladimir Ya, 03
Anwar, Mehdi, 0G, 0N, 10
Asada, M., 0O
Azad, Abul K., 0W
Bagsican, Filchito R., 05
Balci, Soner, 0B
Beruete, Miguel, 0R
Boubanga Tombet, Stephane, 03
Brown, Kathryn E., 0W
Cunningham, Paul D., 0Y
Diebold, Sebastian, 0U
Domier, C. W., 0H
Dubinov, Alexander, 03
Esenturk, Okan, 0Y
Fujita, Masayuki, 0P, 0U
Gu, Xiaohong, 0Z
Heilweil, Edwin J., 0Y
Hokmabadi, Mohammad P., 0B
Ikeda, Makoto, 0H
Irizawa, Akinori, 0I
Ishi, Tsutomu, 0I
Ishibashi, Tadao, 0S
Isoyama, Goro, 0I
Ito, Hiroshi, 0S
Kato, Ryukou, 0I
Kawase, Keigo, 0I
Kawayama, Iwao, 05
Kim, Jae-Young, 0U
Kim, Juhyung, 0B
Kim, Seongsin M., 0B
Kitahara, Yasuyuki, 0H
Kono, Junichiro, 05
Koseki, Yuki, 0F
Kung, Patrick, 0B
Lane, Paul A., 0Y
Li, Lanyu, 0Z
Luhmann, Neville C., Jr., 0H
Ma, Lulu, 05
Melinger, Joseph S., 0Y
Mitin, Vladimir, 03
Mittleman, Daniel M., 05
Moore, David S., 0W
Mukai, Toshikazu, 0U
Murakami, Hironaru, 05
Nagatsuma, Tadao, 0P, 0U
Oda, Naoki, 0I
Okubo, Syuichi, 0I
Otsuji, Taiichi, 03, 0F
Pham, Anh-Vu, 0H
Philip, Elizabath, 0B
Popov, Vyacheslav V., 0F
Razanoelina, Manjakavahoaka, 05
Rivera, Elmer, 0B
Ryzhii, Maxim, 03
Ryzhii, Victor, 03, 0F
Satou, Akira, 03, 0F
Shur, Michael S., 03
Sorensen, Christian J., 0W
Sudou, Takayuki, 0I
Suzuki, S., 0O
Svintsov, Dmitry, 03
Tonouchi, Masayoshi, 05
Trofimov, Vladislav V., 0M
Trofimov, Vyacheslav A., 0M
Tsuruda, Kazuisao, 0U
Vajtai, Robert, 05
Wang, Qiang, 0Z
Watanabe, Takayuki, 0F
Whitley, Von H., 0W
Yadav, Deepika, 03
Zhang, Xiang, 05
Zhu, Muliang, 0B

Conference Committee

Symposium Chair

Ming C. Wu, University of California, Berkeley (United States)

Symposium Co-chair

Majid Rabbani, Eastman Kodak Company (United States)

Conference Chairs

Mehdi F. Anwar, University of Connecticut (United States)
Thomas W. Crowe, Virginia Diodes, Inc. (United States)
Tariq Manzur, Naval Undersea Warfare Center (United States)

Conference Program Committee

Abul K. Azad, Los Alamos National Laboratory (United States)
Giles Davies, University of Leeds (United Kingdom)
Gottfried H. Döhler, Max Planck Institute for the Science of Light (Germany)
Achyut K. Dutta, Banpil Photonics, Inc. (United States)
M. Saif Islam, University of California, Davis (United States)
Hiroshi Ito, Kitasato University (Japan)
Peter Uhd Jepsen, Technical University of Denmark (Denmark)
Edmund H. Linfield, University of Leeds (United Kingdom)
Amir Hamed Majedi, University of Waterloo (Canada)
Taiichi Otsuji, Tohoku University (Japan)
Nezih Pala, Florida International University (United States)
B. M. Azizur Rahman, City University London (United Kingdom)
Victor Ryzhii, University of Aizu (Japan)
Ashok K. Sood, Magnolia Optical Technologies, Inc. (United States)
Sigfrid K. Yngvesson, University of Massachusetts Amherst (United States)
Weili Zhang, Oklahoma State University (United States)

Session Chairs

1 Keynote Session
Tariq Manzur, Naval Undersea Warfare Center (United States)

2 THz Spectroscopy I
Abul K. Azad, Los Alamos National Laboratory (United States)
Tariq Manzur, Naval Undersea Warfare Center (United States)

3 THz: Advanced Concepts I
Taiichi Otsuji, Tohoku University (Japan)
Weili Zhang, Oklahoma State University (United States)

4 THz Imaging
Mehdi Anwar, University of Connecticut (United States)
Taiichi Otsuji, Tohoku University (Japan)

5 THz: Advanced Concepts II
Nezih Pala, Florida International University (United States)
Tariq Manzur, Naval Undersea Warfare Center (United States)

6 THz Detection
Mehdi Anwar, University of Connecticut (United States)
Abul K. Azad, Los Alamos National Laboratory (United States)

7 THz Spectroscopy II
Taiichi Otsuji, Tohoku University (Japan)
Tariq Manzur, Naval Undersea Warfare Center (United States)