PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 9483

, "Front Matter: Volume 9483," Proc. SPIE 9483, Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense, 948301 (1 June 2015); doi: 10.1117/12.2197714

SPIE.

Event: SPIE Sensing Technology + Applications, 2015, Baltimore, MD, United States

PROCEEDINGS OF SPIE

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

**Mehdi F. Anwar
Thomas W. Crowe
Tariq Manzur**
Editors

**22–23 April 2015
Baltimore, Maryland, United States**

Sponsored and Published by
SPIE

Volume 9483

Proceedings of SPIE 0277-786X, V. 9483

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

Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense
edited by Mehdi F. Anwar, Thomas W. Crowe, Tariq Manzur, Proc. of SPIE Vol. 9483, 948301
© 2015 SPIE · CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2197714

Proc. of SPIE Vol. 9483 948301-1

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 *Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense*, edited by Mehdi F. Anwar, Thomas W. Crowe, Tariq Manzur, Proceedings of SPIE Vol. 9483 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X

ISBN: 9781628415995

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 © 2015, 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/15/\$18.00.

Printed in the United States of America.

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

SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique 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 as 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.

Contents

v *Authors*
vii *Conference Committee*

SESSION 1 NOVEL CONCEPTS I

- 9483 02 **Terahertz isolator in asymmetry magneto-metasurface (Invited Paper)** [9483-1]
9483 04 **GaN-based terahertz quantum cascade lasers (Invited Paper)** [9483-39]

SESSION 2 THZ SOURCES I

- 9483 06 **Terahertz metamaterials for modulation and detection (Invited Paper)** [9483-5]
9483 07 **Broadband terahertz-wave detector implementing zero-biased InGaAsP Schottky-barrier diode (Invited Paper)** [9483-6]
9483 09 **Terahertz oscillators and receivers using electron devices for high-capacity wireless communication (Invited Paper)** [9483-8]

SESSION 3 THZ SOURCES II

- 9483 0C **Radar system components to detect small and fast objects** [9483-11]
9483 0D **Optical simulation of terahertz antenna using finite difference time domain method** [9483-12]

SESSION 4 ADVANCED MATERIALS AND DEVICES

- 9483 0G **Tuning of terahertz metamaterials' resonances via near field coupling (Invited Paper)** [9483-15]
9483 0H **Phase characteristics of subwavelength antenna elements for efficient design of terahertz frequency and millimeter wave metasurfaces** [9483-16]

SESSION 5 NOVEL CONCEPTS II

- 9483 0K **Terahertz characterization of electronic components and comparison of terahertz imaging with x-ray imaging techniques (Invited Paper)** [9483-18]

SESSION 6	THZ SPECTROSCOPY
9483 OM	Nonlinear optical frequency up-conversion broadening terahertz horizons in sensitive detection (Invited Paper) [9483-20]
9483 ON	Laminated helmet materials characterization by terahertz kinetics spectroscopy [9483-21]
9483 OO	Experimental determination of terahertz atmospheric absorption parameters [9483-22]
9483 OP	Possibility of the detection and identification of substance at long distance using the noisy reflected THz pulse under real conditions [9483-23]
SESSION 7	THZ IMAGING
9483 OS	Performances of THz cameras with enhanced sensitivity in sub-terahertz region [9483-26]
9483 OT	Robust identification of concealed dangerous substances using THz imaging spectroscopy [9483-29]
9483 OU	Transmission imaging measurements at 188 GHz with 0.35μm CMOS technology [9483-30]
	POSTER SESSION
9483 OV	MCT as sub-terahertz and infrared detector [9483-27]
9483 OW	Inspection of mechanical and electrical properties of silicon wafers using terahertz tomography and spectroscopy [9483-31]
9483 OX	Growth dependent optical properties of ZnMgO at THz frequencies [9483-32]

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, 0K, 0X	Minamide, H., 0M
Ambacher, Oliver, 0C	Miyoshi, Masaru, 0S
Andreyeva, Katerina V., 0V	Morimoto, Takao, 0S
Anwar, Mehdi F., 0K, 0X	Muehleisen, Wolfgang, 0W
Arnold, Thomas, 0W	Nawata, K., 0M
Asada, Masahiro, 09	Newman, J. Daniel, 0D, 0U
Asadizanjani, Navid, 0K	Ninkov, Zoran, 0D, 0U
Azad, Abul K., 0G	Nixon, William E., 0H, 0O
Bhandari, Sahil, 0U	Nystad, Helle E., 0T
Bocko, Mark V., 0U	Oda, Naoki, 0S
Chang, Shengjiang, 02	Osborn, John H., 0U
Chen, Hou-Tong, 0G	Petryakov, Vladimir A., 0V
Chen, Sai, 02	Pipher, Judith L., 0D, 0U
Chowdhury, Dibakar Roy, 0G	Rahman, Anis, 0N
Dayalu, Jagannath, 0D, 0U	Rahman, Aunik K., 0N
Dieguez, Ernesto, 0V	Rivera, Abdiel, 0X
Doi, Kohei, 0S	Rout, Saroj, 06
Dvoretzky, Sergey A., 0V	Sacco, Andrew P., 0D, 0U
Fan, Fei, 02	Sasaki, Tokuhito, 0S
Fertig, Greg, 0D	Schicker, Johannes, 0W
Fiete, Robert D., 0U	Schlechtweg, Michael, 0C
Fourspring, Kenneth D., 0D, 0U	Seery, Katherine, 0U
Fu, Guoqing, 06	Shahbazmohamadi, Sina, 0K
Gatesman, Andrew J., 0H	Shevchik-Shekera, Anna V., 0V
Giles, Robert H., 0H, 0O	Singh, Pramod, 06
Golenkov, Aleksandr G., 0V	Sizov, Fiodor F., 0V
Goto, Hideki, 0S	Slocum, David M., 0O
Goyette, Thomas M., 0O	Sonkusale, Sameer, 06
Haakestad, Magnus W., 0T	Sudou, Takayuki, 0S
Hayashi, S., 0M	Suzuki, Safumi, 09
Hirayama, Hideki, 04	Taylor, Antoinette J., 0G
Hirschl, Christina, 0W	Tehranipoor, Mark, 0K
Hülsmann, Axel, 0C	Terashima, Wataru, 04
Ignjatovic, Zeljko, 0D, 0U	Tessmann, Axel, 0C
Irizawa, Akinori, 0S	Trofimov, Vladislav V., 0P
Ishi, Tsutomu, 0S	Trofimov, Vyacheslav A., 0P
Isoyama, Goro, 0S	Tsybrii, Zinoviia F., 0V
Ito, Hiroshi, 07	van Rheezen, Arthur D., 0T
Kato, Ryukou, 0S	Varentsova, Svetlana A., 0P
Kawase, Keigo, 0S	Williams, Richard J., 0H
Klenner, Mathias, 0C	Wu, Pengfei, 02
Kremens, Robert, 0D	Xu, Wangren, 06
Kurashina, Seiji, 0S	Zabudsky, Vyacheslav V., 0V
Lee, Paul P. K., 0D, 0U	Zech, Christian, 0C
Leuther, Arnulf, 0C	Zhang, Chao X., 0D, 0U
Liu, Bo, 02	Zhang, Xi-Cheng, 0U
Lopez-Diaz, Daniel, 0C	
Mazady, Anas, 0X	
McMurtry, Craig W., 0D, 0U	

Conference Committee

Symposium Chair

Wolfgang Schade, Clausthal University of Technology (Germany) and
Fraunhofer Heinrich-Hertz Institute (Germany))

Symposium Co-chair

Ming C. Wu, University of California, Berkeley (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

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)
Azizur Rahman, City University London (United Kingdom)
Victor Ryzhii, University of Aizu (Japan)
Andre U. Sokolnikov, Visual Solutions and Applications (United States)
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 Novel Concepts I
Thomas W. Crowe, Virginia Diodes, Inc. (United States)
B. M. Azizur Rahman, City University London (United Kingdom)

- 2 THz Sources I
Mehdi F. Anwar, University of Connecticut (United States)
Tariq Manzur, Naval Undersea Warfare Center (United States)
- 3 THz Sources II
Mehdi F. Anwar, University of Connecticut (United States)
- 4 Advanced Materials and Devices
Weili Zhang, Oklahoma State University (United States)
- 5 Novel Concepts II
Thomas W. Crowe, Virginia Diodes, Inc. (United States)
B. M. Azizur Rahman, City University London (United Kingdom)
- 6 THz Spectroscopy
Mehdi F. Anwar, University of Connecticut (United States)
Hiroshi Ito, Kitasato University (Japan)
- 7 THz Imaging
Thomas W. Crowe, Virginia Diodes, Inc. (United States)
B. M. Azizur Rahman, City University London (United Kingdom)