

PROCEEDINGS OF SPIE

Terahertz Emitters, Receivers, and Applications V

Manijeh Razeghi
Alexei N. Baranov
John M. Zavada
Dimitris Pavlidis
Editors

17–18 August 2014
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 9199

Proceedings of SPIE 0277-786X, V. 9199

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

Terahertz Emitters, Receivers, and Applications V, edited by Manijeh Razeghi, Alexei N. Baranov,
John M. Zavada, Dimitris Pavlidis, Proc. of SPIE Vol. 9199, 919901 · © 2014 SPIE
CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2084658

Proc. of SPIE Vol. 9199 919901-1

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 Emitters, Receivers, and Applications V*, edited by Manijeh Razeghi, Alexei N. Baranov, John M. Zavada, Dimitris Pavlidis, Proceedings of SPIE Vol. 9199 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X
ISBN: 9781628412260

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 © 2014, 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/14/\$18.00.

Printed in the United States of America.

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



SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent 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. Numbers in the index correspond to the last two digits of the six-digit CID Number.

Contents

v	Authors
vii	Conference Committee

THZ EMITTERS BASED ON QUANTUM CASCADE LASERS

- 9199 02 Room temperature continuous wave THz quantum cascade laser source with high power operation (Invited Paper) [9199-1]
- 9199 03 Processing of AlGaAs/GaAs QC structures for terahertz laser (Invited Paper) [9199-2]

THZ EMITTERS

- 9199 08 Widely tunable THz-wave emitter with linear polarization characteristics based on antenna-integrated UTC-PD [9199-8]
- 9199 09 Experimental imaging research on continuous-wave terahertz in-line digital holography [9199-36]

FUNDAMENTALS OF THZ TECHNOLOGY I

- 9199 0C Terahertz coded aperture mask using vanadium dioxide bowtie antenna array [9199-11]
- 9199 0D High-efficiency terahertz-wave generation in silicon membrane waveguides [9199-12]
- 9199 0E Transmission of THz pulse with a few circles through opaque samples placed at long distance (4-6 metres) [9199-13]

FUNDAMENTALS OF THZ TECHNOLOGY II

- 9199 0F Graphene plasmonic heterostructures for new types of terahertz lasers (Invited Paper) [9199-14]
- 9199 0G Terahertz magnetospectroscopy of a point contact based on CdTe/CdMgTe quantum well [9199-15]
- 9199 0H THz valence band polaritons and antipolaritons [9199-16]
- 9199 0I Terahertz waveguides with low transmission losses: characterization and applications (Invited Paper) [9199-17]

THZ DETECTORS

- 9199 0J **Magnetic-field tunable THz detectors based on GaAs/AlGaAs and CdTe/CdMgTe quantum wells (Invited Paper)** [9199-18]
- 9199 0K **A high performance room temperature THz sensor** [9199-19]
- 9199 0L **Emerging electronic devices for THz sensing and imaging (Invited Paper)** [9199-20]

THZ IMAGING

- 9199 0M **THz QCL self-mixing interferometry for biomedical applications (Invited Paper)** [9199-21]
- 9199 0O **Expectation maximisation algorithms for terahertz transmission tomography** [9199-23]
- 9199 0P **Resolution enhancing of commercially available passive THz cameras due to computer processing** [9199-24]
- 9199 0Q **THz imaging studies of painted samples to guide cultural heritage investigations at the Enkleistra of St. Neophytos in Paphos, Cyprus** [9199-25]

SPECTROSCOPY AND BIOMEDICAL APPLICATIONS

- 9199 0S **THz optical design considerations and optimization for medical imaging applications** [9199-27]
- 9199 0U **In vivo confirmation of hydration based contrast mechanisms for terahertz medical imaging using MRI** [9199-29]

POSTER SESSION

- 9199 0Z **Visible-light controlled plasma excitations in high electron mobility GaAs/AlGaAs heterostructure** [9199-34]
- 9199 10 **Mid infrared luminescence of dilute nitride semiconductors: microscopic approach vs experiments** [9199-35]

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.

Adamus, Z., 0J	Łusakowski, J., 0G, 0J, 0Z
Aleshkin, Vladimir Ya., 0F	Marcinkiewicz, M., 0Z
Alger, Jeffery, 0U	Melzer, Jeffrey E., 0I
Arsenovic, Alex, 0C	Mitin, Vladimir, 0F
Bai, Y., 02	Mitrofanov, Oleg, 0I
Bajwa, Neha, 0Q, 0S, 0U	Mounaix, Patrick, 0O
Balacey, H., 0O	Nadri, Souheil, 0C
Balonis-Sant, Magdalena, 0Q	Navarro-Cia, Miguel, 0I
Bandyopadhyay, N., 02	Nikolić, Milan, 0M
Bertling, Karl, 0M	Nowroozi, Bryan, 0S, 0U
Biatek, M., 0G, 0J, 0Z	Oriaku, C. I., 10
Boubanga Tombet, Stephane Albon, 0F	Otsuji, Taiichi, 0F
Czapkiewicz, M., 0G	Pałka, N., 03
Davies, A. Giles, 0M	Percy, Rebecca, 0C
Diakonova, N., 0G	Pereira, M. F., 0H, 10
Dubinov, Alexander, 0F	Piętka, B., 0Z
Ennis, Daniel B., 0U	Piotrowska, A., 03
Faragai, I. A., 0H	Płuska, M., 03
Fay, P., 0L	Popov, Vyacheslav, 0F
Ferguson, Blake, 0M	Radpour, Roxanne, 0Q
Garritano, James, 0Q, 0S, 0U	Rahman, S., 0L
Gołaszewska, K., 03	Rakić, Aleksandar D., 0M
Grigellionis, I., 0G, 0J	Razeghi, M., 02
Grundfest, Warren, 0Q, 0S, 0U	Recur, B., 0O
Grynberg, M., 0G, 0J	Rong, Lu, 09
Harrington, James A., 0I	Ryzhii, Maxim, 0F
Huang, Haochong, 09	Ryzhii, Victor, 0F
Huang, Nan, 0D	Sakowicz, M., 03
Indjin, Dragan, 0M	Satou, Akira, 0F
Ishibashi, Tadao, 08	Schaider, Helmut, 0M
Ito, Hiroshi, 08	Sensale-Rodriguez, B., 0L
Jakieła, R., 03	Sešek, Aleksander, 0K
Jiang, Z., 0L	Shur, Michael, 0F
Kakoulli, Ioanna, 0Q	Slivken, S., 02
Karczewski, G., 0J	Soyer, H. Peter, 0M
Kašalynas, Irmantas, 0K	Sun, Qibing, 0D
Kittiwatanakul, Lin, 0C	Sung, Shijun, 0Q, 0S, 0U
Knap, W., 0G	Švigelj, Andrej, 0K
Kolkovski, V., 0G	Szerling, A., 03
Kosiel, K., 03	Szymański, M., 03
Kuchik, Igor E., 0P	Taimre, Thomas, 0M
Łaszcz, A., 03	Tarkowski, T., 0Z
Lim, Yah Leng, 0M	Taylor, Zachary D., 0Q, 0S, 0U
Linfield, Edmund H., 0M	Tewari, Priyamvada, 0Q, 0U
Liu, Hongjun, 0D	Trajnerowicz, A., 03
Liu, L., 0L	Trofimov, Vladislav V., 0E, 0P
Llombart, Nuria, 0S	Trofimov, Vyacheslav A., 0E, 0P
Lu, Jiwei, 0C	Trontelj, Janez, 0K
Lu, Q. Y., 02	Umansky, V., 0J, 0Z

Valavanis, Alexander, 0M
Valušis, Gintaras, 0K
Varentsova, Svetlana A., 0E
Venckevičius, Rimvydas, 0K
Vitiello, Miriam S., 0I
Walczakowski, M., 03
Walker, Graeme, 0M
Wang, Dayong, 09
Wang, Yunxin, 09
Wang, Zhaolu, 0D
Wasilewski, Z., 03
Watanabe, Takayuki, 0F
Weikle, Robert M. II, 0C
Wiater, M., 0G
Wilson, Stephen J., 0M
Wojciechowski, M., 0G
Wojtowicz, T., 0G, 0J
Wolf, Stu, 0C
Wróbel, J., 0G, 0J, 0Z
Xie, Y., 0L
Xing, H., 0L
Yamamoto, Hiroshi, 08
Yoshimatsu, Toshihide, 08
Zhao, Y., 0L

Conference Committee

Program Track Chairs

Shizhuo Yin, The Pennsylvania State University (United States)
Ruyan Guo, The University of Texas at San Antonio (United States)

Conference Chairs

Manijeh Razeghi, Northwestern University (United States)
Alexei N. Baranov, Université Montpellier 2 (France)
John M. Zavada, National Science Foundation (United States)
Dimitris Pavlidis, National Science Foundation (United States)

Conference Program Committee

Joshua Abell, U.S. Naval Research Laboratory (United States)
Stefano Barbieri, Université Paris 7-Denis Diderot (France)
Henry O. Everitt, U.S. Army Research, Development and Engineering Command (United States)
Jérôme Faist, ETH Zürich (Switzerland)
Mauro F. Pereira, Sheffield Hallam University (United Kingdom)
Sven Höfling, Julius-Maximilians-Universität Würzburg (Germany)
Qing Hu, Massachusetts Institute of Technology (United States)
Hiroshi Ito, Kitasato University (Japan)
Mona Jarrahi, University of Michigan (United States)
Wojciech Knap, Université Montpellier 2 (France)
Stephen A. Lynch, Cardiff University (United Kingdom)
Juliette Mangeney, Ecole Normale Supérieure (France)
Tariq Manzur, Naval Undersea Warfare Center (United States)
Gaël Mouret, Université du Littoral Côte d'Opale (France)
Gregory S. Nusinovich, University of Maryland, College Park (United States)
Naoki Oda, NEC Corporation (Japan)
Pascale Roy, Synchrotron SOLEIL (France)
Carlo Sirtori, Université Paris 7-Denis Diderot (France)
Zachary D. Taylor, University of California, Los Angeles (United States)
Roland Teissier, Université Montpellier 2 (France)
Gintaras Valušis, Center for Physical Sciences and Technology (Lithuania)

Miriam S. Vitiello, Consiglio Nazionale delle Ricerche (Italy)
Benjamin S. Williams, University of California, Los Angeles
(United States)

Session Chairs

- 1 THz Emitters Based on Quantum Cascade Lasers
John M. Zavada, National Science Foundation (United States)
Mauro F. Pereira, Sheffield Hallam University (United Kingdom)
- 2 THz Emitters
Oleg Mitrofanov, University College London (United Kingdom)
Vyacheslav A. Trofimov, Lomonosov Moscow State University
(Russian Federation)
- 3 Fundamentals of THz Technology I
Mikhail A. Belkin, The University of Texas at Austin (United States)
Giacomo Scalari, ETH Zürich (Switzerland)
- 4 Fundamentals of THz Technology II
Aleksandar D. Rakic, The University of Queensland (Australia)
Anna Mazhorova, Institut National de la Recherche Scientifique
(Canada)
- 5 THz Detectors
Sukhdeep S. Dhillon, Laboratoire Pierre Aigrain (France)
Anna Szerling, Institute of Electron Technology (Poland)
- 6 THz Imaging
Elliott R. Brown, Wright State University (United States)
Zachary D. Taylor, University of California, Los Angeles (United States)
- 7 Spectroscopy and Biomedical Applications
Patrick Fay, University of Notre Dame (United States)
Jerzy Lusakowski, University of Warsaw (Poland)
- 8 Novel Concepts and Materials for THz Technology
Manijeh Razeghi, Northwestern University (United States)
Alexei N. Baranov, Université Montpellier 2 (France)