Terahertz and Ultrashort Electromagnetic Pulses for Biomedical Applications

Gerald J. Wilmink
Bennett L. Ibey
Editors

6–7 February 2013
San Francisco, California, United States

Sponsored by
SPIE

Cosponsored by
LongWave Photonics LLC (United States)
M Squared (United States)

Published by
SPIE

Volume 8585
Contents

vii Conference Committee
ix Introduction

SESSION 1 TERAHERTZ TECHNOLOGIES

8585 06 Development of terahertz (THz) microfluidic devices for “Lab-on-a-Chip” applications (Invited Paper) [8585-5]
Q. Tang, M. Liang, Y. Lu, P. K. Wong, The Univ. of Arizona (United States); G. J. Wilmink, Air Force Research Lab. (United States); H. Xin, Univ. of Arizona (United States) and Air Force Research Lab. (United States)

8585 07 Terahertz sensing with meta-surfaces and integrated circuits (Invited Paper) [8585-6]
B. Reinhard, Univ. of Kaiserslautern (Germany); K. Schmitt, Univ. of Kaiserslautern (Germany) and Fraunhofer Institute for Physical Measurement Techniques IPM (Germany); T. Fip, Univ. of Kaiserslautern (Germany); M. Volk, Univ. of Kaiserslautern (Germany) and Fraunhofer Institute for Physical Measurement Techniques IPM (Germany); J. Neu, A.-K. Mahro, Univ. of Kaiserslautern (Germany); R. Beigang, Univ. of Kaiserslautern (Germany) and Fraunhofer Institute for Physical Measurement Techniques IPM (Germany); M. Rahm, Univ. of Kaiserslautern (Germany)

8585 08 Terahertz quantum cascade laser based optical coherence tomography (Invited Paper) [8585-7]
A. W. M. Lee, LongWave Photonics LLC (United States) and Massachusetts Institute of Technology (United States); T.-Y. Kao, Q. Hu, Massachusetts Institute of Technology (United States); J. L. Reno, Sandia National Labs. (United States)

8585 09 Terahertz and mid-infrared photoexpansion nanospectroscopy (Invited Paper) [8585-8]
F. Lu, M. Jin, Univ. of Texas at Austin (United States); M. Salih, P. Dean, S. P. Khanna, L. H. Li, G. Davies, E. H. Linfield, Univ. of Leeds (United Kingdom); M. A. Belkin, Univ. of Texas at Austin (United States)

SESSION 2 SPECTROSCOPY AND THEORY

8585 0D Molecular modeling of membrane modifications after exposure to nanosecond, pulsed electric fields (Keynote Paper) [8585-12]
P. T. Vernier, Univ. of Southern California (United States) and Old Dominion Univ. (United States)

8585 0E Protein-water network dynamics during metalloenzyme hydrolysis observed by kinetic THz absorption (KITA) (Invited Paper) [8585-13]
B. Born, Ruhr-Univ. Bochum (Germany) and Weizmann Institute of Science (Israel); M. Heyden, Univ. of California, Irvine (United States); M. Grossman, I. Sagi, Weizmann Institute of Science (Israel); M. Havenith, Ruhr-Univ. Bochum (Germany)

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 19 Nov 2022
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use
Determination of the optical properties of melanin-pigmented human skin equivalents using terahertz time-domain spectroscopy [8585-14]
D. Lipscomb, Air Force Research Lab. (United States) and Univ. of California, Berkeley (United States); I. Echchgadda, National Academy of Sciences NRC Research Associateship (United States); X. G. Peralta, Univ. of Texas at San Antonio (United States); G. J. Wilmink, Air Force Research Lab. (United States)

SESSION 3 NSEP AND THZ BIOMEDICAL APPLICATIONS

Nanoelectroablation for human carcinoma therapy (Keynote Paper) [8585-15]
R. Nuccitelli, M. Kreis, B. Athos, R. Wood, J. Huynh, K. Lul, P. Nuccitelli, BioElectroMed Corp. (United States); E. Epstein, Children’s Hospital Oakland Research Institute (United States)

Hemorrhage control by microsecond electrical pulses [8585-17]
Y. Mandel M.D., Hansen Experimental Physics Lab., Stanford Univ. (United States); R. Manivanh, R. Dalai, Stanford Univ. (United States); P. Huie, J. Wang, M. Brinton, D. Palanker, Hansen Experimental Physics Lab., Stanford Univ. (United States)

Using a portable terahertz spectrometer to measure the optical properties of in vivo human skin [8585-18]
I. Echchgadda, National Academy of Sciences NRC Research Associateship (United States); J. E. Grundt, Air Force Research Lab. (United States); M. Tarango, General Dynamics Information Technology (United States); B. L. Ibey, Air Force Research Lab. (United States); T. Tongue, Zomega Terahertz Corp. (United States); M. Liang, H. Xin, The Univ. of Arizona (United States); G. J. Wilmink, Air Force Research Lab. (United States)

Identification of tissue interaction of terahertz radiation toward functional tissue imaging [8585-19]
H. Yokus, W. Baughman, S. Balci, M. Bolus, D. Wilbert, P. Kung, S. M. Kim, Univ. of Alabama (United States)

SESSION 4 NERVE STIMULATION

Neurostimulation using subnanosecond electric pulses (Invited Paper) [8585-21]
S. Xiao, A. Pakhomov, F. Guo, Frank Reidy Research Ctr. for Bioelectronics, Old Dominion Univ. (United States); S. Polisetty, Old Dominion Univ. (United States); K. H. Schoenbach, Frank Reidy Research Ctr. for Bioelectronics, Old Dominion Univ. (United States)

Comparison of the effects of millimeter wave irradiation, general bath heating, and localized heating on neuronal activity in the leech ganglion (Invited Paper) [8585-22]
S. Romanenko, P. H. Siegel, D. A. Wagenaar, California Institute of Technology (United States); V. Pikov, Huntington Medical Research Institutes (United States)

Effects of nano-second electrical pulses (nsPEFs) on cell cycle progression and susceptibility at various phases [8585-37]
M. A. Mahlke, Air Force Research Lab. (United States) and Univ. of Texas at San Antonio (United States); G. Thompson, National Research Council (United States); L. Estlack, General Dynamics Information Technology (United States); C. Navara, Univ. of Texas at San Antonio (United States); B. L. Ibey, Air Force Research Lab. (United States)
SESSION 5  BIOLOGICAL EFFECTS

8585 0Q  Intense picosecond THz pulses alter gene expression in human skin tissue in vivo [8585-26]
L. V. Titova, A. K. Ayesheshim, Univ. of Alberta (Canada); A. Golubov, R. Rodriguez-Juarez,
A. Kovalchuk, Univ. of Lethbridge (Canada); F. A. Hegmann, Univ. of Alberta (Canada);
O. Kovalchuk, Univ. of Lethbridge (Canada)

8585 OR  Changes in protein expression of U937 and Jurkat cells exposed to nanosecond pulsed
electric fields [8585-27]
E. K. Moen, Univ. of Southern California (United States); C. C. Roth, General Dynamics
Information Technology (United States); C. Cerna, L. Estalck, G. Wilmink, B. L. Ibey, Air Force
Research Lab. (United States)

8585 OS  Measurement of changes in plasma membrane phospholipid polarization following
nanosecond pulsed electric field exposure [8585-28]
S. Franklin, Univ. of Texas at San Antonio (United States); B. L. Ibey, Air Force Research Lab.
(United States); K. Nash, Univ. of Texas at San Antonio (United States); H. T. Beier, Air Force
Research Lab. (United States)

8585 OT  Role of cytoskeleton and elastic moduli in cellular response to nanosecond pulsed electric
fields  [8585-29]
G. L. Thompson, National Research Council (United States); C. Roth, Univ. of Texas Health
Science Ctr. at San Antonio (United States); G. Tolstykh, National Research Council (United
States); M. Kuipers, B. L. Ibey, Air Force Research Lab. (United States)

SESSION 6  ENHANCEMENT OF APPLICATIONS

8585 OX  Reflectivity measurements of water and dioxane mixtures using a 100 GHz Gunn diode
source [8585-33]
A. Maccabi, D. B. Bennett, N. Bajwa, P. Tewari, S. Sung, W. S. Grundfest, Z. D. Taylor, Univ. of
California, Los Angeles (United States)

8585 OY  Terahertz metamaterials perfect absorbers for sensing and imaging [8585-34]
D. S. Wilbert, M. P. Hokmabadi, J. Martinez, P. Kung, S. M. Kim, Univ. of Alabama (United
States)

8585 10  Aperture-less terahertz near-field imaging [8585-38]
W. E. Baughman, Z. Smithson, M. Baker, D. S. Wilbert, P. Kung, S. M. Kim, Univ. of Alabama
(United States)

Author Index
Conference Committee

Symposium Chairs

James Fujimoto, Massachusetts Institute of Technology (United States)
R. Rox Anderson, Wellman Center for Photomedicine, Massachusetts General Hospital (United States) and Harvard School of Medicine (United States)

Program Track Chairs

Steven L. Jacques, Oregon Health & Science University (United States)
William P. Roach, U.S. Air Force (United States)

Conference Chairs

Gerald J. Wilmink, Air Force Research Laboratory (United States)
Bennett L. Ibey, Air Force Research Laboratory (United States)

Conference Program Committee

Hope T. Beier, Air Force Research Laboratory (United States)
Benjamin P. Born, Weizmann Institute of Science (Israel)
Patrick O. Bradshaw, Air Force Office of Scientific Research (United States)
Elliott R. Brown, Wright State University (United States)
Ibtissam Echchgadda, National Academy of Sciences (United States)
Yuri Feldman, The Hebrew University of Jerusalem (Israel)
Gian Piero Gallerano, ENEA (Italy)
Martina Havenith, Ruhr-Universität Bochum (Germany)
Peter Uhd Jepsen, Technical University of Denmark (Denmark)
Kodo Kawase, Nagoya University (Japan)
Martin Koch, Technische Universität Braunschweig (Germany)
Richard Nuccitelli, BioElectroMed Corporation (United States)
Gun-Sil Park, Seoul National University (Korea, Republic of)
Emma Pickwell-MacPherson, Hong Kong University of Science and Technology (Hong Kong, China)
W. Pat Roach, Air Force Research Laboratory (United States)
Peter H. Siegel, Jet Propulsion Laboratory (United States)
Joo-Hiuk Son, The University of Seoul (Korea, Republic of)
Koichiro Tanaka, Kyoto University (Japan)
Robert J. Thomas, Air Force Research Laboratory (United States)
P. Thomas Vernier, The University of Southern California (United States)
Shu Xiao, Old Dominion University (United States)
Hao Xin, The University of Arizona (United States)
Session Chairs

1. Terahertz Technologies
   **Elliott R. Brown**, Wright State University (United States)

2. Spectroscopy and Theory
   **Richard Nuccitelli**, BioElectroMed Corporation (United States)

3. nsEP and THz Biomedical Applications
   **M. Hassan Arbab**, University of Washington (United States)

4. Nerve Stimulation
   **Peter Uhd Jepsen**, Technical University of Denmark (Denmark)

5. Biological Effects
   **Elliott R. Brown**, Wright State University (United States)

6. Enhancement of Applications
   **Paul Thomas Vernier**, The University of Southern California (United States)
Introduction

The terahertz (THz) region of the electromagnetic (EM) spectrum is defined as frequencies ranging from 0.1 to 10 THz (1 THz = $10^{12}$ Hz = 1 ps). Historically, few sources have been available to efficiently generate THz radiation; however, several recent technological advances have resulted in the unprecedented development of many new types of THz sources and components. These technologies are now being used as tools for a plethora of novel basic science investigations, and they are increasingly being integrated into innovative sensing and imaging operational schemes, which are finding widespread use in a host of medical, military, and defense applications.

Ultrashort electromagnetic pulses (USEP) are defined as pulses with duration below one microsecond and a rise time at or below a nanosecond. Direct application of USEP on tissue has been shown to elicit an array of biological effects including plasma membrane breakdown, cellular swelling, nuclear granulation, and initiation of apoptotic death. These observed phenomena have spawned quick advancement of USEP-based techniques into clinical devices to treat both superficial and deep cancers. USEP-based technologies have a distinct advantage of causing desired effects only within the profile of the electric field with little to no thermal footprint. Future technology is pushing beyond direct application into shorter pulse regimes (picoseconds) to enable free field propagation of USEP into deep tissue. These efforts have required advancements in pulse generators and antenna construction. The drive to shorter pulse duration bridges the gap between electrical pulses and those commonly generated by THz sources.

Fundamental knowledge gaps exist regarding how electric fields with frequency components from the MHz to the THz interact with biological structures. This conference aims to highlight USEP and THz source development, biological applications, and fundamental interactions with tissues, cells, and biomolecules.