

PROCEEDINGS OF SPIE

Emerging Imaging and Sensing Technologies

Keith L. Lewis
Richard C. Hollins
Editors

28–29 September 2016
Edinburgh, United Kingdom

Sponsored by
SPIE

Cooperating Organisations
Innovation Centre for Sensor and Imaging Systems (United Kingdom)
ADS Scotland (United Kingdom)
The Knowledge Transfer Network (United Kingdom)
Visit Scotland (United Kingdom)
European Regional Development Fund (Belgium)
Technology Scotland (United Kingdom)

Published by
SPIE

Volume 9992

Proceedings of SPIE 0277-786X, V. 9992

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

Emerging Imaging and Sensing Technologies, edited by Keith L. Lewis,
Richard C. Hollins, Proc. of SPIE Vol. 9992, 999201 · © 2016 SPIE
CCC code: 0277-786X/16/\$18 · doi: 10.1117/12.2264106

Proc. of SPIE Vol. 9992 999201-1

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 SPIDigitalLibrary.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 *Emerging Imaging and Sensing Technologies*, edited by Keith L. Lewis, Richard C. Hollins, Proceedings of SPIE Vol. 9992 (SPIE, Bellingham, WA, 2016) six-digit Article CID Number.

ISSN: 0277-786X
ISSN:1996-756X (electronic)
ISBN: 9781510603882
ISBN: 9781510603899 (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 © 2016, 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/16/\$18.00.

Printed in the United States of America.

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

**SPIE. DIGITAL
LIBRARY**
SPIDigitalLibrary.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*
- ix *Introduction*

INFRARED AND OPTICAL DEVICES

- 9992 03 **MWIR optical modulation using structured silicon membranes (Invited Paper) [9992-2]**
- 9992 05 **Design of a miniature SWIR hyperspectral snapshot imager utilizing multivariate optical elements [9992-27]**

OPTICAL DEVICES AND MATERIALS

- 9992 06 **Mid-infrared (MIR) photonics: MIR passive and active fiber optics for chemical and biomedical, sensing and imaging (Invited Paper) [9992-5]**
- 9992 07 **Picosecond laser bonding of highly dissimilar materials (Invited Paper) [9992-6]**
- 9992 0A **The comparison of the influence of centrifugal forces and the Sagnac effect on a rotating whispering gallery modes resonators [9992-9]**

LASERS AND LASER APPLICATIONS

- 9992 0C **Advances in AlGaInN laser diode technology for defence, security and sensing applications [9992-11]**
- 9992 0D **Environmental stability of actively mode locked fibre lasers [9992-12]**
- 9992 0E **Pulsed x-ray imaging of high-density objects using a ten picosecond high-intensity laser driver [9992-13]**

COMPUTATIONAL IMAGING AND IMAGE PROCESSING

- 9992 0F **Compressive imaging using fast transform coding (Invited Paper) [9992-14]**
- 9992 0G **Comparative noise performance of a coded aperture spectral imager [9992-15]**
- 9992 0H **Recognition of complex human behaviours using 3D imaging for intelligent surveillance applications [9992-16]**

9992 0I **Coherent imaging by using defocus grating** [9992-17]

QUANTUM TECHNOLOGIES

9992 0J **Accelerated technology transfer: the UK quantum initiative (Invited Paper)** [9992-18]

9992 0M **Bayesian signal processing techniques for the detection of highly localised gravity anomalies using quantum interferometry technology** [9992-21]

CORRELATED IMAGERY

9992 0N **Picosecond time-resolved imaging using SPAD cameras (Invited Paper)** [9992-22]

9992 0O **TACImager: a high frame rate 256 x 256 SPAD time to amplitude converter array with adjustable time zoom (Invited Paper)** [9992-23]

9992 0R **Depth imaging in highly scattering underwater environments using time-correlated single-photon counting** [9992-26]

POSTER SESSION

9992 0S **The investigation of a shift of the whispering gallery modes caused by deformations and tensions** [9992-8]

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.

Ahmed, H., 0E
Alejo, A., 0E
Allott, R., 0E
Armstrong, C., 0E
Baili, Ghaya, 0D
Bennett, Simon D., 0J
Bikov, Leonid, 05
Boćkowski, M., 0C
Brenner, C. M., 0E
Brown, Gareth, 0M
Buller, Gerald S., 0R
Burgess, C. D., 03
Butler, Michael, 0H
Butler, N. M. H., 0E
Calder, Neil J., 0O
Calderbank, Robert, 0F
Canham, Leigh T., 03
Carter, Richard M., 07
Chan, Susan, 0N
Chen, Jianyong, 07
Clarke, R., 0E
Cohen, Omer, 05
Czernecki, R., 0C
Davies, John, 0D
de Villiers, Geoffrey, 0M
Ding, Mengia, 0G
Dmitrieva, Anna D., 0A
Dougherty, John, 05
Dutton, Neale A. W., 0O
Elder, Ian, 07
Esser, M. J. Daniel, 07
Faccio, Daniele, 0N
Filatov, Yuri V., 0A, 0S
Finlayson, Neil, 0O
Gariepy, Genevieve, 0N
Godfree, Peter, 0G
Haddock, D., 0E
Hagras, Haní, 0H
Halimi, Abderrahim, 0R
Hand, Duncan P., 07
Henderson, Robert K., 0N, 0O
Hernandez-Gomez, C., 0E
Higginson, A., 0E
Hill, Calum H., 0D
Hirsh, Itay, 05
James, David, 0G
Kaplan, A., 03
Kar, S., 0E
Kukaev, Alexander S., 0S
Lamb, Robert A., 07
Leach, Jonathan, 0N
Lee, Stephen T., 0D
Lepley, Jason J., 0H
Leszczyński, M., 0C
Lewis, K. L., 03
Ma, Haotong, 0I
Maccarone, Aurora, 0R
Marona, L., 0C
McCarthy, Aongus, 0R
McClymont, A., 0E
McKenna, P., 0E
McLaughlin, Steve, 0R
Mirfayzi, S. R., 0E
Murphy, C., 0E
Najda, S. P., 0C
Neely, D., 0E
Nofley, M., 0E
Oliver, P., 0E
Park, S. J., 03
Parmesan, Luca, 0O
Peall, Robert, 0H
Perlin, P., 0C
Pefillot, Yvan, 0R
Piper, Jonathan, 0G
Priore, Ryan, 05
Qi, Bo, 0I
Reid, Deryck T., 0D
Ren, Ge, 0I
Ridley, Kevin, 0M
Rodgers, Anthony, 0M
Rusby, D. R., 0E
Seddon, Angela B., 06
Selvagumar, Senthurran, 0G
Shalymov, Egor V., 0A, 0S
Soori, Umair, 0G
Suski, T., 0C
Targowski, G., 0C
Thompson, Andrew, 0F
Thomson, Robert R., 07
Tobin, Rachael, 0R
Troughton, Michael, 07
Venediktov, Vladimir Yu., 0A, 0S
Wallace, Andy M., 0R
Wang, Sanhong, 0I
Warburton, Ryan, 0N
Wilson, L. A., 0E
Wisniewski, P., 0C
Xie, Zongliang, 0I

Yao, Bo, 0H
Yuen, Peter, 0G
Zakar, A., 03
Zerova, V., 03
Zhang, Guowen, 0I

Conference Committee

Symposium Chairs

David H. Titterton, United Kingdom Defence Academy
(United Kingdom)

Symposium Co-Chairs

Ric Schleijpen, TNO Defence, Security and Safety (Netherlands)
Karin Stein, Fraunhofer-Institut für Optronik, Systemtechnik und
Bildauswertung (Germany)
Stuart S. Duncan, Leonardo-Finmeccanica (United Kingdom)

Conference Chairs

Keith L. Lewis, Sciovis Ltd. (United Kingdom)
Richard C. Hollins, Defence Science and Technology Laboratory
(United Kingdom)

Conference Program Committee

Tibor Berceli, Budapest University of Technology and Economics
(Hungary)
Arnaud Brignon, Thales Research & Technology (France)
Gerald S. Buller, Heriot-Watt University (United Kingdom)
Béatrice Cabon, Minatec (France)
John J. R. David, The University of Sheffield (United Kingdom)
Didier Decoster, Université des Sciences et Technologies de Lille
(France)
Dominique Hamoir, ONERA (France)
Andrew R. Harvey, University of Glasgow (United Kingdom)
Christopher Hill, Malvern Lidar Consultants (United Kingdom)
Robert A. Lamb, SELEX Galileo Ltd. (United Kingdom)
Javier Marti-Sendra, Universidad Politècnica de València (Spain)
Stephen P. McGeoch, Thales Optronics Ltd. (United Kingdom)
Ralf Ostendorf, Fraunhofer-Institut für Angewandte Festkörperphysik
(Germany)
Miles J. Padgett, University of Glasgow (United Kingdom)
Miguel A. Piqueras, DAS Photonics (Spain)
Julien Poette, Institut National Polytechnique de Grenoble (France)
Béla Szentpáli, Research Institute for Technical Physics and Materials
Science (Hungary)
Alexander Toet, TNO Defence, Security and Safety (Netherlands)
Mauro G. Varasi, Finmeccanica (Italy)

Jean-Pierre Vilcot, Université des Sciences et Technologies de Lille
(France)

Session Chairs

- 1 Infrared and Optical Devices
Keith L. Lewis, Sciovis Ltd. (United Kingdom)
Richard C. Hollins, Defence Science and Technology Laboratory
(United Kingdom)
- 2 Optical Devices and Materials
Richard C. Hollins, Defence Science and Technology Laboratory
(United Kingdom)
Keith L. Lewis, Sciovis Ltd. (United Kingdom)
- 3 Lasers and Laser Applications
Robert A. Lamb, Leonardo-Finmeccanica (United Kingdom)
- 4 Computational Imaging and Image Processing
Keith L. Lewis, Sciovis Ltd. (United Kingdom)
Robert A. Lamb, Leonardo-Finmeccanica (United Kingdom)
- 5 Quantum Technologies
Keith L. Lewis, Sciovis Ltd. (United Kingdom)
Gerald S. Buller, Heriot-Watt University (United Kingdom)
- 6 Correlated Imagery
Gerald S. Buller, Heriot-Watt University (United Kingdom)
Keith L. Lewis, Sciovis Ltd. (United Kingdom)

Introduction

Interest in emerging technologies has been of fundamental importance to the security and defence community for many years where it has informed the process of horizon scanning for both governments and industry. Indeed, in the United States, the Defence Advanced Research Projects Agency (DARPA) recognised its role at the outset as an enabler for the development of disruptive solutions for providing enhanced capability in military operations. Challenges posed when sensing under the difficult conditions encountered in military environments lie at the heart of many applications of photonics. Evolving threats have necessitated the need for innovation in the way that reliable solutions are brought to bear when armed forces are deployed. This conference brought together emerging activities in sensor and optical technologies and explored their application for those areas of application that are of current interest. The conference was organised around six topical areas:

- Infrared and optical devices
- Optical materials and devices
- Lasers and laser applications
- Computational imaging and image processing
- Quantum technologies
- Correlated imagery

At the device level, significant activity in optical integration was evident, with new solutions emerging for compact multispectral cameras capable of extracting more information from the scene. Such devices could potentially find application on autonomous platforms where there are requirements to address the size, weight, power and manufacturing cost of those components and devices. The understanding of plasmonics is advancing, as is the realization of metamaterials at optical wavelengths, supported by the evolution of effective techniques for the fabrication of nano-structured devices. There is always a need for improved active and passive components including laser sources, modulators and photo-detectors and that requirement was addressed by several authors. Advances in mid-infrared fibre-optics are enabling a number of applications especially for remote chemical sensing in the mid-infrared fingerprint region. Photon-counting sensing technologies can provide the basis for wide area terrain mapping and improved target identification as well as more exotic opportunities such as in quantum communications, quantum sensing and quantum ghost imaging. New approaches in the area of avalanche photodiode array technologies are particularly relevant here to allow operation across wide spectral ranges, especially in the SWIR band. But it is not only developments at the component level that are important. Techniques to understand and improve target discrimination, to enable more accurate target tracking and provide vision through turbulent atmospheres, can benefit from the application of both pre-detector and post-

detector processing techniques. Improvements in computational imaging and compressive sensing help to reduce the overhead in managing large data sets, especially when communication bandwidths are limited.

Some of these topics were featured in SPIE's first European Symposium on Optics and Photonics for Defence and Security held in London in 2004, but the themes have evolved over successive years to support the basis of current requirements. An example addressed at the conference this year was the current Quantum Technology Initiative in the United Kingdom, with several papers offering highly disruptive capabilities that could be of great economic significance.

Keith L. Lewis
Richard C. Hollins