

PROCEEDINGS OF SPIE

Polarization Science and Remote Sensing VI

Joseph A. Shaw
Daniel A. LeMaster
Editors

26 and 28–29 August 2013
San Diego, California, United States

Sponsored and Published by
SPIE

Volume 8873

Proceedings of SPIE 0277-786X, V. 8873

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

Polarization Science and Remote Sensing VI, edited by Joseph A. Shaw, Daniel A. LeMaster, Proc. of SPIE
Vol. 8873, 887301 · © 2013 SPIE · CCC code: 0277-786X/13/\$18 · doi: 10.1117/12.2048634

Proc. of SPIE Vol. 8873 887301-1

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 *Polarization Science and Remote Sensing VI*, edited by Joseph A. Shaw, Daniel A. LeMaster, Proceedings of SPIE Vol. 8873 (SPIE, Bellingham, WA, 2013) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819497239

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 © 2013, 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/13/\$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 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

vii	<i>Conference Committee</i>
ix	<i>Introduction</i>

SESSION 1 POLARIZATION METROLOGY AND INSTRUMENTATION

- 8873 02 **Infrared wire grid polarizers: metrology and modeling** [8873-1]
M. C. George, J. Bergquist, R. Petrova, B. Wang, E. Gardner, MOXTEK, Inc. (United States)
- 8873 03 **Assessing consistency of a Mueller matrix measurement by rotation of the sample under test** [8873-2]
T. A. Germer, National Institute of Standards and Technology (United States)
- 8873 04 **Single-angle-of-incidence single-element rotating-polarizer (Single SERP) ellipsometer for film-substrate systems** [8873-3]
A. R. M. Zaghoul, Cairo Univ. (Egypt)
- 8873 05 **Real-time combined reflection and transmission ellipsometry for film-substrate systems** [8873-4]
M. Elshazly-Zaghoul, Cairo Univ. (Egypt)
- 8873 06 **Evaluation of calibration methods for visible-spectrum division-of-focal-plane polarimeters** [8873-5]
S. B. Powell, V. Gruev, Washington Univ. in St. Louis (United States)

SESSION 2 MATHEMATICS OF COHERENCE, POLARIZATION, AND SCATTERING POLARIZATION

- 8873 07 **Mathematical tools for the analysis and exploitation of polarimetric measurements (Invited Paper)** [8873-6]
J. J. Gil, Univ. de Zaragoza (Spain)
- 8873 09 **3D radiative transfer effects in multi-angle/multispectral radio-polarimetric signals from a mixture of clouds and aerosols viewed by a non-imaging sensor** [8873-8]
A. B. Davis, M. J. Garay, F. Xu, Jet Propulsion Lab. (United States); Z. Qu, Jet Propulsion Lab. (United States) and Raytheon Co. (United States); C. Emde, Ludwig-Maximilians-Univ. München (Germany)

SESSION 3 POLARIZATION IN REMOTE SENSING

- 8873 0B **Airborne multiangle spectropolarimetric imager (AirMSPI) observations over California during NASA's polarimeter definition experiment (PODEX) (Invited Paper)** [8873-9]
D. J. Diner, M. J. Garay, O. V. Kalashnikova, B. E. Rheingans, S. Geier, M. A. Bull, V. M. Jovanovic, F. Xu, C. J. Bruegge, Jet Propulsion Lab. (United States); A. Davis, The Univ. of Texas at Austin Ctr. for Space Research (United States); K. Crabtree, R. A. Chipman, College of Optical Sciences, The Univ. of Arizona (United States)
- 8873 0C **Influence of polarization phenomenology on material discriminability using multi-view polarimetric imagery** [8873-10]
C. Devaraj, South Dakota State Univ. (United States); M. Gartley, J. Schott, Rochester Institute of Technology (United States)
- 8873 0D **How clear-sky polarization varies with wavelength in the visible-NIR** [8873-11]
N. J. Pust, J. A. Shaw, Montana State Univ. (United States)

SESSION 4 POLARIZATION APPLICATIONS I

- 8873 0E **Mueller matrix microscopy (Invited Paper)** [8873-12]
M. Mujat, R. D. Ferguson, N. Iftimia, Physical Sciences Inc. (United States)
- 8873 0F **Extracting the inclination angle of nerve fibers within the human brain with 3D-PLI independent of system properties** [8873-13]
J. Reckfort, H. Wiese, Forschungszentrum Jülich GmbH (Germany) and Bergische Univ. Wuppertal (Germany); M. Dohmen, D. Grässel, Forschungszentrum Jülich GmbH (Germany); U. Pietrzyk, Forschungszentrum Jülich GmbH (Germany) and Bergische Univ. Wuppertal (Germany); K. Zilles, Forschungszentrum Jülich GmbH (Germany), RWTH Aachen Univ. (Germany), and JARA Translational Brain Medicine (Germany); K. Amunts, Forschungszentrum Jülich GmbH (Germany) and Heinrich-Heine-Univ. Düsseldorf (Germany); M. Axer, Forschungszentrum Jülich GmbH (Germany)
- 8873 0H **LWIR polarization sensing: investigation of liquids and solids with MoDDIFS** [8873-15]
G. Fortin, AEREX Avionics Inc. (Canada); J.-M. Thériault, Defence Research and Development Canada, Valcartier (Canada); P. Lacasse, AEREX Avionics Inc. (Canada)
- 8873 0I **Using linear polarization for LWIR hyperspectral sensing of liquid contaminants** [8873-16]
J.-M. Thériault, Defence Research and Development Canada, Valcartier (Canada); G. Fortin, P. Lacasse, AEREX Avionics Inc. (Canada); F. Bouffard, H. Lavoie, Defence Research and Development Canada, Valcartier (Canada)

SESSION 5 POLARIZATION IMAGING SYSTEMS AND COMPONENTS

- 8873 0J **Thermally stable imaging channeled spectropolarimetry** [8873-17]
J. Craven-Jones, B. M. Way, J. Hunt, Sandia National Labs. (United States); M. W. Kudenov, North Carolina State Univ. (United States); J. A. Mercier, Sandia National Labs. (United States)

- 8873 OK **A novel design for a spectropolarimeter: SPEX** [8873-18]
A. L. Verlaan, H. van Brug, H. Visser, TNO (Netherlands)
- 8873 OL **Fabrication and performance evaluation of pixelated nano-wire grid polarizer** [8873-19]
S. Gao, R. Njuguna, V. Gruev, Washington Univ. in St. Louis (United States)
- 8873 OM **Wide field snapshot imaging polarimeter using modified Savart plates** [8873-20]
N. Saito, S. Odate, K. Otaki, Nikon Corp. (Japan); M. Kubota, R. Kitahara, K. Oka, Hokkaido Univ. (Japan)
- 8873 OO **SWIR active polarization imaging for material identification** [8873-22]
D. A. LeMaster, Air Force Research Lab. (United States); A. H. Mahamat, College of Optical Sciences, The Univ. of Arizona (United States); B. M. Ratliff, Space Computer Corp. (United States); A. S. Alenin, J. S. Tyo, College of Optical Sciences, The Univ. of Arizona (United States); B. M. Koch, Air Force Research Lab. (United States)

SESSION 6 POLARIZATION-BASED OPTICAL SYSTEMS AND COMPONENTS

- 8873 OP **Evaluation of Mueller matrix of achromatic axially symmetric wave plate** [8873-23]
T. Wakayama, Saitama Medical Univ. (Japan); K. Komaki, Saitama Medical Univ. (Japan) and Utsunomiya Univ. (Japan); I. J. Vaughn, J. S. Tyo, College of Optical Sciences, The Univ. of Arizona (United States); Y. Otani, Utsunomiya Univ. (Japan); T. Yoshizawa, NPO 3D Associates (Japan)
- 8873 OQ **Compact spatial heterodyne interferometer using polarization gratings** [8873-24]
M. W. Kudenov, M. N. Miskiewicz, M. J. Escuti, North Carolina State Univ. (United States); J. Coward, SA Photonics (United States)
- 8873 OR **Spectroscopic full polarimeters using spatial carriers** [8873-25]
K. Oka, Y. Haga, Y. Komaki, Hokkaido Univ. (Japan)
- 8873 OS **Design of a polarimeter with two ferroelectric liquid crystal panels** [8873-26]
A. Peinado, A. Lizana, J. Campos, Univ. Autònoma de Barcelona (Spain)

SESSION 7 POLARIZATION APPLICATIONS II

- 8873 OU **The retrieval of scattering coefficient of marine particles from polarimetric observations** [8873-29]
A. Ibrahim, A. Gilerson, J. Stepinski, A. El-Habashi, S. Ahmed, The City College of New York (United States)

SESSION 8 POLARIZATION IN MM-WAVE IMAGING

- 8873 OV **Fully polarimetric passive W-band millimeter wave imager for wide area search** [8873-30]
J. Tedeschi, B. Bernacki, D. Sheen, J. Kelly, D. McMakin, Pacific Northwest National Lab. (United States)

- 8873 0W **Simulations of polarization dependent contrast during the diurnal heating cycle for passive millimeter-wave imagery (Invited Paper)** [8873-31]
J. P. Wilson, M. Murakowski, Univ. of Delaware (United States); C. A. Schuetz, Phase Sensitive Innovations, Inc. (United States); D. W. Prather, Univ. of Delaware (United States)

SESSION 9 PROCESSING AND DISPLAYING POLARIMETRIC IMAGERY

- 8873 0Y **Material characterization using passive multispectral polarimetric imagery** [8873-35]
M. A. Sawyer, M. W. Hyde IV, Air Force Institute of Technology (United States)

POSTER SESSION

- 8873 0Z **Photoelastic modulator non-idealities in magneto-optical polarization measurements** [8873-37]
S. Vandendriessche, T. Verbiest, Katholieke Univ. Leuven (Belgium)
- 8873 11 **Optical characterization of amber from Chiapas, Mexico** [8873-39]
G. López-Morales, R. Espinosa-Luna, C. Frausto-Reyes, Ctr. de Investigaciones en Óptica, A.C. (Mexico)
- 8873 12 **A compact and robust method for spectropolarimetry** [8873-40]
W. B. Sparks, Space Telescope Science Institute (United States)
- 8873 13 **Oriental tomography of optical axes directions distributions of multilayer biological tissues birefringent polycrystalline networks** [8873-41]
N. I. Zabolotna, R. Y. Dovhaliuk, Vinnytsia National Technical Univ. (Ukraine)
- 8873 16 **CALIOP receiver transient response study** [8873-45]
X. Lu, Y. Hu, NASA Langley Research Ctr. (United States); Z. Liu, NASA Langley Research Ctr. (United States) and Science Systems and Applications, Inc. (United States); S. Zeng, C. Trepte, NASA Langley Research Ctr. (United States)

Author Index

Conference Committee

Program Track Chair

Allen H.-L. Huang, University of Wisconsin-Madison (United States)

Conference Chairs

Joseph A. Shaw, Montana State University (United States)

Daniel A. LeMaster, Air Force Research Laboratory (United States)

Conference Program Committee

Bruce E. Bernacki, Pacific Northwest National Laboratory (United States)

David B. Chenault, Polaris Sensor Technologies, Inc. (United States)

Russell A. Chipman, College of Optical Sciences, The University of Arizona
(United States)

Julia M. Craven-Jones, Sandia National Laboratories (United States)

Aristide C. Dogariu, CREOL, The College of Optics and Photonics,
University of Central Florida (United States)

Dennis H. Goldstein, Polaris Sensor Technologies Inc. (United States)

Brian G. Hoover, Advanced Optical Technologies (United States)

Michael W. Kudenov, North Carolina State University (United States)

Kazuhiko Oka, Hokkaido University (Japan)

Jean-Marc Thériault, Defence Research and Development Canada,
Valcartier (Canada)

J. Scott Tyo, College of Optical Sciences, The University of Arizona
(United States)

Yoav Y. Schechner, Technion-Israel Institute of Technology (Israel)

Session Chairs

- 1 Polarization Metrology and Instrumentation
Julia M. Craven-Jones, Sandia National Laboratories (United States)
- 2 Mathematics of Coherence, Polarization, and Scattering Polarization
Joseph A. Shaw, Montana State University (United States)
- 3 Polarization in Remote Sensing
Jean-Marc Thériault, Defence Research and Development Canada,
Valcartier (Canada)
- 4 Polarization Applications I
Joseph A. Shaw, Montana State University (United States)

- 5 Polarization Imaging Systems and Components
J. Scott Tyo, College of Optical Sciences, The University of Arizona (United States)
- 6 Polarization-based Optical Systems and Components
Michael W. Kudenov, North Carolina State University (United States)
- 7 Polarization Applications II
Michael W. Kudenov, College of Optical Sciences, The University of Arizona (United States)
- 8 Polarization in mm-wave Imaging
Bruce E. Bernacki, Pacific Northwest National Laboratory (United States)
- 9 Processing and Displaying Polarimetric Imagery
Bradley M. Ratliff, Space Computer Corporation (United States)

Introduction

The broad appeal of polarization science was highlighted once again in the sixth meeting of our conference, *Polarization Science and Remote Sensing VI*. This year, authors hailed from ten countries and the presentations included a mix of contributions from academia, industry, and government laboratories. These enthusiastic researchers presented on applications of polarimetry that included the characterization of materials, the atmosphere, the ocean, and biological systems; the calibration, optimization, and metrology of polarimeters and related components; and the diverse considerations that go into the collection, processing, and display of polarimetric imagery. Contributing technologies spanned the ultraviolet, optical, and infrared wavelengths and, for the first time this year, extended to the millimeter-wave regime. The organizers of this conference and our sister conference, *Polarization: Measurement, Analysis, and Remote Sensing*, which will be meeting for the eleventh time in the spring of 2014 in Baltimore, are delighted to be the venue of choice for so many talented and prolific research professionals.

We are especially pleased to present in this volume, an invited paper by the 2013 recipient of the SPIE G.G. Stokes Award, José Jorge Gil from the University of Zaragoza, Spain. His presentation entitled, "Mathematical tools for the analysis and exploitation of polarimetric measurements," reviews how Mueller matrices may be decomposed into physically significant invariant quantities. We are grateful to Professor Gil for both his contributions to our conference and to the study of optical polarization. With the intent of establishing a new tradition, a similar invitation will be extended to future Stokes award winners when this conference convenes again in 2015.

Joseph A. Shaw
Daniel A. LeMaster

