

PROCEEDINGS OF SPIE

Polarization: Measurement, Analysis, and Remote Sensing VIII

David B. Chenault
Dennis H. Goldstein
Editors

18–19 March 2008
Orlando, Florida, USA

Sponsored and Published by
SPIE

Volume 6972

Proceedings of SPIE, 0277-786X, v. 6972

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

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: Measurement, Analysis, and Remote Sensing VIII*, edited by David B. Chenault, Dennis H. Goldstein, Proceedings of SPIE Vol. 6972 (SPIE, Bellingham, WA, 2008) Article CID Number.

ISSN 0277-786X
ISBN 9780819471635

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 © 2008, 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/08/\$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 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	Conference Committee
ix	Introduction

SESSION 1 INVITED PRESENTATION

- 6972 03 **Fine structure and optical properties of biological polarizers in crustaceans and cephalopods (Invited Paper)** [6972-02]
T.-H. Chiou, Univ. of Maryland, Baltimore County (USA); R. L. Caldwell, Univ. of California, Berkeley (USA); R. T. Hanlon, Marine Biological Lab. (USA); T. W. Cronin, Univ. of Maryland, Baltimore County (USA)

SESSION 2 POLARIZATION-BASED DEVICES I

- 6972 04 **Fiber faceplates to mitigate diffraction effects in an imaging snapshot polarimeter** [6972-03]
A. A. Cruz-Cabrera, S. A. Kemme, Sandia National Labs. (USA); T. R. Carter, L&M Technologies (USA)
- 6972 05 **High-speed polarization imaging camera based on electrically driven PLZT waveplate and split focal plane** [6972-04]
N. Lefaudeux, N. Lechocinski, S. Breugnot, P. Clemenceau, Bossa Nova Technologies (USA)
- 6972 06 **Hybrid optical retarders fabricated from liquid crystal polymer and form birefringent thin films** [6972-05]
P. A. McKenzie, K. Hendrix, D. Shemo, K. Tan, JDSU Advanced Optical Technologies (USA)
- 6972 07 **Automated detection of EOS-ESD in electronic circuits using a polarization modulation sensing system** [6972-06]
N. Jacksen, VCD Technologies (USA) and Pukoa Scientific (USA); J. Karins, Pukoa Scientific (USA); T. Odom, S. Hampton, J. Slawenski, VCD Technologies (USA); R. Cox, W. Robinson, Pukoa Scientific (USA)

SESSION 3 DEVELOPMENTS IN POLARIZATION INSTRUMENTATION I

- 6972 09 **Liquid crystal tunable polarization filter for target detection applications** [6972-08]
B. Winker, D.-F. Gu, B. Wen, K. Zachery, J. Mansell, D. Taber, K. Sage, W. Gunning III, M. Aguilar, Teledyne Scientific and Imaging, LLC (USA)
- 6972 0B **Compact and robust linear Stokes polarization camera** [6972-10]
N. Lefaudeux, N. Lechocinski, S. Breugnot, P. Clemenceau, Bossa Nova Technologies (USA)
- 6972 0C **Acousto-optic tunable filter based spectropolarimetric imagers** [6972-11]
N. Gupta, U.S. Army Research Lab. (USA)

- 6972 0D **Snapshot imaging spectropolarimetry in the visible and infrared** [6972-12]
R. W. Aumiller, C. Vanderlugt, E. L. Dereniak, College of Optical Sciences, The Univ. of Arizona (USA); R. Sampson, I Technology Applications (USA); R. W. McMillan, U.S. Army Space and Missile Defense Command (USA)

SESSION 4 POLARIZATION IN REMOTE SENSING

- 6972 0E **Polarimetric lidar signatures for remote detection of biological warfare agents** [6972-13]
J. M. Richardson, J. C. Aldridge, A. B. Milstein, MIT Lincoln Lab. (USA)
- 6972 0F **Utility of polarimetric imagery as ancillary data for thematic classification as predicted by using measures of spectral separability** [6972-14]
C. H. Spencer, Ball Aerospace and Technologies Corp. (USA)
- 6972 0G **Visible-NIR imaging polarimetry of painted metal surfaces viewed under a variably cloudy atmosphere** [6972-15]
N. J. Pust, J. A. Shaw, A. Dahlberg, Montana State Univ. (USA)

SESSION 5 DEVELOPMENTS IN POLARIZATION INSTRUMENTATION II

- 6972 0I **Astrophysical polarimetry: science, techniques, and methodology (Invited Paper)** [6972-18]
C. Packham, Univ. of Florida (USA)
- 6972 0J **Four camera complete Stokes imaging polarimeter (Invited Paper)** [6972-19]
J. L. Pezzaniti, D. Chenault, M. Roche, J. Reinhardt, J. P. Pezzaniti, Polaris Sensor Technologies (USA); H. Schultz, Univ. of Massachusetts (USA)
- 6972 0K **2-Cam LWIR imaging Stokes polarimeter** [6972-20]
M. W. Kudenov, E. L. Dereniak, College of Optical Sciences, The Univ. of Arizona (USA); L. Pezzaniti, Polaris Sensor Technologies, Inc. (USA); G. R. Gerhart, U.S. Army Tank-Automotive Research (USA)

SESSION 6 ANALYSIS: POLARIZATION MATHEMATICS, ALGORITHMS, AND PROCESSING I

- 6972 0N **Polarization visual enhancement technique for LWIR microgrid polarimeter imagery** [6972-23]
B. M. Ratliff, J. S. Tyo, W. T. Black, College of Optical Sciences, The Univ. of Arizona (USA); J. K. Boger, D. L. Bowers, Applied Technology Associates (USA)
- 6972 0O **Emission polarization from rough surfaces** [6972-24]
C. An, K. Zeringue, Raytheon/Photon Research Associates (USA)
- 6972 0P **Detection comparisons between LWIR and MWIR polarimetric sensors** [6972-25]
N. R. Malone, A. Hampp, E. E. Gordon, M. V. Liguori, Y. Thai, J. Vodicka, J. W. Bangs, Raytheon Vision Systems (USA)

SESSION 7 ANALYSIS: POLARIZATION MATHEMATICS, ALGORITHMS, AND PROCESSING II

- 6972 0Q **Fusion of Stokes vector imagery using simple logical operators: application to the problem of surface land mine detection** [6972-28]
A. El-Saba, T. Bezuayehu, Univ. of South Alabama (USA)
- 6972 0R **Correction of erroneous degree of polarization of moving objects in a video sequence** [6972-29]
L. Gendre, A. Foulonneau, L. Bigué, Univ. de Haute Alsace (France)
- 6972 0S **Estimation of target geometry from Mueller matrix imagery** [6972-30]
V. Thilak, Q. Wang, D. G. Voelz, C. D. Creusere, New Mexico State Univ. (USA)
- 6972 0T **Single-frame polarization measurement techniques** [6972-31]
R. W. McMillan, U.S. Army Space and Missile Defense Command (USA); E. Dereniak, R. Aumiller, N. Hagen, Univ. of Arizona, Optical Sciences Ctr. (USA)

SESSION 8 POLARIZATION MEASUREMENTS

- 6972 0U **Higher probability of detection of subsurface land mines with a single sensor using multiple polarized and unpolarized image fusion** [6972-32]
A. El-Saba, T. Bezuayehu, Univ. of South Alabama (USA)
- 6972 0V **Polarization measurements of automobile paints** [6972-33]
D. H. Goldstein, Polaris Sensor Technologies, Inc. (USA)
- 6972 0W **Variation in MidIR and LWIR polarimetric imagery due to diurnal and meteorological impacts** [6972-34]
K. P. Gurton, M. Felton, U.S. Army Research Lab. (USA)
- 6972 0X **Evaluation of active and passive polarimetric electro-optic imagery for civilian and military targets discrimination** [6972-35]
D. A. Lavigne, Defence Research and Development Canada (Canada); M. Breton, AEREX Avionic, Inc. (Canada); M. Pichette, V. Larochelle, J.-R. Simard, Defence Research and Development Canada (Canada)

POSTER SESSION

- 6972 0Z **Design and performance of a polarized IR scene generator** [6972-38]
P. S. Erbach, J. L. Pezzaniti, D. B. Chenault, Polaris Sensor Technologies, Inc. (USA); D. Saylor, Optical Sciences Corp., Inc. (USA); H. S. Lowry, Aerospace Testing Alliance (USA)
- 6972 10 **Generalized conditions for eigenpolarizations orthogonality: Jones matrix calculus** [6972-39]
S. N. Savenkov, Y. A. Oberemok, Taras Shevchenko Kiev National Univ. (Ukraine)
- 6972 11 **Comparing a MWIR and LWIR polarimetric imager for surface swimmer detection** [6972-40]
J. S. Harchanko, L. Pezzaniti, D. Chenault, G. Eades, Polaris Sensor Technologies, Inc. (USA)

- 6972 12 **Introducing depolarisation into an inexpensive simple cloud sensor for standoff aerosol detection** [6972-41]
R. J. Hopkins, J. W. Jones, S. J. Barrington, V. Foot, K. L. Baxter, DSTL (United Kingdom)

ADDITIONAL PAPER

- 6972 13 **Micro-scale surface and contaminate modeling for polarimetric signature prediction**
[6972-42]
M. G. Gartley, S. D. Brown, J. R. Schott, Rochester Institute of Technology (USA)

Author Index

Conference Committee

Symposium Chair

Larry B. Stotts, Defense Advanced Research Projects Agency (USA)

Symposium Cochair

Ray O. Johnson, Lockheed Martin Corporation (USA)

Program Track Chair

Ivan Kadar, Interlink Systems Sciences, Inc. (USA)

Conference Chairs

David B. Chenault, Polaris Sensor Technologies, Inc. (USA)

Dennis H. Goldstein, Polaris Sensor Technologies, Inc. (USA)

Program Committee

Thomas R. Caudill, Air Force Research Laboratory (USA)

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

Joseph L. Cox, Air Force Space and Missile Systems Center (USA)

Aed M. El-Saba, University of South Alabama (USA)

Matthew P. Fetrow, Air Force Research Laboratory (USA)

Joseph A. Shaw, Montana State University, Bozeman (USA)

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

Kyle J. Zeringue, Photon Research Associates, Inc. (USA)

Session Chairs

Welcome and Nomenclature Overview

David B. Chenault, Polaris Sensor Technologies, Inc. (USA)

Dennis H. Goldstein, Polaris Sensor Technologies, Inc. (USA)

1 Invited Presentation

David B. Chenault, Polaris Sensor Technologies, Inc. (USA)

2 Polarization-based Devices I

Dennis H. Goldstein, Polaris Sensor Technologies, Inc. (USA)

- 3 Developments in Polarization Instrumentation I
Joseph A. Shaw, Montana State University, Bozeman (USA)
- 4 Polarization in Remote Sensing
Joseph L. Cox, Air Force Space and Missile Systems Center (USA)
- 5 Developments in Polarization Instrumentation II
J. Scott Tyo, College of Optical Sciences, The University of Arizona
(USA)
- 6 Analysis: Polarization Mathematics, Algorithms, and Processing I
Aed M. El-Saba, University of South Alabama (USA)
- 7 Analysis: Polarization Mathematics, Algorithms, and Processing II
Dennis H. Goldstein, Air Force Research Laboratory (USA)
- 8 Polarization Measurements
David B. Chenault, Polaris Sensor Technologies, Inc. (USA)

Introduction

Current work in polarization research is contained within this volume, with an emphasis on remote sensing for defense and security applications. A record number of papers on applications of polarization were submitted. The applications of polarimetry presented in this conference range from monitoring effects of electrostatic discharge on electric circuits to detection of biological warfare agents to astrophysics, and from characterization of reflection from painted metal samples in the lab to monitoring of painted metal, wetlands, and water surfaces in the field. The field continues to mature through advances in instrumentation, modeling, and processing.

These proceedings are made up of papers from eight conference sessions. The first session consisted of an invited paper on biological polarizers in creatures of the sea. This was followed on the first day of the conference by sessions on Devices, Polarization Instrumentation, and Remote Sensing. The second day started with a second session on Instrumentation. This was followed by two sessions on Polarization Mathematics, Algorithms, and Processing. A final session focused on Measurements.

This conference marks the tenth year in a row that a polarization conference has been held, due in part to high interest and to the establishment of the Polarization Technical Group. Over the last four years, the polarization conferences have alternated from the Annual Meeting in odd years to the DSS meeting in even years. The nine prior conferences of 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, and 1999 are documented in Proceedings of SPIE Vols. 6682, 6240, 5888, 5432, 4819, 4481, 3754, and 3121, respectively. Previous conferences in this series include *Polarization: Measurement, Analysis, and Remote Sensing* held in San Diego in 1997 (Proceedings of SPIE Vol. 3121) and *Polarization and Remote Sensing* held in San Diego in 1992 (Proceedings of SPIE Vol. 1747). Conferences on polarization, without the specific emphasis and inclusion of the remote sensing application and entitled *Polarization Analysis and Measurement* and *Polarization Analysis and Measurement I and II* (Proceedings of SPIE Vols. 1746 and 2265), were held in San Diego in 1992 and 1994. Earlier conferences include *Polarimetry: Radar, Infrared, Visible, Ultraviolet, and X-Ray* (Proceedings of SPIE Vol. 1317, 1990), and *Polarization Considerations in Optical Systems* and *Polarization Considerations in Optical Systems I and II* (Proceedings of SPIE Vol. 891 in 1988 and Vol. 1166 in 1989).

Our appreciation is given to our program committee members and session chairs for their efforts in making this conference a success, and to the contributing authors for the high quality of the papers in this volume.

David B. Chenault
Dennis H. Goldstein