PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 8971

, "Front Matter: Volume 8971," Proc. SPIE 8971, Free-Space Laser Communication and Atmospheric Propagation XXVI, 897101 (27 March 2014); doi: 10.1117/12.2062636

SPIE.

Event: SPIE LASE, 2014, San Francisco, California, United States

PROCEEDINGS OF SPIE

Free-Space Laser Communication and Atmospheric Propagation XXVI

**Hamid Hemmati
Don M. Boroson**
Editors

**2–4 February 2014
San Francisco, California, United States**

Sponsored and Published by
SPIE

Volume 8971

Proceedings of SPIE 0277-786X, V. 8971

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

Free-Space Laser Communication and Atmospheric Propagation XXVI, edited by Hamid Hemmati, Don M. Boroson,
Proc. of SPIE Vol. 8971, 897101 · © 2014 SPIE · CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2062636

Proc. of SPIE Vol. 8971 897101-1

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 *Free-Space Laser Communication and Atmospheric Propagation XXVI*, edited by Hamid Hemmati, Don M. Boroson, Proceedings of SPIE Vol. 8971 (SPIE, Bellingham, WA, 2014) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819498847

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.

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 *Conference Committee*

SESSION 1 ATMOSPHERIC PROPAGATION

- 8971 02 **Investigation of profiled beam propagation through a turbulent layer and temporal statistics of diffracted output for a modified von Karman phase screen** [8971-1]
M. R. Chatterjee, F. H. A. Mohamed, Univ. of Dayton (United States)
- 8971 03 **Optical beam spreading in the presence of both atmospheric turbulence and quartic aberration** [8971-2]
N. Mosavi, Johns Hopkins Univ. Applied Physics Lab. (United States) and Univ. of Maryland, Baltimore County (United States); B. S. Marks, B. G. Boone, Johns Hopkins Univ. Applied Physics Lab. (United States); C. R. Menyuk, Univ. of Maryland, Baltimore County (United States)
- 8971 04 **Transmitter diversity verification on ARTEMIS geostationary satellite** [8971-3]
R. Mata Calvo, P. Becker, D. Giggenbach, F. Moll, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); M. Schwarzer, M. Hinz, Cassidian Optronics GmbH (Germany); Z. Sodnik, European Space Agency (Netherlands)
- 8971 05 **Simultaneous scintillation measurements of coherent and partially coherent beams in an open atmosphere experiment (Invited Paper)** [8971-4]
A. Efimov, K. Velizhanin, Los Alamos National Lab. (United States); G. Gelikonov, Institute of Applied Physics (Russian Federation)
- 8971 06 **Evaluation of performance of ground to satellite free space optical link under turbulence conditions for different intensity modulation schemes** [8971-5]
A. Viswanath, Indian Institute of Technology Delhi (India); H. Kaushal, Institute of Technology and Management (India); V. K. Jain, S. Kar, Indian Institute of Technology Delhi (India)
- 8971 07 **High altitude clouds impacts on the design of optical feeder link and optical ground station network for future broadband satellite services** [8971-6]
S. Poulenard, M. Ruellan, B. Roy, Airbus Defence and Space (France); J. Riédi, F. Parol, Univ. de Lille 1 (France); A. Rissons, Institut Supérieur de l'Aéronautique et de l'Espace (France)
- 8971 08 **Channel characterization for air-to-ground free-space optical communication links** [8971-7]
K. Shortt, D. Giggenbach, R. Mata-Calvo, F. Moll, C. Fuchs, C. Schmidt, J. Horwath, J. Yeh, V. Selvaraj, R. Banerjee, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

- 8971 09 **Performance analysis of a coherent tiled fiber-array beam director with near-field phase locking and programmable control of tip/tilt and piston phases** [8971-8]
G. A. Filimonov, Univ. of Dayton (United States) and V.E. Zuev Institute of Atmospheric Optics (Russian Federation); M. A. Vorontsov, Univ. of Dayton (United States) and Optonicus (United States); S. L. Lachinova, Optonicus (United States)

SESSION 2 LASER TRANSMITTERS

- 8971 0B **Pulsed fiber amplifiers in simulated space environmental tests** [8971-10]
M. W. Wright, H. Hemmati, Jet Propulsion Lab. (United States)
- 8971 0D **1030nm Yb-fiber-MOPA-based, multi-aperture high power, high energy uplink laser beacon for deep space communication** [8971-12]
D. Engin, J. Burton, I. Darab, F. Kimpel, B. Mathason, S. Gupta, Fibertek, Inc. (United States)
- 8971 0E **Radiation-hardened Erbium-doped optical fibers and amplifiers for future high-dose space missions** [8971-13]
S. Girard, Lab. Hubert Curien, CNRS, Univ. Jean Monnet Saint-Etienne (France); A. Laurent, E. Pinsard, T. Robin, B. Cadier, ilxFiber SAS (France); M. Boutillier, Ctr. National d'Études Spatiales (France); C. Marcandella, Commissariat à l'Énergie Atomique (France); A. Boukenter, Y. Ouerdane, Lab. Hubert Curien, CNRS, Univ. Jean Monnet Saint-Etienne (France)

SESSION 3 MODELING AND ANALYSIS

- 8971 0H **Pointing, acquisition, and tracking architecture tools for deep-space optical communications** [8971-17]
S. Mohan, O. Alvarez-Salazar, K. Birnbaum, A. Biswas, W. Farr, H. Hemmati, S. Johnson, G. Ortiz, K. Quirk, Z. Rahman, M. Regher, F. Rizvi, J. Shields, M. Srinivasan, Jet Propulsion Lab. (United States)
- 8971 0I **Improving the efficiency of undersea laser communications** [8971-18]
H. Hemmati, A. Biswas, Jet Propulsion Lab. (United States)

SESSION 4 RECEIVER/OPTICS/BEAM-STEERING

- 8971 0J **A multi-rate DPSK modem for free-space laser communications** [8971-36]
N. W. Spellmeyer, C. A. Browne, D. O. Caplan, J. J. Carney, M. L. Chavez, A. S. Fletcher, J. J. Fitzgerald, R. D. Kaminsky, G. Lund, S. A. Hamilton, R. J. Magliocco, O. V. Mikulina, R. J. Murphy, H. G. Rao, M. S. Scheinbart, M. M. Seaver, J. P. Wang, MIT Lincoln Lab. (United States)
- 8971 0K **Multi-rate DPSK optical transceivers for free-space applications** [8971-37]
D. O. Caplan, J. J. Carney, J. J. Fitzgerald, I. Gaschits, R. Kaminsky, G. Lund, S. A. Hamilton, R. J. Magliocco, R. J. Murphy, H. G. Rao, N. W. Spellmeyer, J. P. Wang, MIT Lincoln Lab. (United States)

- 8971 OM **Ground receiver unit for optical communication between LADEE spacecraft and ESA ground station** [8971-21]
F. Arnold, M. Mosberger, J. Widmer, F. Gambarara, RUAG Space AG (Switzerland)
- 8971 ON **Monolithic telescopes for free-space optical communications** [8971-22]
W. T. Roberts, Jet Propulsion Lab. (United States)
- 8971 OO **Recent developments in the production of spin-cast epoxy mirrors** [8971-23]
K. L. Brodhacker, Lander Univ. (United States); J. Ritter, Univ. of Hawai'i (United States); A. La Croix, Lander Univ. (United States); B. Holenstein, Gravic, Inc. (United States); R. M. Genet, California Polytechnic State Univ., San Luis Obispo (United States)
- 8971 OP **Infrared Risley beam pointer** [8971-24]
S. T. Harford, H. Gutierrez, M. Newman, R. Pierce, T. Quakenbush, J. Wallace, M. Bornstein, Ball Aerospace & Technologies Corp. (United States)
- 8971 OQ **Liquid crystal optical phased array multiple-beam forming methods** [8971-26]
F. Xiao, L. Kong, Univ. of Electronic Science and Technology of China (China); X. Liu, X. Zhang, Science and Technology on Electro-Optical Information Security Control Lab. (China)

SESSION 5 FIELD DEMONSTRATIONS

- 8971 OR **Introduction of a terrestrial free-space optical communications network facility: IN-orbit and Networked Optical ground stations experimental Verification Advanced testbed (INNOVA) (Invited Paper)** [8971-28]
M. Toyoshima, Y. Munemasa, H. Takenaka, Y. Takayama, Y. Koyama, H. Kunimori, T. Kubooka, K. Suzuki, S. Yamamoto, S. Taira, H. Tsuji, I. Nakazawa, M. Akioka, National Institute of Information and Communications Technology (Japan)
- 8971 OS **Overview and results of the Lunar Laser Communication Demonstration (Invited Paper)** [8971-29]
D. M. Boroson, B. S. Robinson, D. V. Murphy, D. A. Burianek, F. Khatri, MIT Lincoln Lab. (United States); J. M. Kovalik, Jet Propulsion Lab. (United States); Z. Sodnik, European Space Research and Technology Ctr. (Netherlands); D. M. Cornwell, NASA Goddard Space Flight Ctr. (United States)
- 8971 OT **Inter-island optical link demonstration using high-data-rate pulse-position modulation** [8971-30]
M. Bacher, F. Arnold, B. Thieme, RUAG Space AG (Switzerland)
- 8971 OU **Optical link design and validation testing of the Optical Payload for Lasercomm Science (OPALS) system** [8971-31]
B. V. Oaida, W. Wu, B. I. Erkmen, A. Biswas, K. S. Andrews, M. Kokorowski, M. Wilkerson, Jet Propulsion Lab. (United States)
- 8971 OV **LLCD operations using the Lunar Lasercom Ground Terminal** [8971-32]
D. V. Murphy, J. E. Kinsky, M. E. Grein, R. T. Schulein, M. M. Willis, MIT Lincoln Lab. (United States); R. E. Lafon, NASA Goddard Space Flight Ctr. (United States)

- 8971 OW **LLCD operations using the Lunar Lasercom OGS Terminal (Invited Paper)** [8971-33]
 Z. Sodnik, H. Smit, M. Sans, European Space Research and Technology Ctr. (Netherlands);
 I. Zayer, M. Lanucara, European Space Operations Ctr. (Germany); I. Montilla, A. Alonso,
 Instituto de Astrofísica de Canarias (Spain)
- 8971 OX **LLCD operations using the Optical Communications Telescope Laboratory (OCTL)** [8971-34]
 A. Biswas, J. M. Kovalik, M. W. Wright, W. T. Roberts, M. K. Cheng, K. J. Quirk, M. Srinivasan,
 M. D. Shaw, K. M. Birnbaum, Jet Propulsion Lab. (United States)
- 8971 OY **Electronics design of a multi-rate DPSK modem for free-space optical communications**
 [8971-38]
 H. G. Rao, C. A. Browne, D. O. Caplan, J. J. Carney, M. L. Chavez, A. S. Fletcher,
 J. J. Fitzgerald, R. D. Kaminsky, G. Lund, S. A. Hamilton, R. J. Magliocco, O. V. Mikulina,
 R. J. Murphy, M. M. Seaver, M. S. Scheinbart, N. W. Spellmeyer, J. P. Wang, MIT Lincoln Lab.
 (United States)
- 8971 OZ **Performance and qualification of a multi-rate DPSK modem** [8971-39]
 J. P. Wang, C. A. Browne, C. D. Burton, D. O. Caplan, J. J. Carney, M. L. Chavez,
 J. J. Fitzgerald, I. Gaschits, D. J. Geisler, S. A. Hamilton, S. R. Henion, G. Lund,
 R. J. Magliocco, O. V. Mikulina, R. J. Murphy, H. G. Rao, M. M. Seaver, N. W. Spellmeyer, MIT
 Lincoln Lab. (United States)

Author Index

Conference Committee

Symposium Chairs

Bo Gu, Bos Photonics (United States)
Andreas Tünnermann, Fraunhofer-Institut für Angewandte Optik und
Feinmechanik (Germany) and Friedrich-Schiller-Universität Jena
(Germany)

Symposium Co-chairs

Guido Hennig, Daetwyler Graphics AG (Switzerland)
Yongfeng Lu, University of Nebraska-Lincoln (United States)

Conference Chairs

Hamid Hemmati, Jet Propulsion Laboratory (United States)
Don M. Boroson, MIT Lincoln Laboratory (United States)

Conference Program Committee

Vincent W. S. Chan, Massachusetts Institute of Technology
(United States)
Renny A. Fields, The Aerospace Corporation (United States)
G. Charmaine Gilbreath, U.S. Naval Research Laboratory
(United States)
Frank F. Heine, Tesat-Spacecom GmbH & Company KG (Germany)
Olga Korotkova, University of Miami (United States)
Michael A. Krainak, NASA Goddard Space Flight Center
(United States)
Ronald L. Phillips, Florida Space Institute (United States)
Zoran Sodnik, European Space Research and Technology Center
(Netherlands)
Morio Toyoshima, National Institute of Information and
Communications Technology (Japan)
Alan E. Willner, The University of Southern California (United States)
Shiro Yamakawa, Japan Aerospace Exploration Agency (Japan)