

PROCEEDINGS OF SPIE

# ***Laser Communication and Propagation through the Atmosphere and Oceans XI***

**Jaime A. Anguita  
Jeremy P. Bos  
David T. Wayne**  
*Editors*

**22–23 August 2022  
San Diego, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 12237**

Proceedings of SPIE 0277-786X, V. 12237

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

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](http://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 *Laser Communication and Propagation through the Atmosphere and Oceans XI*, edited by Jaime A. Anguita, Jeremy P. Bos, David T. Wayne, Proc. of SPIE 12237, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510654587

ISBN: 9781510654594 (electronic)

Published by

**SPIE**

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time)

[SPIE.org](http://SPIE.org)

Copyright © 2022 Society of Photo-Optical Instrumentation Engineers (SPIE).

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 fees. To obtain permission to use and share articles in this volume, visit Copyright Clearance Center at [copyright.com](http://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.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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

**SPIE. DIGITAL  
LIBRARY**

[SPIDigitalLibrary.org](http://SPIDigitalLibrary.org)

---

**Paper Numbering:** A unique citation identifier (CID) number is assigned to each article in the Proceedings of SPIE 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 seven-digit CID article numbering system structured as follows:

- The first five 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 *Conference Committee*

---

## OPTICAL COMMUNICATIONS IN THE ATMOSPHERE

---

- 12237 01 **Measuring the effect of real atmospheric turbulence on coherent free-space optical communications links (Invited Paper)** [12237-1]
- 12237 02 **Common analog and digital design for flexible radio and optical wireless systems** [12237-2]
- 12237 03 **Adaptive optics for daytime deep-space optical communications** [12237-3]
- 12237 05 **Experimental study on the effects of turbulence induced scintillations on a practical free-space communication link at high bandwidth** [12237-5]

---

## ADVANCED TOPICS ON LASER PROPAGATION

---

- 12237 06 **Generation of RF radiation by laser pulse trains in air** [12237-6]
- 12237 07 **Free-space, pulsed optical time transfer through turbid water** [12237-7]
- 12237 08 **Optimal transport theory for processing and classifying OAM superpositions distorted by turbulence** [12237-8]

---

## TURBULENCE EFFECTS ON LASER PROPAGATION: MODELING AND SIMULATION

---

- 12237 09 **Simulations of uplink precompensation for laser communications** [12237-10]
- 12237 0A **Long-term beam size analysis in the focal plane for atmospheric turbulence-affected laser beams** [12237-11]

---

## ATMOSPHERIC PROPAGATION AND CHARACTERIZATION I: JOINT SESSION WITH CONFERENCES 12237 AND 12239

---

- 12237 0B **Characterization of C-band laser transmitter through atmosphere in littoral environment** [12237-14]
- 12237 0C **Low-altitude laser propagation link over a marine surface** [12237-15]

- 12237 OD **Digital adaptive optics for turbulence mitigation with QR codes** [12237-16]
- 12237 OE **Reduction of scintillation using broad spectrum optical source for use in FSO** [12237-17]
- 12237 OF **Experimental campaign for the propagation and measurement of OAM beams over a 1-km terrestrial range** [12237-18]

---

**ATMOSPHERIC PROPAGATION AND CHARACTERIZATION III: JOINT SESSION WITH CONFERENCES  
12237 AND 12239**

---

- 12237 OG **Comparison of power spectrum and structure function methods to calculate turbulence parameters from sonic anemometer data (Invited Paper)** [12237-19]
- 12237 OH **TISTEF Camera and Anemometer Turbulence System (T-CATS) for estimating  $C_n^2$  with ground temperature** [12237-22]
- 12237 OI **Impact of rainfall on the propagation of 1.5 $\mu$ m** [12237-23]

---

**POSTER SESSION**

---

- 12237 OK **Generation of orbital angular momentum in a C-band laser** [12237-24]
- 12237 OL **Fast phase locking method for homodyne laser communication based on direct phase control** [12237-25]
- 12237 OM **Analysis of atmospheric conditions for optimizing optical communications** [12237-27]