PROCEEDINGS OF SPIE

Advanced Photon Counting Techniques IX

Mark A. Itzler Joe C. Campbell Editors

22–23 April 2015 Baltimore, Maryland, United States

Sponsored and Published by SPIE

Volume 9492

Proceedings of SPIE 0277-786X, V. 9492

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

Advanced Photon Counting Techniques IX, edited by Mark A. Itzler, Joe C. Campbell, Proc. of SPIE Vol. 9492, 949201 · © 2015 SPIE · CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2199548

Proc. of SPIE Vol. 9492 949201-1

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 Advanced Photon Counting Techniques IX, edited by Mark A. Itzler, Joe C. Campbell, Proceedings of SPIE Vol. 9492 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X ISBN: '9781628416084

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 © 2015, 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/15/\$18.00.

Printed in the United States of America.

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



Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique 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.

Contents

- v Authors
- vii Conference Committee

SINGLE-PHOTON APPLICATIONS I

9492 02 Cutting the cord: toward wireless optical intensity interferometry (Invited Paper) [9492-1]

SINGLE-PHOTON APPLICATIONS II

- 9492 08 An optical receiver for the Lunar Laser Communication Demonstration based on photoncounting superconducting nanowires (Invited Paper) [9492-7]
- 9492 09 Single photon counting for space based quantum experiments [9492-8]

SUPERCONDUCTING SINGLE-PHOTON DETECTORS

9492 OE Large-area NbN superconducting nanowire avalanche photon detectors with saturated detection efficiency [9492-13]

SINGLE-PHOTON LIDAR I

9492 01 Underwater depth imaging using time-correlated single photon counting [9492-17]

SINGLE-PHOTON LIDAR II

- 9492 OK Study of single photon counting for non-line-of-sight vision [9492-19]
- 9492 OL Hybrid receiver system for single photon sensitive direct and coherent detection (Best Paper Award) [9492-20]

GEIGER-MODE APDs

- 9492 0M Silicon Geiger-mode avalanche photodiode arrays for photon-starved imaging (Invited Paper) [9492-21]
- 9492 0N Gun muzzle flash detection using a single photon avalanche diode array in 0.18µm CMOS technology (Invited Paper) [9492-22]

9492 00	Analysis and modeling of optical crosstalk in InP-based Geiger-mode avalanche photodiode FPAs [9492-23]
9492 OP	Model of turn-on characteristics of InP-based Geiger-mode avalanche photodiodes suitable for circuit simulations [9492-24]
9492 OQ	Low noise InGaAs/InP single-photon negative feedback avalanche diodes: characterization and applications (Invited Paper) [9492-25]
	NOVEL AVALANCHE DIODE SPDs

9492 0T Linear mode photon counting from visible to MWIR with HgCdTe avalanche photodiode focal plane arrays (Invited Paper, Best Paper Award) [9492-28]

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.

Abshire, James, OT Aull, Brian F., OM Beck, Jeffrey, OT Berggren, Karl K., OE Boroson, Don M., 08 Boso, Gianluca, OQ Bratcher, Andrew, OL Brouk, Igor, ON Buller, Gerald S., Ol Carpenter, Darren, OT Chandrasekara, R., 09 Chau, Quan, 00 Cheng, C., 09 Christnacher, Frank, OK Dauler, Eric A., 08, 0E Donnelly, Joseph, OP Entwistle, Mark, 00 Glennon, John, OL Grein, Matthew E., 08, 0E Gudmundsen, Theodore J., OE Horch, Elliott P., 02 Hullin, Matthias B., OK Itzler, Mark A., 00 Jakobson, Claudio, ON Jiang, Xudong, 00 Jordy, George, 0P Kerman, Andrew J., 08 Klein, Jonathan, OK Kondratko, Piotr Konrad, OL Korzh, Boris, OQ Lane, Barry, OT Laurenzis, Martin, OK Ling, A., 09 Lunghi, Tommaso, OQ Maccarone, Aurora, Ol Marsili, Francesco, OE McCarthy, Aongus, Ol McCaughan, Adam, 0E Merhav, Tomer, ON Mitra, Pradip, OT Moffat, James, Ol Molnar, Richard J., 08 Murphy, Daniel V., 08 Murphy, Ryan P., OE Najafi, Faraz, OE Nemirovsky, Yael, ON Owens, Mark, 00 Petillot, Yvan, Ol Piccione, Brian, 00

Ren, Ximing, Ol Robinson, Bryan S., 08 Romkey, Barry, 08 Savuskan, Vitali, ON Scritchfield, Richard, OT Shoham, Avi, ON Skokan, Mark, OT Slomkowski, Krystyna, 00 Sullivan, William, III, OT Sun, Xiaoli, OT Suni, Paul, OL Tan, Y. C., 09 Tang, Z. K., 09 Velten, Andreas, OK Wallace, Andy M., Ol Warburton, Ryan E., Ol Wildfeuer, C., 09 Willis, Matthew M., 08 Zbinden, Hugo, 0Q

Conference Committee

Symposium Chair

Wolfgang Schade, Clausthal University of Technology and Fraunhofer Heinrich-Hertz Institute (Germany)

Symposium Co-chair

Ming C. Wu, University of California, Berkeley (United States)

Conference Chair

Mark A. Itzler, Princeton Lightwave, Inc. (United States)

Conference Co-chair

Joe C. Campbell, University of Virginia (United States)

Conference Program Committee

Gerald S. Buller, Heriot-Watt University (United Kingdom)
Sergio Cova, Politecnico di Milano (Italy)
William H. Farr, Jet Propulsion Laboratory (United States)
Robert H. Hadfield, University of Glasgow (United Kingdom)
Majeed Hayat, The University of New Mexico (United States)
Michael A. Krainak, NASA Goddard Space Flight Center (United States)
Robert A. Lamb, SELEX Galileo Ltd. (United Kingdom)
K. Alex McIntosh, MIT Lincoln Laboratory (United States)
Alan L. Migdall, National Institute of Standards and Technology (United States)
Michael Wahl, PicoQuant GmbH (Germany)
Hugo Zbinden, University of Geneva (Switzerland)

Session Chairs

- Single-Photon Applications I
 Joe C. Campbell, University of Virginia (United States)
- 2 Keynote: SPDs and Quantum Sensing Mark A. Itzler, Princeton Lightwave, Inc. (United States)
- 3 Single-Photon Applications II Mark A. Itzler, Princeton Lightwave, Inc. (United States)

- 4 Superconducting Single-Photon Detectors Matthew E. Grein, MIT Lincoln Laboratory (United States)
- 5 Single-Photon LIDAR I Mark A. Itzler, Princeton Lightwave, Inc. (United States)
- 6 Single-Photon LIDAR II Mark A. Itzler, Princeton Lightwave, Inc. (United States)
- 7 Geiger-Mode APDsK. Alex McIntosh, MIT Lincoln Laboratory (United States)
- 8 Novel Avalanche Diode SPDs
 Alan L. Migdall, National Institute of Standards and Technology (United States)