

PROCEEDINGS OF SPIE

Advanced Photon Counting Techniques XII

**Mark A. Itzler
Joe C. Campbell**
Editors

**18–19 April 2018
Orlando, Florida, United States**

Sponsored and Published by
SPIE

Volume 10659

Proceedings of SPIE 0277-786X, V. 10659

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

Advanced Photon Counting Techniques XII, edited by Mark A. Itzler, Joe Campbell,
Proc. of SPIE Vol. 10659, 1065901 · © 2018 SPIE · CCC code:
0277-786X/18/\$18 · doi: 10.1117/12.2502379

Proc. of SPIE Vol. 10659 1065901-1

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.

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 *Advanced Photon Counting Techniques XII*, edited by Mark A. Itzler, Joe C. Campbell, Proceedings of SPIE Vol. 10659 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510618299
ISBN: 9781510618305 (electronic)

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 © 2018, 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/18/\$18.00.

Printed in the United States of America.

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

**SPIE. DIGITAL
LIBRARY**

SPIDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article 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	<i>Authors</i>
vii	<i>Confidence Committee</i>

SINGLE-PHOTON IMAGING WITHOUT APDs

10659 02	Quanta image sensors: photon-number-resolving megapixel image sensors at room temperature without avalanche gain (Keynote Paper) [10659-1]
10659 03	Testing the limits of human vision with quantum states of light: past, present, and future experiments (Invited Paper) [10659-3]

SPADs AND INTEGRATED CIRCUITS I

10659 05	Fully integrated electronics for high-performance time-resolved imagers with single photon avalanche diode arrays (Invited Paper) [10659-5]
----------	--

SPADs AND INTEGRATED CIRCUITS II

10659 06	Smart routing logic for highly efficient readout of single photon avalanche diode arrays for time-resolved imaging [10659-6]
10659 07	Time-gated CMOS SPAD array in 0.16-μm BCD with shared timing electronics and background light rejection for LIDAR applications [10659-7]
10659 08	Towards high-speed low-distortion time-correlated single photon counting measurements [10659-8]

NOVEL SINGLE-PHOTON DETECTORS

10659 0C	Single photon HgCdTe avalanche photodiode and integrated detector cooler assemblies for space lidar applications [10659-12]
10659 0D	0.16-μm BCD single-photon avalanche diode with 30-ps timing jitter, high detection efficiency and low noise [10659-13]

SUPERCONDUCTING NANOWIRE SPDs

10659 OF **Design of efficient superconducting nanowire single photon detectors for near-infrared wavelengths (Invited Paper)** [10659-15]

APPLICATIONS OF PHOTON COUNTING I

10659 OK **Towards nondegenerate polarization entanglement from a waveguide down-conversion source** [10659-20]

APPLICATIONS OF PHOTON COUNTING II

10659 OL **Effect of lattice topology on photon statistics (Invited Paper)** [10659-21]

10659 OM **Progress on ELROI satellite license plate flight prototypes** [10659-23]

SINGLE-PHOTON 3D IMAGING II

10659 OS **Depth imaging through obscurants using time-correlated single-photon counting** [10659-28]

Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five 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.

Abouraddy, Ayman F., 0L
Abshire, James, 0C
Acconcia, Giulia, 05, 06, 08
Beck, Jeff, 0C
Buller, Gerald S., 0S
Christnacher, Frank, 0S
Cominelli, Alessandro, 05, 06, 08
Conca, Enrico, 07
Croce, Giuseppe, 0D
de Dood, Michiel, 0F
Deng, W., 02
Fields, Renny, 0C
Fossum, E. R., 02
Gattari, Paolo, 0D
Ghioni, Massimo, 05, 06, 08
Gill, Sawyer, 0M
Halimi, Abderrahim, 0S
Harris, James Z., 0M
Hinkley, David, 0C
Hirasuna, Bradley, 0C
Holmes, Rebecca M., 03, 0M
Jorgensen, Anders M., 0M
Kaneda, Fumihiko, 0K
Kondakci, H. Esat, 0L
Krainak, Michael, 0C
Kwiat, Paul G., 03, 0K
Lansford, Joellen S., 0M
Laurenzis, Martin, 0S
Lu, Wei, 0C
Ma, J., 02
Masoodian, S., 02
McCarthy, Aongus, 0S
Meier, Kristina A., 0K
Mitra, Pradip, 0C
Myers, Riley, 0M
Palmer, David M., 0M
Portaluppi, Davide, 07
Rawlings, Dick, 0C
Rech, Ivan, 05, 06, 08
Saleh, Bahaa E. A., 0L
Sanzaro, Mirko, 0D
Starkey, D., 02
Sullivan, William, 0C
Sun, Xiaoli, 0C
Tobin, Rachael, 0S
Tosi, Alberto, 0D
Victoria, Michelle M., 03
Villa, Federica, 07, 0D
Wang, Ranxiao Frances, 03
Weaver, Charles T., 0M
Zappa, Franco, 07, 0D
Zucherman, Aaron P., 0M

Conference Committee

Symposium Chair

Robert Fiete, Harris Corporation (United States)

Symposium Co-chair

Jay Kumler, JENOPTIK Optical Systems, LLC (United States)

Conference Chair

Mark A. Itzler, Argo AI, LLC (United States)

Conference Co-chair

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

Conference Program Committee

Joshua C. Bienfang, National Institute of Standards and Technology
(United States)

Gerald S. Buller, Heriot-Watt University (United Kingdom)

William H. Farr, Facebook Inc. (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, Leonardo MW 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)

Ivan Rech, Politecnico di Milano (Italy)

Session Chairs

- 1 Single-photon Imaging Without APDs
Joe C. Campbell, University of Virginia (United States)
- 2 SPADs and Integrated Circuits I
Mark Itzler, Argo AI, LLC (United States)

- 3 SPADs and Integrated Circuits II
Joshua C. Bienfang, National Institute of Standards and Technology
(United States)
- 4 Novel Single-photon Detectors
K. Alex McIntosh, MIT Lincoln Laboratory (United States)
- 5 Superconducting Nanowire SPDs
Mark A. Itzler, Argo AI, LLC (United States)
- 6 Applications of Photon Counting I
Alan L. Migdall, National Institute of Standards and Technology
(United States)
- 7 Applications of Photon Counting II
Mark Itzler, Argo AI, LLC (United States)
- 8 Single-photon 3D Imaging I
Robert A. Lamb, Leonardo MW Ltd. (United Kingdom)
- 9 Single-photon 3D Imaging II
Gerald S. Buller, Heriot-Watt University (United Kingdom)