

PROCEEDINGS OF SPIE

Advanced Photon Counting Techniques XIII

**Mark A. Itzler
Joshua C. Bienfang
K. Alex McIntosh**
Editors

**17–18 April 2019
Baltimore, Maryland, United States**

Sponsored and Published by
SPIE

Volume 10978

Proceedings of SPIE 0277-786X, V. 10978

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

Advanced Photon Counting Techniques XIII, edited by Mark A. Itzler, Joshua C. Bienfang,
K. Alex McIntosh, Proc. of SPIE Vol. 10978, 1097801 · © 2019 SPIE
CCC code: 0277-786X/19/\$18 · doi: 10.1117/12.2536822

Proc. of SPIE Vol. 10978 1097801-1

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 XIII*, edited by Mark A. Itzler, Joshua C. Bienfang, K. Alex McIntosh, Proceedings of SPIE Vol. 10978 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

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

ISBN: 9781510626218
ISBN: 9781510626225 (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 © 2019, 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/19/\$18.00.

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

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>Conference Committee</i>

SESSION 1 SPD APPLICATIONS I: TOF IMAGING

10978 03	Detection, identification, and tracking of objects hidden from view with neural networks (Invited Paper) [10978-2]
----------	---

SESSION 2 SPD APPLICATIONS II: LADAR IMAGING

10978 07	Outdoor single-photon counting panoramic 3D imaging (Invited Paper) [10978-6]
----------	--

SESSION 3 SPD APPLICATIONS III: SPACE DETECTION

10978 08	Status of ELROI satellite license plate demonstration on the CubeSat NMTSat (Invited Paper) [10978-7]
10978 09	Photon counting camera for the NASA deep space optical communication demonstration on the PSYCHE mission (Invited Paper) [10978-8]
10978 0A	The SAPHIRA detector: a near-infrared photon counter for astronomy (Invited Paper) [10978-9]
10978 0B	IceSat-2 ATLAS photon-counting receiver: initial on-orbit performance (Invited Paper) [10978-10]

SESSION 4 SPADS AND ELECTRONICS

10978 0C	Design and performance study of actively holding-off GHz-gated InGaAs/InP SPADs [10978-11]
10978 0D	Fast fully integrated active quenching circuit for single photon counting up to 160 Mcounts/s (Rising Researcher Paper) [10978-12]
10978 0F	Design of low noise avalanche photodiode single element detectors and linear arrays through CMOS process [10978-25]

SESSION 5 SPADS I

10978 0H **Modeling the missing part of CMOS silicon photomultiplier: the ultimate photon counting and timing sensor (Invited Paper)** [10978-15]

10978 0I **High performance single photon counting and timing with single photon avalanche diodes (Invited Paper)** [10978-16]

SESSION 6 NOVEL SPDS

10978 0M **From single photon counting to high rate capability with fast timing MCP-PMTs for LIDAR** [10978-20]

SESSION 7 SNSPDS

10978 0N **Towards single-photon spectroscopy in the mid-infrared using superconducting nanowire single-photon detectors (Invited Paper)** [10978-21]

SESSION 8 SPADS II

10978 0Q **256 x 256 dual-mode CMOS SPAD image sensor** [10978-26]

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.

Acconcia, G., 0D, 0I
Allard, Lars, 07
Allen, Gregory D., 09
Atkinson, Dani E., 0A
Axelsson, Maria, 07
Baker, Ian M., 0A
Bienfang, Joshua C., 0C
Bock, Megan, 0B
Buck, Benjamin R., 09
Caramazza, Piergiorgio, 03
Cavanaugh, John, 0B
Chen, Yongping, 0F
Cheng, Zhengxi, 0F
Dhulla, Vinit, 0Q
Dissanayake, Nanditha, 0Q
Duerr, Erik K., 09
Eshkoli, A., 0H
Faccio, Daniele, 03
Ghioni, M., 0D, 0I
Gill, Sawyer, 08
Glazenberg, René, 0M
Gulinatti, A., 0D, 0I
Hall, Donald N. B., 0A
Harris, James Z., 08
Henriksson, Markus, 07
Higham, Catherine F., 03
Holmes, Rebecca M., 08
Jacobson, Shane M., 0A
Jonsson, Per, 07
Jorgensen, Anders M., 08
Kernen, Emilie, 0M
Korzh, B., 0N
Krainak, Michael A., 0B
Labanca, I., 0D
Lansford, Joellen S., 08
Lee, Adam O., 0Q
Lita, A. E., 0N
Lu, Wei, 0B
Lyons, Ashley, 03
Martino, Anthony J., 0B
McIntosh, K. Alexander, 09
Migdall, Alan L., 0C
Mirin, R. P., 0N
Moynihan, Shawn T., 09
Mukherjee, Sapna S., 0Q
Murray-Smith, Roderick, 03
Musarra, Gabriella, 03
Myers, Charles, 0Q
Myers, Riley, 08
Nam, S. W., 0N
Nemirovsky, A., 0H
Nemirovsky, Y., 0H
Orlov, Dmitry A., 0M
Ortega, Raquel, 0M
Palmer, David M., 08
Rech, I., 0D, 0I
Restelli, Alessandro, 0C
Ryu, Booshik, 0Q
Shaw, M. D., 0N
Shukla, Vishva N., 09
Sjöqvist, Lars, 07
Tolt, Gustav, 07
Turpin, Alex, 03
Verma, V. B., 0N
Wang, Jeffrey D., 09
Weaver, Charles T., 08
Wollman, E., 0N
Xu, Heliang, 0F
Yang, Guangning, 0B
Zucherman, Aaron P., 08

Conference Committee

Symposium Chairs

Jay Kumler, JENOPTIK Optical Systems, LLC (United States)
Ruth L. Moser, Air Force Research Laboratory (United States)

Symposium Co-chair

John M. Pellegrino, Electro-Optical Systems Laboratory, Georgia
Institute of Technology (United States)

Conference Chair

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

Conference Co-chairs

Joshua C. Bienfang, National Institute of Standards and Technology
(United States)
K. Alex McIntosh, MIT Lincoln Laboratory (United States)

Conference Program Committee

Gerald S. Buller, Heriot-Watt University (United Kingdom)
Joe C. Campbell, University of Virginia (United States)
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)
Alan L. Migdall, National Institute of Standards and Technology
(United States)
Ivan Rech, Politecnico di Milano (Italy)
Michael Wahl, PicoQuant GmbH (Germany)

Session Chairs

- 1 SPD Applications I: TOF Imaging
Mark A. Itzler, Argo AI, LLC (United States)
- 2 SPD Applications II: LADAR Imaging
K. Alexander McIntosh, MIT Lincoln Laboratory (United States)

- 3 SPD Applications III: Space Detection
Michael A. Krainak, NASA Goddard Space Flight Center
(United States)
- 4 SPADs and Electronics
Joshua C. Bienfang, National Institute of Standards and Technology
(United States)
- 5 SPADs I
Alan L. Migdall, National Institute of Standards and Technology
(United States)
- 6 Novel SPDs
Joe C. Campbell, University of Virginia (United States)
- 7 SNSPDs
Gerald S. Buller, Heriot-Watt University (United Kingdom)
- 8 SPADs II
Ivan Rech, Politecnico di Milano (Italy)