

PROCEEDINGS OF SPIE

Quantum Information Science and Technology IV

**Mark T. Gruneisen
Miloslav Dusek
John G. Rarity**
Editors

**10–12 September 2018
Berlin, Germany**

Sponsored by
SPIE

Cooperating Organisations
European Optical Society
Cranfield University (United Kingdom)

Published by
SPIE

Volume 10803

Proceedings of SPIE 0277-786X, V. 10803

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

Quantum Information Science and Technology IV, edited by Mark T. Gruneisen, Miloslav Dusek, John G. Rarity,
Proc. of SPIE Vol. 10803, 1080301 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2518696

Proc. of SPIE Vol. 10803 1080301-1

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 *Quantum Information Science and Technology IV*, edited by Mark T. Gruneisen, Miloslav Dusek, John G. Rarity, Proceedings of SPIE Vol. 10803 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510621893
ISBN: 9781510621909 (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 *Authors*
vii *Conference Committee*

QUANTUM CRYPTOGRAPHY AND QUANTUM NETWORKS I

- 10803 03 **Quantum cryptography with malicious devices (Invited Paper)** [10803-2]
10803 04 **Simulation of a submarine to submarine QKD system** [10803-3]

QUANTUM CRYPTOGRAPHY AND QUANTUM NETWORKS III

- 10803 08 **Bootstrapped QKD: improving key rate and multi-photon resistance** [10803-7]
10803 09 **Bit-error-rate guarantee for quantum key distribution and its characteristics compared to leftover hash lemma** [10803-8]
10803 0A **Using fewer qubits to correct errors in the three-stage QKD protocol** [10803-9]
10803 0B **Polarization attack on continuous-variable quantum key distribution system** [10803-10]

QUANTUM TECHNOLOGIES, QUANTUM METROLOGY, AND QUANTUM DEVICES II

- 10803 0I **A quantum Bell Test homodyne interferometer at ambient temperature for millimetre wave entangled photons** [10803-17]

QUANTUM COMPUTING, QUANTUM OPERATIONS, AND QUANTUM INFORMATION PROCESSING

- 10803 0K **Feasibility of quantum fingerprinting using optical signals with random global phase (Invited Paper)** [10803-19]
10803 0M **An optical nonlinear sign shift gate using microring resonators** [10803-21]

10803 00 **Quantifying record entanglement in extremely large Hilbert spaces with adaptively sampled EPR correlations** [10803-23]

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.

Alsing, Paul M., 0M, 0O
Banaszek, Konrad, 0K
Curty, Marcos, 03
Djordjevic, Ivan B., 04
Fanto, Michael L., 0O
Gariano, John, 04
Guo, Hong, 0B
Hach, E. E., III, 0M
Howland, Gregory A., 0O
Huang, Yundi, 0B
Iwakoshi, T., 09
Jarzyna, Marcin, 0K
Lipka, Michał, 0K
Lo, Hoi-Kwong, 03
Parakh, Abhishek, 08, 0A
Salmon, Neil A., 0I
Schneeloch, James, 0O
Subramaniam, Mahadevan, 08
Tison, Christopher C., 0O
Xiang, Yi, 04
Yu, Song, 0B
Zhang, Yichen, 0B
Zhao, Yijia, 0B

Conference Committee

Symposium Chair

Ric Schleijsen, TNO Defense, Security and Safety (Netherlands)

Symposium Co-chair

Karin Stein, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Conference Chairs

Mark T. Gruneisen, Air Force Research Laboratory (United States)

Miloslav Dusek, Palacký University Olomouc (Czech Republic)

John G. Rarity, University of Bristol (United Kingdom)

Conference Programme Committee

Paul M. Alsing, Air Force Research Laboratory (United States)

Konrad Banaszek, University of Warsaw (Poland)

Jan Bouda, Masaryk University (Czech Republic)

Robert W. Boyd, University of Ottawa (Canada)

Michael Brodsky, U.S. Army Research Laboratory (United States)

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

Ryan M. Camacho, Sandia National Laboratories (United States)

Marcos Curty, Universidad de Vigo (Spain)

Michael L. Fanto, Air Force Research Laboratory (United States)

John D. Gonglewski, European Office of Aerospace Research and Development (United Kingdom)

Gregory S. Kanter, NuCrypt LLC (United States)

Prem Kumar, Northwestern University (United States)

Norbert Lütkenhaus, University of Waterloo (Canada)

Vadim V. Makarov, University of Waterloo (Canada)

Ronald E. Meyers, U.S. Army Research Laboratory (United States)

Momtchil Peev, Austrian Research Centres GmbH - ARC (Austria)

Renato Renner, ETH Zürich (Switzerland)

Andrew J. Shields, Toshiba Research Europe Ltd. (United Kingdom)

Kathy-Anne Soderberg, Air Force Research Laboratory (United States)

Rupert Ursin, Austrian Academy of Sciences (Austria)

Session Chairs

1 Quantum Cryptography and Quantum Networks I

Mark T. Gruneisen, Air Force Research Laboratory (United States)

- 2 Quantum Cryptography and Quantum Networks II
Marcos Curty, Universidad de Vigo (Spain)
- 3 Quantum Cryptography and Quantum Networks III
Robert Fickler, Institute for Quantum Optics and Quantum Information (Austria)
- 4 Quantum Technologies, Quantum Metrology, and Quantum Devices I
Ryan M. Camacho, Brigham Young University (United States)
- 5 Quantum Technologies, Quantum Metrology, and Quantum Devices II
Nana Liu, National University of Singapore (Singapore)
- 6 Quantum Computing, Quantum Operations, and Quantum Information Processing
Michael L. Fanto, Air Force Research Laboratory (United States)
- 7 Quantum Devices, Quantum Operations, and Quantum Information Processing
Paul M. Alsing, Air Force Research Laboratory (United States)
- 8 Quantum Cryptography and Quantum Networks IV
P. Benjamin Dixon, MIT Lincoln Laboratory (United States)