

PROCEEDINGS OF SPIE

Quantum Communications Realized II

**Yasuhiko Arakawa
Masahide Sasaki
Hideyuki Sotobayashi**
Editors

**28–29 January 2009
San Jose, California, United States**

Sponsored and Published by
SPIE

Volume 7236

Proceedings of SPIE, 0277-786X, v. 7236

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

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 *Quantum Communications Realized II*, edited by Yasuhiko Arakawa, Masahide Sasaki, Hideyuki Sotobayashi, Proceedings of SPIE Vol. 7236 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X
ISBN 9780819474827

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 © 2009, 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/09/\$18.00.

Printed in the United States of America.

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

The logo for SPIE Digital Library features the word "SPIE" in a bold, sans-serif font above the words "Digital Library" in a smaller, lighter font. To the right of the text is a stylized graphic consisting of three vertical bars of increasing height, resembling a bar chart or a signal waveform.

SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent 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 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. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

v *Conference Committee*

SESSION 1 QUANTUM INFORMATION PROCESSING

- 7236 02 **2-photon multiqubit cluster states (Invited Paper)** [7236-01]
G. Vallone, R. Ceccarelli, P. Mataloni, Univ. La Sapienza (Italy)
- 7236 03 **Physical and architectural considerations in quantum repeaters (Invited Paper)** [7236-02]
M. Razavi, K. Thompson, H. Farmanbar, M. Piani, N. Lütkenhaus, Univ. of Waterloo (Canada)
- 7236 05 **Quantum mechanics of adding and subtracting a photon (Invited Paper)** [7236-04]
M. S. Kim, Queen's Univ. Belfast (United Kingdom)

SESSION 2 ATOM-LIGHT INTERACTIONS

- 7236 06 **Interfacing light and single atoms with a lens** [7236-05]
M. K. Tey, S. A. Aljunid, National Univ. of Singapore (Singapore); F. Huber, Technical Univ. of Munich (Germany); B. Chng, National Univ. of Singapore (Singapore); Z. Chen, Institute of Materials Research and Engineering (Singapore); G. Maslennikov, C. Kurtsiefer, National Univ. of Singapore (Singapore)

SESSION 3 QUANTUM COMMUNICATION

- 7236 09 **Space-QUEST: quantum physics and quantum communication in space (Invited Paper)** [7236-08]
R. Ursin, Univ. of Vienna (Austria); T. Jennewein, Institute for Quantum Optics and Quantum Information (Austria); A. Zeilinger, Univ. of Vienna (Austria) and Institute for Quantum Optics and Quantum Information (Austria)

SESSION 4 SUPERCONDUCTING PHOTON DETECTORS I

- 7236 0C **Titanium TES based photon number resolving detectors with 1 MHz counting rate and 65% quantum efficiency (Invited Paper)** [7236-11]
D. Fukuda, National Institute of Advanced Industrial Science and Technology (Japan); G. Fujii, National Institute of Advanced Industrial Science and Technology (Japan) and Nihon Univ. (Japan); T. Numata, A. Yoshizawa, H. Tsuchida, National Institute of Advanced Industrial Science and Technology (Japan); S. Inoue, Nihon Univ. (Japan); T. Zama, National Institute of Advanced Industrial Science and Technology (Japan)

SESSION 5 SUPERCONDUCTING PHOTON DETECTORS II

7236 0D **Ultrafast nanowire superconducting single-photon detector with photon number resolving capability** [7236-12]

G. N. Goltsman, Moscow State Pedagogical Univ. (Russian Federation)

7236 0G **Nano-optical studies of superconducting nanowire single-photon detectors (Invited Paper)** [7236-21]

R. H. Hadfield, P. A. Dalgarno, J. A. O'Connor, E. J. Ramsay, R. J. Warburton, Heriot-Watt Univ. (United Kingdom); E. J. Gansen, University of Wisconsin-La Crosse (United States); B. Baek, M. J. Stevens, R. P. Mirin, S. W. Nam, National Institute of Standards and Technology (United States)

SESSION 6 QUANTUM CRYPTOGRAPHY I

7236 0I **DPS quantum key distribution and related technologies (Invited Paper)** [7236-16]

K. Inoue, Osaka Univ. (Japan), NTT Corp. (Japan), and JST-CREST (Japan); H. Takesue, T. Honjo, NTT Corp. (Japan) and JST-CREST (Japan)

7236 0J **One-chip quantum random number generator** [7236-17]

S. Tisa, Micro Photon Devices (Italy); F. Zappa, Politecnico di Milano (Italy)

SESSION 7 QUANTUM CRYPTOGRAPHY II

7236 0K **Test and measurement on quantum key distribution systems (Invited Paper)** [7236-18]

A. Tomita, ERATO-SORST, JST (Japan) and NEC Corp. (Japan)

7236 0L **Quantum key distribution at GHz transmission rates (Invited Paper)** [7236-19]

A. Restelli, National Institute of Standards and Technology (United States) and Univ. of Maryland (United States); J. C. Bienfang, A. Mink, C. W. Clark, National Institute of Standards and Technology (United States)

7236 0M **Sagnac quantum key distribution and secret sharing** [7236-20]

J. Bogdanski, J. Ahrens, M. Bourennane, Stockholm Univ. (Sweden)

Author Index

Conference Committee

Symposium Chair

James G. Grote, Air Force Research Laboratory (United States)

Symposium Cochair

E. Fred Schubert, Rensselaer Polytechnic Institute (United States)

Program Track Chair

Benjamin B. Dingel, Nasfinc Photonics, Inc. (United States)

Conference Chairs

Yasuhiko Arakawa, The University of Tokyo (Japan)

Masahide Sasaki, National Institute of Information and
Communications Technology (Japan)

Hideyuki Sotobayashi, Aoyama Gakuin University (Japan)

Program Committee

Kyo Inoue, Osaka University (Japan)

Prem Kumar, Northwestern University (United States)

Christian Kurtsiefer, National University of Singapore (Singapore)

Paul G. Kwiat, University of Illinois at Urbana-Champaign (United States)

Norbert Lütkenhaus, University of Waterloo (Canada)

Paolo Mataloni, Università degli Studi di Roma, La Sapienza (Italy)

Gregoire Ribordy, id Quantique SA (Switzerland)

Alexander V. Sergienko, Boston University (United States)

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

Masahiro Takeoka, National Institute of Information and
Communications Technology (Japan)

Akihisa Tomita, NEC Corporation (Japan)

Harald Weinfurter, Ludwig-Maximilians-Universität München (Germany)

Andrew G. White, The University of Queensland (Australia)

Carl J. Williams, National Institute of Standards and Technology (United
States)

Session Chairs

- 1 Quantum Information Processing
Andrew J. Shields, Toshiba Research Europe, Ltd. (United Kingdom)
Akihisa Tomita, NEC Corporation (Japan)
- 2 Atom-Light Interactions
Kazuhiro Hayasaka, National Institute of Information and
Communications Technology (Japan)
- 3 Quantum Communication
Myungshik S. Kim, Queen's University Belfast (United Kingdom)
- 4 Superconducting Photon Detectors I
Gregory N. Goltsman, Moscow State Pedagogical University (Russian
Federation)
- 5 Superconducting Photon Detectors II
Masahide Sasaki, National Institute of Information and
Communications Technology (Japan)
- 6 Quantum Cryptography I
Christian Kurtsiefer, National University of Singapore (Singapore)
- 7 Quantum Cryptography II
Rupert Ursin, Universität Wien (Austria)