PROCEEDINGS OF SPIE

Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2019

Ryszard S. Romaniuk
Maciej Linczuk
Editors

26 May – 2 June 2019
Wilga, Poland

Organized by
Institute of Electronic Systems, Faculty of Electronics and Information Technologies,
Warsaw University of Technology (Poland)

Sponsored by
PSP—Photonics Society of Poland • Committee of Electronics and Telecommunications, Polish Academy of Sciences • ARIES—Accelerator Research and Innovation for European Science and Society (CERN, EU H2020) • PKOpto—Polish Committee of Optoelectronics of SEP—The Association of Polish Electrical Engineers • EuroFusion Collaboration • EuroFusion Poland

Published by
SPIE

Volume 11176

Proceedings of SPIE 0277-786X, V. 11176

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

Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2019,
edited by Ryszard S. Romaniuk, Maciej Linczuk, Proc. of SPIE Vol. 11176, 1117601

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 SPIEDigitalLibrary.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 *Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2019*, edited by Ryszard S. Romaniuk, Maciej Linczuk, Proceedings of SPIE Vol. 11176 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

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

ISBN: 9781510630659
ISBN: 9781510630666 (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

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
SPIEDigitalLibrary.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

COMPUTATIONAL INTELLIGENCE

Part Two

BIOMEDICAL APPLICATIONS

ASTRONOMY, PLANETARY GEODESY, AND SPACE ENGINEERING

Part Three

NUCLEAR FUSION AND HIGH ENERGY PHYSICS

MATERIAL ENGINEERING

ADVANCED APPLICATIONS AND MEASUREMENTS

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.

Conference Committees

WILGA Symposia Steering Committee

Andrzej Domański, Warsaw University of Technology (Poland)
Jan Dorosz, Białystok University of Technology (Poland)
Tadeusz Kaczorek, Białystok University of Technology (Poland)
Lech Mankiewicz, Centre of Theoretical Physics (Poland)
Krzysztof Poźniak, Warsaw University of Technology (Poland)
Ryszard S. Romaniuk, Warsaw University of Technology (Poland)
Iwona Stanisławska, Space Research Centre (Poland)
Jerzy Weremczuk, Warsaw University of Technology (Poland)
Tomasz R. Woliński, Warsaw University of Technology (Poland)
Waldemar Wójcik, Lublin University of Technology (Poland)
Filip A. Żarnecki, University of Warsaw (Poland)

WILGA 2019 Symposium Chair

Ryszard S. Romaniuk, Warsaw University of Technology (Poland)

WILGA 2019 Symposium Committee

Michał Borecki, Warsaw University of Technology (Poland)
Elżbieta Czerwosz, Tele and Radio Research Institute (Poland)
Dominik Dorosz, Białystok University of Technology (Poland)
Jan Dorosz, Białystok University of Technology (Poland)
Małgorzata Jakubowska, ITME Warsaw (Poland)
Konrad Jędrzejewski, Warsaw University of Technology (Poland)
Grzegorz Kasprowicz, Warsaw University of Technology (Poland)
Adam Kisiel, Warsaw University of Technology (Poland)
Andrzej Kotyra, Lublin University of Technology (Poland)
Maciej Linczuk, Warsaw University of Technology (Poland)
Lech Mankiewicz, Centre of Theoretical Physics (Poland)
Robert Nietubyć, National Center for Nuclear Research (Poland)
Robert Nowak, Warsaw University of Technology (Poland)
Piotr Orleański, Space Research Centre (Poland)
Tomasz Osuch, Warsaw University of Technology (Poland)
Anatoli Płatonow, Warsaw University of Technology (Poland)
Krzysztof Poźniak, Warsaw University of Technology (Poland)
Mirosław Rataj, Space Research Centre (Poland)
Ryszard S. Romaniuk, Warsaw University of Technology (Poland)
Jerzy Siuzdak, Warsaw University of Technology (Poland)
Władysław Skarbek, Warsaw University of Technology (Poland)

Andrzej Skorupski, Warsaw University of Technology (Poland)
Andrzej Smolarz, Lublin University of Technology (Poland)
Janusz Sosnowski, Warsaw University of Technology (Poland)
Iwona Stanisławska, Space Research Centre (Poland)
Piotr Turkiewicz, Warsaw University of Technology (Poland)
Wojciech Walendziuk, Lublin University of Technology (Poland)
Jerzy Weremczuk, Warsaw University of Technology (Poland)
Andrzej Wróbel, Nencki Institute of Experimental Biology (Poland)
Wojciech Zabołotny, Warsaw University of Technology (Poland)
Filip A. Żarnecki, University of Warsaw (Poland)

WILGA 2019 Organizing Committee

Maciej Linczuk, *Chair*, Warsaw University of Technology (Poland)
Krzysztof Hackiewicz, Warsaw University of Technology (Poland)

WILGA 2019 Symposium Session Chairs

Photonics Applications and Web Engineering
Ryszard S. Romaniuk, Warsaw University of Technology (Poland)

Metrology and Measurement Systems
Wojciech Walendziuk, Lublin University of Technology (Poland)

Astronomy, Planetary Geodesy and Space Engineering
Iwona Stanisławska, Space Research Centre (Poland)

Materials and Technologies
Małgorzata Jakubowska, Warsaw University of Technology (Poland)

Free Electron Lasers and POLFEL
Jacek Sekutowicz, DESY (Germany)
Robert Nietubyć, National Centre for Nuclear Research (Poland)

Polish Contribution to CLIC Detector at CERN and Physics Studies
Filip A. Żarnecki, University of Warsaw (Poland)

Compressed Baryonic Matter Experiment at FAIR
Wojciech Zabołotny, Warsaw University of Technology (Poland)

Integrated Video Systems for Security and Law Enforcement
Krzysztof Poźniak, Warsaw University of Technology (Poland)

Photonic Materials and Structures
Jan Dorosz, Białystok University of Technology (Poland)

Nuclear Fusion Related Studies, Instrumentation for Tokamaks
Krzysztof Poźniak, Warsaw University of Technology (Poland)

Polish Contribution to ATLAS Experiment at LHC CERN
Macjej Trzebiński, The Niewodniczański Institute of Nuclear Physics (Poland)

Optical Communications and Sensing
Jerzy Siuzdak, Warsaw University of Technology (Poland)

Sensing Devices, Technologies and Applications
Michał Borecki, Warsaw University of Technology (Poland

Modeling, Simulation and Monitoring of Machining
Andrzej Matras, AGH University of Science and Technology (Poland)

Deep Networks in Digital Media
Władysław Skarbek, Warsaw University of Technology (Poland)

Imaging and Vision Measuring Systems
Andrzej Sioma, AGH University of Science and Technology (Poland)

Neuroengineering Control and Regulation of Behavior
Lech Mankiewicz, Centre of Theoretical Physics (Poland)

Adaptive Signal Processing, Measurement and Communication Systems
Anatoli Płatonow, Warsaw University of Technology (Poland)

Dependable Computing
Janusz Sosnowski, Warsaw University of Technology (Poland)

Artificial Intelligence and Bioinformatics
Robert Nowak, Warsaw University of Technology (Poland)

Fiber Bragg Gratings and High-Speed Optical Data Transmission
Konrad Markowski, Warsaw University of Technology (Poland)

Advanced Applications of Photonic and Electronic Systems, Poster Sessions
Waldemar Wójcik, Lublin University of Technology (Poland)
Andrzej Smolarz, Lublin University of Technology (Poland)
Maciej Linczuk, Warsaw University of Technology (Poland)

WILGA 2019 Best Student Paper Awards
Maciej Linczuk, Warsaw University of Technology (Poland)

Introduction

This volume contains papers from the 44th WILGA 2019 Symposium on Photonics Applications and Web Engineering and is devoted to the 10th anniversary of the Photonics Letters of Poland, a quarterly research journal published by the Photonics Society of Poland. The PLP journal was established by PSP society with essential support from SPIE. The editors of this volume acknowledge this strong support by SPIE, without which the Photonics Letters of Poland would never have been established.

The **SPIE-IEEE-PSP WILGA** symposium [wilga.ise.pw.edu.pl], is a multi-conference event, a kind of international Forum of Young Science in Photonics, Advanced Electronics and Internet Engineering. It is organized twice a year under the eminent patronage of two big international engineering institutions, SPIE [www.spie.org] and IEEE [www.ieee.org] and their Polish Counterparts: PSP—Photonics Society of Poland [www.photonics.pl], successor of the Polish Chapter of SPIE [www.spie.pl] and IEEE Poland Section [www.ieee.pl], with participation of IEEE R8 [ewh.ieee.org/reg/8/sac/cms]. The patrons of the symposium are: PAS—Polish Academy of Science (The Committee on Electronics and Telecommunication) [keit.pan.pl], Association of Polish Electrical Engineers (SEP) [www.sep.com.pl], Polish Committee of Optoelectronics SEP [pkopto.ise.pw.edu.pl], Warsaw University of Technology [www.pw.edu.pl], Faculty of Electronics and Information Technology [www.elka.pw.edu.pl], Institute of Electronic Systems [www.ise.pw.edu.pl].

WILGA Organizers: The Symposium is organized by a group of devoted young people—photonics, mechatronics and electronics researchers—gathered in the PERG/ELHEP Research Group of the Institute of Electronic Systems at the Faculty of Electronics and Information Technology of WUT. Most of these young researchers are active members of PSP, SEP, SPIE, OSA, and IEEE. The symposium is diligently run by young researchers for young fellow researchers and the main aim is to have a lot of fun and to learn a lot.

WILGA Publications: The WILGA Symposium publishes its papers in the following proceedings series, technical and peer-reviewed journals: Proceedings of SPIE, since 2002; IEEE eXplore, Internet publication data base; Photonics Letters of Poland, since 2009; Elektronika, SEP Journal, since 1998; IJET—International Journal of Electronics and Telecommunications, PAS [ijet.pl].

WILGA Proceedings of SPIE: There has been a long tradition of WILGA publishing its works in the Proceedings of SPIE. This volume is the 18th published with WILGA papers. All of the WILGA-SPIE volumes contain over 1,500 papers. All WILGA symposia have published more than 2,500 papers with over 5,000 participants. This is an extraordinary achievement for a modest symposium oriented solely on young

researchers. No one event of similar character could compare to this achievement. This success was only possible due to big involvement of young researchers in their work. The following WILGA Proc. SPIE were published: Wilga 2002 – Proc. SPIE 5125; Wilga 2003 – Proc. SPIE 5484; Wilga 2004 – Proc. SPIE 5775; Wilga 2005 bis – Proc. SPIE 5948; Wilga 2005 – Proc SPIE 6159; Wilga 2006 – Proc. SPIE 6347; Wilga 2007 – Proc. SPIE 6937; Wilga 2008 – Proc. SPIE 7124; Wilga 2009 – Proc. SPIE 7502; Wilga 2010 – Proc. SPIE 7745; WILGA 2011 – Proc. SPIE 8008; WILGA 2012 – Proc. SPIE 8454, WILGA 2013 – Proc. SPIE 8903, WILGA 2014 – Proc. SPIE 9290; WILGA 2015 – Proc. SPIE 9662; WILGA 2016 – Proc.SPIE. 10031; WILGA 2017 – Proc. SPIE 10445; WILGA2018 – Proc. SPIE 10808.

WILGA ways and topics: The official language of the Symposium is English. Peer reviewed papers are published in a renowned, worldwide recognized series, Proceedings of SPIE. The Symposium is designed mainly for young researchers who just finished their Ph.D. degree, but also Ph.D., M.Sc., and B.Sc. students (from physics, photonics, electronics, electrical engineering and mechatronics, as well as material research) and their tutors/mentors. WILGA has a number of main topical tracks. Historically, the first one was Photonics and Web Engineering. Generally, WILGA embraces advanced photonic, mechatronic and electronic systems, in the following aspects: theory, modeling, algorithms, simulations, emulations, design, hardware, software, hardware-software interaction and integration, measurements, testing, commissioning and exploitation. WILGA also addresses new research tendencies like 3D photonics and electronics design, micro and nano-systems, material engineering including meta-materials. Topical sessions are organized by leading experts. Sessions usually begin with current tutorials and are filled with contributed papers by Ph.D. students and young researchers. One of the most important session tracks in WILGA are photonics applications and systems for superconductive accelerator (and free electron laser) technology and high energy physics experiments. We invite warmly students, young researchers and their tutors to participate in WILGA.

WILGA offspring: The WILGA Symposium gave birth to a few topical meetings and conferences which then struck out on their own. These include students and young researcher regional meetings (Opole, Wrocław, Kielce, Białystok, Lublin, Toruń, Kraków and others), of SPIE student chapters, IEEE student branches, OSA student chapters, but also stand-alone conferences. Some of these meetings are still held periodically with Wilga, while some of them gained complete independence. WILGA is very proud of this sort of parenthood, since the very good idea of WILGA is proliferating elsewhere. One of such meetings is, now fully nondependent, SPS—Signal Processing Symposium which started at Wilga in 2003. Another meeting which originated from Wilga is Photoacoustics which started as a nondependent session.

The Wilga Symposium tries to address critical research and technical issues currently under discussion in Poland. Air pollution associated with coal-based energy generation and common usage of old types of inefficient furnaces is widely

debated. A session was organized on distributed measurements of air pollution using mobile devices equipped in multi-parameter sensors. Different flame measurement techniques were compared. Poland, called a coal country, faces a difficult decision on the governmental level concerning the development of big scale nuclear power facilities. This decision must be taken soon in order to avoid serious energy balance issues. A review paper was presented and a separate session on this subject was organized with participation of young researchers and nuclear energy infrastructure proponents and supporters.

WILGA 1998–2001: Early Wilga Symposia usually gathered around 100 young researchers each. The proceedings were published in Elektronika Journal of SEP, and on CD discs. Some of the reports from these meetings are available on Wilga webpage [wilga.ise.pw.edu.pl].

WILGA 2002: This was the tenth WILGA Symposium. This was the first time the proceedings were published SPIE (Proc. SPIE vol. 5125). Fifty-five papers were published under the following topical sessions: Optical Fibers, Links, and Networks I: Fundamentals of Optical Networking; Optical Fibers, Links, and Networks II: Technologies, Measurements, and Components; Electronic and Photonic Systems for High-Energy Physics (HEP) Experiments I: Subsystem Design; Electronic and Photonic Systems for High-Energy Physics Experiments (HEP) II: Numerical Calculations and Technical Solutions; Optical Fibers, Waveguides, and Communication Channel Theory; Optical Fiber Sensors and Optoelectronics: Industrial Applications; Lighting Technology; Materials Science and Optoelectronic Technologies; Photonics for Astronomy; Biomedical Applications of Electronics and Photonics; Software for Optical Networks and the Internet; Digital Holography, and 3D Object Measurements, and Recognition. WILGA 2002 was reported in the IEEE Region 8 News, August 2002 edition.

WILGA 2003: The number of participants exceeded 200 persons for the first time. Proc. SPIE vol. 5484 was published containing 95 papers. The topical sessions were: Optical Communications, Optical Computing, and Control Theory; Tesla: Superconductiong Linac and Free Electron X-Ray Laser; Advanced Electronic and Photonic Systems for the BAC/ZEUS Detector at the Hera Accelerator; Advanced Electronic and Photonic Systems for the CMS Detector at the LHC Accelerator; Advanced Electronic and Photonic Systems for Astronomy; Materials Science and Materials for Optoelectronics; Optical Fibers; Optical Fiber Lasers; Advanced Optoelectronic and Optical Fiber Sensors; Diffraction, Holography, Interferometry, and Image Processing; Optoelectronic Components: Photodiodes and LEDs; Optical Fiber Lighting Technology; Optical Broadband Internet Technologies and Techniques; and DSP and Radar Imaging. Wilga 2003 was reported in IEEE Region 8 News, November 2003 issue.

WILGA 2004: The number of participants was close to 300. An official agreement of cooperation was signed during Wilga 2004 between the Polish Chapters of SPIE and IEEE. Ninety-two papers were published in SPIE vol. 5775. The sessions were: RF

Control System for Tesla and European Superconducting X-ray Free Electron Lasers; Radiation Hardening of Photonics and Electronics for Accelerator/Detector Technologies; Electronic and Photonic Systems for Accelerator/Detector Technology and Astronomy; Optical Communications; Fiber Bragg Gratings and Photonic Crystal Structures; Optoelectronic Materials and Technologies; Digital Holography, Interferometry, and Image Processing; Flame Photometry and Combustion Process Control; FPGA and VHDL; Calculation and Measurement Techniques in Optoelectronics and Electronics; Telemetric Networks for Municipal Systems; Optical and Broadband Internet Technologies and Techniques.

WILGA 2005 and SPIE Poland 2005 Congress on Optics and Optoelectronics: The SPIE Poland meetings in 2005 were very special because then the Polish Chapter of SPIE (predecessor of Photonics Society of Poland) hosted together with SPIE and some other regional SPIE Chapters, the SPIE Warsaw Congress on Optics and Optoelectronics – SPIE COO Warsaw 2005. The WILGA 2005 Symposium was split into two parts: one held in WILGA and the second jointly with the COO'05 at Warsaw University of Technology. Two separate proceedings volumes were published, SPIE Proc. 5948 and 6159. SPIE COO Warsaw 2005 hosted nearly 800 participants. The two Wilga volumes gathered together over 250 papers.

WILGA 2006: The number of participants stabilized at around 300 persons. Proc. SPIE vol. 6347 was published containing 111 peer reviewed papers. Several sessions were organized devoted to trial defenses of Ph.D. and M.Sc. theses, mainly in photonics and electronics. The sessions included: Free electron laser instrumentation; HEP instrumentation and measurements; International linear Collider, Software and hardware aspects of photonics; Hardware and software co-design; Experiments in space research, astronomy, and astroparticle physics; Bragg gratings and nonlinear optical fibers; Capillary and ring core optical fibers; Materials for optical fiber technology; Photoacoustics; Optoelectronic equipment; Optical fiber sensors and lighting technology; Optical interconnections, packaging, soldering, and RFID technology; Biometrics; Biomedical applications of photonics and electronics; HF circuits; Simulation and control theory; Virtual laboratories and optical Internet technology; and Intelligent computing in optoelectronics.

WILGA 2007: This was the 20th WILGA Symposium. Proc. SPIE 6937 was published containing 152 papers. Nearly 250 presentations filled over 20 topical sessions. The aggregated participation was again around 300 persons. Wilga 2007 was again reported in the IEEE Region 8 News, December 2007 issue. The sessions were on topics such as: Apparatus for optical and gamma-ray astrophysical observations; Flash laser and European x-ray laser development; Superconductive accelerator technology for free electron laser and high energy photon physics; Photoacoustics and ultrashort pulse technology; Optical fiber technology and measurements; Optical fiber applications; Nanomaterials and material research for photonics and electronics; Optical and quantum cryptography; Medical x-ray accelerators and biomedical applications; Warmer program sensory networks for water

management/preservation and environment protection; Image processing; Passive and active radar imaging; Signal processing; Radar technology, Optical and radiofrequency technology; Optical measurements; and Algorithms for data processing.

WILGA 2008: WILGA 2008 gathered over 200 participants and the proceedings volume (SPIE vol. 7124) contained 35 papers. The introduction to this volume contains a report on the establishment of the Polish Photonics Society, which evolved from the local SPIE Chapter in Poland. PSP immediately opened its publishing body which is Photonics Letters of Poland. The sessions included: Photonic materials research; Liquid crystal and Bragg optical fibers; Photonic micro-components; Apparatus for optical and gamma ray astrophysical observations; Photonic equipment for high energy physics experiments and accelerator technology; Optimal learning systems for photonics and medicine; Warmer project: sensory networks for water management/preservation and environment protection; Broadband pulse technology; and Photonic broadband networks.

WILGA 2009: Proc. SPIE vol. 7502 was published containing 100 papers. There were around 200 presentations, and over 300 participants in two parts, optical and radar. The sessions included: Image processing, Optical biometry; Optical astronomy and space technology; Radar technology; Navigation and target tracking; Signal filters and DSP; Signal modulation, transmission and detection; Laser materials, optical fibers and optoelectronics; Sensors, remote sensing, and measuring networks; Genetics databases and biomedical applications.

WILGA 2010: Proc. SPIE vol. 7745 contained 73 papers. The symposium gathered around 300 participants in two parts, optical and radar. Over 200 presentations filled 25 topical sessions. The sessions included: Development of photonics and electronics in Europe and Poland; Photonics applications in astronomy and space technology; Optoelectronics and optical fiber technology; Photonics and IT applications in biology and medicine; Acoustic signal processing; Optoelectronics and electronic, image processing, material nanotechnology; Multiprocessor co-integration platforms. The volume features a series of program articles on development of electronics and telecommunications in Poland.

WILGA 2011: Proc. SPIE vol. 8008 contained 71 papers. There were over 250 participants and over 200 presentations. Wilga 2011 featured SPIE-PSP award for the best student paper presentation. The sessions included: Development of photonics and electronics in Europe and Poland: knowledge representation; Advanced photonics and electronics systems: hardware aspects; Advanced photonics and electronics systems: software aspects; Applications of photonics in astronomy; Communications technologies; Multimedia technologies; Advanced biomedical systems; Radar technologies; Materials for photonics and optoelectronics, optical fibers.

WILGA XXXth Jubilee Symposium: WILGA 2012, January Edition was held on 26–29 January 2012 at WUT's FE&IT. The WILGA 2012 May edition was held on 28 May–2 June 2012 in a resort owned by Warsaw University of Technology. Over 300 presentations were given during both editions of Wilga, covering a broad area of photonics applications and web engineering. Nearly 350 persons participated. Proc. SPIE 8454 contained 85 papers. The sessions were: Photonics overview for XXX Wilga Symposium, Pi-of-the-sky: a network of astronomical telescopes; Satellite and space technology; High energy physics experiments; Communications and multimedia technology; Optoelectronic technologies, components, devices and systems; Materials and technologies; Components and systems modelling; Biomedical and DNA computing; Airborne applications of computational intelligence; Artificial intelligence, cryptography, software and ontological ICT systems.

WILGA 2013: Proc. SPIE 8903 was published and contained 100 papers. The working research sessions of 32nd WILGA 2013 were: general photonics, optical fiber technology, optical communications, optoelectronics, applications of optical fibers, integration of electronics, photonics and mechatronics, distributed measurement systems, LHC and CMS at CERN, JET and ITER photomasks, optics and optoelectronics for astronomy, fundamentals of FPGA-DSP systems, object oriented design of hardware, terabit optical data links, software-hardware co-design, biomedical engineering, computational intelligence of advanced systems, development of photonics and electronics in Europe and Poland, radar technology, terahertz photonics, free electron lasers, E-XFEL and POLFEL lasers, EuCARD—European Coordination of Accelerator Research and Development, and TIARA, etc. A special session was devoted to a project EuCARD^2 (2013–2017), which is a continuation of EuCARD.

WILGA 2014: Proc. SPIE 9290 was published containing 125 papers. The Wilga 2014 Symposium was held during the last week of May 2014. The working research sessions of the 34th WILGA 2014 symposium were held traditionally as in previous years: general photonics, optical fiber technology, optical communications, optoelectronics, applications of optical fibers, integration of electronics, photonics and mechatronics, distributed measurement systems, LHC and CMS at CERN, JET and ITER tokomaks, optics and optoelectronics for astronomy, fundamentals of FPGA-DSP systems, object oriented design of hardware, terabit optical data links, software-hardware codesign, biomedical engineering, computational intelligence of advanced systems, development of photonics and electronics in Europe and Poland, radar technology, terahertz photonics, free electron lasers, E-XFEL and POLFEL lasers, EuCARD2 – Enhanced European Coordination of Accelerator Research and Development, TIARA, EuroFusion Project, etc.

WILGA 2015: Proc. SPIE 9662 was published containing 169 papers. The Symposium was held during the last whole week of May 2015, plus during two adjacent weekends. The working research Sessions of 36th WILGA were traditionally as in previous years: general photonics, optical fiber technology, optical

communications, optoelectronics, applications of optical fibers, integration of electronics, photonics and mechatronics, distributed measurement systems, LHC and CMS at CERN, JET and ITER tokomaks, optics and optoelectronics for astronomy, fundamentals of FPGA-DSP systems, object oriented design of hardware, terabit optical data links, software-hardware co-design, biomedical engineering, computational intelligence of advanced systems, development of photonics and electronics in Europe and Poland, radar technology, terahertz photonics, free electron lasers, E-XFEL and POLFEL lasers, EuCARD2 – Enhanced European Coordination of Accelerator Research and Development, TIARA, EuroFusion Project, etc.

WILGA 2016: The 38th Edition of Wilga Symposium was held on 29 May–6 June. It gathered more than 350 participants from Poland and Europe. Over 250 papers were presented orally and around 50 posters. Proc. SPIE volume 10031 contains 194 papers. The 2013–2016 Wilga Symposia were under friendly research patronage of the EuCARD2 EC Program on accelerator technology. The following topical sessions were organized: material engineering, photonics, sensors and measurements, biomedical applications, research experiments, and high-performance computing.

XL SPIE – PSP WILGA 2017: Proc. SPIE 10445 contained 238 papers. WILGA 2017, the 40th Symposium Jubilee Edition, was held 28 May–5 June 2016, and gathered a record number of nearly 400 participants. Wilga 2017 and hopefully the next Wilga meetings will cooperate with the ARIES EC H2020 Project on Accelerator Research and Innovation for European Science and Society. Wilga 2017 saw in Warsaw two important SPIE Conferences on Remote Sensing, also on Security and Defense. The Symposium featured the following sessions: Photonics and Optoelectronics, Computational intelligence, Biomedical applications, Research Experiments, Material research, and Advanced applications.

WILGA 2018: Wilga 2018 took place 3–10 June and gathered over 300 participants. Wilga 2018 was attended by participants from Czech Republic, Germany, France, Ukraine, Belarus, and Kazakhstan. Traditionally the following topical sessions were organized: Photonics Applications, Photonics Technologies and Components, Instrumentation for High Energy Physics Experiments, Free Electron Lasers, Instrumentation for Tokamaks and Hot Plasma Fusion Experiments, Astronomy and Wide Sky observations, Biophotonics and Optogenetics, Photonics – Electronics – Mechatronics Co-integration, Hardware – Software Co-design, High Performance Computing and Artificial Intelligence, etc.

Wilga 2019: Wilga 2019, the 44th edition of the meeting, was held 26 May–2 June 2019. The Symposium gathered more than 350 participants, with nearly 300 presentations. Most of the papers presented are published in this volume, and some of the presentations will be published in archival journals on photonics including the Photonics Letters of Poland by Polish Photonics Society and the International Journal of Electronics and Telecommunications. One of the observed

positive accomplishments of the symposium was the broadening of photonics applications beyond the classical fields of research interests like communications, sensing, and information processing. These include manufacturing industries, mechanical engineering and robotics, as well as intelligent infrastructures, smart environments, law enforcement, security, and safety. The interest in these fields is reflected by the increased number of Ph.D. theses realized in these fields and reported during the 2019 Wilga Symposium. Yet another success of the Wilga Symposium's development is the increased interest of the industry in cooperation with young photonics researchers.

WILGA 2020: The WILGA 2020 summer meeting on Photonics Applications and Web Engineering will be held on 24–31 May 2020. The Wilga 2020 winter meeting will be held 23–26 January 2020. The organizers warmly invite interested young researchers and students in photonics and related fields to participate in this exceptional and very friendly research event oriented toward young researchers from Poland and all over Europe, and the World. WILGA 2020 proceedings will incorporate the papers presented during the winter and summer editions of the symposium.

Ryszard S. Romaniuk
Maciej Linczuk