50th Edition of WILGA Symposium on Photonics Applications

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Abstract—The Jubilee 50th edition of the WILGA Symposium on Photonics Applications crowns 25 years of diligent service by this exceptional series of scientific and technical meetings to the local and international photonics research, academic, industrial, business, and societal communities. The paper reviews concisely, without details, some of the chosen topical tracks related to photonics presented during the previous meetings, particularly during the WILGA 2022 sessions. The paper summarizes the achievements of WILGA Photonics Applications meetings of young researchers shortly and gives a general sense of the unique nature of these meetings. More comprehensive descriptions of WILGA achievements are available in around 30 Proc. SPIE volumes published continuously under the common title Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments since 2002.

On the occasion of the 50th edition of the WILGA meeting, it is necessary to summarize their role and impact on the photonics community in Poland, and in this geographical region, during the last quarter of a century. WILGA Symposium [1-2] on Photonics Applications 2022 was split traditionally into two parts, held in January as the 49th winter edition, in May/June, and in September during the split 50th summer edition [3]. All sessions gathered more than 150 participants, national and international young researchers in photonics, optical engineering, electronics, mechatronics, applied physics, and related areas in which photonics plays a key role. A characteristic feature of WILGA 2021 and 2022 Symposia on Photonics Applications was the numerable participation of researchers, students, and presented works from Ukraine. The post-pandemic situation forced the organizers to split and reduce some of the plenary WILGA meetings considerably, with the traditional participation of several hundred young researchers, to more confined hybrid events. WILGA Symposium is a research, technical and social event organized by students for students with a leading motto: Come here to have fun, to have much fun, and to learn a lot! WILGA Symposium for young researchers, in her middle age, was a research event ahead of its time in terms of organization, research program, and the way of presentation. The very current and exciting scope of topical tracks and unique way of conducting the research and technical session were the factors that attracted, literally speaking, crowds of young researchers.

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This unique and incomparable research and teaching event has now reached a round number of fifty editions. During the quarter of a century, WILGA gathered more than 8000 young researchers, most post-graduated and Ph.D. students active in photonics applications and related fields. More than 3000 indexed papers were published in WILGA proceedings and journals. WILGA proceedings have been published since 2002 (editions 9th and 10th) in the series Proc. SPIE [4-6]. Patronage over WILGA Symposium was held by the Photonics Society of Poland, IEEE Poland Section, Association of Polish Electrical Engineers, Polish Optoelectronics Committee, Committee of Electronics and Telecommunications of Polish Academy of Sciences, and Warsaw University of Technology. WILGA Symposium was generously co-sponsored by SPIE, PSP, IEEE, and WUT. Wilga sessions on material science in the field of photonics, apart from laser semiconductors and optically active dielectrics, were usually centered around glass technology for photonics, sensors, optical fibers, integrated optics, nano-photonics, etc. This year, these sessions were correlated with the International Year of Glass declared by the United Nations [7]. Wilga's session on glass technology development was devoted to the dedication of the Year of Glass. Similarly to the International Year of Glass of 2022, Wilga celebrated the International Year of Light in 2015 with several dedicated sessions and invited tutorials by international experts in photonics. Wilga Symposium also participated in the exceptional Warsaw SPIE Congress on Optics and Optoelectronics with over 1500 participants in 2005. Glass played an essential role in the development of laser technologies. In 1961, Elias Snitzer fired the first optical fiber laser, which was 1 m long. Lasers, glass, and optical fibers have changed everything in science and societal applications. Femtosecond lasers gave birth to new tooling for femto-physics and femto-chemistry and to much more detailed research of liquid-to-glass transition. Observations of glass behavior under the interaction with femtosecond laser pulses are the key to understand the glass transition phenomenon. This research led to fs-laser glass micromachining technologies with sub-nm precision. Glass is a non-crystalline amorphous solid, formed by quenching, with an internal atomic arrangement similar to liquid but more tightly packed. The glass-liquid thermal transition region T_g is always the subject of research using

statistical and rheological approaches. The non-crystalline character of glass means that there is no long-range order inside the material, and the material is in a complete disorder, even microscopically. Glass is in a non-equilibrium state from the point of view of thermodynamics. Chemical bonding constraints impose that glasses possess a high degree of short-range order concerning local atomic polyhedra. A few strong glass research centers do high-quality applied science in Poland and used to participate in Wilga with their engaged young researchers.

Ergodicity of the dynamic system, like glass, shows how the properties of a small random sample of glass images average the behavior of a large sample with time. This is necessary to master the material more precisely and safely apply glass as a miraculous base in up-and-coming solutions of nano-photonics. Nano-photonic circuits based on glass enable near-field and nonclassical, sub-Poissonian light functionalities, including shaping and managing single photons, dressed photons, trapped and virtual photons, and photon-based quantum emergencies like coupled photon-electrons, photon-polaritons, which are impossible, or difficult to obtain in other conditions. Other Wilga nonclassical light sessions concentrated on practical applications of squeezed light and other nonclassical light states like Bessel beams.

Nanometre size and periodic glass structures enable the manufacturing of functional devices compatible with the photonic integrated circuits PIC and optical fiber technology and resigning from volume optics using even miniature but classical lenses. The boundary between ergodic and nonergodic areas in glass is indicated by the value of the Deborah number, which is the subject of research using physical phenomena of very different timescales like ablation, thermal diffusion, re-solidification, carrier-carrier and carrier-phonon scattering, radiative recombination, and photon absorption. These effects span from 10^{-5}s to 10^{-16}s. These effects are grouped into four basic categories, thermal and structural effects, carrier removal, thermalization, and carrier excitation.

Wilga sessions on quantum information technologies QIT were mainly associated with building a two hundred qubit quantum computer at WUT and an ultraprecise quantum optical fiber link for data transfer to/from the trapped ion-based NISQ (noisy intermediate-scale quantum) processor to the distant computational center. The quantum processor is controlled, on the hardware layer, by a network of associated microwave and laser beams. Physical qubits are organized up the software stack into functional, logical qubits, which, even higher in the computational stack, are available by the NISQ users. Ph.D. students are engaged in the project and report some of the results in Wilga. Active work goes on cybersecurity, including providing secure computation and transmission on the photonics layer of the QIT infrastructure. Classified algorithms are implemented for quantum error correction on physical and logical layers. Ironically, the infrastructure will also be used for works on post-quantum-era cybersecurity technologies. Building middle-size quantum computing and QIT infrastructure at WUT encouraged the group to launch a series of lectures on quantum computing, emphasizing linear photonic solutions and QIT for M.Sc. and Ph.D. students to attract them to these technologies. QIT has a substantial impact on the development of biomedical engineering. Wilga optogenetics, biophotonics, and quantum biophotonics sessions were associated with the new track of research and didactic designed for postgrad and Ph.D. students to familiarize them with new technologies and encourage them to join the quantum information technology research teams formed at WUT and other universities. The Optogenetics hardware layer was constructed in cooperation between WUT, innovative spin-offs, and Medical University in Warsaw. The tiny integrated electronics-photonics probe was implanted into the animals' brains to test control of their behavior induced via quantum opto-chemical reaction in their organisms. Some of these pioneering optogenetics results were published in Wilga proceedings. Other Wilga sessions on biophotonics included photoacoustic spectroscopy, photodynamic and low-level laser therapy, laser equipment for biomedicine, but primarily biofluorescence with a green fluorescent protein, and bioluminescence as well as biophosphorescence. Integrated photonic equipment was constructed and tested in several laboratories for biophotonics measurements.

Wilga sessions on optical networking were, in a sense, associated with the development of wireless networking by light and photonic options for the 5G/6G. Light-assisted networking includes a massive data layer at TB rates, at the network core, with optical pipes, and the wireless Li-Fi user access layer, at MB/GB rates, at the network access peripheries. Numerable Li-Fi solutions were implemented in various, intentionally chosen, easy, and challenging infrastructural conditions to test the photonic signal integrity, availability, practically available transmission rates, multipath disturbances, environmental noise, reliability, energy efficiency, etc. Li-Fi research results presented in Wilga have shown the beauty of this technology by its availability for extended and quite advanced research for students. The number and variety of tested LED lamps, and other compatible light sources applicable for the Li-Fi in various environmental conditions were impressive. Some of these solutions have found real-life applications and started to be manufactured by innovative photonic spin-offs.

An extraordinary, dedicated Wilga session was organized on attosecond and exawatt laser pulses, and laser pulse compression technologies. The exceptional occasion for this session was that the Military Academy of Technology in Warsaw awarded professor Gerard

Mourou (Nobel Prize 2018 in Physics with Donna Strickland) with the honorary doctorate for his work on chirped pulse amplification and laser pulse compression.

Ph.D. students and young researchers from WUT, UW, and other universities, are engaged in several projects associated with large, scientific, discovery class infrastructures in Europe. These infrastructures contain a lot of combined and frequently well-integrated electronics and photonics functional instrumentation. The functions include measurements, equipment diagnostics, the realization of work tasks, routine system maintenance, control, timing, and synchronization, and providing safety. The infrastructures with active engagement of students from Poland are European X-ray Free Electron Laser in DESY, European Spallation Neutron Source in Lund, ATLAS and CMS experiments at LHC in CERN, CBM – compressed baryonic matter, and other experiments at GSI/FAIR in Darmstadt, Tokamak development projects associated with the ITER infrastructure, etc. During these 25 years, WILGA organized numerous sessions on developing research equipment for these extensive experiments starting many years ago with reports on the ZEUS/HERA developments and achievements in DESY Hamburg. One of the leading topics is developing precise photonic and electronic equipment for the compressed baryonic matter experiment at the Facility of Antiproton and Ion Research. Wilga groups of young researchers were involved in several astronomical and space research projects. In this respect, close cooperation was developed between WUT, UW and the Centre of Space Research CBK PAN. Pi-of-the sky project and constructed round-the-globe optical observatory, performing continuous measurements for more than a decade, culminating in the discovery and co-discovery, as the first observer, of several optical flashes accompanying significant GRB effects. Young researcher groups from CBK PAN, which report their results in Wilga, specialize in constructing innovative, specialized board computers for satellites. These constructions contain highly reliable photonics components integrated into the system functionality. Wilga sessions on space and satellite engineering have always been attended by young researchers from several research and technical centers and innovative firms in Poland. Wilga was lucky to carefully observe the birth of these technologies in Poland by establishing many dedicated spin-offs to space research.

Wilga continuous Photonics Applications sessions were devoted to developing many components, devices, sensors, and larger pieces of functional equipment containing key photonics components. It is interesting to list a few of such systems, presented in Wilga at an early stage of development, which work today as standards, in some cases, worldwide. One of the birthplaces of the optical fiber-based White Rabbit system of precise time distribution was WUT, with initial ideas presented in Wilga around 20 years ago. Now the system is a widely adopted standard adding to the PTP protocol.

Wilga Symposium was correlated with other domestic and international photonics meetings organized in Poland inside the local, very active photonics research community. After gaining initial experience in Wilga, the young researchers frequently presented their works during the meetings co-organized by the Photonics Society of Poland and other national photonics organizations like Symposium on Laser Technology, Optical Fibres and Their Applications, Optical and Electronic Sensors, Integrated Optics, etc. All of these meetings published, for some time, their works in Proc. SPIE. The Wilga symposium on Photonics Applications undoubtedly left an indelible mark on the Polish photonics research community. Many then young researchers starting their research careers with Wilga are now leaders of their research groups in governmental laboratories, academia, and the industry. A number of them opened their own start-ups and spin-offs and operated successfully in the demanding high technology market. Twenty-five years ago, when we started with the first Wilga, it was a novel approach and initiative, adding decisively and firmly to the education style via dynamically changed projects rather than via the permanent, not often changed, curriculum. Today, these early participants, now established experts, admire very frequently the foundations of this initiative when looking back into the past. The distinguished 25th anniversary of the Wilga symposium and its 50th edition raises questions about its future. Wilga meetings are older than the Photonics Letters of Poland and contributed their numerous papers. The first one was WILGA Symposium on Photonics Applications, published as an editorial in PLP 1(2) 2009. The question about Wilga's future has to be answered by the new generations of young researchers in photonics and their tutors supervising the development of their scientific and technical careers, choosing and fitting the appropriate methods to the changing research environment and legal academic requirements. These have recently changed a lot, requiring form Wilga to find new ways of attracting interaction with young researchers.

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