doi: 10.4302/plp.v11i2.900 PHOTONICS LETTERS OF POLAND, VOL. 11(2), 35-37 (2019)

Wilga 2019 – Photonics Applications

Ryszard S. Romaniuk*

Faculty of Electronics and Information Technology, Warsaw University of Technology, Nowowiejska 15-19, 00-665 Warszawa

Received June 05, 2019; accepted June 15, 2019; published June 30, 2019

Abstract—Wilga Symposium on Photonics Applications [1] has been serving the national and international communities of young researchers for nearly a quarter of century. Ph.D. students, active in photonics research and technology, optoelectronics, optical engineering, and associated fields like electronics, materials engineering, mechatronics, and ITC present successive developments of their work. The subjects embrace optical fiber technology, optical communications, sensors, light sources and lighting, research and industrial applications. Since its beginning Wilga has gathered more than 5000 presentations by Ph.D. students, out of which around 3000 were published internationally in the Proceedings of SPIE [2–5]. The paper digests concisely some of the achievements of Wilga 2019 [6] on the 10th Anniversary of the Photonics Letters of Poland. Wilga Symposium on Photonics Applications is a very important pillar of the PSP Society focusing strongly its interest on young photonics researchers.

Wilga Symposium on Photonics Applications is organized twice a year under the patronage of SPIE, IEEE, Polish Optoelectronics Committee of the Association of Polish Electrical Engineers, Committee of Electronics and Telecommunications of the Polish Academy of Sciences and by the Photonics Society of Poland. Each year it gathers more than 350 young photonics researchers in its summer edition and around 100 in winter edition. Wilga Symposium organizes usually topical sessions on digital modifications of classical and modern optical measurement and functional techniques like refractomerty, interferometry, polarimetry, scatterometry, nefelometry, spectrometry, etc. Separate Wilga sessions concern astronomical observations, space and satellite engineering, biophotonics including biogenetics, massive photonic data acquisition and transmission including image processing, optical data evaluation in-flight and photonics-based cybersecurity systems. Emphasis is on large applications of photonics and its integration with other functional layers of research, biomedical and industrial applications

Optical wireless communications uses unguided VIS, IR and UV light to transmit digital and analog signals. Visual light communications VLC and Li-Fi technologies are under development in university laboratories to address a number of particular issues with measurement data acquisition and distribution in demanding technical conditions. A variety of OWC/VLC systems are under construction to fit specialized applications including biomedical. An Intelligent cage (Intellicage) hosting a group of mice for behavioural research is equipped with the OWC, in parallel to other electronic and magnetic methods, to distribute and collect data on mice movements and from the on-body markers and sensors. Li-Fi replaces in this application very efficiently, in the sense of transmission rate, data quality and system availability, the classical Wi-Fi and NFC technologies.

VLC systems are modified to boost their performance in frequency domain, nonlinearity, latency and range. VLC LEDs input and output signals are subject to pre-equalization and post-equalization. The receiver SNR is improved using a distributed method with equalization done simultaneously at the transmitter and the receiver. The SNR improvement using the distributed way reaches optimally a few dB comparing to a single equalization method. Additionally, the Matlab deep learning toolbox for ANN was used to model, train and approximate the channel impulse response for a closed space VLC system. A nonlinear model of the VLC channel includes dimensions and shapes of the considered closed space, reflection - absorption characteristics, obstacles, and transmitter - receiver positions and orientation. VLC channel characteristics are dynamically changing with the movements of the receiver, and are pre-mapped to the communication system database of particular closed space under investigation.

SDO – software defined optics is a comparatively new tendency in the construction of functional photonic equipment. VLC communication channel impaired essentially by rain was analysed, modelled and measured. The solution is based on software defined radio SDR and radio over fibre hardware with commercially available LED car taillights. Multistate QAM modulation formats were tested for performance in different rain conditions. The influence of variable rain intensity was correlated to changing basic communication parameters including EVM, BER, and available transmission rate. Dense fog was proven to impair the optical communication system parameters more than even high rain. The presence of fog requires different optics to partially solve the impairment. Advanced signal processing performed on-line during the transmission of digital codes optimized for fog improves

* email: ryszard.romaniuk@cern.ch

the BER to the levels comparable with the transmission through the rain.

Biophotonics methods add a set of efficient tools to research physiology, pathology, individual and social reactions of animals to precisely directed, primarily internal, interaction with wave excitations. Opto-genetics experiments are done on mice to research the control of mammals' behaviour with light. A sub-miniature light probe is inserted to a mice's brain to trigger a specific opto-chemical reaction, finally changing the behaviour. The photonic measurement system excites particular biological structures, transmits data and supplies power wirelessly not to hamper the mice's social interactions and deteriorate its living conditions. The research contributes to the studies on subtle brain structures and physiological biochemistry.

Variable wavelength micro-interferometric measurement methods, in transmission and reflection modes, are developed using classical advanced microscopes and continuously tuneable coherent and incoherent light sources. The uncertainty of determination of optical path difference (or retardation) is determined by the precision of wavelength tuning. Confocal sensors and VAWI techniques enable high precision photonic measurements of small investigated object areas, now in a very short time. The distribution of refraction and birefringence are measured in major geometric directions of the object. Optical parameters are next translated to physical, chemical and mechanical properties of the object, in particular stress distribution, material health and strength. The distribution of object structural inhomogeneities are acquired. The flaws are generated on-surface and internally by successive technological, or final device assembly, processes.

Advanced image corrections rely on photonic and software methods. Fisheye lens and telephoto lens for long distance are becoming more widely used because of their larger field of view or much longer focal length than those of a normal pinhole camera. The larger field of view is obtained by image radial distortion. This image distortion should be rectified not only for visualization but for use by numerable applications performing image-based measurements. Deep learning was used to improve the quality of computer vision using a single image radially distorted and acquired by an unknown camera. Such a condition is frequently met in practice. The ANN learns the distortion information from the input images and performs the image rectification without explicit use of image semantic information. A database of distortion models and their inversions for training was generated.

Work on the modernization of existing older optoelectronic systems showed that their characteristics can be optimized using signal processing algorithms based on stochastic-deterministic signal and image processing, in particular considering a complete physical, mathematical and statistical description. Statistical models of interaction of an optical signal in an optoelectronic system based on distribution laws and characterized by particular dispersion was applied to process signals and images in a photonic telemetry and ranging system working now for several years. The aim of the system is to differentiate between small and weakly visible objects of very low contrast and determine their parameters. The following methods were applied to update the existing photonic field equipment. The sensitivity threshold was reduced by improving optical components in functional devices. The dynamic range of the equipment was equalized and coordinated by applying spectral and neutral filtering methods. Algorithms for image processing were updated by including a layer of advanced statistical analyses of received signals. Considerable improvements of photonic tele-detection system parameters were observed including overall image quality, resolution and visual range. The modernized photonic system works in law enforcement, safety, security and military applications.

High speed IR cameras were applied in the CNC milling machine diagnostics. Machine vision methods were used to measure the positioning table and thermal expansion of a screw realizing the feed of the milling table. Tests were conducted on machining centre HAAS MiniMill 2. The linear motion of the table was recorded using a high-speed camera Phantom 5.2. To determine the positioning error of the worktable as a function of temperature of the lead screw, an infrared camera SC620 Flir was adopted. The positioning error and the maximum value of temperature of the lead screw were determined. The research demonstrates the suitability of thermal and high-speed cameras to determine the positioning errors of the milling table as a function of temperature of the lead screw. The analysis allowed to present the dependence of the accuracy of table positioning in the Y axis as a function of temperature of the lead screw. The table positioning error determined is around 69 μm after the table has completed all cycles, i.e. after covering the total distance of 72 meters. The temperature of the lead screw increased by an average of 1ºC for each cycle and reached the value of T_{max} approximately 35ºC.

3D imaging methods were applied to determine the orientation of an object based on the CAD model. A laser triangulation method was used for non-contact scanning of an object to obtain a three-dimensional point cloud. The system consists of a camera and a laser illuminator. The aim of research is to enable collision free realization of manipulation tasks for the arm of an industrial robot.

A photonic sensor was developed to determine the colour and distinguish between very distant objects located on the horizon. The differentiation ability includes different stationary and movable objects, artefacts, artificial and natural obstacles including rain, fog, snow, fumes and clouds. The application tests were performed in different environments including differentiation between very similar and distant skyscrapers with glassy walls in a dense urban area. Object classification was done in real-time scanning the distant horizon. Low cost photonic sensors were used, mounted in a high quality optical monocular. Different types of sensors were compared to choose the optimal ones for colour recognition in a particular observational environment. Large sets of signals were acquired for different observational conditions to do statistical analyses for optical device optimization.

A photonic spectrometric capillary sensor was used for determination of fuel quality and photo-stability. The sensing device is fast, low-cost and disposable in comparison with classical chemical measuring sets and methods used routinely by mobile fuel quality checking laboratories. Fuel photo-stability was measured during its exposure for high power UV LED light. Fuel was irradiated sequentially with a 385 nm high power LED for approximately 1 h with 5-minute breaks for relaxation and subsequent measurements. The measuring head was constructed in hybrid MOEMS technology and consisted of a microfluidic device situated on small substrate, micro-pumps, micro-spectrometer for scattered signal detection, UV light source, optical fibre and photonic capillary holders. The head is assumed to be commercialized by a start-up business.

Smart light systems are an important part in the smart city solutions improving the lighting conditions and considerably saving energy and costs, while increasing functionality. There were assumed several key assumptions while designing a smart light system in the urban testing ground. The pillar of the public lighting is no longer used only for the lighting. The column becomes a public service provider for optimized lighting levels, electrical and EM energy, gateway for city information system, safety and other types of sensors, multimedia signals streaming adaptable to the local needs. Academic campus turned out to be an ideal area for testing a fully networked multifunctional smart light system to be next potentially widely extended for smart city applications. The constructed smart light testing system consisted of light sources, cameras, audio sensors, city radio module, Wi-Fi spot, VLC Li-Fi spot, meteorological module, SOS button, and damage resistant information panel. The system collects exploitation data to evaluate the relevancy of the practical value of its particular functional components and modules.

Optical node working in dense wavelength add-drop DWDM multiplexing network of the next generation was optimised using ANN evolutionary algorithms. The aim was to reduce the operational costs of the photonic system and increase its service flexibility. The costs include lowering the use of reconfigurable photonic node resources, depending on node architecture, and including transponders and narrowband optical filters. A model based on integer and mixed integer programming was applied. The efficiency of integer-based programming software was compared with the evolutionary algorithms. There is a big advantage of using the ANN evolutionary algorithms for optimizing large (number of nodes more than 20) realistic optical networks of different, dynamically changing dimension, and traffic demands. The results were used to plan DWDM network expansion.

Pb ions from a thin 100 nm foil were accelerated by an ultra-intense multi PW, 10^{23} W/cm^2, 30 fs, circularly polarized laser pulse. The target and ions are subject to dynamic ionization. The dynamic process results in wide distribution of ionization degree ranging from z=25 to z=80 with strong statistical maximum for z=72. Most of the laser beam energy is accumulated in the ions located in the statistical maximum. The mean and peak energy acquired by the z=72 ions are respectively: around 15 GeV and over 70 GeV. At a small distance from the target (<50 um), the intensity of the ion beam with z=72 exceeds 10^{20} W/cm^2, and the duration of the ion pulse lies in the sub-picosecond range. Such intensities and durations of heavy ion beams are unachievable in currently operating RF-driven accelerators. The demonstrated laser driven ion beams can thus open the door to new areas of research and applications not available for conventional accelerators.

Wilga Symposium on Photonics Applications is organized by a group of volunteers, young researchers working in the PERG (Photonics Engineering Research Group) and ELHEP (Electronics for High Energy Physics Experiments) laboratories of the Institute of Electronic Systems at WUT. The author would like to acknowledge big efforts of the members of these laboratories. These efforts are invested to make Wilga Symposium contribute essentially to the development and integration of the local, technical photonics community. Wilga Symposium on Photonics Applications is organized uniquely by young researchers for young adepts of advanced photonics research and technology.

References

[1] WILGA Symposium on Photonics Applications web page: [wilga.ise.pw.edu.pl]
[2] R.S. Romaniuk, K.T. Pozniak, Proc. SPIE **5125** (2002).
[3] R.S. Romaniuk, Proc. SPIE **8698**, 86980S (2012).
[4] R.S. Romaniuk, Proc. SPIE **10808**, 1080802 (2018).
[5] R.S. Romaniuk, Int. Journ. on Electronics and Telecommunications, IJET **64**, 3 (2018).
[6] R.S. Romaniuk, M. Linczuk, Proc. SPIE **11176** (2019).

