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Electronic and Photonic Systems WILGA 2014

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***Abstract*— Symposium Wilga 2014, in its 34th edition, was organized during the last week of May. Symposium is organized under the auspices of SPIE, IEEE, Photonics Society of Poland, WEiTI PW, and PKOpto SEP. The event gathered around 350 persons, mainly young researchers from the whole country. There were presented around 250 speeches and communications. The main book of Symposium Proceedings is Proc. SPIE vol.9290 which contains around 130 papers. A few tens of papers were also published in technical journals. The leading topics of Wilga 2014 were gathered in key sessions: nano-materials for photonics and electronics, astronomy and space technology, biomedicine, computational intelligence, visualization and multimedia, and large research experiments. The paper presents a digest of some topical tracks, and chosen work results presented during WILGA 2014 Symposium.**

***Keywords* electronic and photonic systems, astronomy, space and satellite technologies, computational intelligence, visualization, multimedia, large research experiments**

I. INTRODUCTION

THE paper describes briefly three chosen topical tracks presented at Wilga Symposium 2014 on Advanced Electronic and Photonic Systems. These are Photonics,Space Electronics and ITER development. During nearly two decades of WILGA Symposium history, 15 volumes of Proc. SPIE has been published with over 1500 technical papers (authored mainly by Polish young researchers) and indexed in Web of Knowledge, Scopus and Google Scholar. It is an absolute exceptional achievement in national scale, perhaps slightly underestimated by relevant research authorities, but fortunately not by the young researchers community. Wilga Symposium works [1-5] have been published in Proc. SPIE, in the following volumes: 2002-5125, 2003-5484, 2004-5774, 2005-5948 and 6159, 2006-6347, 2007-6937, 2008-7124, 2009-7502, 2010-7376, 2011-8008, 2012-8454, 2013-8903, and 2014-9290. Extended reports on WILGA Symposium have been traditionally published in Elektronika Journal by SEP. Leading topics of Wilga Symposium are associated with high energy physics experiments, thermonuclear plasma fusion, compressed barionic matter, free electron lasers, astronomy and space technologies [7-11].

II. PHOTONICS

The basis for the development of photonic circuits and systems are passive and active functional components. One of the families of such components are fiber Bragg gratings (FBG). Laboratory of photonics fibers in ISE PW carries out research on methods of writing fiber Bragg gratings and their optimization. Bragg gratings can be inscribed using a femtosecond laser. FBG is the structure wherein the periodic refractive index change in the core of the fiber cause strong coupling of the fundamental mode, leading ultimately to change the direction of propagation of the beam. Reflected in the FBG are only these wavelengths of light that satisfy the Bragg resonance. Consequently, the FBG can be characterized as an optical band-pass filter of technologically tuned width. The classic FBG writing technology uses a photosensitive, hydrogenated, Ge-doped optical fiber. The fiber is then treated by UV radiation of low power density. Application of a femtosecond IR laser of high power to write the grating, requires no special preparation of the fiber. Fiber jacket may also be left intact. Gratings written in a photosensitive optical fiber by UV radiation have a small refractive index contrast of the order of 10^{-4} and are not resistant to high temperature work conditions. While exposed to such adverse environment they are subject to relaxation and disappear. Gratings written by high power laser in a classic high-quality telecommunication fiber are resistant to high temperatures of several hundred ^{o}C, and have greater contrast than refractive gratings written by low power UV radiation. The average contrast is 10^{-3}. A fs laser writes the grating with a single shot through a phase mask, or without the phase mask, by means of numerable shots along the fiber – point-by-point method. The multipoint method, with scanning of the laser beam along the fiber, allows one to record higher-order reflective gratings and of complex filtering characteristics. The mechanism of the writing the grating by the fs laser is non-thermal and leads to local densification of the amorphous matrix, thus, increase of the refraction. Other writing mechanism is localized photoionization with a deterministic threshold for the fs pulse. For a longer pulse, the threshold for avalanche photoionization is probabilistic. High-power femtosecond laser based ablation allows for precise building of periodic structures on the surface of the fibre. Such structures, also contain FBGs, but are more complex, like micro-grooved spiral lines inscribed on the rotating fiber. The pitch of the screw is comparable to the length of the propagated light wave. Covering of such a spirally grooved fiber by a magnetostrictive coat (Tefenol-D) leads to a photonic magnetic field sensor of very good transducing properties. Other adiabatic ablative operations on optical fiber result in specialized fibers for sensing applications. Technological procedures on FBG of the II type (made by fs laser), such as annealing and residual stress relaxation lead to further increase of their resistance to high temperature up to 1200 °C.

Applications of FBG to measure ionizing radiation environments in nuclear power, fusion, plasma and accelerator technologies are researched in IFPiLM. Ionizing radiation has a significant impact on optical fibers. In many cases it is the negative impact that increases the spectral loss. The effect of induced loss is also used for the construction of optical radiation sensors. Mechanisms of absorption induced by

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radiation depends on the type of radiation – neutrons, electrons, gamma radiation, optical wavelength, fiber type, fiber-dopant F, N, B, Ge, P, Er, pure SiO_2, hydrogenation by H_2, kind of coating – metal or polymer, etc. The Bragg peak wavelength is shifted toward longer wavelengths when irradiated. The biggest shift is observed in hydrogenated fibers, the smallest in Ge-doped fibers. Increased temperature relaxes partially the induced absorption in irradiated fibers. The FBG reflection coefficient generally decreases after irradiation. The FBGs written by fs laser are more resistant to the ionizing radiation. The most radiation resistant fibers are made of pure SiO_2 glass coated by metal. The doped fibers and FBGs, more sensitive to ionizing irradiation, are suitable for the construction of dosimeters for biomedical applications.

A large class of photonic sensors is based on FBG. Properties of the sensing system depend on its configuration. The system can be: passive, active, tree like or circular topology, transmission, reflection, single-color, multi-color, with simultaneous measurements of multiple measurands, etc. The systems differ among each other by the way of reading of the sensor status by an optical fiber network. Reading the sensor is done using reflection or transmission of the reference signal. If there are multiple and different narrowband sensors in the network for measuring strain and temperature, then the applied light source has to be tunable. It is necessary to avoid spectral coverage of the sensor characteristics. A single measuring branch coupled out from optical circulator comprises two gratings, one reference and one measurement. The photonic system is two-color. Other branches of the circulator, in tree like configuration are: a tunable or broadband light source, a detector with optical spectrum analyzer, and potentially other branches with next sensors. A simple branched system has many drawbacks. In a ring fiber laser arrangement, the circulator with a sensing branch is inserted in the laser loop. The ring comprises an optical amplifier, a polarization controller, a circulator and decoupler. The loop may also include an EDFA fiber laser and polarizing optical fiber. The detector is decoupled from the ring laser at a relatively low power level, for example several %. It is possible to work in the CW and pulse work modes. The FBG determines the wavelength of the laser. Two laser colors are narrow and clearly separated from each other in the ring laser system, in distinction from the wide spectral response by the system with tree like branches. The system is sensitive to polarization. A simple loop laser in the basic solution may be more complicated in advanced solutions. In such a complex loop, a MZ modulator is inserted, driven by a generator of arbitrary functions. Active switching modes in EDFA laser allows wavelength keying and electronic addressing of the FBGs. The branch of the detector is also expanded with additional diagnostic functions, transmission, data acquisition and processing, signal conversion, etc. The sensing branch is also more complicated. There is inserted a polarization controller, or it is used polarization maintaining fiber. A long stretch of optical transmission fiber is used to reach a remote sensing location. The use of such advanced photonic network system with a complex loop laser and complex sensing are: universal multi-wavelength laser tuned with FBG signal, two-color FBG strain sensor not sensitive to temperature, for simultaneous measurements of strain and temperature. When the temperature changes, both generated wavelengths are shifted in the same manner as determined by the temperature sensitivity of the FBG, for example by 12 pm/°C. Instead of EDFA in the loop, a semiconductor SOA (optical amplifier) is used. For a very long measurement branch, of the order of 10 to several tens of km, the insertion loss and Rayleigh scattering gain in importance. The photonic measuring system, with the exception of the access sensor branch can be made soon in the PIC technology.

Four wave mixing (FWM) has potentially a significant impact on the quality of the fiber transmission in the 1300 nm transmission window. In this band, the chromatic dispersion is close to zero in non-DSF (G.652) optical fibers. FWM is a nonlinear optical phenomenon, when two or more EM waves of slightly different frequencies are propagated in the same transmission channel and an additional wave is generated in accordance with the mixing rules, ie. of summation and subtraction frequencies. The phenomenon of FWM depends on the parameters of the fiber, some of which contribute actively to its generation. These parameters are as follows: inter-channel distances, input power per channel, effective area of core of the fiber, fiber dispersion, dispersion slope of the fiber, and the fiber attenuation. G.652 fiber is accurately known and standardized in the band of 1310 nm. Therefore, the level of non-linear phenomena is well defined. It is also known their impact on the deterioration of signal quality. The effect of these parameters on the quality of the signal is non-uniform. The biggest impact have changes in the effective modal field, and then change in the attenuation, dispersion slope, depth of modulation, and channel spacing. Small spacing results in a significant increase in the sensitivity of the transmission quality on the dispersion and attenuation slope. The increase in the effective field allows to transmit more power in the fiber without compromising quality.

In low-cost systems, there are used step-index polymer optical fibers SI-POF. Such fibers have not very broad bandwidth of the order of several tens of MHz/100m, which also depends on the type of modulation of the signal. A research group at IT WEiTI is working on practical applications of multimode plastic optical fibers with limited bandwidth. There are used in the tests spectrally efficient modulation method like OFDM/DMT, M-CAP and M-PAM. A question was raised which modulation method maximizes the BER coefficient in SI-POF. For the same transmitted power and BER, the maximum bit rates of OFDM/DMT, PAM, and CAP/QAM systems are similar. OFDM/DMT spectrum is the most concentrated but the spectral efficiency is deteriorated by the inter-channel gap and carrier frequency of the pilot wave. PAM takes less bandwidth than CAP/QAM but includes DC, which not everywhere can be accepted. The average optical power in the fiber is determined by the dynamic range of the source. PAPR parameter of the modulating signal determines the average signal power. PAPR for OFDM/DMT is much higher than that of PAM and CAP/QAM. Practical experiments were carried out for the section of optical fiber 50 and 100m, and PAM, CAP and DTM modulations, and FEC confinement at BER=10^{-3}. All modulations have similar efficiency. The average transmitted power was greatest for PAM and the worst for OFDM/DMT, due to the impact of PAPR and inter-band gap.

Passive optical networks use multimode fiber MM-PON. Such networks have different characteristics than the single mode. Work on multimode, cheap and effective PON optical networks are conducted in IT WEiTI PW. Such fibers have significant attenuation, mode dispersion, and chromatic interference phenomena. All these effects are deteriorating the quality of transmission. The noises in these fibers are thermal, shot, RIN, modal noise, noise like transmission changes, transmitter nonlinearity and optical beat frequency OBI. There are different types of PON networks, referred to as BPON, EPON, GPON, 10GEPON, XGPON, etc. Gigabit networks use standard single mode fibers. However, for short sections of transmission and not demanding flow rate requirements, multimode fibers can be used, which substantially reduce the cost of installing of such a network. Small office and home networks belong to this category. These network provide WiFi and services with limited bandwidth. In multimode fiber the noise is generated by excitation with coherent source and application of spatial filters. Modal noise is not present in a single-mode fiber powered by a non-coherent source. Spatial filtering is introduced by mismatched optical connectors, couplers, and splitters. In the absence of the spatial filter, in the ideal case, the modal noise does not occur. Variable speckle pattern is caused by the change of modes interference generated by a change in the instantaneous frequency of the laser. These changes are spatially filtered by aperture elements of the channel, causing a change of power, and consequently the modal noise. The less modes is propagated in the optical multimode system, the greater is the modal noise. Noise band is correlated with the spectral width of the laser. The frequency response of multimode fiber and, consequently, the PON network bandwidth depends on what modes are activated and what is their group delay. The optical aperture components are present in the PON branches, and differently distributed in the network, such as couplers and splitters, and connectors. Optical modes are variously filtered in these places. In different parts of the network, distribution of modes is different before and after passing through the elements. The network is not symmetrical optically (optical aperturing is not the same in the branches and in different directions of transmission) and is not stable in terms of frequency response. Modal filtering properties of the aperturing elements depend on the spatial distribution and temporal changes of interference speckle pattern. Variable spot pattern changes the characteristics of couplers and power dividers directing optical power to various branches of the network. Power level in network branches and their frequency band fluctuates over time. The optical interference beating phenomenon occurs when two or more optical signals from different sources illuminate one photodetector. Photodetection process has square characteristics, that is electric power is proportional to the square of the optical power. As a result, detection signals are generated at beating frequencies - differential and summation, and combinations thereof. Some of these signals may be in the effective band, if the wavelength of light sources are sufficiently close to each other. This type of interference phenomena can be very harmful and lead to the reduction or prevention of the transmission. This phenomenon occurs in the network configuration with numerable transmitters and a single receiver. In a single-mode WDM-PON system the network wavelengths are strictly controlled by the WDM device. The use of TDM-PON solution is impractical. The TDMA protocol is used with simultaneously active only one transmitter - TDMA-PON. In the multimode network MM-PON, the OBI phenomenon is solely due to the mixing of just the same modes. Various modes do not mix because they are orthogonal. OBI factors resulting from the mixing of different modes add up non-coherently because they experience uncorrelated phase shift during the propagation. As a result, the OBI is significantly smaller in the MM-PON networks than in the SM-PON networks. The modal noise is important in optical networks but it affects only the lower frequencies. The phenomena of frequency response fluctuations are less significant at higher bandwidth fibers. The noise is reduced in the fiber optic network with large number of modes propagated. Such networks are using MM step index optical fibers (not gradient) with high numerical aperture, including plastic optical fibers

Many concepts and data communications networking solutions for intelligent buildings involve the use of relatively low-cost multimode fiber-optic networks operating in the WLAN standard IEEE 802.11 (g or n). Work on this type of network associated with home automation and video distribution are carried out in the IT WEiTI PW. This experimental network integrates WLAN standard with optical MM-PON. The network is controlled by a central panel accessible via the Internet. The network topology is constructed in a two-level tree structure composed of a single access point AP and several remote access units RAU. The transmission in both directions is in a single fiber at two different wavelengths 850 and 1310 nm. RAUs are connected to the AP multimode fiber-optic network. One or two video cameras are attached to RAU points. Transmission rate was more than 20Mbit/s for fiber lengths up to 100m. There was realized a full-featured video surveillance system. The range of the accessibility of Wi-Fi network with one AP was extended several times with the help of several RAU units. The installation cost of the system is relatively low.

There is carried out a development work, at IT WEiTI PW, on a mobile device for the measurement of optical transparency of the atmosphere. Visual range estimation is done by analyzing maximum and the slope of the autocorrelation function. The device uses back scattered radiation to measure the transparency. The transmitter operates with a semiconductor laser and the receiver with an avalanche photodiode. Transmitter and receiver operate concurrently, and the laser beam and detector visibility beam start to cover at the distance of over 250m. Separation of the transmitter and the receiver in the unit head is 15cm.

Telecommunications systems, including optical - open and fiber, of command and control type (C2) must satisfy a number of additional requirements relating to the availability and resistance to adverse environmental conditions. Such systems are working in the army, police, border guards, firefighters, etc. C2 systems, on which work is carried out in PIT-Radwar and PHO Electronics, are standardized and consist of hardware, software, common procedures, applications, and interfaces, implementing together a communications network operating at all levels of the chain of command. For optical transmission systems used in the open space there are considered the following bands where the atmosphere is transparent and there is efficient light source. The band of 850 nm sources is efficient and cheap, but the radiation is harmful to the eye because it penetrates to the retina. In the 1060 nm band there exisst atmospheric transmission window, but there are not good semiconductor light sources. In the 1250 nm band there is the transmission window, but there are no sources. The 1550 nm emission band is safer for the eye than the band at 850 nm, and there are good sources and detectors. Open optical link is tested under the environmental conditions, for distances in the range of 1 km, and in conditions of strong EM interference. Multiplexing transmission is spatial and spectral. The test devices are hybrid optical and RF.

III. SPACE ELECTRONICS

The electronics for space applications should be reliable. Factory guaranteed additional reliability, over the standard market level, is very expensive. The use of standard electronic components in space experiments, especially smaller ones, is significantly cheapening the satellite experiment, but requires the use of a number of hardware and software techniques that increase the reliability. It also requires a thorough understanding of the mechanisms of destruction of electronics in space conditions and the generation of digital errors. Different kinds of errors are generated in the programmable electronic circuits and are propagated differently in a digital system, leading to different consequences. Research on the space electronics are carried out in SRC PAS. The works concern the analysis of the phenomena of single-event effects SEE in the antifuse FPGAs (one time programmable), evaluation of error propagation, the construction of a probabilistic model, and on this basis the development methods for mitigation and building of a relevant toolkit for comparison of effectiveness of various techniques to prevent errors. Antifuse FPGAs are used frequently in the electronics for space. In the radiation environments, the electronic systems exhibit increased susceptibility to a family of SET-SEU effects. SEE are generated by energetic particles or instantaneous ionization of the sensitive area by a gamma photon. They bring frequently transient errors in digital electronics, such as: single switching - single event latch-up (SEL) – functional break unrelated to the used configuration of the system; Single-detuning - single event upset (SEU) - inversion of the state of the SRAM cell or flip-flop; single transients - single event transient (SET) - erroneous pulses in combinatorial logic and routing resources. FPGAs contain hundreds of thousands of gates, so they are prone to distortion of the signal. Distortions propagate and cause errors. Some types of errors can be critical (fatal) for executing function, for example: disrupting the work of the local oscillator. Functional features of the proposed tools are: compare the effectiveness of mitigation techniques of soft errors for the architecture of the FPGA and the environment radiation, isolate possible distortion that may be critical functionally, to support the functional analysis of the flight electronics for debugging of critical decision-making systems. The designed tool uses: simulation techniques; statistical models; probability of interference induced SEE; vendor data - critical value of charges, LETth, cross sections for SEU; radiation test results; models of the radiation environment; time delays in the signal paths, etc. The utility converts VHDL code then simulated in ModelSim environment. The simulation takes place in the domain of probability rather than the regular logic.

Mission of the Solar Orbiter (SO) is planned for the period 2017-2020. The aim is to learn the details of the mechanisms how the Sun creates and "controls" the heliosphere. SO will study the interaction of the Sun and the heliosphere, the solar wind and the mechanisms of its acceleration, the phenomenon of solar energy. The satellite will be targeted precisely at the sun, has 3 axial stability, enables telemetry to a distance of 1 AU at 150 kbps, weights 1800kg with load of 180kg. The satellite will reach its target orbit within three years, after 4 gravitational assists. Its orbit will be in resonance with Venus, and the nominal duration of the mission is four years with an extension of three years. A telescopic spectrometer STIX (Spectrometer Telescope for Imaging X-rays), co-built by CBK PAN, one of the key instruments of the SO, measures the intensity, spectrum, timing and geographical distribution of hard X-rays (in the range of 4-150 keV of photon energy) generated by bremmstrahlung and thermal and non-thermal electrons in the solar corona. STIX parameters are: energy resolution 1-15 keV, effective area 6cm^2, 7arcsec of angular resolution, accuracy of indicating the direction - 4 arcsec, field of view 2°, temporal resolution 0.1s, limited statistically. The detector electronics module includes: a mechanical damper for photon flux, 32 CdTe sensors located on hybrid elements Caliste-SO, ADC converters, data processing unit, and a low-voltage power systems for sensors. The spectrometer comprises an enclosure for the thermal imaging system and the detector electronics module.

A simulator of hardware-software interface to the SO instrument is build. It includes tools for power interface and validation tools for the electrical interface TM/TC IPU (family Spacelink telemetry solutions NGT) and data protocols, SpaceWire LAN. The interface is used to integrate and test the specified instrument models for standardized stages of preparing for the flight model, via several intermediate models. The hardware interface contains two platforms SpaceWire and PDFE – combined power supply front end and discrete PCB, in particular: on-board computer, SW interface, commercial power supply, power supply current limiter module, discrete interface module, and LAN. The software interface includes: software platforms, the CMDVS core - control, monitoring, data processing, data visualization, sequential test controller, synoptic editor and animator, database management, tele-commands and telemetry, browser of archives, GUI for users, API events and calls, etc. The instrument database contains the on-board data import utility. The data "payload" are subject to import and export, can be calibrated numerically and textually, identified, configured, monitored, checked and submitted in terms of syntax, and loaded into packets of fixed or variable content. Assembly, integration and verification of the interface contains the following components: verification of payload interfaces, program acceptance, qualification interfaces for data payload, electrical interface tests, tests of data interfaces, as well as short and full functional test of the instrument. Such tests for space equipment are highly formalized and are implemented by the state machine. The full test is performed two times, before and after the environmental tests, and demonstrates the functionality of the instrument in all its operating modes. Short test is performed repeatedly and has the character of inter-operational checks.

Detector Caliste-SO, a part of the STIX telescope, is a hybrid element integrating the sensing material with a dedicated electronic input stage. It consists of a pixel CdTe detector nano-layered Pt-CdTe-Al-Ti-Au structure, passive filters, high voltage power supply, high voltage detector, low voltage power supply for ASICs, I/O interfaces for the "slow control", differential analog output, input for injection of test signals. Calibration of the detector is performed using the response matrix reference of the detector. It allows one to reconstruct the detector response based on the spectrum of the incident photon. Simulation of the detector assumes the following conditions: monoenergetic photons in the energy range 4-150 keV are detected, the active area is the whole crystal or a large pixel, photon beam covers the entire surface of the detector, the typical X-ray photon density is $10^5/cm^2$. Simultaneous physical processes associated with photons, electrons and positrons at the detector are: photons - the photoelectric effect, Compton scattering, gamma conversion, and Rayleigh scattering; electrons - multiple scattering, ionization, bremsstrahlung; positrons - multiple scattering, ionization, bremsstrahlung, annihilation of electron-positron. The simulation is performed in a development environment Geant4. Geant4 (Geometry and Tracking) is used for space research in the field of X-ray cosmic particles interactions with the atmosphere and magnetosphere, and the interaction of particles with microelectronics. There is used Monte Carlo methods which allows for simulations of - geometry, material, particle, ray tracing, physical processes, detector response, data aggregation, visualization, and has a convenient user interface.

Hardware and software for space is subject to extensive testing to ensure reliable and uninterrupted work, as specified rigorously in formal requirements. Formally, such a feature of the system is called dependability. This is a specific, strictly defined, parameter in terms of theoretical and technical features. This allows the modeling of dependability for specific functional electronic circuits and systems under certain application conditions - here in the space. Modern space systems are characterized by increasing complexity, there are used large FPGAs, more powerful microprocessors in terms of computing power, much more system functionality, computing power increases exponentially, the hardware-software coexistence must display considerable flexibility in changing functions, all solutions should not be very expensive. Dependability is the ability of the system to ensure its functionality at a reasonable level of confidence. Dependability attributes are: availability - readiness to ensure proper functionality, reliability - continual normal functionality, safety – complete lack of catastrophic consequences, serviceability - the ability to accept effective repairs. Arming any space system with the attribute of dependability (and all its components) involves costs: increased usage of resources, considerably increased effort of tests, and bigger overall complexity. Research on modeling of dependability for space systems is carried out in the SRC PAS. The modeling consists of three parts. The input data is description of the space mission and the technology used for its implementation. Description of the project includes environmental and architectural model, connected/combined by a channel for which there are specified defects factors. The model of dependability outputs a certain well-defined dependability metric. Methodology of modeling the dependability includes several steps: definition of mission details, definition of technological details, determination of the output and then its normalization – to the form of effective rate of failure, definition of system architecture using Petri nets, mapping of the system behavior to the states of the Markov model, construction of the transition matrix, and finally calculation of dependability metrics. System designers are looking for stable states of the system in which it spends a significant proportion of operating time, and taking into account the law of conservation of probability (continuity equation) one can calculate the probability of the stationary states. The metric of dependability as a function of time is the sum of the stationary states of the particular architecture of the system under certain conditions. Calculations are carried out for different architectures and operating conditions. Properties of the method are: it takes into account the dynamic behavior of the system, contains information about functional dependencies, the resulting transition matrix can be modeled in MatLab environment, there are necessary external information on the reliability from component vendors, the use of Petri nets and Markov chains can lead to instability of the state space, the lack of tools to implement the system according to the model. The model of dependability is tested by injection of errors.

Rocket propulsion is based on the Tsiolkovsky equation binding initial mass and velocity with the end values, and with the characteristic speed: $m_p=m_k \exp[(v_k-v_p)/v_c]$. The space rockets are using chemical and electric propulsion. The thrust of a large chemical rocket (fuel and oxidizer) is up to t=15MN, speed of the propelling medium (exhaust) v = 5km/s, engine power p=5 GW, the efficiency of the drive is up to e=60%. The corresponding data for the electric power (power source energy and the ionized propellant) are: t=1N, v= 50km/s, p=20 kW, e=90%. Characteristic speed is limited by the energy of a chemical reaction and by the available electrical power – at the required thrust. Electric drive is used to correct satellites orbit - to maintain geosynchronous orbit; for long distance travel in pace; overcoming the gravitation attraction; change orbit LEO-GEO; and deorbitation. At present, approximately 400 active satellites is operating the electric drive. Electric drives are divided into Electrothermal - resistors and arc (driving medium N_2H_4, NH_3, H_2); Electrostatic - emission field, colloidal, ionic, Hall (Cs, Indium, glycerol, ionic liquids, Xe, Kr); and Electromagnetic - magneto-plasma-dynamic, plasma-pulse (Ar, Xe, Li, N_2H_4, Teflon, H_2O). Practical efficiency is achieved within the range 20-80%, currently the highest in electrostatic engines. Ion thruster uses a gaseous medium Xe, ionized by fast electron beam or by microwave heating. The ions are accelerated by a voltage difference between two mesh electrodes. Thrust force is now approx. 300mN. Hall thruster uses a medium Xe, Kr, where the electrons are entrapped in the azimuthal drift of the ExB field to enable ionization. The ions are accelerated by an external electrical field. Hall current interaction with the magnetic field generates thrust. The thrust now exceeds 1N. International cooperation work is underway on the light, miniature, pulsed plasma thrusters, using liquid medium propulsion, potentially destined for operation in space. The goal is the construction of a Hall thruster with medium Cr, class 500 W, with thrust in the range of around 20mN, with life cycle for 10^7 pulses, designed for Cubesat series of microsatellites. Laboratory tests were preceded by computer simulation and analysis of a Hall thruster. A vacuum chamber was build to test the thruster. The chamber and its environment requires a lot of diagnostics: measuring the balance of thrust, Faraday probe, retarding potential analyzer RPA, mass analyzer, spectrometer, fast camera, sensors of temperature and magnetic field. The media used in propulsors were argon gas and water - in the form of steam (disposed by a rapid valve) or injected in micro-droplet (through electro-mechanical injector). Water is not a good medium for driving plasma thruster because of the high freezing point and volume expansion after freezing. Features of a good driving medium are: low volatility in vacuum, not explosive, non-flammable, non-toxic, chemically stable, stable liquid phase in a wide temperature range, appropriate dielectric characteristics and high density storage. The thruster comprises a drive fluid from the reservoir, a micro-pump, the spark gap, the electrodes of the main fluid outlet. The engine operates on the principle of mechanical pulsed injection of the medium, and electric spark ablation and ionization of the drive medium and then its acceleration in the output electrode channel. To test the thruster in vacuum (10^{-6}mbar) there was used aqueous medium in the form of a periodic injection of droplets with a diameter of approx. 0.1mm, volume 3nl, and a weight of 5μg. A prototype of the propulsor was made with a syringe pump. The role of the spark gap is to trigger the main discharge, and ablation of a sufficient amount of the drive medium, so that the main discharge is able to form the thrust. The quantity of the medium depends on the micro-pump and the medium surface subject to ablation. The spark gap was powered by a set of high-voltage capacitors. A diffusion plasma stream between the electrodes was observed as a result of ionization and acceleration of the drive medium. The value of merit in this propulsor, which is driving force over discharge energy, equals to 45μNs/J.

IV. Research on ITER

Now the most important European fusion energy experiment is ITER. The project brings together a number of national institutions such as IF PAN, NCBJ, IFPiLM, UW, PW and others. There are also run side experiments like JET tokamak and Greifswald stellarator. Tokamak holds a stream of high-temperature (over 10^8C), fast moving (10km/s), vacuum D-T plasma (10^{-6}), creating a toroidal current around a central coil, and trapped by sufficiently strong magnetic field. The trap and plasma path in stellarator is of Mobius tape shape, i.e. toroidal and poloidal, and additionally helical. Plasma current creates a secondary coil in the transformer with the central primary coil. The aim of D-T plasma fusion in tokamaks is generation of energy. Three conditions have to be fulfilled to ignite plasma: existence of ion plasma of sufficient density, ion temperature, time and space confinement of energy. Tokamak and its vacuum chamber requires a lot of advanced control, measurement, diagnostics, and safety equipment. A number of these instrumentation is build in Poland with the participation of young researchers, including Ph.D. students. The cost of instrumentation is a considerable part of the total costs. Vacuum chamber is lined with Be, and divertor with tungsten. Fusion power is planned for ITER as 500MW. ITER timing is: construction work till 2019, first H plasma 2020, D-D plasma, D-T fusion 2027. Research challenges are: 12T and 40GJ superconducting magnets, plasma touch components 10MW/m^2; tens of advanced pieces of instrumentation, active recycling of tritium, magneto-hydrodynamic stability of plasma, interaction of plasma with tokamak wall, confinement of heat area, turbulences, kinetic and magnetic control of plasma – shape and position, disruptions, superconducting cables for high currents, etc. IFPiLM team runs research on plasma contacts with wall and plasma pollution by highly ionized Be, C and W atoms. LIBS method (Laser Induced Breakdown Spectroscopy) is used for laboratory experiments. LIBS software is under development to work and be compatible with ITER instrumentation environment. Multichannel measurement system is under development for plasma diagnostics, in cooperation with the ELHEP ISE laboratory.

V. Concusions

WILGA Symposium shows year by year a very positive development of young science in the area of advanced electronics and photonics in Poland and this geographical region. It also shows internationalization of local research.

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