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Institute of Plasma Physics and Laser Microfusion

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Editors J. Wołowski
A. Gałkowski
Layout A. Pokorska
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INSTITUTE OF PLASMA PHYSICS AND LASER MICROFUSION
23 Hery Str., 01-497 Warsaw, Poland

Tel. + 48 22 6381460
Fax + 48 22 6668372
E-mail sekretariat@ifpilm.pl
www.ifpilm.pl

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Preface

The year 2012 was for IPPLM the 37th year of research for the future – creating, based on the international collaboration, of the new source of useful energy which would take advantage of the thermonuclear fusion phenomenon. It is a scientific and technical venture which engages many branches of science and technology. IPPLM is active in the development of two basic ways which can lead to attaining this goal: magnetic confinement fusion and inertial confinement fusion. In the first case the international projects, in which IPPLM is involved, are ITER, JET, W7-X and DEMO, the second one refers to the European program HiPER.

Moreover, in 2012 Poland joined the European Space Agency. IPPLM marked this event by opening the completely new laboratory of electric propulsion thrusters. It is the next example, apart from the Lightning Tests Laboratory, of the fact that IPPLM does not content itself with the realization of the long-term aim, which is a thermonuclear power plant, but its almost forty-year experience in research and applications of hot plasma is engaged in achieving less time-consuming goals.

In 2011, the Institute began to expand and upgrade a high-power laser laboratory, which houses a 10 TW laser of pulse duration of 30-40 femtoseconds. The funds for this purpose come from the Regional Operational Program of the Mazovia Province financial resources. The new infrastructure will enable further development of research on laser thermonuclear fusion and taking up innovative work in the field of high-power laser implementation in various fields of modern science, technology and medicine. In 2012 this process achieved the intended goals: designing and preparation of two vacuum chambers and a set of diagnostics: the fast four frame VUV and soft X-ray camera, the multi frame polaro-interferometer, the X-ray spectrometer and Thompson parabola spectrometer. It is predicted that in the second half of 2013, the High Power Laser Laboratory will reach its full operational capacity and commence experimental works in the area of power and duration of laser pulse which has been not available in Poland so far. The scientific team received a grant of the National Science Center in Harmonia-type competition for this purpose.

In 2011, we started to implement a project called "Research and development of technology for the controlled thermonuclear fusion". It is part of the strategic research programme „Technologies supporting the development of safe nuclear energy", financed by the National Center for Research and Development. In 2012, this project brought about in particular the modernization of PF-1000 device which was equipped with an additional condenser banks well as the gas-puff systems that could make the plasma pulse longer in the device. The modernization was substantial enough to rename the equipment into DPF-1000U (*upgraded*). The experiments were carried out with the implementation of this new device in the scope of investigation of intense plasma streams interaction with solid targets. These experiments will be interpreted based on the theoretical model describing interaction of pulsed plasma beams with targets. The modernization of the PF-1000 device was accompanied with development of the diagnostics system of the DMP laboratory. For instance, in 2012 the new, high-resolution electro-optical camera, capable to record pictures of plasma in the hard X rays range (E> 30 keV), with the frame duration 3ns - 1µs was manufactured and tested.

The activity of the IPPLM in theory and modelling covers very broad list of subjects. The research work devoted to tokamak modelling is focused on edge plasma physics, plasma wall-interactions and core-edge coupling studies. This activity expresses the experience of the IPPLM theory group in the theoretical investigations of plasmas in toroidal devices and is aimed at the developing of validated models and numerical codes for present day tokamaks and for the ITER and DEMO reactors. It is based on extensive co-operation with European Fusion Laboratories (JET, TEXTOR, FTU, JET, Tore Supra) regarding the theoretical investigations of the edge plasma and interpretation of experimental measurements. Important part of our research program is devoted to the development of numerical models and codes for ITER and DEMO, in particular global models being able to describe self-consistently burning plasma in fusion reactors. In that respect we participate in the ITM TF and contribute to the development of the European Transport Solver (ETS) and provide support to the users of ITM tools.

The work conducted in the framework of the Plasma Diagnostics EFDA Task in 2012 included activities in the area of development of soft X-ray triple GEM gas detector for energy resolved soft X-ray plasma diagnostics as well as a prototype GEM neutron yield monitor as an indicator of fast particle confinement and fuel ratio determination in tokamaks.

The first piece of equipment was installed in JET and underwent the first tests successfully: spectra lines emitted by Ni^{26+} and W^{46+} ions were recorded. In addition, using the VUV spectrometer, measurements of Ni impurity content during ICRH (Ion Cyclotron Resonance Heating) and NBI (Neutral Beam Injection) heating were investigated. Studying the behaviour of impurities is important to understand and minimize their effects on tokamak plasma performance. The impurity release during Ion Cyclotron Resonance Heating (ICRF) operation was investigated in the full tungsten (W) wall ASDEX Upgrade (AUG) tokamak. This contribution mainly focuses on documenting the W behavior in the plasma. Moreover, the numerical analyses of impurity seeded plasma discharges in JET with the help of the COREDIV code were done. In the frame of JET Fusion Technology task, the neutron activation measurements were performed as a benchmark against numerical calculations for neutron diagnostics calibration at JET.

Works in the framework of EFDA program dealing with Plasma-Wall interaction issues were continued. They referred to study of codeposits and dust in the tokamak's chamber and wall. Laser removal of fuel and codeposit in thermonuclear devices is thought to be inevitably accompanied with massive generation of fuel-containing dust and damage to the bulk structure of the components. Nevertheless, it was proposed that these drawbacks result mainly from the high power densities characteristic for Nd:YAG Q-switched lasers which significantly exceeds the threshold for the layer removal. Based on this observation it was suggested to test the laser removal method which would use rather sublimation than ablation mechanisms. To realise this type of experiment, a fiber laser has been used and the effects of its irradiation of the mixed materials layers were compared with the effects obtained by the Nd:YAG laser.

In the framework of Emerging technologies EFDA Task, a fast Fourier Transform (FFT) based algorithm has been developed to interpret the speckle interferometry measurements of erosion under mechanical vibrations of few tenths of mm in amplitude and of hundreds of Hz to KHz frequency range. The second task was mainly focused on qualification of the LIBS applicability for characterization of samples with ITER relevant material mix. Research included investigation of calibrated samples in order to assess the possibility of conducting measurements of fuel inventory in in-vessel reactor components.

The preparations were underway to participate in research projects on W7-X stellarator, which will be launched in Greifswald, Germany, in 2014. The IPPLM scientists have developed diagnostics to register X-ray radiation by PHA (*pulse height analysis)* and MFS (*multi-foil spectrometry*) methods. In 2012, works were carried out to finally build those two diagnostics.

The researchers of the Division of Laser Plasma carried out a series of experiments on the PALS system in Prague. IPPLM received the funding of those experiments from the European LaserLab programme and from the Ministry of Science and Higher Education (international co-financed projects). The aim was to examine mutual interactions of laser-produced plasmas with different atomic numbers in an axially symetrical geometry. With this aim, new two-channel targtes were prepared specifically for the needs of PALS experiments.

The effect of preformed plasma on a laser-driven shock produced in a planar target at the conditions relevant to shock ignition has been studied in the LaserLab-PALS experiment. The investigations were focused on the determination of total energy and pressure of the shock as a function of energy/intensity of the intense subnanosecond 3ω PALS laser pulse and the characteristics of preformed plasma produced by the auxiliary 1ω beam. The characteristics of plasma ablated from the plastic target were measured with the use of 3-frame interferometry, ion diagnostics, an X-ray spectrometer.

Works, co-financed by the European Commission within the European fusion programme of Euratom Community, were continued in the framework of IFE Keep-in-touch activity programme.

We continued works regarding plasma thrusters to be applied in space. Financial resources come from the grants of the 7^{th} EU Framework Programme. In 2012, LµPPT (Innovative Liquid Micro Pulsed Plasma Thruster system for nanosatellites) project was continued in collaboration with research centers and industrial companies from Spain, Switzerland, Sweden, and Poland. For the needs of this (and other projects), the Laboratory of Plasma Space Propulsion was built from scratch in IPPLM. A vacuum chamber of around 2 m^3 capacity is installed and turbomolecular pumps are able to create space-like vacuum ($2x10^{-7}$ mbar). In 2013, it is planned to install cryogenic pumps of 30000 l/s capacity, which will make it possible to obtain higher vacuum.

These works are complemented with the computer models developed by two PhD candidates for the French company called Snecma. They deal with Electron Guiding Centre Modelling for Hall Thruster Simulations and Quasineutral PIC electron guiding center modeling in the presence of slow cross-field electron transport in a Hall thruster.

In 2012, five young researchers were awarded the academic degree of the doctor. Moreover, two applications were sent to National Centre for Nuclear Research to be conferred the full profesor title.

Two experimental sessions in the framework of the International Centre of Dense Magnetised Plasma were carried out on DPF-1000U plasma focus system. The aim was to investigate the relations of neutron emission and the intensity of electric current in the phase of pinch discharge.

Technological works were continued including optimization of laser generated Ge ion source with additional electrostatic field for ion implantation technology.

In 2012, IPPLM's laboratories were visited by students from Maria Skłodowska-Curie University and high-school students from LXIII High School named after L. Kossuth. The researchers delivered lectures on thermonuclear fusion in the context of energy crisis, magnetic and inertial confinement, fusion technology and plasma thrusters. Younger scientifically oriented children could take part in the "Art for Science" organised by the small professional GO Theatre which collaborates actively with IPPLM. Thanks to this activity, young participants built their trust in science. All age groups were encouraged to getting acquainted with science thanks to the XVI Science Festival. Lessons on weekdays and during weekends gathered 200 persons in total. Scientific ideas were conferred to the public also through the IPPLM's website updated with domestic and plasma-related news, international conferences and workshops with the appropriate links as well as conferences organised by IPPLM, seminars and publications.

The Institute of Plasma Physics and Laser Microfusion is highly regarded, both in Poland by the Ministry of Science and Higher Education, and also abroad by the international science community. The reputation rests on its high number of top quality publications in well-known science journals, and effective, broad international cooperation. As a result, in 2012 the IPPLM kept the second best position on the Ministry's list of all the research institutions within the scope of physics and astronomy in Poland. This was mainly thanks to a large number of publications in prestigious journals. In 2012, the IPPLM scientists published 44 articles in top-rank scientific journals and presented many contributions to the international scientific conferences.

All those achievements would not have been possible without the involvement, professionalism and passion of the personnel of the IPPLM. I would like to congratulate the staff of the Institute and to thank them for their impressive work.

Andrzej Gałkowski
Director

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Prof. Jerzy Wołowski	Institute of Plasma Physics and Laser Microfusion, Warsaw
Prof. Grzegorz Wrochna	National Centre for Nuclear Research, Otwock
Prof. Roman Zagórski	Institute of Plasma Physics and Laser Microfusion, Warsaw

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  - Department of Laser Fusion
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  - Department of Spectroscopy and Thermonuclear Technology
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  - Department of Plasma Diagnostics
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Scientific Staff of the Institute

Professors

J. Badziak
V. Gribkov
M.J. Sadowski

IPPLM Professors

A. Gałkowski
T. Pisarczyk
J. Wołowski
R. Zagórski

Senior researchers (PhD)

S.Barral
S. Borodziuk
M. Chernyshova
T. Chodukowski
A. Czarnecka
T. Czarski
P. Gąsior
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