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Self-assessment report for previous 4 years of NILPRP and ISS

The National Institute for Laser, Plasma & Radiation Physics (INFLPR) is an independent, national importance research institution established by the Government of Romania. INFLPR was founded in 1977, with the mission to advance the knowledge in several strategic areas of the sciences and technologies related to laser, plasma, and radiation physics. In 1996 INFLPR was reorganized to include the Institute of Space Sciences (ISS).

2.1 Administrative structure diagram of the institution

Bellow is presented the administrative structure approved by the order of Minister of Education and Research 4130/09/05/2010

Autoritatea Naţională pentru Cercetare Ştiinţifică

MINISTERUL EDUCAŢIEI CERCETĂRII TINERETULUI ŞI SPORTULUI

ORDIN

pentru aprobarea structurii organizatorice a Institutului Naţional de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei şi Radiaţiei – INFLPR Bucureşti

Având în vedere Decizia Primului Ministru nr.232/21.10.2010 privind numirea domnului Dragoş Mihael Ciuparu, în funcţia de preşedinte, cu rang de secretar de stat, al Autorităţii Naţionale pentru Cercetare Ştiinţifică, coroborat cu prevederile Ordinului MECTS nr.5727/25.11.2010 privind stabilirea atribuţiilor, competenţelor de coordonare şi pentru delegarea competenţei de ordonator principal de credite domnului Dragoş Mihael Ciuparu,

Având în vedere prevederile art.5 alin.2 din Anexa la Hotărârea Guvernului nr.1581/30.09.2004 privind aprobarea Regulamentului de organizare şi funcţionare a Institutului Naţional de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei şi Radiaţiei – INFLPR Bucureşti,

În temeiul prevederilor din Hotărârea Guvernului nr.1449/2005 privind organizarea şi funcţionarea Autorităţii Naţionale pentru Cercetare Ştiinţifică, cu modificările şi completările ulterioare, coroborat cu prevederile din Hotărârea Guvernului nr. 81/2010 privind organizarea şi funcţionarea Ministerului Educaţiei, Cercetării, Tineretului şi Sportului, cu completările ulterioare,

Ministrul Educaţiei, Cercetării,Tineretului şi Sportului
emite prezentul
Ordin:

Art 1. Cu data prezentului ordin, se aprobă structura organizatorică a Institutului Naţional de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei şi Radiaţiei – INFLPR Bucureşti, prevăzută în anexa care face parte integrantă din prezentul ordin.

Art.2 Cu aceeaşi dată, Ordinul MECT nr. 1230/05.06.2007 privind aprobarea structurii organizatorice a Institutului Naţional de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei şi Radiaţiei –INFLPR Bucureşti îşi încetează aplicabilitatea.

Art.3 Institutul Naţional de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei şi Radiaţiei – INFLPR Bucureşti va duce la îndeplinire prevederile prezentului ordin.

Ministru,

Daniel Petru FUNERIU

Nr. 4130 Data 09.05.2011

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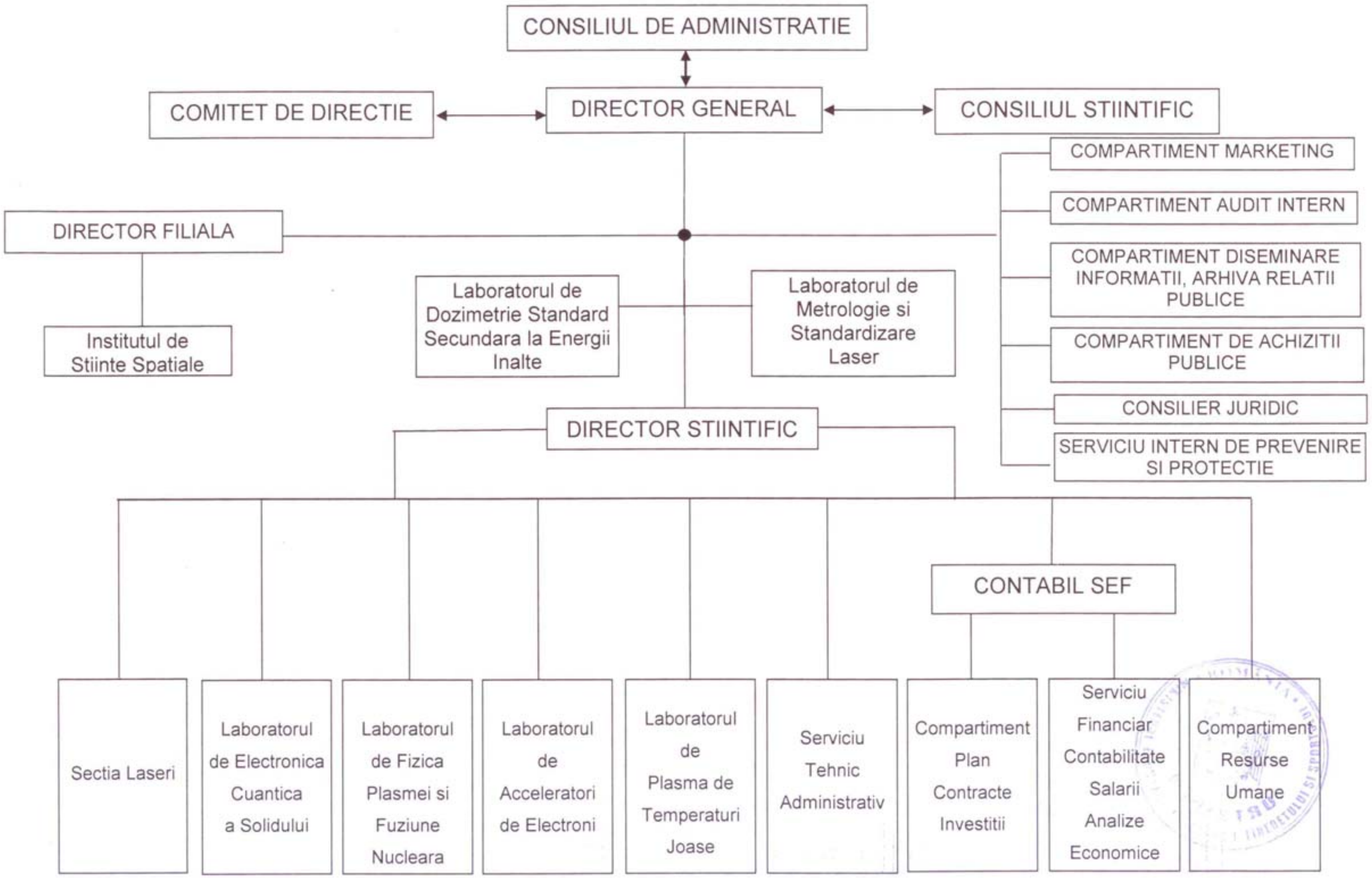
Anexă la Ordinul MECTS nr. 4130 / 09.05.2011

STRUCTURA ORGANIZATORICA A INSTITUTULUI NATIONAL DE CERCETARE DEZVOLTARE PENTRU FIZICA LASERILOR, PLASMEI SI RADIATIEI



General activity report

General description of the state

The institute employs about 450 staff members. In terms of scientific and technology output, INFLPR outperforms most Romanian research institutes and universities, being comparable to only a hand of top national institutes and universities. The Institute lead and conduct research programs and carry out theoretical and experimental studies to push forward the human knowledge on the laser plasma and radiation physics, as well as space science; develop instrumentation for photonics &plasma & space experiments; develop and qualify the human resources by involving students in the research process; commit ourselves to education and public outreach, and free dissemination of knowledge; applications and transfer the knowledge and technology for the benefit of the society; encourage the pursuit of appropriate partnerships with the industry.

INFLPR's Mission

To advance, transmit and sustain knowledge and understanding in fields of laser, plasma and electron beam physics as well as space science by conducting research at the highest international standards, for the benefit of Romania, and international science communities.

The main domains of the activity are: high power lasers and applications, bio/nano photonics & nanomaterials, plasma research for fusion, space related sciences and technology, applications of space communication techniques.

The main research areas of INFLPR are:

A. - High power lasers and applications:

- active centers in photonic materials;
- quantum electronic processes;
- X-ray laser development;
- laser biomedicine & laser micromachining;
- high energy secondary standard dosimetry;

B. - Bio/Nano Photonics & Nanomaterials:

- nanoparticles synthesis by laser pyrolisis;
- nanometrology;
- nanostructured films & particle functionalization;
- nanomaterials synthesis by plasma;
- biomolecular laser spectroscopy;
- biocompatible thin film deposition by PLD and MAPLE;
- soliton waveguide arrays;
- nonlinear nanophotonics;
- quantum dots and metamaterials; plasmonic structures;
- micro/nano patterning;

C. - Plasma Research for Fusion:

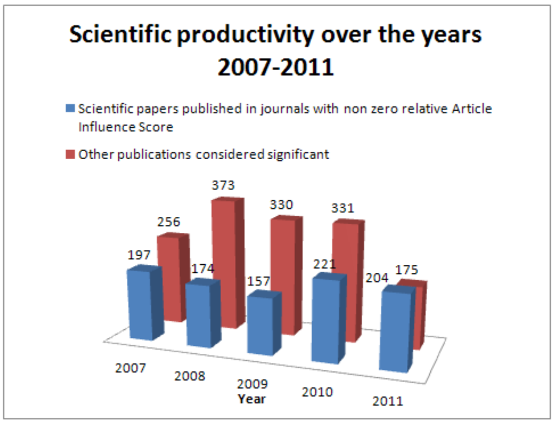
- atomic processes and fusion related atomic physics;
- hot plasmas and nuclear fusion;
- plasma surface engineering;
- plasma theory;
- X ray tomography analysis;
- plasma sources & plasma coatings for fusion technology;

D. Space Science and Applications:

1. Theoretical physics and Mathematical Physics;
2. High Energy Physics and Astrophysics;
3. Astroparticle Physics and Cosmology;
4. Space technology and Hardware for space experiments (on-board and ground segment) and satellite data processing;
5. Experiments, data analysis, and theoretical developments on space plasma;
6. Microgravity, Space dynamics and Microsatellits;
7. Distributed and parallel computing in Space and Terrestrial researches and applications;
8. Applications of space and communication technologies.

Activity and evolution for the previous 4 years - The most important achievements

The entire R&D activity of the NILPRP and ISS is performed under national and international research project-contracts. Part of the national projects are realized through partnerships with other research institutions and industry while the international projects are based on the international cooperation mainly with the European Organizations, European research institutes and major universities and most of them are/were funded trough FP6, FP7 and ESA-PECS programs. NILPRP has had a constant presence in the European FP programs. The evolution was however spectacular, from 5 in FP6 to about 42 projects in FP 7. NILPRP is a partner alongside other Romanian institutions in the Extreme Light Infrastructure-Nuclear Pillar (ELI-NP) project, providing essential expertise in the fields of laser and plasma physics as well as electron beams.
Despite of economic crisis that cut off 2/3 (during the years 2009 and 2010) of the financial support for many R&D project supported by Minister of Education and Science the Institute continued its hard work and the number of scientific publications and the quality increased (for year 2011 – 204 paper number is not final, still papers are refereed), next figure. For reasons of fund reducing, the number of conferences attended by INFLPR' scientists diminished. The staff number fluctuation was small, the number of national project won by NILPRP members increased.



Major achievements in the last four years

- Development of the Combined Magnetron Sputtering and Ion Implantation (CMSII) technology from laboratory to industrial scale; application of this technique for the first wall in nuclear fusion devices JET, Culham Centre for Fusion Energy, UK and ASDEX Upgrade, Max-Planck Institute for Plasma Physics, Garching Germany.
- The first Romanian space experiment aboard the International Space Station (uploaded by the Space Shuttle "Discovery" in February 2011)
- The first Romanian nano-satellite "Goliat", selected by the European Space Agency (ESA) to be launched by the VEGA rocket in January 2012
- Development of methods for the tomographic inspection of fusion materials and devices: i) official inspection procedure for the assessment of the structural integrity of an instrumented IFMIF high flux test module rig, ii) consistent evaluation of porosity factors for all fusion technology relevant CFC and multilayer SiC materials, 2D erosion mapping of metal coated graphite/CFC tiles from ASDEX Upgrade and JET tokamaks.
- SAW sensor for the detection of chemical warfare agents
- New materials and processes for coherent and noncoherent photon sources (68 scientific papers ISI journals, 1 patent, 286 citations in ISI papers).
- laser spark-plug for car engine ignition (cooperation with Japanese team, over 300 citation in international mass media!).
- calculations and evaluations of radiation source terms (high energy electrons, X-rays, protons) for the future Integrated Center for Advanced Laser Technologies (CETAL) which hosts a 1 Petawatt pulsed laser, and in the design of radiological shielding of this facility.
- Metrological international intercomparison on high power laser at the wavelengths of λ = 488 nm and λ = 1.06 µm
- research on Pulsed Transient Plasma granted with two French patents, already applied (http://www.bulletins-electroniques.com/actualites/59514.htm) in the frame of NILPRP-Horiba Jobin Yvon collaboration, following EU-FP6 STREP project EMDPA . The patents are the subject of world patent applications (WO/2009/130424A1, WO/2010/092301A1).

- TVA thermionic vacuum arc technology was used to produce beryllium and boron coatings in the frame of some „supply contracts” with HEIKKI SIPILA OY Finland, and FZJ Juelich, Germany.
- “Romanian GRID middleware repository for Space Science Applications” - PECS project
- “Portable Telemedicine Workstation Definition and Specification– PTW” – ESA - PECS Project

Investment

The investment policy is focused on insuring as good as possible conditions to obtain the best results in the research activity according to the institute’s research & development domains. The funds are obtained mainly from three sources: national projects, international projects,structural funds and state budget. Bellow are listed several important investments, for a complete image please see excel table “Insfrastructures”:

- **GW-TW femtosecond laser facility The GW laser**, (CPA 2101, Clark-MXR, USA), **multi-TW laser (TEWALAS)** is operated since May 2009. It is a 20-TW class laser system Ti:sapphire laser oscillator-high energy amplifier-temporal compressor (805 nm central wavelength, 450 mJ pulse energy at 25 fs pulse duration, 10 Hz repetition rate), a reaction vacuum chamber for high power laser interactions and measuring devices for laser beam characterization;
- **CETAL** (under development): The center includes a laboratory for frontier research on hyperintense laser beam-matter interaction (which includes a Petawatt laser);
- **ISOTEST**-all equipments necessary for optical componets characterization under hiperintense pulse irradiation (aiming for unique position in this field in Europe);
- **Major equipments** for research activity: XRD, SEM, AFM, MAPLE, PLD, spray drying system, cold press, high temperature furnance, OPO+high performance spectroscopic systems, Glow Discharge Optical Spectrometer, GDA 750HP, etc.;
- **Major home made equipment** CMSII Industrial coating unit. The equipment was designed, manufactured and commissioned in Plasma Surface Engineering group. The deposition chamber was built in a specialized company, but under supervision of our engineers.
- **New ISS infrastructure**: One of the bigest investment of the Institute for Space Sciences consists in a new building and equipments;

Recruiting actions and events

The strategy for human resources is focused especially on recruiting young students and hiring them even during their faculty studies. The skilled graduates are hired and involved in projects, mainly in the international ones. In this way they learn quickly which the world level for the scientific research is, get linked with the research international community learning what the up-to-date directions, theories and techniques are in their field of activity, etc. As a result many young

researchers realize and defend their PhD thesis in universities and institutes abroad.
The institute participated in various dissemination events ("The researcher's night" or "Open doors" events, targeting the high school and undergraduate students. The Institute is a sponsor of international student conference on photonics ISWLA and has good opportunities to recruit capable young students.
Also many Romanian researchers working abroad and gaining experience from training at the PhD or postdoctoral level have chosen to return to the institute on NATO funded reintegration grants and other national grants (RP), increasing the number of highly-skilled human resources.

The people that graduates and obtain a PhD in our institute (in collaboration with University of Bucharest) are encouraged to apply for post-doctoral grants, being hired during the scholarship and having the opportunity for permanent hiring.

Technology transfer activities

There are many research activities that are oriented to technology and ready to be transferred to hi-tech companies. The main problem we face with is the lack of interest from industry. The task of technology transfer was leaved to the scientists and engineers that developed it and they are not the best in marketing hi-tech activities. Our future strategy aims to resolve this problem. However several technology treansfers were done in the last few years. That activity was done in the frame of government projects "Innovations …".
An example is the *Thermionic-Vacuum Arc (TVA) technology* that was transferred in the optical industry (whithin the frame of an Innovation project, leaded by the SME „SC OPTICOAT SRL", 300 kEuro). Diamond like carbon (DLC) films were produced by the same company in order to increase the mechanical resistance and to increase the infrared transmission of some optical devices.
Several others are related to medicine and space weather.

Space weather data were transferred to European Space Acency catalogues

The expertise and capabilities gained during the satellites and theoretical space plasma and magnetometry studies are exploited in predictions of space weather and earthquakes.

Telemedicine

The Institute for Space Sciences develops social beneficial applications for human health and security protection, using telemedicine with satellite communication.
The "Portable Telemedicine Workstation Definition and Specification–PTW" is in process to be implemented with Romanian official body for emergency situations and its potential users are:

- Public and private health-care system;
- Critical medicine, trauma and emergency medical units;
- Police, fire-defense, civil guard, border police, military.

The PTW helps for:

- - Public health-care system covering remote, infrastructure-less, unprivileged areas;
- - Management of natural and industrial disasters, providing health-care support;

- - Hazardous situations connected to human security, border security, conflict; critical medicine, trauma and emergency situations in pre-clinic phase.

Publications and communication initiatives

As a general rule the studies, experiments, and the results of the research are published mainly in the international publications and at the international conferences. The institute has a vast array of scientific articles, book chapters, books, posters and presentations in all its declared fields of investigations.
More so, the institute has a proactive approach by supporting and initiating public outreach and laser-plasma-space themed events. These opportunities are used as means of informing the public of the level of research, the results and their socio-economical impact on the everyday life. The interactions with the young students are emphasized for increasing their general interest to laser-plasma-space science. The presence in mass media was considerable due to general interest of the Romanian people toward ELI infrastructure, fusion, satellites etc, over 20 INFLPR associated events,TV, radio, newpapers, were reported (see annual reports for details).

Other aspects considered significant for the institution evolution and development
NILPRP.
ELI NP. The research activity in cooperation with research groups from abroad continued and was strongly enforced by the ELI project preparatory phase. The interactions with the representatives from various countries as well as with the Romanian officials concluded in Romanian Government approval for ELI Nuclear Pillar project, and our institute is part of the consortium in charge with its construction.

Fusion research in the frame of the Association Euratom-MEdC Romania

NILPRP has by far the most important contribution within the Romanian participation to the research on controlled thermonuclear fusion in magnetically confined plasma, which is probably the most important domain in the contemporary research in physics, with the objective of creating a clean, safe and sustainable source of energy. The fusion research is organized in Europe with the direct involvement of the European Commission as an effectively integrated activity with common work plan and very strong collaborations.
Created in 1999, the Association EURATOM – MEdC Romania coordinates at the national level the activities of many groups of research, from four national institutes and two universities. It has a flexible structure, which involves now around 90 professionals and 30 non-professionals, with about 34 ppy. Part research founding and the mobility costs are provided by the European Commission. The average over the period 2007-2011 of the EC contribution is of 31% of the budget of 1,250,000 E/year and the mobility cost of the order 100,000 E/year.

NILPRP has the central role in this structure, and since 2008 it provides the leadership of the EURATOM-MEdC Association (Florin

Spineanu in the period 2008-2011 and Madalina Vlad since April 2011). The research program includes topics of tokamak plasmas physics, plasma wall interaction, wall coatings and analysis, technologies and micro production tasks. Each topic represents Romanian contribution to a task of the European Fusion Programme and is performed in close collaboration with several European Associations. Research teams from several Laboratories of the NILPRP (E15, E17, E20, E22, E28, E29, E11, E4) participate in this program. The broad topics combined with the very strong European collaborations within each topic explains the existence of small groups. Each small group must be seen as part of larger groups which include researchers from several countries, according to the concept of integrated research in fusion, developed by the European Commission. A series of important results have been obtained both in understanding fundamental aspects of the complex plasma processes in tokamak and in technological research.

NILPRP has a tradition of more than thirty years of research in fusion plasma. Taking the most complex tasks and the most important responsabilities in the Association EURATOM – MEdC Romania, NILPRP has also benefited from resource input from the Commission and has greatly enhanced the competence of the researchers in the highly exigent environment of the European fusion project. NILPRP is now prepared to design the participation of Romania at the exploitation of the International Thermonuclear Experimental Reactor (ITER), under construction.

The budget of NILPRP Euratom contracts was in this period 844,000 E/year including the European contribution of 241,000 E/year and implies 19 ppy from 49 professionals and 14 non-professionals.

Researchers from NILPRP have been designated to represent Romania in the essential European structures related to fusion: EURATOM Consultative Committee for Fusion (CCE-FU), Steering Committee of the European Fusion Development Agreement (EFDA-SC), Governing Board of Fusion for Energy (F4E).

Space Science. Based on the ISS space and on-ground tradition, its strategy is focused on the connection with the world scientific community in its own domains. Therefore the human resources and investment institute policies were elaborated to support mainly the international cooperation. This is why the Institute for Space Sciences was accepted as a partner in big international collaborations based on signed Memoranda of Understanding. This strategy paid back and when Romania signed the Agreement with ESA for the Programme for European Cooperating States, in 2006, all ISS project proposals were selected by ESA. In time, scientists from the institute were included in the teams, which made proposals for missions for the ESA "Cosmic Vision 2025" (Euclid, Cross Scale, Cosmic Origins Explorer – COrE).

Due to the high researchers quality, the institute was also accepted in big on-ground European experiments like ALICE - CERN, R3B-GSI-Darmstadt-Germany, ANTARES, KM3Net, "BEQUEREL" – JINR-Dubna, Russian Federation, to name a few. The National Authority for Scientific Research awarded the Institute for Space Sciences in 2011 with the **"Diploma of Excellence".**

2.3. Activity report by team

Team E1: Laser Interferometry and Applications Group
Team Leader: Dr. Dan Apostol

Laser Interferometry Laboratory is dedicated to basic research and applications of coherent optics and its related (consecutive) fields, such as interferometry, holography, digital speckle pattern interferometry (DSPI) and diffractive optics.
Measurement of length and shape, holographic optical elements (HOE), diffractive optical elements (DOE) are among the applications we have the expertise in. Nanosciences lead our interest to nanometrology with special emphasize on length and flatness measurement at micrometric scale, with sensitivity on the order of nanometer. Diffractive methods, like scatterometry, are also developed to appreciate the shape and the specific dimensions of micro-structured patterns.
Sensitivity analysis of interferometric and scatterometric measuring methods together with the corresponding algorithms and software are under investigation or already developed.

History
The group came to be around 1978 around a product requested by the Engineering Industry, namely LASINTERF laser interferometer for measuring parts (20 m) and speeds. The instrument was approved in 1982 and introduced into series production in two factories. None of them succeeded to manufacture a reliable product, so complex for that time. In the following years the group continued on creating devices: flatness laser interferometers (5 – 6 pieces) requested and realized for Semiconductor Industry, holographic interferometry installation (8 – 10 pieces), straightness measuring interferometer for machines and tools industry approved to the number zero, gravitational acceleration measuring interferometer and vibration calibration installation for the Metrology National Institute and a laser interferometer for defectoscopy for the Soviet Union (1989!).
After 1990 the group went through big changes in order to adapt to the new requirements. First of all, it lost the engineers (3) who migrated towards better paid jobs. Then, the structures that allowed for realization of devices were lost, namely: mechanical facilities, design facility and optical facility; groups that had the technology and expertise in laser manufacturing devices.

Expertise of the Laser Interferometry and Applications Group

- Classic interferometry for surfaces characterization (Möller-Wedel interferometer, Germany);
- Laser interferometry for length measurement (SIOS, Germany with 5 m range and 0.1 nm resolution);
- All reflective (diffractive) interferometry for high power laser interferometry;
- Digital holography (experimental setup);
- Digital and classic holographic interferometry;
- Interferential microscopy (Linnik, Russia; white light interferometer microscopy, USA; total interference contrast (TIC) Zeiss microscopy, Germany);
- Speckle pattern laser interferometry for 1D and 2D vibration characterization;
- Lateral shear interferometry for short laser pulses characterization;
- Adaptive optics (Shack-Hartmann wavefront sensor, deformable mirror (Adaptica), Italy; spatial light modulator (SLM), USA);
- Visible range digital microscopy (optics, dark field, bright field, transmission, reflection, polarization, fluorescence, interferential, phase contrast (Zeiss AxioImager, Germany and Optika, Italy));
- Cultural heritage: laser cleaning (France with short laser pulses (@ 350 nm wavelength);
- Laser induced break down spectroscopy (LIBS), Fourier spectral instrument;
- Fourier optics, diffractive optical elements (DOE);
- Scatterometry;
- THz imaging and spectroscopy;
- Plasma diagnosis (Mach-Zehnder interferometry);
- Spectral interferometry (…..)

The most important achievements:

A. **Nanometrology of Microsystems**: Realization of structured diffractive optical elements (e.g. optical encoder) with one or two dimensions, *traceably* characterized with laser interferometry;

B. A **traceable vibration amplitude measurement** was demonstrated for calibration of 2D vibrations purpose. Work includes an improved quadrature interferometer able of λ/8 or even λ/16 resolution in measurement of displacement;

C. **Lateral shearing interferometry** (LSI), where a wavefront is made to interfere with a displaced version of it. The resulting interference pattern consists of fringes of equal wavefront slope with respect to the shear. For a sufficiently small shear, they can be approximated as lines of equal directional derivative. The fringes of a shearing interferogram are the loci of constant average wavefront slope over the shear distance;

D. **3D active-adaptive optical metrology research for nano- sciences and technologies. Experimental model of adaptive digital holography (MAST)**. Adaptive optics device for digital comparison of two 3D phase distributions in different locations. This device has nanometre scale resolution and uses nanotechnology specific components (e.g. DOE, MEMS, SLM, DLM digital μmirror device and CCD);

E. **Development and design of diffractive optical elements (DOE)**. Diffractive optical elements (DOEs) for laser beam shaping and sampling. Scalar diffraction theory is used to determine the transmittance or reflectance of a DOE designed to generate a certain light structure by transmission or by reflection respectively;

F. **Speckle interferometry**. We build a Mach-Zehnder interferometer setup in order to imagine and characterize small 2D vibrations of a *rough surface* steel plate and for defectoscopy. The vibrations were induced to the plate with a shaker and the plate was attached by the centre;

G. **InArt. Innovative Laser Based System and Techonologies for In-Situ Cleaning of Painting Artworks.** The main objectives of InArt international project was: development of a mobile and flexible device for in-situ cleaning of artwork, a system for quality control. This system is used to clean artwork painted on canvas, wood, mural painting, fresco and any painted surface in general regardless of the substrate. The prototype comprises diagnosis and monitoring tools for the control of the cleaning operation. Such device is necessary due to the very sensitive nature of pigments, binding media and varnishes, which require a precise and controllable cleaning tool. In parallel, cleaning methodologies for the most relevant problems encountered in painted artworks have been studied and integrated in a *specific database*;

H. **Advanced Microsystems based on MEMS micro-console**. AFM micro-console characterization (e.g. form deviation, time evolution and temperature dependence) by optical and interferometric methods (e.g. optical microscopy, white light interferometry or diffractometry);

I. **Polymers (surface relief grating)**. Two classes of polymeric films (e.g. photoresists and azopolymers) were analyzed from the point of view of the capability to induce single step surface relief modulation in the form of SRGs under the action of a UV interference field, having a pulsed laser radiation (@ 193 nm and 355 nm wavelength) as the source. The incident laser fluency was lower than the ablation threshold of the material and the transversal profile of the induced structures has a continuous shape, without phase changes. There were obtained SRGs with a pitch of 250 nm and 1 μm, depending on the irradiation setup. The modulation depth was between 10 and 800 nm, depending on the incident fluency/intensity and the number of subsequent incident pulses. The surface relief modulation time is of the order of laser pulse duration (5 – 7 ns). There were obtained surface relief gratings with sinusoidal profile on photoresist films;

J. **Bionanolas**. The **international** project BIO.NANO.LAS - Laser-based manufacturing system for biotech nanoparticles production, (R.T.M. SpA, Italy, Cyanine Technologies srl, Italy, MIDATECH BIOGUNE, S.L., Spain, INFLPR, I. Biologie Buc, GENETIC Lab) Surface relief grating is aimed to design and realise an innovative laser-based manufacturing system for nanoparticles production. The system is be based on the process of laser ablation of a proper solid target in liquid environment. Al, Au, Cu, Ti nanoparticles with dimension of 3 – 4 nm, 10 – 20 nm (minimum) and 100 nm were produced;

K. **LIBS**. We have used LIBS to evidence the laser induced selective removal step by step of the painting layers and to analyze their composition. We have correlated the obtained LIBS spectra with profilometric measurements. We have analyzed: emission spectrum dependence on incident laser fluency and the minimum incident fluency correlated with a detectable spectrum was estimated and used in the experiments.

Research dynamics

Our expertise in precision measurement brings partnership requests from partners doing research in the field of micro and nano- technologies. This is a reason why we developed and ensured, by personal research and equipment, all interferometric methods, older or newer (e.g. Talbot, digital holography, phase shift interferometry, lateral shearing interferometry or diffractive interfeometry).

Our thematics in the last years, extended towards:

- Diffractive optics (e.g. DOE);
- Application of interferometry in polymeric materials physics;
- Laser cleaning;
- LIBS spectroscopy;
- Short laser pulses characterization;
- THz imaging and spectroscopy (e.g. time domain spectroscopy, TDS)

PhD theses

Florin GAROI 2011
Iuliana IORDACHE 2010
Drd: Bojan Mihaela, Udrea Cristian, Vasile Tiberiu

Personnel dynamics

Marius Necsoiu / USA/ NASA
Remy Tumbar/ USA/ Urbana University
Adrian Dobroiu /Japan/ RIKEN
Andrei Dolocan/
Madalin Rosu / Germany/ Technische Universität Darmstadt/ Institut für Kernphysik
Bogdan Ionita / Germany GSI Helmholtz Centre for Heavy Ion Research GmbH

In 2010 we employed one engineer (Tiberius Vasile) and a physicist (Cristian Udrea).
The group is also working with a temporarily employed mathematician, Narcis Cernescu.

E2: Photonic Processing of Advanced Materials (PPAM)
Team Leader: Dr. Maria Dinescu

Photonic Processing of Advanced Materials (PPAM) group was organized in 1996 under the supervision of Dr. Maria Dinescu and is made up of a dynamic team of both young and experienced researchers, as well as several technicians.

In last 4 years, the number of people involved in the research activities was kept constant around 21, but they evolved to higher research degrees. In the present time there are 2 CS I, 7 CS III, 8 CS, 2 ACS, 2 technicians. Within this period, ***nine*** of the young researchers employed in the PPAM group sustained their PhD thesis.

The research activities of the group are mainly based on laser processing of advance materials in terms of thin films growth by pulsed laser deposition, surface treatment and patterning by laser irradiation, laser processing of soft materials (polymers, proteins, cells).

The experimental facilities include ***some unique in Romania equipment*** as: i) microprocessing systems with precise XYZ translation stages in air and in vacuum (two systems) for Laser Induced Forward Transfer (LIFT); ii) Multi-substrate Matrix Assisted Pulsed Laser Deposition (MAPLE) system (NEOCERA); iii) Secondary Ions Mass Spectroscopy (SIMS) system and iv) Radiofrequency Assisted Pulsed Laser Deposition Systems (RF-PLD)(3 systems). Other performant equipment for deposition and characterization include lasers (2 Nd-YAG with harmonics: 1060nm, 530 nm, 355 nm, 265 nm, ArF laser: 193 nm), PLD systems, 2 Atomic Force Microscopes -AFM (in air and liquid) with piezoresponse facility, spectroellipsometer, X-ray diffractometer for thin films with pole figure, grazing incidence, reflectrometry facilities, Impedance Analyzer for dielectric characterization, Epifluorescent microscope, FTIR, time gated optical emission spectroscopy system.

The expertise of the group has several unique attributes, based on the existing equipment.

- A combined laser/plasma system for material processing was built; **it is unique in the country** and between the very few in the world. This technique implies the laser processing of materials under a constant influence of a 13.56 MHz radiofrequency generated beam of excited and ionised species. The system, developed in INFLPR laboratories, has the capability to use the laser and plasma beams separately or combined, in controlled environment (vacuum, reactive, atmospheric pressures). The processing system ensures the improvement of film/material’s surface morphology, roughness and structure, the control of layer texture and layer doping. It was successfully used for deposition of heterostructures from different materials.
- We have demonstrated, **for the first time in Romania**, the possibility of using Laser Induced Forward Transfer (LIFT) technique for *viable cells, DNA, liposome and polymer* printing.
- We used, again **for the first time in Romania**, *laser direct writing (LDW) via multi photon absorption (MPA) process* for the preparation of ormosil scaffolds for tissue engineering and we demonstrated *in vitro* culture and proliferation of human dermal fibroblasts.
- We demonstrated, **for the first time**, the possibility of using Matrix Assisted Pulsed Laser Evaporation (MAPLE) for polymer blends and polymer blends/antibiotics thin films growth.

The outcome of these research activities are founded in international projects in the frame of FP5, FP6, FP 7 and NATO Science for Peace programs: i) NATO SfP 97 1934 *"Laser-based clean technologies for smart sensors fabrication"* (1998-2002); ii)**FP5**, IST –2001-33326 *"Piezoelectric sensor arrays for biomolecular interactions and gas monitoring"* (PISARRO) (2001-2005); iii) **FP6**, STREP 033297 *"Single step 3D DEposition of complex nanopatterned Multifunctional Oxides thin films (3D DEMO)"*, (2006-2010); iv) NATO-SfP Project 982671 project, *Polymers based piezoelectric sensor array for chemical warfare agents detection*, (2007-2011) *and v)***FP7**, e-LIFT *"Laser printing of organic/inorganic material for the fabrication of electronic devices"* (2009-2013). Together with them, many national projects were won, in all competitions, in partnership, ideeas, post-doc, young research team.

The dynamic of the research subjects and directions consists in**:**

1. Thin films and heterostructures deposition by PLD and RF-PLD

- Ferroelectrics, piezoelectrics and relaxors: $Pb(Zr_xTi_{1-x})O_3$ - PZT, La doped PZT, $Pb(Mg_{1/3}Nb_{2/3})O_3$ - PMN, lead free materials as $(Ba_{1-x}Sr_x)TiO_3$ – BST and (1-x)-$Na_{0.5}Bi_{0.5}TiO_3$-x$BaTiO_3$ (NBT-BT)
- Zinc oxide (ZnO): Piezoelectric, n-type semiconductor, p-type semiconductor ZnO/$Mg_xZn_{1-x}O$ and Mg_xZn_{1-x}/ ZnO /Mg_xZn_{1-x} QW's
- III-V compounds: AlN, InN, GaN and their combinations
- Biocompatibles: Hydroxyapatite, NiTi
- Heterostructures: PMN/LSCO; PZT/TiN; CN/SiCN/SiC
- High-k dielectric materials: ZrO_2, $ZrSi_xO_y$, HfO_2, $HfSi_xO_y$, Nb_2O_5, $NbSi_xO_y$, Ta_2O_5, $TaSi_xO_y$
- Wide band gap semiconductor metallic oxide: WO_x
- Magnetic materials: Hard magnetic materials (NdFeB, SmCo, Ferrites), Soft magnetic materials (Permalloy, FeSi)

2. Matrix Assisted Pulsed Laser Evaporation - MAPLE

- Thin films of Bioorganic materials and Polymers: (i.e. Polysiloxane, Polyaniline, Polyethylene glycol, Polyethylene imine, Polyisobutylene, Polyepichlorhidrine, polymers blends), Proteins (i.e. Lysozyme, myoglobin, ovalbumin)

3. Matrix Assisted Pulsed Laser Evaporation Direct Write (MAPLE-DW) and Laser Induced Forward Transfer (LIFT)

- Polymers and biological compounds patterning (synthetic polymers, proteins, cells, DNA)

4. Modeling and simulations of ablation and radiofrequency plasmas

- Particle in Cell (PIC) simulation of plasma desorption and evolution in different one and two dimensional geometries.
- Direct Simulation Monte Carlo (DSMC) of various processes in plasmas (three body recombination, collisions charge – neutral, charge exchange etc.)

5. Plasma spectroscopy

- Optical emission spectroscopy

6. Nanomaterials for catalytic and biological applications

- Al_2O_3 / SiO_2 / TiO_2 / ZrO_2
- Catalytic systems and porous materials fabrication by laser and conventional techniques
- Nanomaterials for drug delivery
- Hydrotalcite- like clays (HT)

7. Nuclear materials

- Silicon Carbide
- Spinel (AlMgO)
- Zirconium dioxide

8. **Structural (XRD), morphological (AFM, STM), optical (ellipsometry, optical microscopy), compositional (SIMS), electrical and ferroelectrical (hysteresis measurements and dielectric spectroscopy) characterizations.**

The most important achievements are related by:

- higher number of papers published (131)
- participation at prestigious conferences in the field of materials processing with poster, oral presentation, invited talks (more than 60)
- the group leader (Maria Dinescu) is in the steering committees of the most important conferences in the field in the world: i)International Conference on Laser Ablation (COLA), European Materials Research Society (E-MRS; was co-Chair of the Laser Symposium in 2006 and will be Co-Chair of the same Symposium in 2012), MRS
- 3 chapters published in collective volumes at international publishers
- 3 patents registered at OSIM
- equipments acquisition over 1.500.000 EURO (from national and international funds)

International collaborations with:

- Institute of Applied Physics, Johannes Kepler University, Linz, Austria, since 1998 resulted in: 4 Phd Thesis, post-doctoral positions, research stages,
- “ La Sapienza” University, Roma, Italy, since 1996
- ETH University of Zurich, Switzerland - 1 Phd Thesis;
- Paul Scherrer Institute, Villigen, Switzerland- research stages, european project;
- FORTH-IESL Institute, Heraklion, Greece - 1 Phd Thesis;
- Uppsala University, Angstrom Laboratory, Sweden.
- Polytechnic University of Milan, Centre for NanoEngineered Materials and Surfaces – NEMAS

Due to the performant equipments and the recognised expertise, the PPAM group has also entrepreneurial initiatives by performing mesurements of: i)XRD (ICEMENERG);ii) AFM (ICPE-CA, ICEM S.A); iii)SIMS (Craiova University); and iv) Ellipsometry (S.C. PRO OPTICA SA).

Team **E3**: Quantum Dots, Nanopowders and Thin Films
(http://qdntf.inflpr.ro/)

Team Leader: Dr. Constantin Grigoriu

Team structure

The team is composed of 6 researchers (2 senior researchers Ist rank, 1 senior researcher IInd rank, 3 scientific researchers) and 1 technician.

Dynamic of research directions and subjects

The "Quantum dots, nanopowders and thin films" research group at the National Institute for Laser, Plasma and Radiation Physics has considerable experience in laser deposition of thin films, in the domain of producing nanoparticles and quantum dots of various materials, and in microprocessing for various applications. The research subjects and directions undertaken and their dynamics, is as follows:

- Production of nanostructures (SiO_2/Si, TiO_2, Al_2O_3, SnO_2, In_2O_3, Fe_3O_4, ZnO, NiO, TiN, AlN) with dimensions below 10 nm, as well as nanowires (ZnO, MgO) and nanotubes. These nanostructures have applications in various nanotechnologies. Research on oxide-nanostructure-based surfaces for energy absorption is one of the dynamic research directions undertaken.

- Electrostatic precipitator systems were developed for the capture and analysis of powders containing particles having sub-micronic dimensions, which are very difficult to eliminate from industrial powders.

- Nanotoxicology research on the effect ultrafine industrial powders, which are extremely hazardous for human health, on lung cells.

- Various types of dye-sensitized solar cells (DSSC) having applications in clean regenerable energy. The types developed were DSSC with TiO_2 photoelectrode (PE) obtained directly by PLD (global efficiency 3.7%), DSSC with laser-ablated nanoparticles embedded in the PE (global efficiency 9.6%), and DSSC with TiO_2-doped PE (global efficiency 1.16%). Research on other materials for solar cell development and improvement of their critical characteristics is being carried out.

- Intelligent sensors for chemical warfare agents with applications in military detection techniques and security. For the first time in Romania, surface acoustic wave (SAW) sensors for the detection of chemical warfare agents were produced. The sensors have the following characteristics: detection limit 10 – 100 ppm, response time 10 – 50 s, repeatability +/- 10%. The detection limits obtained by our group are the same or better than the ones reported in scientific papers in the domain. The chemical warfare agents detected using our sensor were: chloropicrin, hydrogen cyanide, soman and lewisite. Nanocomposites (nanoparticles, nanotubes, fullerenes) were developed for the improvement of SAW properties, as well as an improved technology for their deposition and techniques for testing for toxic and lethal gases. Further development of SAW sensors for various applications will be undertaken.

- The production and study of quantum dots (QD). The study of QDs using microscopy techniques, with laser excitation both in the continuous and fs regime was carried out. For the first time in Romania, the detection of antibodies specific to Actinobacillus pleuropneumoniae was achieved using a Western blot method based on QDs. The SiO_2/Si QDs which were used for the detection of the antibodies have the advantage of presenting non degradation by exposure to UV radiation. In addition, the QD-based method used proved to be more sensitive than classical ones. Markers applicable in toxicology have also been produced, and their domain of applicability is being extended .

- The realization of nanocomposites with improved magnetic and nonlinear optical properties. The nanocomposites, obtained by sequential laser deposition, consist in nm-size metal nanoparticles of various shapes embedded in dielectric matrixes. The magnetic nanocomposites have high blocking temperatures (150 K) and small dimensions (2 nm), with applicability in magnetic memories. The development of nanocomposites for the latest generation of high-density magnetic memories with large thermal stability has been initiated and will continue.

- Y-based High Temperature Superconducting (HTSC) thin films obtained by PLD having critical temperatures > 90K and transition widths < 0.5 K. HTSC thin films with critical currents increased by one order of magnitude were also obtained by incorporating in the thin films nanostructures that produce vortex pinning. Research on the improvement of superconducting nano-structures for applications in superconducting coatings for the transmission of energy with no loss is being undertaken and will be carried on.

- Laser welding of radioactive sources with cylindrical geometries using a YAG-Nd laser with a 50 μm focused beam. Welding process automation is obtained by syncronization of the laser system and the positioning system.. The system has applications in the technology of nuclear materials, being a non-contact technique which ensures safety of the human operator. The system was developed for cylindrical radioactive sources of various dimensions, but can be reconfigured for other geometries and we envision the development along this direction.

- Systems for rapid micrometric texturing of plane and cylindrical surfaces, with applications in tribology, using a ps laser focused to 1 μm, with a positioning resolution of 500 nm. The existing system is being expanded to allow other types of micro- and nano-structuring of various materials using the ps laser we posess.

Most important achievements

- SAW for the detection of chemical warfare agents produced for the first time in Romania

- Detection of antibodies specific to Actinobacillus pleuropneumoniae using the Western blot method based on QDs achieved for the first time in Romania

- Dye sensitized solar cells with high global efficiency

- Improved HTSC thin films with critical currents increased by one order of magnitude

Interdisciplinary research

A considerable part of our research has a pronounced interdisciplinary character:

- Interdisciplinary laser physics, materials physics and biology research for the production, study and application of QDs in medicine and toxicology
- Physics of laser-target interaction, materials science and engineering, for micro- and nano-structuring of various materials (welding, texturing, drilling, etc.)
- Production, collection and analysis of nanopowders, combined with nanotoxicology research of their effects
- Production of materials, characterization of their optical, electrical, magnetic and superconducting properties and their optimization for energy-related applications: clean regenerable energy (solar cells) and lossless transmission of energy (superconductors).

Evolution of human resources

The evolution of the human resources in the group is summarized as follows:

- Cornelia Sima has obtained her PhD (2009) with a thesis entitled: "Thin films deposited by laser ablation method for solar cells" ;
- Cristian Viespe has obtained his PhD (2010) with a thesis entitled: "Surface Acoustic Wave Sensors";
- Ionut Nicolae has completed his doctoral thesis and presented it to the comission members;
- Dr Dana Miu was promoted to Senior Scientific Researcher I;
- Dr. Aurelian Marcu promoted to Senior Scientific Researcher II.

International cooperation

- Technological University Nagaoka, Japan - bilateral agreement.
- Wuhan Sunic Photoelectricity Equipment Manufacturing Co., Ltd., China - International Agreement.
- Huazhong University of Science and Technology, China - International Agreement.
- Sincrotrone Trieste ScpA, Basoreizza Trieste, Italia – Joint Research project 2012 – 2013.
- Osaka University, Institute of Scientific and Industrial Research, Division of Advanced Materials Science and Technology, Japan – JSPS (Japanese Society for the Promotion of Science) Post-Doctoral Fellowship (2 years, ending in 2008) Dr. Aurelian Marcu.
- „Johannes Gutenberg" University, Mainz, Germany - research stages
- Washington University, Faculty of Engineering and Material Science, Seattle, USA - research stage.
- Laser Center Leoben, Austria - research stage.
- National University of Singapore, Department of Engineering and Material Science, Singapore - research stage.

Entrepreneurial initiatives

- Surface texturing of various bearings for reducing friction in operation, for companies which produce such bearings
- Development of hybrid electrostatic filter for nanoparticle capture in industrial gas emissions from metallurgical plants, with testing in plant facilities under normal operating conditions.

Team E4: The Laser-Surface-Plasma Interactions Laboratory

(http://lspi.inflpr.ro)

Team Leader: Prof. Dr. Ion N. Mihailescu

The Laser-Surface-Plasma Interactions Laboratory in Lasers Department has more than 35 years of experience in the field of laser generated plasmas, laser-surface interactions, and material processing with lasers. The permanent staff of the Laboratory consists of one university professor, 12 PhDs, 7 PhD students, 1 graduate student and 1 laboratory technician:

- Ion N. Mihailescu (CS I, Prof. Dr.) – Laboratory Head, **ion.mihailescu@inflpr.ro**
- CS I: Doina Craciun, Eniko Gyorgy, Carmen Ristoscu, Valentin Craciun, Gabriel Socol
- CS III: Rodica Cristescu, Felix Sima, Emanuel Axente
- CS: Gabriela Dorcioman, Marimona Miroiu, Camelia Popescu, Sorin Grigorescu, Andrei Popescu, Nicolaie Stefan, Cristian Mihailescu, Natalia Serban, Liviu Duta,
- AC: Anita Visan
- ACS: Gianina Popescu-Pelin, Mihai Sopronyi
- Anton Ionita (laboratory technician)

Our current research interests are focused on:

-biocompatible (doped calcium phosphates, polymers, bioglasses, composites) and hybrid bio-inorganic nanocomposite films deposition for biomimetic implants,

-inorganic nanostructured thin films and nanocomposites for gas sensors and photocatalytic applications (ZnO, WO_3, TiO_2, SnO_2, Al:ZnO, Au:ZnO, Au:TiO_2, Ag:TiO_2, Ag:WO_3, TiO_xN_y, NiO),

-organic thin films (porphyrin, urease, papain, creatinine, ribonuclease A, immunoglobulin) and inorganic core-shell quantum dots (CdSe/ZnS) for bio-sensing,

-thin films for spintronics (Cr oxides)

-laser transfer of delicate complex molecules of polymers (mussel-adhesive polymers, fibrinogen, cryoglobulin, collagen, fibronectin, fibroin) and living cells,

-investigation of chemical composition and the kinetics of interfacial layer growth during pulsed laser deposition of thin oxide films on various substrates, hard coatings (TiN, ZrC, ZrN); antibacterial coatings; chalcogenides, laser generated nanopowders.

We supply valuable expertise in:

- Laser interactions with ns and sub-ps pulses;
- Surface studies with lasers; surface processing; direct laser irradiation of nanomaterials
- Deposition and modification of thin solid structures;
- Laser processing of thin films; nanostructured thin films technology;
- (Reactive or Combinatorial) Pulsed laser deposition (PLD/RPLD) (nitrides, carbides, metal silicides, oxides, ferrites, ferroelectrics (BST), high-k dielectrics, biomaterials, calcium phosphates, composite materials);
- Matrix assisted pulsed laser evaporation (MAPLE);
- Laser induced forward transfer (LIFT)
- Laser generation and characterization of nanoparticles;
- Monitoring of plasmas with temporal and/or spatial resolution
- Characterization of laser ablation plasmas (OES, TOF, imaging investigations);
- Physics engineering;
- Biophysics and medical engineering, nano- and bio- technologies;
- Biomimetic metallic implants;
- Biocompatible and bioactive coatings;
- Bioglass thin films;
- Morphological, structural, optical, electrical, and mechanical characterization of thin films (FTIR, XRD, GI-XRD, SEM, TEM, AFM, XPS, X rays reflectivity, variable angle spectroscopic ellipsometry, current-voltage and capacitance-voltage measurements, nanoindentation)
- Numerical codes temperature gradients in laser ablated targets

We can supply, at request, the following technologies:

1. Fabrication of thin films and nanoparticles from inorganic materials using pulsed laser radiation, for applications in electronics, medicine, chemistry, metallurgy

2. Fabrication of thin films from organic or biological materials by MAPLE, for applications in biology, chemistry, medicine

3. Synthesis by LIFT of organic structures (including biological) with sub-micronic accuracy following a given model, for applications in medicine, electronics, biology

The current and past international projects of the LSPI include 12 international and 25 national projects and 20 bilateral agreements.

Every year, stating with 2007, 2 students from Institute Universitaire de Technologie (IUT) Marseille, France, are coming in our lab for a 10 weeks stage. The studies conducted here are the subject of their diploma. All of them obtained the highest marks from IUT.

The most important results are:

- synthesis of nanostructured thin films of biocompatible material doped with drugs for efficient treatment of osteoporosis

- miniaturized urea biosensors for medical applications

- electrical gas sensors based on chalcogenide materials

- double layers HA + extracellular matrix proteins for coating of metallic implants

-remarcable antibacterial and antifungal efficiency of impregnated textiles (56%cotton/44% polyester fabrics impregnated with hydrophobins) after deposition of nanostructured ZnO thin films.

- deposition of biomimetic calcium phosphate or hydroxyapatite–polymers coatings with enhanced adherence to Ti substrates compared with mere HA coatings;

- deposition of bioglass/hydroxyapatite multilayers with an enhanced adherence to Ti substrates compared with mere HA on Ti;

- transfer and immobilizion of rabbit anti-human antiserum immunoglobulin G IgG thin films by MAPLE.

- PLD of ZrC coatings in $2x10^{-3}$ Pa CH4 atmosphere exhibiting 27,6 GPa hardness and 228 GPa reduced modulus, between the best values worldwide reported.

- ultrahard, smooth crystalline ZrC/ZrN and ZrC/TiN multilayers with hardness values of 30-33 GPa, higher than that of 27-30 GPa measured for pure ZrC, TiN and ZrN films.

-compact, homogenous, adherent, high-quality coatings of chalcogenic material in the binary systems As_2S_3 and AsSe, undoped or doped with AgI or paraffin, for applications in gas detection, data storage or UV litography.

- ITO-ZnO coatings synthesized by Combinatorial Pulsed Laser Deposition whose mechanical and optical properties may be adjusted/tuned.

-deposition of biocompatible hybrid nanocomposite thin films formed by biomolecules and inorganic, oxide nanoparticles

-noble metal – transition metal oxide nanocomposites with tunable optical and electrical properties

-immobilization onto solid substrates of CdSe/ZnS core shell QDs with unaltered functional properties

Team E5: laser spectroscopy (http://lsg.inflpr.ro/)

Team Leader: Prof. Dr. MIHAIL LUCIAN PASCU

Team structure

The team is composed of 10 researchers (2 senior researchers Ist rank, 3 senior researchers IIIrd rank, 4 scientific researchers, 1 research assistants), and 1 technician. Out of 10 researchers 3 are PhD and 5 PhD students. M.L.Pascu is PhD head at the Physics Faculty.

Dynamic of research directions and subjects

The group worked along three research lines: tunable lasers; laser biomolecular spectroscopy; laser optofluidics. All the approached research reflects the dynamics of these fields at international scale and the experience acquired by the group during previous research.

Most important achievements (58 papers; more than 60 communications at conferences). Obtained results:

a). Laser beams interaction with biomolecular systems to fight multiple drug resistance.

* A new method was developed: the modification of the molecular structure of medicines to make them efficient in fighting the multiple drug resistance (MDR) acquired by bacteria or tumors. We have demonstrated that exposure of phenothiazines (PTZ) to laser beams in specific sequences yields molecules/reaction products with altered activities over that of unexposed parent. Chlorpromazine (CPZ), thioridazine (TZ) and promethazine (PMT) were studied. The CPZ molecular structure was modified and reaction products were obtained in solutions in ultrapure water, using a specific exposure sequence to laser radiation, which made the obtained compound(s) efficient in killing ATCC 25923 resistant strain of Staphylococcus Aureus (S. aureus). This was made in the context of the analysis of recently recorded patents. Our studies showed that instead of acting as efflux pump inhibitor, CPZ developed antibacterial activity after exposure to laser radiation. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of CPZ, TZ, PMZ and of their irradiated solutions was determined for S. aureus, Pseudomonas aeruginosa, Klebsiella pneunomiae, and Enterobacter aerogenes reference and resistant strains. The MIC and MBC values obtained for the S. aureus isolates showed a much higher activity of the irradiated compounds than the activity of the parental PTZ. Taken together, the data show that the irradiated compounds have a higher activity against Gram-positive strains (S. aureus) than against Gram-negative strains (K. pneumoniae, P. aeruginosa, E. aerogenes). This research is developed cooperating with research centers from Portugal and Ireland.

*Stability studies using spectrophotometry or optical microscopy on: 1). Samples of racemate TZ (TZR), (-) compound (TZ-) and (+) compound (TZ+) prepared at the Clinical Microbiology Dept., Sønderborg Sygehus (DK), were analyzed by 1H NMR spectroscopy. The stability of irradiated TZ solutions proved to be less than 20h. 2).Samples of quinazoline derivative 3-[2-(dimethylamino)ethyl]-6-nitroquinazolin-4(3H)-one, prepared at Faculté de Médecine et de Pharmacie, Université de la Méditerranée, Marseille. The absorption spectra at 10^{-3}M in ultra-pure water show stability within ±1.045% for more than 40 days after preparation. The product is not stable in DMSO.

b). Basic research on laser beam interaction with tissues, cells and medicines.

A computer controlled experimental set-ups was developed, that include tunable lasers, high performance optical arrangements and high resolution spectral analysis systems. Several kinds of experiments were made and results were obtained:

* Spectral studies of Polydocanol (POL) as sclerosant agent in varicose veins treatment were

made to understand physical bases that may explain why the POL effect in varicose veins treatment may be enhanced when utilized as a foam and exposed to laser radiation within the tissues: the light scattering in the tissue becomes more important and the absorption of the laser beam becomes larger. We measured Raman spectra obtaining signals more intense for foam than for simple solution samples. The exposure of the varicose veins, injected with POL foam, to laser beam should be made in the first two minutes after foam injection, according to the Raman studies. These studies are made in cooperation with Spanish institutions.

* Autofluorescence (AF) studies on in vitro samples of normal and malignant brain tumor tissues were performed when excitation was made at 337.1nm, 370nm and 410nm. We demonstrated that the comparison of the AF spectra allows to distinguish between the brain tumor and normal tissues. We concluded that AF spectra of the tumor samples are close to those measured for normal tissues, but there are differences between them such as: for each pair of tumor/normal tissue samples the AF peak for normal tissue shifts with respect to that for the tumor–typically between 10 and 20nm; overall AF intensity differs with 15%-30% for the components of the same pair; the variation of the ratio of some fluorescence intensity peaks between normal and tumor tissue samples ranges between 10% and 40%.

*Phthalocyanine photosensitizers that contain diamagnetic metals for photodynamic therapy were prepared and studied. The compounds contained Al, Cu, Co, Fe, Zn. There were developed methods and experimental set-ups to measure photophysics parameters of these compounds which control the singlet oxygen responsible for tumor cell destructions: laser flash photolysis, transient absorption, time resolved phosphorescence (for singlet oxygen measurement). A preliminary technology was reported to measure through laser optoacoustic spectroscopy, parameters related to triplet states of the photosensitizing molecules.

* In the Partenariat Hubert Curien with University of Besancon studies were performed by Raman and singlet Oxygen phosporescence spectroscopy on the photo-oxidation of proteins (BSA, HSA) and aminoacids (tryptophan, tyrosine).

* Gas-phase laser spectroscopy of astrophysically relevant molecules was performed at Joint Laboratory Astrophysics Group/Max-Planck-Institute for Astronomy at the Friedrich Schiller University Jena. Pulsed jet cavity ring-down spectroscopy was employed to study several poliaromatic hidrocarbons and the aminoacid tryptophan. Benzoghiperylene, benzofluorene were studied for the first time in the gas phase by direct absorption spectroscopy. The jet-cooled ultraviolet direct absorption spectrum of the amino acid tryptophan was reported.

c). Laser beams interaction with microdroplets (μ-droplets);

*The laser beams interaction with μ-droplets of solutions generated and kept in pendant position was studied: to modify fast (tens of seconds) the molecules in the beads that absorb laser radiation (example Vancomicine and Doxorubicine class of medicines); to produce, by unresonant interaction with laser beams, modifications of the shapes of the droplet, bubbles in the droplet, fast emission of high speed nanodroplets and of μ-droplets with smaller dimensions than the initial bead. Surface tensions for simple μ-droplets and interfacial tensions for compound μ-droplets as well as contact angles (wetting properties) of the droplets were measured in view of nanomedicine and nanoscience applications.

*Results are currently reported on lasing by μ-droplets containing laser dyes while pumped with external laser beams. These results place the Group among the pioneers in the field of laser beam interactions with μ-droplets in pendant position containing liquid samples and development of spherical micro and nanolasers in pendant positions that emit in 4π.

* Nanodroplets were produced in cooperation with the Department of Chemistry, Aristotle University of Thessaloniki, by mixing two immiscible solutions at high rotating speed and/or high pressure difference. We studied the generation of emulsions of Vitamin A diluted in sunflower oil and a solution of Tween 80 surfactant in distilled water. The dependence of the droplets dimensions in emulsion on the mixing rotation speed, agitation time and components

ratio was studied. The droplets diameters were measured by laser light scattering method. We obtained droplets of 65nm diameters (Gaussian distribution).

d).Chaotic properties of laser beams emitted by diode lasers mounted in optical cavities.

A solution was obtained for synchronization of chaotic laser diodes by developing new experimental methods to control the laser chaotic emission when an External Cavity (EC) is used; the chaotic emission was obtained by injection current (IC) and electro-optical (EO) modulation. We obtained synchronization between two identical coupled EC with applications in encoded communications with chaos. The degree of novelty was represented by the log-book of measurements which include the presentation of different techniques for the control of chaotic emission by modulation.

Interdisciplinary research

The scientific activity, as it results from the presentation of results and from the publications list, is by its own nature interdisciplinary and multidisciplinary. The fields implied in our research are: laser physics, laser spectroscopy, optics, microfluidics, optofluidics, chemistry, physical chemistry, biomolecular spectroscopy, cell biology, pharmacology, medicine, animal welfare, environment sciences, nanoscience etc.

Evolution of human resources

The team has broad international scientific cooperation and includes personnel educated/qualified in USA, NL, DE, FR, GR, IT, TK, ES, PT. The human resources were stable since 2007; 5 persons were hired in the group, out of whom one PhD who came back from USA and four young students who graduated from the Physics Faculty of the University of Bucharest. Since 2007 one member became CSI, another one became CSIII and two CS. The head of the group (M. L. Pascu) is Professor and PhD head at the Physics Faculty of the University of Bucharest, in the field Optics, Spectroscopy, Lasers.

International cooperation

* The Group has a dynamic and flexible approach of activities. It was/ it is participating in the COST Actions: P21, Physics of droplets; B30, Neural regeneration and plasticity; BM0601, Advanced methods for the estimation of human brain activity and connectivity; BM0605, Consciousness: A transdisciplinary, integrated approach; BM0701, Antibiotic transport and efflux: new strategies to combat bacterial resistance (M.L.Pascu was elected Vice-Chair).

*Working stages abroad or participation in training schools were made by scientists members of the Group: I.R.Andrei: France, Italy, Romania; V.Nastasa: Germany, Greece, Bulgaria, Romania; A.Smarandache: Italy, Turkey, Romania; A.Militaru: Portugal, Ireland, Romania; M.L.Pascu France, Hungary; A.Staicu: Germany, France; A.Pascu: France; G. Popescu: USA.

*The Group received scientists for working stages from Czech Republic (Jan Barkal, Prague in 2009), Leonard Amaral (Portugal/USA in 2010 and 2011), Spain (Mario Trelles and Xavier Moreno – Moraga in 2010), Hungary (Attila Huniady and Balazs Danko in 2011). At this very moment in the laboratory are working with the group L. Amaral, and B. Danko.

*The group had a bilateral cooperation with France (Hubert Curien , University of Besancon, “Mechanisms of thiols photo-oxidation by reactive species generated in the phthalocyanines photosensitising”, 2009-2010) and has one with Italy (CNR-IENI, Institute for Energetics and Interphases, Genoa, “Laser beams interaction with micro-droplets having controlled content”, 2012 – 2014) which is currently under evaluation.

* Between 2001 and 2006 M.L.Pascu was Science Officer at EU DG RTD COST Secretariat (2001–2004) and ESF COST Office (2004 – 2006). He is currently Romanian expert at COST Domain Committee Biomedicine and Biomedical Sciences.

Entrepreneurial initiatives

No significant data to report.

Team E6: Nonlinear and Information Optics Group

Team Leader: Academician Prof. Dr. Valentin I. Vlad

Members of the Nonlinear and Information Optics (NIO) group: Acad. Prof. Dr. Valentin I. Vlad, CSI - Head; Dr. Adrian Petris, CS I; Dr. Mircea Udrea, CS I; Dr. Mihaela Stoica, CS II; Dr. Ioan Dancus, CS; Dr. Tatiana Bazaru, CS; PhD student Petronela Gheorghe, CS; PhD student Silviu Popescu, ACS; Mariana Buzatu, technician.

The **main research directions** of NIO group are:

- Nonlinear nanophotonics for information technologies at molecular level: optical nonlinearities in quantum dots, in "nano-patterning" and "nano-imaging" (AFM, SNOM);
- Optical nonlinearities in metamaterials with sub-wavelength periodic and random structures - characterization and applications of enhanced and ultra-fast (fs) nonlinearities;
- Soliton photonics and laser wave interactions in nonlinear optical materials (wave mixing, stimulated scattering, optical phase conjugation);
- Properties of quantum systems in micro- and nano-cavities. Information in quantum systems;
- Micro-processing with excimer UV lasers, development of laser equipments;
- Quantum cryptography for secure communications.

Scientific expertise:

The group NIO has experience in modeling of complex electromagnetic wave propagation, nano-composite nonlinearity, waveguide arrays, measurement of ultra-fast optical nonlinearities in nanostructured Silicon-on-Insulator (SOI), nonlinearities in porous silicon, silicon quantum dots (QDs), in CdTe QDs and new functionalities using these nonlinearities and photo-detection, new laser designs and development, laser based devices, quantum information processing

NIO laboratory is equipped for studies of nonlinear optics in different samples with c.w. lasers, ns-, ps- and fs-laser pulses and with instruments with 10 nm resolution.

Involvement in International and National projects

In period 2007-2011, NIO was involved in 10 projects (3 international and 7 national)

International projects:

- EU-NoE "PHOREMOST" - Nanophotonics to Realize Molecular Scale Technologies (2004-2008);
- EU-COST Action MP0702 "Towards Functional Sub-wavelength Photonic Devices" (2007-2012).
- Bilateral Collaboration INFLPR – Univ. “La Sapienza” Roma, ”Optical devices using spatial solitons and nonlinear interactions in photorefractive crystals for communication”, Project 18 (Intergovernmental Agreement Italy – Romania, 2006-2008)

Main scientific results in the period 2007-2011

Spatial optical solitons

We studied the generation of spatial optical solitons and soliton waveguides (SWGs) in photorefractive crystals. We characterized the SWGs and we analyzed the light propagation in these waveguides. Theoretical and experimental studies were realized at different wavelengths, continuous wave (cw) and ultra-short pulses. A part of these results were realized in collaboration with the University “La Sapienza”, Rome.

We have observed for the first time that this beam confinement is induced by the second harmonic generated with the IR fs pulses in non-phase matching conditions. These results show the possibility to extend the photorefractive sensitivity range of LN crystals, towards near-IR telecom wavelengths. We showed that waveguide dispersion is negligible compared to material dispersion in visible and near-IR.

We have demonstrated SWGs optical writing with low-intensity in long LN crystals (> 15 diffraction lengths) and the reconfigurability property of SWGs by showing the erasure possibility with light beams in the photorefractive sensitivity range. We have experimentally showed the guided propagation of beams with different wavelengths (532nm, 808nm, 1030nm, 1557nm) through SWGs recorded with 532nm and 405nm wavelength. At 405nm, we observed very fast recording process, three orders of magnitude faster than recording at 532nm, for the same light intensity. We showed that SWGs are robust to propagation of IR beams. We demonstrated the guiding of fs IR beams at 1550nm with 6 orders of magnitude higher peak power than the recording optical power. We have demonstrated the temporal stability (> 9 months) in ambient laboratory light of these SWGs without any additional fixing techniques. By creating an array of SWGs using a serial approach, we have showed the reproducibility of SWGs and the possibility to record thousands of waveguides in mm-size crystals with possible applications in ultrafast parallel interconnections and sensor arrays.

We have studied for the first time the possibility to record soliton waveguides and wave propagation through them in active materials like erbium-doped lithium niobate (Er:LN). We have studied the effect of Er doping on the electro-optic, photorefractive and photovoltaic properties of the material. We have demonstrated very good guiding properties of SWGs recorded in Er:LN for beams with wavelengths from the visible to near-IR (cw and fs pulses).

Nanophotonics

We have designed, synthesized and studied semiconductor nano-structures with controlled electronic properties, to obtain resonant interaction with light at the desired wavelength. Due to this type of resonant interaction the nonlinearities are highly increased. In the same time, by nano-structuring we have also obtained the strong quantum confinement regime (the dimensions of the nano-crystal are much smaller than the exciton Bohr radius of the material), regime in which the nonlinear optical effects are strongly enhanced. The final result of these studies was the obtaining of the highest reported value for the nonlinear refractive index of the CdTe nano-crystals, ~10^{-7} cm^2/W. We have also obtained the dependence of the refractive index on the nano-crystal size and their concentration. Another remarkable result was the obtaining of a saturation of the nonlinear refractive index change at low incident intensities (~1 kW/cm^2). After the embedding the nano-crystals in polymer matrices, we have demonstrated the possibility of utilizing this new structure in two important optical functionalities for information technologies at molecular level: optical limiter and phase modulator. A part of these results were obtained in collaboration with TU Dresden (PHOREMOST partner). The team has demonstrated that by controlling the optical linear properties, one can tune the nonlinear response of quantum dots.

We studied the linear and third-order optical nonlinear properties of sub-wavelength nanostructured materials, i.e. periodic nanostructures on SOI and nanoporous silicon. Appropriate methods of optical linear and nonlinear characterization of these materials were selected and improved. The thermal and electronic nonlinear indexes of periodic nanostructured SOI, non-patterned SOI and bulk Si were measured by reflection Z-Scan method (with fs laser pulses, at wavelength of 800 nm) and by using a new procedure introduced by us for discrimination between electronic nonlinear effects and thermal ones. The study of nonlinear optical properties of SOI periodic nanostructures demonstrated a significant increase of the electronic response of SOI periodic nanostructures in comparison with electronic response of bulk Si. A part of these results were realized in collaboration with Univ. “La Sapienza” of Rome and CNRS-LPN – Paris (PHOREMOST partners).

We studied theoretically and experimentally the linear and nonlinear optical properties of nanoporous silicon (nPS). We analyzed the emission and absorption properties of this nano-composite material. The structural properties of the nPS layers were studied by high-resolution microscopy (AFM and SEM). The effective refractive index of the investigated nPS samples was determined by reflectivity measurements. The third-order optical nonlinearity of nPS was determined. Starting from the complex Bruggeman formulae, we derived simplified formulae that describe the dependence of the linear and nonlinear properties of nPS on porosity and wavelength. We demonstrated that using the new formalism, the effective linear refractive index and the third-order optical nonlinearity of nPS can be controlled by controlling the porosity of nPS.

These results are important in photonics for realization the nonlinear optical devices with properties controlled by nanostructuring.

Evolution of human resources

Acad. Prof. Dr. Valentin I. Vlad

- Elected Vice-president of the Romanian Academy in 2010.
- Member of Academia Europaea
- Fellow Optical Society of America, Fellow of Institute of Physics (UK), Fellow of The International Society for Optical Engineering - SPIE (2007);
- Chairman of the Advisory Committee of European Optical Society and EOS Board of Directors, 2011
- Decorated with the National Order "Loyal Service" in grade of Knight (2008).
- Associate Professor at the Bucharest University, Faculty of Physics (since 1991) and Doctoral School of Physics; supervised 7 PhD students.
- Senior Associate Member of International Centre for Theoretical Physics (ICTP), Trieste, Italy; Initiator of ICTP-RO, part of Romanian Institute f. Advanced Studies–UNESCO Institute, 2011
- Coordinator of the School of Advanced Studies of Romanian Academy, 2011
- Member of the Project Coord. Committee for elaboration of the Romanian Strategy in Physics (ESFRO)
- Member of the Coordination Committee for elaboration of the Romanian Strategy in Nanotechnology “NANOPROSPECT” – Section Photonics
- Member of The Romanian Society of Physics – President of the Section of Optics and Quantum Electronics, 1991-2009, and of The European Physical Society

- 2011 Session Chairman at the “13th International Conference on Transparent Optical Networks” ICTON, Stockholm, Sweden; Invited Plenary Lecture at Intl. Conf. on Theory and Applications in Mathematics and Informatics, Alba Iulia; 5 conferences on history of science
- Session Chairman and Plenary Paper at 33rd Intl. Semiconductor Conference, Sinaia (2010)
- Chairman at Intl. Conf. "Micro-to-nano photonics II" ROMOPTO 2009, Sibiu, Romania (2009)
- Session Chairman and Invited Paper at EOS Topical Meeting on Photonic Devices, Utrecht (2008)
- Congress of the European Universitaries, Rome (2007)
- Member of Editorial board of Journal of the European Optical Society (JEOS), London (2006-present)
- Member of the Editorial board of the journal SPIE Review, SUA (2008-present)
- Member in the Scientific Council of the Publishing House of Romanian Academy (PHoRA)
- Chief Editor of the journal Proceedings of the Romanian Academy, Series A: Mathematics, Physics, Technical Sciences, Information Science and Technology *(*ISI – Journal, 2009)
- Chief Editor of the journal Romanian Reports in Physics (PHoRA)(ISI – Journal, 2009 IF:~0.5)
- Scientific referee for more than 10 scientific journals

Dr. Adrian Petris

- Senior scientific researcher I (CS I) from 2009
- Associate Member of International Centre for Theoretical Physics - ICTP, Trieste, Italy.
- Expert for elaboration of the Romanian Strategy in Physics (ESFRO)
- Member of the Romanian Physics Society and of the European Optical Society
- Member of Program and Coordinator of the Organizing Committee of Intl. Conf. ROMOPTO 2009, Session Chairman at ROMOPTO 2009
- Member of Program and Organizing Committee of Intl. Conf. “Modern Laser Applications” - INDLAS 2008, Bran, Romania
- Member of Program and Organizing Committee of Intl. Conf. “Industrial Applications of Lasers” – INDLAS 2007, Bran, Romania
- Scientific referee - Physica Scripta, Romanian Reports in Physics, Romanian Journal of Physics

Dr. Mircea Udrea

- Senior scientific researcher I (CS I) from 2009
- Participation at “Exhibition of Romanian research achievements”: Laser Devices
- Participant in “Salon de la Recherche”, Paris (2009)
- Chairman of Intl. Conferences INDLAS 2008, INDLAS 2007, Bran, Romania

Young researchers

In 2011, two PhD students of the group successfully defended their PhD theses: **I. Dancus** –“Nonlinear optics in nanostructures”, **T. Bazaru**-"Characterization methods of some nonlinear optical materials for photonics", their scientific coord. being Acad. Prof. V. I. Vlad. In 2010, **S. T. Popescu** finished his dissertation thesis entitled "Experimental characterization of spatial soliton in LiNbO3 and applications" coord. by Acad. Prof. V. I. Vlad, Dr. A. Petris and Prof. P. Schiopu. In 2010, started his PhD, “Spatial solitons in bulk and on interfaces of nonlinear optical media”, scientific coord. Acad. Prof. V. I. Vlad.

For improvement of their scientific knowledge, young members of NIO group attended prestigious international schools on optics and nanophotonics:

- Winter College on Fibre Optics (2007) and on Micro and Nano Photonics for Life Sciences, ICTP (2008), ICTP, Trieste – **P. Gheorghe, T. Bazaru, I. Dancus**.
- Intl. School of Quantum Electronics: Advances on Nanophotonics II, Erice, Italy (2007) – **I. Dancus**
- Winter College on Optics and Energy, ICTP, Italy (2010) – **I. Dancus, S. T. Popescu**
- Winter College on Optics in Imaging Science (2011) **- I. Dancus, S. T. Popescu**
- 6th Intl. School New Frontiers in Optical Technologies (2011), Finland – **I. Dancus, S. T. Popescu**

Dr. Ioan Dancus - Scientific referee: Optics Express

In 2007-2011, the NIO group has been involved in organization of several International Conferences:

- 9th Intl. Conf. ROMOPTO 2009”, Sibiu, Romania, Aug. 31 – Sept. 3, 2009
- The 1st Intl. Conf. INDLAS 2007, Bran, Romania, May 23-25, 2007
- The 2nd Intl. Conf. INDLAS 2008, Bran, Romania, May 20-23, 2008
- Intl. Student Workshop on Laser Applications–ISWLA, Bran, Romania, May 25–28, 2010
- Intl Student Workshop on Laser Applications–ISWLA, Bran, Romania, May 31–June 4, 2011.
- In 2011, NIO group started the organization of Intl. Conf. "Micro-to-nano photonics III" ROMOPTO 2012, which will be held in Bucharest, Romania in September 2012.

Team E7: Solid-State Lasers Laboratory (SSLL, http://ssll.inflpr.ro)

Team leader: Dr. Razvan Dabu

Team structure

The team is composed of 15 researchers (4 senior researchers Ist rank, 3 senior researchers IInd rank, 4 scientific researchers, 4 research assistants) – 12.5 full equivalent time, 2 research assistants in the probation period, and 2 technicians -1.5 full equivalent time.

Dynamic of research directions and subjects.

SSLL is the main research group from INFLPR working in the field of ultrashort pulsed lasers in Romania, currently involved in strategic national projects for the development of ultra-fast and ultra-intense laser infrastructures. SSLL participated in 16 research projects, 14 of them funded from national sources (F1-8, F11-14) and 2 European projects (F9-10). At present, SSLL participates in 5 national projects (CF1-4, CF6) and 1 European project (CF5). SSLL is involved in a PCCE 2011 project proposal and 7 PCCA 2011 projects proposals currently submitted for evaluation to UEFISCDI.

Main research subjects in the last years:

- Development of a high power femtosecond laser facility.
- Material processing and characterization at micro- and nanoscale using the nonlinear absorption induced by ultrashort laser pulses.
- High-power ultrashort laser pulses related studies: multiple femtosecond pulses generation, coherent beam combination, X-ray laser development.
- Modeling of stationary systems and interactions between very intense electromagnetic fields and electrons or atoms. Modeling and design of advanced diode-pumped solid-state lasers.

Research work will continue in the field of materials processing using femtosecond laser pulses with modulated spatial and temporal profile, surface nano-structuring, 3D structures writing in photo-polymers for micro-fluidics, biosensors, and micrometer-targets.

Further studies of the group in the field of high power laser and high field interactions include optical distortions of ultrashort laser pulses, coherent beam combination, filamentation and supercontinuum generation, plasma mirror studies, ultra-intense pulse laser induced damage in coatings, laser produced plasmas.

High field interactions modeling will be continued in the frame of a PCE 2011 project by: a) exact model for generation of backscattered hard radiations in interactions between very intense laser beams and relativistic electrons; b) new problems in modeling the generation of hard radiations by relativistic Thomson scattering; c) new problems in modeling the generation of hard radiations by relativistic interactions between very intense laser beams and atoms.

Most important achievements in the 2007-2011 years:

1. High power femtosecond laser facility.

The SSLL fs laser facility, developed in 2007-11 years, consists in the following laser systems:

- Frequency doubled Er:glass fiber oscillator – Ti:sapphire regenerative amplifier, Clark MXR CPA 2101 (775 nm central wavelength, 0.7 mJ maximum pulse energy, 200 fs pulse duration, 2 kHz repetition rate);
- Multi-terawatt femtosecond laser amplifier system (TEWALAS), Amplitude Technology (805 nm central wavelength, 450 mJ pulse energy, 25 fs pulse duration, 10 Hz repetition rate);
- Home-made multi-wavelength (1064, 532, 266 nm) picosecond microchip oscillator-multi-pass laser amplifier (pulse energy 10 mJ @ 1064 nm, 5 mJ @ 532 nm, 2 mJ @ 266 nm; pulse-width, less than 400 ps; repetition rate up to 10 Hz).
- Two computer controlled laser workstations (coupled to the Clark laser and the fs oscillator of the TEWALAS laser, respectively), equipped with nanometer precision translation stages and optics for laser beams steering and tightly focusing, designed and built by SSLL researchers for materials micro-processing and 2D, 3D micro/nano-structuring.

SSLL disposes of various devices for ultra-short laser beams characterization: power/energy-meters (Ophir, Gentec), large-bandwidth oscilloscopes (1 GHz, 500 MHz, Tektronix), fast photodiodes, second order auto-correlators (Femtochrome), SPIDER for the spectral phase and pulse duration measurement, spectrometer (Ocean Optics), CCD cameras.

2. Micro/nano-processing and characterization of materials.

Recently, through a series on national projects (F3-6, F15) the team implemented at INFLPR techniques for micro and nanoprocessing of materials by femtoseconds lasers. The SSLL team developed scientific and technical knowledge for surface engraving via direct laser writing (DWL) and near-field enhancement, laser induced forward transfer (LIFT), 3D material structuring by micro-stereo-lithography based on two-photon polymerization (TPP) technique, as well as set-ups for spectroscopic characterisation techniques with high spatial resolution by femtosecond lasers. Main obtained results:

- Technology and equipment for direct laser structuring of metallic thin film with application in microelectronics and microwave devices. Composite Right-Left-Handed Metamaterials (CRLH-MTM) structures were fabricated by laser ablation in coplanar waveguide (CPW) configuration for millimetre waves. Interdigital capacitors were produced as components of pass-band filters, directional couplers, antenna working at 40 GHz spectral range.
- Technology and equipment for direct laser structuring of photosensitive materials by two-photon absorption and photopolymerization. Scaffold structures in biocompatible polymers were produced as substrate for tissue engineering. The two-photon absorption effect was used as method for generation of photonic structures in calcogenic glasses and photoresists.
- Experimental setups for two-photon excitation spectroscopy with high spatial resolution using femtosecond Ti:Sapphire lasers. The setups were used for characterization of biological samples, rare-earth doped materials and fluorophors.
- Nanostructuring methods for laser surface processing. Nanoholes with diameters down to 100 nm were produced on metallic and dielectric surfaces such as Au, Ag, Co, SiO_2, Si, using optical near-field enhancement by self-organized colloidal particles.
- Self-organized surface nanostructures produced in air and liquids by laser irradiation with ultrashort pulses on various materials and alloys (Si, SiO2, ZnO, Pt, Ti, W, Cr, TiAlN) for applications in generation of hydrophilic/hydrophobic surfaces.

3. Studies related to high power femtosecond lasers development and applications.

3.1. Related to a new method of multiple pulses generation and its impact in a new x-ray laser pumping scheme, an European project (CF5) was coordinated by our group. After the experimental demonstration of the multiple pulses generation method, published in A35, the method was used to perform a proof of principle demonstration for a new coherent combination method with faster-than-linear power adding, within LASERLAB Europe FP7 contract. The recently published results (A50) could have a high potential impact in the development of multi-PW laser systems such as ELI.

In the framework of ELI-Preparatory Phase (FP7), our group contributed in the finalization of two important documents: ELI-PP White Book that synthesize the state of the art in the ultra intense lasers field and the technologies envisaged for building the most powerful laser systems in the world within the European Extreme Light Infrastructure project; White Book of the ELI-Nuclear Physics laser system (www.eli-np.ro) coordinated by Dr. Jean Paul Chambaret, Razvan Dabu, and Daniel Ursescu as co-editors. These two documents are the scientific and technical references for the ELI-NP facility to be built in Magurele, one of the most important scientific projects currently developed in Romania.

3.2. Further expertise is related to XUV sources development, coordinated by Dr. D. Ursescu, member in the management committee for the COST Action MP0601 “Short wavelength laboratory sources”. Some X-ray laser related studies were published in 2010. Experimental demonstration of X-ray laser emission was recently experimentally demonstrated in Mo and Zr targets at TEWALAS facility.

4. Modeling of the laser beams properties. Study of connections between quantum and classical equations with applications to the modeling of stationary systems and of interactions between very intense electromagnetic fields and electrons or atoms.

4.1. We proved a connection between Schrödinger and Hamilton-Jacobi equations, in the case of the systems composed of electrons and very intense electromagnetic fields. This property is potential important in the new field of interactions between very intense electromagnetic fields and atoms, on the domain in which the electrostatic interaction between electrons and nuclei is negligible [A. Popa, A3].

4.2. It has been elaborated a semi-classical method for the calculation of the energies of atomic stationary states [A15, A22] and for the calculation of the energies of molecular stationary states [A43].

4.3. It has been elaborated a model of Thomson scattering of the very intense electromagnetic waves on electrons, which leads to a good agreement with the experimental data in two cases: for small initial velocities of the electrons [A14] and for relativistic initial velocities of the electrons [A21].

4.4. It has been elaborated an exact calculation method of the spectral and geometric properties of the Thomson scattered radiations, in the most general case, when are taken into account the components of the initial velocity of the electron, the phase of the incident field, and the direction for which are calculated properties of the scattered wave is arbitrary [A44].

5. Modeling and design of advanced diode-pumped solid-state lasers

Thermal modeling of the grazing-incidence bounce laser amplifier used for power scaling was achieved by [S. Amarande, O11,12,15]:

- development of a model which includes the main heating mechanism
- numerical solving of the heat flux equation by the finite element method
- calculation of the optical path difference and of the thermally induced lens.

The scientific results of the team in the 2007-2011 years were published in more than 50 publications and presented in international conferences such as LAMP, ALT, EMRS, ROMOPTO. Five patents were submitted, among them four OSIM patents in the field of nanotechnologies and high power lasers technologies, and a US Patent.

<u>Interdisciplinary research</u>

Besides the main research direction of physics and engineering of ultra-short pulse lasers, SSLL participated in studies and applications related to this subject: micro/nano-technologies, microwave electronics, biophotonics, plasma physics, nuclear physics.

<u>Evolution of human resources</u>

In the last four years, the SSLL staff increased by hiring two young PhD researchers, specialized in Germany, France and Italy, and six graduates of Faculty of Physics, Bucharest University, and Polytechnic University Bucharest. 2 researchers have been promoted to CS1 rank, one researcher to CS2, and 2 assistant researchers to CS rank. One researcher defended his PhD thesis, 6 researchers are currently PhD students.

<u>International cooperation</u>

SSLL participated in 3 European projects (F9-10, CF5). In the frame of bilateral collaborations, common experiments with German researchers (MBI-Berlin) and Japanese researchers (Tohoku University) were developed using TEWALAS facility. One researcher elaborated his PhD thesis during a two-years working stage at Kent University, UK. Three working stages of three months each (two in the field of high-power fs laser amplifiers and one in the field of nano-technologies based on fs lasers) were developed by SSLL researchers in the frame of collaboration with LOA-Paris and Saint-Etienne University, France. Young SSLL researchers participated in more than 20 training schools and short working stages in France, UK, Germany, Spain, China.

<u>Entrepreneurial initiatives</u>

Surface marking of various materials was performed using the Clark laser for a private company (Zoom Soft SRL). A new PCCA 2011 project having this subject has been recently submitted.

The configuration of a multi-angle surface-plasmon-resonance (SPR) microscope was elaborated together with PRO-OPTICA SA and CI Biodinamica. A new PCCA 2011 project related to the SPR microscope applications in biodynamic studies has been submitted.

Team E8 ISOTEST

Team leader: Dr. G. Nemes

The project and the team ISOTEST (http://ssll.inflpr.ro/isotest/index.htm) started their activity on 16 June 2010, by winning a research project sponsored by the National Agency for Scientific Research (NASR, or ANCS in Romanian) under the following program:

Operational program: Increase of economic competitiveness

Priority axis 2: Research, technological development, and innovation for competitiveness

Operation 2.1.2: Complex research projects fostering the participation of high-level international experts

Project title/Acronym: Facility for laser beam diagnosis and ISO characterization / certification of optical components / materials behavior under the action of high power laser beams / ISOTEST

The project extends for 36 months and has well defined objectives, mentioned below.

The main objective of this project is to develop a facility for laser beam diagnosis and for testing, characterization and certification of the behavior of optical components and materials subjected to high power laser beams, according to ISO standards (ISOTEST facility). This main objective is divided in four specific objectives, O1 – O4:

O1. Developing a method and a device for diagnosis of the main characteristics of high power laser beams according to the standards ISO 11146-1,2,3 and ISO 11554.

O2. Developing an automated test station for beam diagnosis and to characterize the behavior of optical components / materials subjected to high power laser beams according to ISO standards.

O3. Developing procedures for laser beams diagnosis and for the testing, measurement and characterization of optical components and materials in high power laser beam, according to ISO standards.

O4. Accreditation of the Solid State laser Laboratory (SSLL) of the Laser Department of INFLPR by the Accreditation Association of Romania (RENAR) to perform testing / measurements and ISO certifications by using the automatic test station ISOTEST. Dissemination of results and opportunities offered by the facility developed in the project.

During the 17 months since the project started, the following important results were obtained:

- A room with facilities to control the quality, the cleanliness, the temperature, and the humidity of the ambient atmosphere, and with well stabilized and filtered electrical circuitry to supply the power to delicate electronic instruments was developed. This laboratory room assures the tight requirements for ISO measurements.

- A relatively high stability, high pulsed energy, nanosecond laser source emitting at 1064 nm, 532 nm, 355 nm, with 10 Hz repetition frequency, for damage studies, was developed.

- Theoretical and preliminary experimental results were obtained validating new ideas on laser beam spatial characterization, to be implemented in the final experimental setup.
- A method for temporal diagnostics of femtosecond laser pulses (50 fs – 500 fs) based on a special measuring device was experimented and implemented.

- An experimental setup for the S-on-1 procedure for damage tests of optical components was conceived, and experimentally implemented.

- An algorithm to automatically perform the S-on-1 test was developed and is currently in the stage of being experimentally implemented.

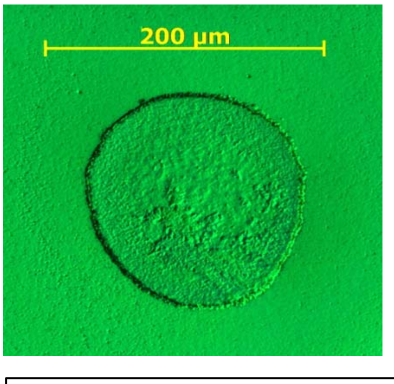
- The first real measurements on good optical components manufactured by the Opticoat SRL company (Bucharest, Romania; now acquired by Ophir-Newport) using the S-on-1 procedure were recently performed. This represents a major breakthrough of the project, the results being perfectly equivalent to those obtained by well-known companies involved in optical damage tests.

- An improvement of the ISO standards dedicated to the damage tests (ISO 21254-1,2,3,4) was recently done by the project director, were accepted by the ISO Committee, and were implemented in the newly issued standards.

- In the ISOTEST team the two young research assistants hired at the beginning of the project started their doctoral study activities and performed at maximum within those requirements.

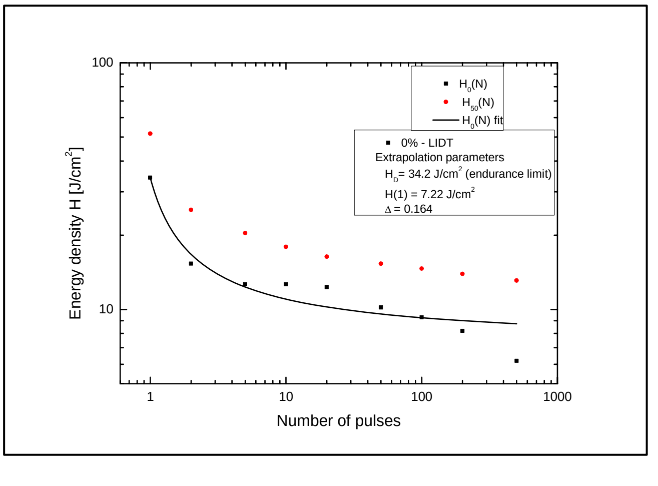
- Four papers were presented at ISWLA11 Conference, Bran, Romania, May 2011, with subjects dedicated to ISOTEST project.

An example of the S-on-1 laser-induced damage test (LIDT) on a high-reflectance mirror in near-infrared, manufactured by Opticoat SRL, is summarized in the figures below.



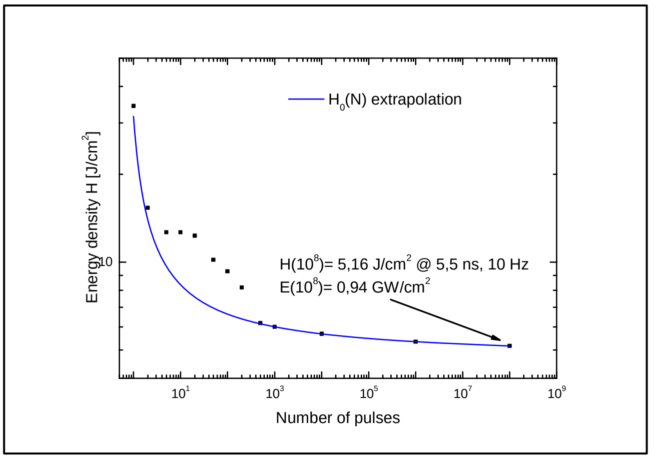
Normarski micrograph of a damaged site.

l – 1064 nm; effective pulse duration – 5.5 ns; effective spot area – 2.15 x 10^{-4} cm^2; energy density – 13.7 J/cm^2; damage after 196 pulses.



Characteristic damage curve of the sample (LIDT, experimental data).

$H_0(N)$ – energy density for 0% damage probability for a specified N; $H_{50}(N)$ – energy density for 50% damage probability for a specified N; N – number of pulses at which the damage occurs.



Extrapolated LIDT to large number of pulses corresponding to 0% damage probability.

N – number of pulses at which the damage occurs; H – pulse energy density; E – pulse power density.

Team ISOTEST

Project Director : Dr. George Nemes – Scientific Researcher 2

Project Director: Dr. Aurel Stratan – Scientific Researcher 1

Scientific Manager: Dr. Constantin Fenic – Scientific Researcher 1

Specialist: Phys. Liviu Neagu – Scientific Researcher

Specialist: Phys. Laurentiu Rusen – Scientific Researcher

Specialist: Phys. Simion Sandel – Research Assistant

Doctorand: Eng. Alexandru Zorila – Research Assistant

Doctorand: Phys. Catalina Radu – Research Assistant

Team E9: **Optics and Lasers in Life Sciences, Environment and Manufacturing**
(http://lamet.inflpr.ro/)

Team Leader: Dr. Ing. Dan C. Dumitras

Team structure

The team is composed of 8 researchers: 1senior researcher I[st] rank, 6 scientific researchers, 1 research assistant, from which 6 are younger than 30 years.

Dynamic of research directions and subjects

The group continues a long tradition, started in 1970, in the field of CO_2 laser physics and technologies, with applications mainly in the medical domain, and secondary in different life sciences directions.

Today, the group activity is distributed on two principal research subjects: Laser Photoacoustic Spectroscopy (LPAS) and Diffuse Optical Tomography (DOT).

Laser Photoacoustic Spectroscopy (LPAS) is a versatile analytical tool for measuring trace gas concentrations at sub ppb level. The LPAS first experiments took place in 1993, and over the years we have built our system, based on in-house developed lasers and photoacoustic cells. Now, the experimental setup has two parallel measuring lines, consisting of 2 line-tunable CO_2 laser emitting radiation in the 9.2 - 10.8 μm region on 68, respectively, 73 different vibrational-rotational lines and 2 photoacoustic cell. The system also includes a complex part dedicated for static and dynamic handling of gas samples, plus electronic devices with high sensitivity dedicated for signal detection. The important features of our system are multicomponent capability, high sensitivity and selectivity, large dynamic range (usually larger than six orders of magnitude, from 100 ppt till 100 ppm - parts per million), none or only minor sample preparation, good temporal resolution, ease of use, robustness.

The applications of LPAS include concentration measurements and trace gas analysis for breath diagnostics, air quality measurements, and plant physiology. In the last 5 years we concentrated on continuously increasing the accuracy and detection limit of the system, performing a lot of optimisation tests. The practical measurements were conducted for the ***biomarker detection of ethylene and ammonia in the breath*** (smokers, patients receiving x-ray treatment or undergoing haemodialysis procedures), in order to assess the level of oxidative stress in the body. In plant physiology, we monitored the specific phytohormone ethylene, both from the point of view of ***plant stress response to heavy conditions*** (mainly, influence of chemical treatments) or as ***marker of activity of cyanobacteria in petroleum bioremediation***.

The second main disciplinary direction, the **Diffuse Optical Tomography (DOT)** is a relatively young one. The design conception started in 2006, following 3 intense years of laboratory system development, with a complete set of assays and calibration tests.

DOT is a non-invasive investigation technique based on light scattering and absorption at the level of tissue. The multi-spectral DOT enables the reconstruction of the internal tissue structure and the evaluation of the tissue main chromophores concentration, based on the low optical absorption and scattering of tissues in the 600 - 880 nm range which ensure tissue penetration of light at relatively large depths (4-10 cm). These feature provides complementary information to traditional clinical imaging modalities (e.g. X-ray, Ultrasound, MRI, PET/SPECT), for non-invasive monitoring of treatment progression or therapeutic response of a disease. In our case, the system was specifically designed for monitoring breast tumours, and consists of 2 laser diodes emitting on 780nm and 835nm, the multiplexing and demultiplexing optical systems, a special measuring head and the fast response electronics. The system works in time-domain, has 8-point light source and 8-point detector circular symmetrical configuration and was used up to now only for laboratory measurements. Before being able to make *in-vivo* measurements, we worked in the last two years on ***phantoms***, both liquid (water, haemoglobin, intralipid and saline solutions) and solid (silicon), ***simulating tumours*** by embeding objects with different optical characteristics. Other measurements were performed in order to assess the ***dynamic process of blood oxygenation***, determining the concentrations of haemoglobin and oxy-haemoglobin in dynamic regime.

Today we work further on developing the system, adding two more wavelengths, improving the detection speed by optimizing the sequential multiplexing/demultiplexing systems, and increasing the functionality (real-time detection of fast changing dynamic processes) introducing the frequency-domain trough the laser diode modulation. A continuous problem remains the image reconstruction algorithms, for which we have started collaboration with a software firm and medical staff specialized in clinical imaging.

Most important achievements

The LPAS set-up developed in our laboratory is considered at this hour the most sensitive of its kind in the world (compared with the other two best developed by Harren and Fink groups). The comparing parameters are the following: limiting sensitivity of the cell S_{cell} ($2.6x10^{-8}$ W cm^{-1} versus $4.0x10^{-8}$), limiting sensitivity of the system S_{sys} (5.9x10-9cm^{-1} vs. $1.1x10^{-9}$), limiting measurable concentration of ethylene c_{lim} (200pptV), minimum detectable pressure amplitude p_{min} ($4.2x10^{-4}$Pa vs. $3.3x10^{-2}$), minimum detectable concentration c_{min} (0.9 ppbV vs. 3.8), minimum detectable absorptivity α_{min} ($2.7x10^{-8}$ cm^{-1} vs. $1.2x10^{-7}$).

The DOT system at this point is the only in the country, and being developed further will be ready in approx. 2 years for clinical protocol.

The work on SLOA and DOT was sustained by the financial support of the national program "Nucleu", as well another **9 projects won in national competitions** (CEEX, PNCDI Programs: Partnerships in Priority Domains; Human Resources), from which 7 are already finalized, and 1 is just starting for the next 3 years (the 9 project total value for our institute was around 1.6 mil. Eur). In the last call of the "Partnerships in Priority Domains" we submitted **4 new proposals**, 3 as Project Leaders and 1 as partner.

The results of our experiments were valued by **53 communications** at International and national conferences and workshops, scientific sessions or invited seminars. The publication list includes at the moment **14 papers published in ISI Journals**, other 5 published in proceedings. 3 papers more are waiting the referee answers.

Interdisciplinary research

All our applicative experiments were developed based on interdisciplinary interactions with specialists mainly from the health domain, but also from universities or software firms. The clinical SLOA measurements on patients were performed with the medical support and infrastructure of "Coltea" Hospital Bucharest, the Radiotherapy and Oncology Clinic, and the Renal Dialysis Clinic of "International Healthcare Systems" Bucharest. Other cooperation included Oncological Hospital Fundeni Bucharest, ENT Clinic "St. Maria", as well the Rheumatology Department of "Carol Davila" Hospital Bucharest. In assessing the activity of cyanobacteria in petroleum bioremediation, partners were national institutes from other branches (National Institute of Marine Geology and Geo-ecology GeoEcoMar, Institute of Biology of the Romanian Academy, Natinol Institut for Optoelectronics INOE-2000). The software design and development was realized with 2 specialized firms, also hardwere distributors for Keithley and National Instruments: Internet S.R.L and DOLSAT S.R.L., Bucharest.

Evolution of human resources

The **group dynamics** was also very intensive in the last years:

- The group leader, prof. dr. Dan Dumitras became *Doctoral Adviser* at University "Politehnica"Bucharest
- *2 new graduated students* were *employed* in 2007, respectively 2008;
- 3 PhD thesis were *defended*;
- 4 new PhD thesis have *started*;
- 4 young research assistants *promoted* at Scientific Researcher grade;
- approx. 3 years cumulative period of *research fellowships abroad* .

International cooperation

There are to mention the networking activities of our scientific team with other main research groups from abroad, as it follow: N. Iftimia - Physical Sciences, Inc., Andover, USA; Prof. H. Jiang, Xiaoping Liang - Department of Biomedical Engineering, University of Florida, Gainesville, USA; Prof. P.N. Prasad - University at Buffalo, State University of New York; Prof. B. J. Tromberg - Laser Microbeam and Medical Program, Beckman Laser Institute and Medical Clinic University of California, USA; S. Andersson - Engels - Departments of Physics and Oncology, Lund University, Sweden, I. Turchin - Institute of Applied Physics RAS, Nizhny Novgorod, Russia. Prof. Dr. Markus Sigrist, Institute for Quantum Electronics, ETH Zurich, Switzerland, Prof. Dr. Frans J.M. Harren**,** Department of Molecular and Laser Physics, Radboud University Nijmegen, The Netherlands.

Other initiatives

Very important to mention is the fact that the group were deeply involved in the **FP7 Project "Extreme Light Infrastructure-Preparatory Phase ELI-PP"** (2007-2010), prof. dr. Dan Dumitras being the Romanian Responsible for the project, and Eng. Consuela Matei the Romanian work package responsible for WP9 "„International networking/ communication", evolving in July 2009 as the Financial Leader of the project.

The whole team together was organizing also the very first **International Conference "Light at Extreme Intensities– LEI 2009"**, which took place between 16-21 Oct. 2009, in Brasov, Romania and started the series dedicated to the ELI concept.

Now, we started already to organize the next **„International Committee on Ultra-High Intensity Lasers - ICUIL 2012" Conference** that will be held (16-21 Sept. 2012), in Constanta, Romania.

Team: **E10** Thin Films Advanced Technologies
(http://gap.inflpr.ro/)

Team Leader: Dr. Eng. Victor Rares MEDIANU

Team structure:

The team is composed of 3 senior researcher 1st rank, 2 senior researcher 3rd rank, 1 engineer for optics and fine mechanics, 2 technicians (1 thin film techniques and 1 IT).

Dynamic of research directions and subjects:

We are coming from a classical and sensible-technological group dealing with laser optical components settled in the past of 2000-2004 years. For us working with the physical dimensions in the range of nanometers, UV-VIS-IR optoelectronics components and devices, use to be normal. Following this way we was our self obliged to up-grade the field of research. Consequently, in the time of 2007-2011 years, the work team has been involved in nine projects within national contest "Research Program for Excellence" and "PNCDI 2007-2013". Our research work has been focused to:

- design of thin film nanostructures for achieving Spin Valve switching device;
- technological procedures for RF magnetron sputtering procedures applied in the field of photo-voltaic / $CuInGaSe_2$ solar cells;
- ITO and ZnO thin film nanostructures to carry out photonic devices;
- Laser Physics and Engineering of optical components;
- 1D-Photonic Crystals, 2D-photonic Crystals and NIM (meta-materials) tuned inside optical frequencies.

Most important achievements:

1. Project "Intricate metal-semiconductor-dielectric nano-structures with optimal quantum efficiency induced by solar radiation interaction". NANOLAYSOL was dedicated to technological procedures for performing photovoltaic devices using RF Magnetron Sputtering thin films deposition of $CuInGaS_2/Se_2$ on plastic substrates. Except the scientific dissemination of technological results, underline by scientific papers published between 2006-2008, we are trying **to build an institutional association** with contribution of INFLPR (CO), ICPE C.A. (P1), UPB (P2) and IOEL S.A. (P3). NANOLAYSOL 279/2006 Nano-layers for photovoltaic devices and solar cells was finalized with a technological protocol between

INFLPR, ICPE C. A., Polytechnic University and IOEL S.A. (representing SME). We have to say that, unfortunately, UPB did not obtain a favourable signature.

2. A pragmatic concept concerning to consolidate the expertise in the domain of nanotechnologies for optoelectronic devices was determinant for approaching the second project "Intelligent, flexible, integrated photo-voltaic with maximized conversion efficiency for solar cells". IFIPVCELLS was developed for a new concept of laboratory technology able to engineering solar cells into the small scale production. IFPVCELLS 21–021/2007 Intelligent flexible solar cells finalized with an ISO 9001 certification for "RF magnetron sputtering technology potential to carry out CIGS (Kapton/Mo/CIGS/ZnO/ZnOAl/Al) solar cells" . ISO 9001 and ISO 14001 certification have been obtained in 2008-2010.

3. Among other seven projects, developed in the frame of "Research Program for Excellence" and national program "PNCDI 2007-2013", as responsible of partnerships we want to underline our technological contribution on the "Intelligent processing of nano-devices like Giant-Magneto-Resistance spin valve for spintronic applications". Project SPIN VALVE (Co Cu Co & Co Al_2O_3 Co, magneto-transport properties and Tunnel effect) have been finalized, within ICPE C.A. at the and of 2010, by a **scientific transfer** of the technology performed in INFLPR on the new RF Magnetron Sputtering equipment functional in the dedicated laboratory / facility of ICPE C. A.

A lot of scientific articles can be connected with laboratory results performed in our team; the articles were reported in the attached document dedicated for the present institutional evaluation.

Interdisciplinary research:

In 2011, the PNCDI project no. 52-139 / 2008 lead by National Institute of Glass (INS S.A.) was transferred at our institute; project entitled „Research about obtaining of phosphate-potassium vitreous fertilizers with controlled solubility and establishing the parameters for their use in plants production" were accomplished next interdisciplinary researche and experiments.

Experiments were made by Lucica BOROICA (senior researchers 1st rank) and Bogdan SAVA (senior researchers 1st rank), for the obtaining of the vitreous fertilizers from AG2 and AG3 series. The parts of fertilizers were sending to U.S.A.M.V. Bucharest and SEMINA S.A. partners for field experiments of corn, sunflower and grain. Other parts of fertilizers were sending to the partner I.C.D.V.V. Valea Calugareasca for vineyard experimentations.

A Romanian patent application from INFLPR side was made entitled: „Vitreous potassium-phosphate fertilizers and method of producing the same". The dissemination on large scale of the results was realized by communications and publishing scientific papers:
1 ISI quoted article, 1 non ISI article and 3 participations at international conferences were done in the very short period of 2011 year.

Evolution of human resources*:*

Dr. Petronela GAROI (Prepelita) a young lady researcher (senior researcher 3rd rank) has a remarkable contribution for the scientific life of our team. So, she is main author in 5 ISI articles and has 6 ISI articles as co-author.
Last but not list she is succeeded in the new contest of "IDEAS" national projects with a Post Doctoral Project "Transparent and conductive oxide thin films deposited on flexible substrates for solar cells applications" 2010-2013.
PhD student Geo GEORGESCU (senior researcher 3rd rank) is first young researcher who is working in the domain of nonlinear photonic crystals and laser mirrors designed like 1D-Photonic Crystal. A number of 5 ISI articles and 2 participations at international conferences were completed within 2007-2011 period of time.
Our engineer and technicians, as active members of the research team, were designer and producer of optoelectronic components as well as laser optical substrates for UV-VIS-IR.

International cooperation:

The research team is in charged within project MNT-ERA-NET, as an experimental-executive partner, for the time of 2011-2013. The project is leaded by National Institute for Optoelectronics / INOE 2000 and the total value of the project is around of 250.000 Euro. Using R.F. Magnetron Sputtering Deposition techniques our research time have to design a technological flux for engineering vitro-ceramic substrates for optoelectronic optical sensors.
Under the name of Dr. Eng. Victor Rares MEDIANU we are active member of United Kingdom Innovation Forum/UKIF R71 G09, Rutherford Appleton Laboratory, Dideot, OX11 OQX, U.K.

Entrepreneurial initiatives:

As a conclusion for future research activities we have to point out, our research team is focused on thin films advanced technologies for optoelectronics devices like: laser optics, miro-sensors, nano-layers for solar cells, photonic crystals and super-lens photonic component tuned inside optical frequencies.

- If we get new procedures for engineering photonic devices as an innovation, we have to look for a SME as investment partner.

- Unfortunately in Romania did not exist, yet, a functional and workable entity a corporate or a corporate committee able to take an intelligent decision concerning technological transfer.
- Keeping up this conception for a possible smart future we are preparing for technological transfer some research products:
  - Technology for yielding civil optical components;
  - ISO 9001 RF Magnetron Sputtering coatings for solar cells prototype;
  - Technological procedures for performing 2D-Photonic Crystal as light amplifier at optical frequencies (400 nm. – 700 nm.)
  - The research team **“T**hin **F**ilms **A**dvanced **T**echnologies” was a main initiator of the internal-institutional project “Integrated Center for CO_2 laser processing/training center Dr. Ing. Iulian GUTU” built as an infrastructure support from our project as well as from the INFLPR investment founds. Owning to the institutional reorganization strategy this facility is on “STANDBY” procedures.

Team E11: Laboratory of Laser Photochemistry (LLP)
Team Leader Dr. Ion Morjan

Members of the Laboratory of Laser Photochemistry (LLP): Dr. Ion Morjan, CSI - Head; Dr. Rodica Alexandrescu, CS I; Dr. Ijon Voicu, CS I; Dr. Ion Sandu, CS II; Dr. Catalin Luculescu CS II; Dr. Morjan Iuliana CS III; Monica Scarisoreanu CS III; Dr. Lavinia Gavrila, CS III; PhD student Florian Dumitrache; PhD student Claudiu Fleaca; PhD student Elena Dutu, CS; PhD student Anca Barbut

During the last 15 years the Laboratory of Laser Photochemistry has been working on the synthesis processes of nanometric particles and composites prepared by the laser pyrolysis technique from gas-phase reactants. Some characteristics of the laser pyrolysis are: high versatility; cleanliness of the process; extremely narrow and controlled particle size distribution and the possibility to scale-up the process to a pilot plant.

The main research directions of LLP are:

- synthesis of a large variety of oxide semiconductor nano powders: magnetic Fe_2O_3 maghemite/magnetite, TiO_2 with prevailing anatase content , SnO_2 :
- synthesis of doped or mixed nano iron oxides:Ti-doped Fe_2O_3, Ti/Fe-doped SnO_2, Fe-doped TiO_2 with sensing properties;
- preparation of anion (N, C, S) nanophase TiO_2 with increased photocatalytic properties:
- synthesis of a large variety of nanocomposites, with core-shell morphology: iron oxide-siloxane polymer nanocomposites, core-shell Fe (Fe_2O_3)-carbon, TiO_2-Fe_2O_3--polymer nanocomposites
- synthesis/surface chemistry of oxide ceramics and nanocomposites: SiO_2 and SiC, TiC, Fe_3C;
- LCVD synthesis and characterization of carbon nanotubes;
- preparation of carbon nanostructures for different applications (elaboration and characterization of carbon-based nanocomposites, the investigation of the interaction between synthesized carbon nanoparticles with micro organisms having a major impact on human healthy).

Scientific expertise:

The group of LLP has experience in the development of new nano-particulate systems with variable stoichiometry and crystallinity for the investigation of their functionalization and their toxicity properties; in achieving tailored properties of nanoparticulate systems by controlling since the preparation method the microstructure of nanometer-size advanced materials; for the complex characterization of nanosized particles and composites by different analytical techniques (XRD, IR, Raman, TEM, SEM)

Involvement in International projects

- International colabvoration in the frame of the Italian Romanian Collaboration:

- Bilateral Collaboration between Italy and Romania 2006-2009, Project INFLPR – ENEA-Frascati-Roma ”Nanoparticles obtained b laser pyrolysis for the obtaining of magnetic iron oxide and matrixew of SiO_2 „
- NATO-CLG-STI 2005-2008 „Iron/Iron oxide/ siloxane polymer nanocomposites of high thermal stability for applications in the field of sensors ” Romanian Director R. Alexandrescu

EU project experience of LLP- NILPRP

- FP6 Contract number LSHB-CT-2006-037639 „Bio-Imaging with Smart Functionalized Nanoparticles” BONSAI, Romanian Director I. Morjan
- FP7 Contract number CP-IP 229335-2-2009- KMPT 2009-2013 „Advanced Magnetic and structured nanoparticles deliver smart Products for Life Sciences with industrial Processes by Linking innovative manufacturing efforts”-MagPro2Llife, Romanian Director I. Morjan

Romanian projects 2007-2011

1. **C 71-083 – 2005-2008** –„Processing of Fe-based advanced magnetic nanostructures in nanoparticulate and nanofluids form for biomedical applications - BIMAPAFLU” – Director de proiect: dr ing. Morjan Ion
2. **IDEI 431 - 2007-2011** – „Advanced researches on the laser pyrolysis synthesis of small – dimensions nanocomposites: Sn/Fe SI SnO/FeO nanoparticle systems - NACOSOF” – Director de proiect: dr. Alexandrescu Rodica
3. **CORINT - 2005-2008 - ”**Laser production of Fe/gFe2O3/Polimer nanocomposites wit superior thermal stability - NATO-STI**” –** Director de proiect: dr. Alexandrescu Rodica
4. **C1-07 IFA-CEA - 2010-2013** – „Doped TiO2-based nanoparticles for applications in solar cells or as bactericide elements - NANOPHOB” – Director de proiect: dr ing. Morjan Ion

- **2010-2011: Four young scientists with recently finished doctoral studies have earned post doc Contracts, of the POSDRU type (structural funds)**

Newly earned competitions for National Contracts:

- Contract PN-II-ID-PCE-no.80/5.10.2011, Novel approach to nanoscale, multi-functional materials, to reduce toxics and bacteria and to manage resources more efficiently. Acronym: MULTINANEF, Director R. Alexandrescu
- Contract PN-II-ID-PCE-no 65/05.10.2011, Novel laser ablation-assisted technique for pure single-walled carbon nanotube synthesis, Director I. Morjan

- PN-II-RU-PD-2011-3-0268 Enhanced photocatalytic properties for band gap engineered TiO_2- based nanoparticles obtained by laser pyrolysis - PROBAG Director M. Scarisoreanu

Main scientific results in the period 2007-2011

1. Nanotechnology solutions for the laboratory and pilot scale production of nanosized particles (carbon, metals, metal oxides, composites) with narrow size distributions and controlled size and shape
2. Surface and colloid chemistry of nanosized oxide particles (particularly magnetic nanoparticles) for stable suspensions (e.g. iron/iron oxide (maghemite)-based and iron/iron carbide, with controlled stoichiometry, configuration, mean particle size-in the range of few nanometers, superparamagnetic effects, etc)
3. Engineered nanomaterial and the study of interaction mechanisms with living systems and/or the environment, including toxicology studies (in the frame of inernal and international collaborations)
4. Photochemical and photocatalytic applications based on our synthesis and characterization of: (i) pure and doped (with metal or C, S) anatase/rutile nanoparticles (mixed TiO_2 phases); (ii) inorganic oxide nano materials embedded in polymer or carbon matrix (single step synthesis, starting from organic / siloxanic / biocompatible monomers)
5. Novel environmental approach for the remediation with embedded elemental nano iron particulate systems

The most important obtained results:

- Using the IR laser co-pyrolysis of $(CH_3)_4Sn$ and $Fe(CO)_5$ in air, $Sn_{(1-x)}Fe_xO_2$ nanoparticulate material at higher Fe doping levels was obtained. Different mixed oxide samples mean particle sizes were obtained with about 7 nm at the highest Fe concentration. The decrease of the mean crystallite dimensions with increasing Fe concentration was observed. ^{57}Fe Mossbauer spectroscopy demonstrates: (i) the formation of very fine Fe oxide nanoparticles (defected magnetite) of average size of less than 3–4nm which are not detectable by XRD; (ii) the existence of an additional magnetic ordered phase (even at temperatures higher than 100 K) which involves relatively large nanoparticles (Fe^{3+} ions dispersed in the Sn–O matrix) and presents a new type of ferromagnetism.
- Iron-based-carbon core–shell Fe@C nanostructures were produced by the one step laser pyrolysis technique. Acetylene/ethylene mixtures were used as carbon precursor. It is demonstrated the possibility to vary the chemical content and the nanoparticle dimensions by essentially varying the nozzle diameter of the emergent reactive gas flow (from 0.55 to 1.5 mm diameter). XRD analysis shows that at increased nozzle diameter, increased ordering of the crystallographic network is evident, with dominance of a-Fe and of the Fe_3C iron carbide phases. EDAX reveals the highest Fe content for the sample produced with the larger nozzle diameter. Onion-like surrounding graphenic layers often cover the buried iron-based (Fe/Fe_3C) cores.
- The synthesis of composite nanoparticles with iron-core/carbon shell structure were prepared. Nanoparticles containing as much as 40 at.% Fe and <6 at.% oxygen are reported. Optimum conditions are found in which ethylene diluted in Ar is the carbon source (50/50 vol.% dilution). The structural analysis identifies Fe and Fe_3C as the main crystalline phases of the iron-based cores wrapped in the carbon sheets. Magnetic measurements show a significant improvement of the properties by the increase of the iron content.
- Undoped and iron doped SnO_2 –based nanoparticles with low Fe concentration have been successfully synthesized by using the IR laser pyrolysis from gas phase reactants. $(CH_3)_4Sn$ and $Fe(CO)_5$ in ethylene sensitized mixtures were employed as vapor-phase precursors. As concerning the Fe-doped SnO_2 nanopowders, controlled Fe/Sn atomic ratios (in at %) ranging from nominal 0 to 0.08 were achieved in a one-step pyrolysis process. From the three identified crystalline phases (SnO_2, SnO and Sn,) the clear dominance of the SnO_2 phase at higher oxygen precursor flow was found. No iron compounds were detected. The major effects of iron doping are: i) an overall decrease of the diffraction peaks of the three phases with increased Fe doping (which could be explained by the perturbation induced by iron in the crystallographic network); ii) an inhibited particle growth probably due to the substitutional introduction of Fe atoms. The mean particle dimensions of the SnO2 phase are about 12 nm.
- Pure and Fe–doped TiO_2 nanoparticles with rather low Fe concentration have been prepared by the IR laser pyrolysis method using specific irradiation geometries and reactant flow concentrations. A mixture of the TiO_2–anatase and TiO_2–rutile phases with a preponderance of the anatase phase is observed in all samples. No amount of any crystalline iron compounds could be detected. According to XRD measurements, the mean particle size for anatase titania was about 14 nm and had a tendency to decrease at Fe doping. For the heat-treated samples, a higher rutile proportion in the iron-doped samples was found. Doping the photocatalyst with Fe shifted the absorption onset of the semiconductor to visible region. The activation efficiency of pure and doped samples was tested by using the SECM in an amperometric approach. Under UV-illumination, bare TiO_2 samples outperformed the reference sample Degussa P25 by about 45% with respect to the consumption of oxygen in the presence of IV-chlorophenol.
- Iron/iron oxide-based nanocomposites were prepared by IR laser-induced and C_2H_4 photosensitized codecomposition of $Fe(CO)_5$ and MMA. Mainly core-shell structures were observed. Different analytical techniques evidence the cores as formed mainly by iron/iron oxide crystalline phases. A partially degraded (carbonized) polymeric matrix is supposed for the coverage of the metallic particles. The nanocomposite structure at the variation of the laser density and of the MMA monomer flow was studied. The potential of the new material for acting as gas sensor was tested on the material prepared as thick films. The variation of the electrical resistance in presence of NO_2, CO, and CO_2, in dry and humid air was recorded. Preliminary results show that the samples obtained at higher laser power density exhibit rather high sensitivity towards NO_2 detection and NO_2 selectivity relatively to CO and CO_2.

- The synthesis by laser pyrolysis of nano iron oxide-based materials has been achieved by two handling procedures: (i) a standard experimental procedure in which the oxidation process initiates and develops inside the laser— induced reaction zone (samples SF); a more complex experimental procedure in which the iron precursor is allowed to dissociate alone in the flame but in a surrounding oxidizing atmosphere (samples F). XRD and TEM analysis reveal a major content of maghemite/magnetite in samples SF. A mixture of three Fe-based phases, namely - Fe_2O_3/Fe_3O_4 iron oxide, cementite Fe_3C and metallic Fe phase is found in samples F.The relative proportion of these phases differs in function of the reaction temperature (laser power). Agglomerated core–shell structures are often observed. For both kinds of samples, the crystallinity (crystallographic order) is enhanced with increased laser power.As determined by TEM, mean particle sizes depend on the laser power density and vary between about 4 nm and 6 nm and between about 9 and 11 nm, respectively. From the hysteresis loops at room temperature, the saturation magnetization values of about 80 Am^2/kg were found.

- We have produced nano-cementite iron carbide from new MMA precursors, with the advantages of (i) almost pure Fe_3C phase and (ii) rather high degree of dispersability, due to the complementary wrapping of nanoparticles in polymer shells. Mean particle diameters of about 8–9 nm were identified. For the same reactive mixture but by using a much lower laser power, the nanopowders exhibited the coexistence of rather large Fe grains and very small crystallites of the maghemite/magnetite type, possibly constituting an outer, oxidized shell.The highest proportion of the Fe_3C phase was found in nanocompo-sites prepared from toluene-containing precursors.

- Sensitive structures obtained from a Fe/Fe_2O_3/ polyoxocarbosilane nanocomposite are reported. Nanocomposite powders with different polymer content were prepared by the IR laser co-pyrolysis of iron pentacarbonyl and hexamethyldisiloxane. They become superficially oxidized in atmosphere. Thick films prepared from the low-polymer content Fe-based/polymer material were examined for the sensing capabilities, by testing the variation of the electrical resistance to CO and CH_4 gases. All the measurements were performed at a temperature of 450 0C, in dry and humid air. It was found that the sensor signal reaches the value of 1.07 for CO concentration of 500 ppm at an operating temperature of 450 ^oC. N-doped TiO_2 nanoparticles were successfully synthesized by the IR laser pyrolysis of sensitized TiCl4(vapors) in the presence of nitrogen protoxide. By varying the experimental conditions (gas flow geometries and the oxidizing agent) in order to favor an increased reaction temperature structural and compositional changes may appear such as the slight variation of the N-doping degree (0.7 and 0.9 at%, respectively), the change of the ratio of anatase to rutile and the decrease of the mean particle diameters from about 18 nm in case of the almost pure anatase sample to about 13 nm in case of the anatase–rutile mixture.

- Using a CO_2 CW low-power laser, the feasibility of using the catalytic-LCVD approach is demonstrated here by studying the growth of CNTs on two different Fe–C nanocomposite systems. The proposed C-LCVD technique could offer a better control of CNT growth conditions and a high versatility as concerning the catalyst nature and preparation. $C_2H_2/C_2H_4/NH_3$ and C_2H_2/C_2H_4 gas precursor mixtures were alternatively used. The nanotubes grown from CFresidue nanoparticles demonstrate the lowest mean diameter that indicates the benefic influence that lighter PAH removal has on MWNT morphology. Prevalent curled and coiled morphologies are obtained for the CNTs grown in presence of ammonia.

- The ability to grow carbon nanotubes by using the catalytic LCVD was demonstrated and also (ii) the possibility to use a new catalyst system, of the Fe/C core-shell type. The catalytic LCVD offers the advantage of high versatility and control since it separates the catalyst preparation from the catalytic growth of nano-tubes. On the other hand, the Fe/C composites in these experiments exhibited (i) very small particle sizes (in the range of about 5 nm); (ii) sharp particle distribution and (iii) the existence of a relatively high dispersion of metal nanoparticles in the carbon matrix. By maintaining a con-stant CO_2 laser irradiation, the growth of CNTs was studied by varying ethylene concentration in the ethylene/acetylene precursor mixture. SEM and TEM showed that the majority of nanotubes are multi-walled carbon nano-tubes grown in tangled forms. Many of the nanotubes were identified as bamboo shaped MWCNTs.

Evolution of human resources

Young researchers

Four PhD students of the group successfully defended their PhD theses, as follows: (i) Popovici E.: 2008 Contributions to the development of laser systems and of processing systems for the obtaining of nanostructured powders (Prof.dr.Mihailescu I.); (ii) Gavrila L.: 2009 Contribution to obtain nanostructures by laser pyrolysis of gas phase and their characterization. (Prof. Dr. Antohe S.); (iii) Morjan Iulia: 2010"Studies concerning the synthesis and characterization of carbon nanostructures obtained by laser pyrolysis". (Prof. Univ. Dr. Antohe S.); (iv) Scarisoreanu Monica: 2011 Studies on the obtaining and characterization of carbon and titanium-based nanopowders produced by laser pyrolysis (Acad.Prof. Dr. Popescu I. I.);

Four members of the LLP are PhD students, with subjects closely related to their tasks in the Laboratory projects. These are: (i) Dumitrache Florin 2010 " Iron based nanoparticle synthesized by laser pyrolysis" (Prof Stefan Antohe); (ii) Fleaca Claudiu 2003 "The obtaining and characterisation of oriented carbon nanotubes by CVD (chemical vapour deposition) methods", activated with laser, plasma and incandescent filaments (Prof. Dr. Mihailescu I.); (iii) Barbut Anca 2010 "Nanomagnetic particles used in medicine for drug delivery" (Dr. Ing. Saban R.); (iv) Dutu Elena 2010 „Study for obtaining Sn, Zn and polymer-matrices nanopowders by laser pyrolysis", (Prof.Dr. Barna E.).

Activity report

Team **E12**: Atomic Processes in Laser Field. Atomic and Ionic Spectroscopy of the Laboratory and Astrophysical Plasmas. (http://atomic.inflpr.ro/)

Team Leader: Dr. Viorica Stancalie

Team structure

The team is composed of 7 researchers (2 senior researchers Ist rank, 1 senior researchers IInd rank, 1 scientific researchers, 3 research assistants)

Dynamic of research directions and subjects.

The scientific activity is dedicated to studying *physics of the atomic and molecular processes* in the presence/ absence of laser field, and to contribute to better understanding of phenomena related to *laser-plasma interactions*, with application in X-ray laser physics, quantum control, population transfer between autoionizing states, population trapping, and inertial confinement fusion. To this end, *large scale production of electron impact data*, including dielectronic recombination, radiative recombination, electron impact ionisation and electron impact excitation, has been provided. These data, necessary for *spectral identification*, are the basis of *laboratory and astrophysical plasma emission models*, and have been used to determine *the gain of X-ray laser* with Li-like ions, *to model fusion plasma and its opacity effects* on line emissivity, and generation, and characterization, of a *volume recombination*, the bridge between *low temperature and fusion plasmas.*

Related Software Research and Development for ITER is the second topic of our activity. This can be summarized as follows:

1) Web services

- usage in distributed systems
- new techniques for integrating web services in distributed applications, such as distributed locking
- transferring large amounts of data using web services; integrating web services and traditional approaches like RPC

2) Large databases for storing atomic data and computation results

3) Parallel code development including interfacing with external data sources and optimal usage of high performance computing infrastructure.

4) Development of portal interfaces for access to resources offered by high performance computing facilities.

Most important achievements

Members of the International Organizations and Scientific Committees

- Members of the International Atomic Data Analysis Structure Project (http://www.adas.ac.uk)
- Members of the IEEE Computer Society
- Members of the International Scientific Board of the International Conferences: CEPAS 2011, FPPT4 2009, FPPT5 2011
- Members of the European Physical Society/ Plasma Physics Branch
- Members of the IAEA working groups for Atomic Data Production**(** http://www-amdis.iaea.org)
- National Representative in the COST P14 Activity ("Laser-matter interactions with ultrashort pulses, high-frequency pulses and ultra intense pulses. From attophysiscs to petawatt physics"
- Member of the International Committee of the European Scientific Foundation (ESF) PESC: SILMI Project (Super-intense laser-matter interactions)

Publications**:** A total of **15** scientific papers published in ISI journals (PRA, JPB, Phys. Scr., Laser and Particle Beams, NIMB and FED) of a total **20,4083** relative AIS, has been reported in the period 2007-2011. More than 19 scientific works were presented at the international conferences in the field;

End Results

- We have developed the portal infrastructure for the Integrated Tokamak Modeling Task Force, allowing web based access to resources offered by the task force HPC cluster.
- During various projects we have began constructing a local atomic data database, available to our partners using various techniques such as web services.

Interdisciplinary research

Requirements derived from the study of atomic data are used to advance the field of computer science, by developing new techniques and algorithms for using and storing large amounts of data in a distributed way.

Furthermore, new algorithms evolved from computing needs are applied to the study of atomic data, by developing massively parallel codes using OpenMPI and using distributed file systems.

Evolution of human resources

Current members:
Dr V Stancalie
Dr G Buica
Dr M Vatasescu

Dr O Budriga
Drd V F Pais
Drd F A Mihailescu
MSc student A Matea
Former members:
MSc student M Totolici
MSc student N Borontis
Dr F Stokker

International cooperation

1) European Fusion Division Agreement (EFDA): European Task Force for Integrated Tokamak Modeling (ITM TF): AMNS (Atomic, Molecular, Nuclear and Surface Data Project), and ISIP (Infrastructure and Software Integration Project).
2) The IAEA under project F1.30.11 Part of the Agency's Coordinated Research Project (CRP): Pathways to energy from inertial fusion –an integrated approach (2007-2010); Agr16265 Part of the Agency's CRP 'Light element atom, molecule and radical behavior in the divertor and edge plasma regions"(2010-2014)
3) The European Science Foundation (ESF-SILMI)– Super Intense Laser-Matter Interaction (2009-2014) project
4) The EU network COST (EU FP 7), Act. P14: Laser-matter interactions with ultrashort pulses, high-frequency pulses and ultra intense pulses. From attophysiscs to petawatt physics
5) The Atomic Data Analysis Structure International Consortium (ADAS)

Entrepreneurial initiatives

We proposed collaborative works with the private sector towards scientific research by participating in the "Partnerships" competition organized by UEFISCDI.

Team **E13**: Solid-State Quantum Electronics (http://ecs.inflpr.ro/)

Team Leader: Dr. Serban Georgescu

The team is composed of 19 researchers (5 senior researchers Ist rank, 4 senior researchers IInd rank, 2 scientific researchers, 8 research assistants).

Research directions and subjects:

The team has been involved in the investigation of the active materials and emission processes for **coherent (lasers)** and **noncoherent (phosphors, radiation convertors**, etc) photonic sources, based on *solid state inorganic media (single crystals, transparent ceramics, nano and polycrystalline phosphors) doped with transitional elements ions (3d, rare earths – RE)*. The main objective is identification and characterization of new materials and processes and optimization of traditional systems to extend/improve the characteristics of these photon sources: emission wavelength range, efficiency, temporal regime, scaling of functional parameters. This involves correlated complex multidisciplinary activity along several successive stages: (i) technology for the production of active media with desired composition, dopant level and dimensions; (ii) characterization of the structural and general properties; (iii) investigation of the spectroscopic static and dynamic characteristics, (iv) modeling the emission processes in order to choose the active medium characteristics (composition, doping species and concentration), pumping system (wavelength, intensity, etc.) and building of the laser resonator, (v) design and construction of the experimental setup and investigation of emission characteristics. Except the resonator, the steps in realization of noncoherent efficient sources are similar.

The main results of the last five years refer to:

I. Coherent photon sources:

I.1. *Spectroscopic properties of the laser materials*. The investigation was concentrated on trivalent rare earth ions (Nd, Sm, Dy, Ho, Er, Tm, Yb) doped single crystals (garnets, tungstates) and transparent ceramic materials (garnets, sesquioxides) produced by solid-state reaction: (i) comparative investigation of *the variety, nature and relative concentration of dopant ions centers* in crystals and ceramics; (ii) Comparative investigation of the *quantum states* (energy levels, radiative transition probabilities, etc.) of doping ions in the garnet ceramics inferred from high-resolution spectroscopy; (iii) Strong *electron-phonon interaction* effects were evidenced by the temperature dependence of the linewidth of absorption lines of various rare earth ions (Nd^{3+}, Yb^{3+} and so on) in the garnet and sesquioxide ceramics; (iv) *interaction between the doping ions, energy transfer, and conventional sensitization schemes*: the characteristics of the energy transfer were investigated by its effect on the emission dynamics for several systems such as single- or multiple-doped garnet or sesquioxide ceramics; (v) *emission wavelength modification* by (self-)sensitized down-conversion or upconversion by energy transfer was investigated in doped ceramics as function of doping concentration; (vi) *connection between structural, spectroscopic and functional properties* was inferred from the modeling of the laser emission properties and the heat generation of the laser materials.

I.2. *Laser engineering*: (i) Improvement of laser emission performances of Nd-based lasers in thin-disc geometry using the pump with diode lasers directly into the emitting level;

(ii) design and realization of Nd-lasers with simultaneous emission at two fundamental wavelengths.

I.3. *Nonlinear optical (NLO) solid-state laser crystals:* the research team developed new $Ln_{1-x}R_xCa_4O(BO_3)_3$. (Ln = Gd, Y and R = Lu, Sc) crystals, with superior and controllable characteristics for the generation of coherent radiation in the blue – near UV range, using the effects induced by the mixed occupation of the cationic positions. Thus, four types of new NLO crystals ($Gd_{1-x}Lu_xCa_4O(BO_3)_3$, $Gd_{1-x}Sc_xCa_4O(BO_3)_3$, $Y_{1-x}Lu_xCa_4O(BO_3)_3$, *and* $Y_{1-x}Sc_xCa_4O(BO_3)_3$) were obtained and their composition was optimized for highly efficient second harmonic generation (SHG) of some laser wavelengths in NIR spectral range in non-critical phase-matching conditions (NCPM).

I.4. Laser and spectroscopy applications:

I.4.1. Home made broadband THz-TDS equipment based on short pulse (19 fs) Ti:Saphire laser. The THz-TDS equipment was used for studying the collective motion of large proteins, proteins identification by using their THz fingerprints, early skin cancer detection.

I.4.2. Developing of passively Q-switched Nd:YAG/Cr^{4+}:YAG lasers with high peak power, suitable for ignition in an automobile engine. Compact, highly reliable diode pumped solid state laser was developed based on technologies owned by the research team. It was demonstrated that the laser work properly at temperatures over 150C degree without cooling system and the laser dimensions are lower than conventional electric spark plug.

II. Non-coherent photon sources.

New types of nanophosphors based on partially disordered crystals from the langasite family (doped with Eu^{3+} or with Yb^{3+} and Er^{3+}) were synthesized and characterized, besides nanophosphors known as efficient (Er:Yb:$NaYF_4$, Er:Yb:Y_2O_3, Eu:YVO_4). The upconversion phosphors based on Yb/Er-doped materials were synthesized for applications in biology as new fluorescent labels. Spectroscopic properties of erbium-doped partially disordered garnets from the calcium niobium gallium garnet family were also investigated for applications in solar energy conversion.

The achievements of team in 2007-2011 are materialized in **73** scientific papers published in ISI journals, **93** communications in international scientific conferences, 1 Romanian patent (http://ecs.inflpr.ro/journals.html). A large number of the concepts and physical models proposed by the team are considered as reference data in the literature, being cited (286 citations in ISI papers). *As a remarkable achievent we mention the design and construction of the **laser spark-plug** for car engine ignition.*

Interdisciplinary research

Our team participates to a series of interdisciplinary projects concerning the synthesis and application in biology and medicine of a new class of luminescent markers based on upconversion of the IR radiation in visible light, utilization of the THz spectroscopy in early detection of cancer, development of coherent photonic sources with multiple wavelength emission for detection and treatment of tumoral tissues, use of the laser ignition to reduce the pollution of cars, etc.

Evolution of human resources

During this period (2007-2011) four ***PhD theses*** have been presented: **2007:** Lucian Gheorghe: "Les oxoborates non linéaires $Gd_{1-x}R_xCa_4O(BO_3)_3$, R= (Lu, Sc, Nd): croissance cristalline et propriétés optiques"; Octavian Toma: "Upconversion processes in solids doped with rare-earth ions". **2008:** Cristina Gheorghe: "Composition and structure effects of RE emission in crystals and ceramics". **2010:** Ana-Maria Voiculescu: "Luminescence properties

of rare-earths-ions-doped oxidic phosphors. Applications.”. 5 ***Master dissertations***: **2009:** 1 (Stefania Hau); **2010:** 4 (Brânduş Cătălina, Sandu Oana, Salamu Gabriela, Matei Cristina).
In **2011** three researchers obtained the senior researcher II (Cristina Gheorghe, Lucian Gheorghe and Octavian Toma) and four young researchers were admitted in the doctoral school organized by the Faculty of Physics of the University of Bucharest (Voicu Flavius, Sandu Oana, Salamu Gabriela, Matei Cristina). Post-doctoral positions were obtained by three researchers in 2010 (Gheorghe Cristina, Toma Octavian) and 2011 (Voiculescu Ana-Maria).
In 2010, one senior researcher (T. Dascalu) became PhD thesis advisor.

International cooperation

Collaboration with: “Laboratoire de Chimie de la Matière Condensée de Paris”-LCMCP of the “École Nationale Supérieure de Chimie de Paris”- (ENSCP) - Chimie ParisTech, France (Romania-France bilateral project “New nonlinear laser systems for efficient laser emission in visible and near UV domains”, code 19547QL); Sofia University "St. Kliment Ohridski" (Romania-Bulgaria bilateral project “Development of a novel infrared laser system for applications in chemistry and medicine”, code 455CB/20.10.2010); Institute for Laser Physics, Hamburg University, Hamburg, Germany; Laser Research Center, Institute for Molecular Science, Okazaki, Japan.

Team: **E14** (http://nanolumin.inflpr.ro/)

Multi - Functional organo- inorganic luminescent materials

Team Leader: Dr. Carmen Tiseanu

Team structure

Presently, the team is composed of single member. Dr. Carmen, is a first rank senior researcher with over 20 years of research experience in physics of luminescent materials.

Dynamics of research directions and subjects

During period of 2007- 2011, three new research themes were initiated along with a fourth theme which was started in 2004. Our research targets the structural and electronic properties of broad range of organic and/or inorganic materials doped with lanthanides, namely micro and mesoporous materials, coordination polymers and nanocrystals. A number of 19 articles were published in ISI- ranked journals with overall AIS (Article Influence Score) of 41. From the total of 19 articles, 18 have international co- authors from US and Europe. The Romanian team was /is the principal investigator for all international collaborative research investigations. Dr. Carmen Tiseanu is the first and corresponding author for sixteen articles published in ISI- ranked journals.

Our main research themes are:

I Nanoscintillators for use in radiotherapy. New research theme initiated in 2011.

II. Luminescence processes at the nano - scale. New research theme initiated in 2010.

III. Energy transfer processes in coordination polymers with lanthanides. New research theme initiated in 2009.

IV. Structure-luminescence relationships in micro / mesoporous compounds. Research theme started in 2004.

Most important achievements

I Nanoscintillators for use in radiotherapy. The exciting role of the high – Z nanoparticles in theranostics together with the existence of unique on national scale X-ray irradiation laboratory within INFLPR motivated us to start this theme in 2011. Preliminary work is underway. A project proposal focusing on this theme was submitted to the recent call "Joint Applied Research Projects", November 2011.

II. Luminescence processes at the nano - scale. This research theme is aiming at the description of the structural and electronic effects induced by doping (lanthanides) in single and mixed tetravalent nano - oxides. We recently demonstrated that the temporal evolution of the lanthanide europium emission with increasing temperature in nano- ceria is fully consistent with a progressive diffusion of the dopant ions from the surface to the inner ceria sites. Our results come at variance with literature which sustains the opposite process, namely a partial expelling of the dopant ions from the nanocrystals core to the surface. Also, we proposed the use of the spectrally and temporarily resolved luminescence as a powerful method to reveal for the crystallinity/order effects within amorphous nanostructures.

Dissemination: Two papers were published in 2011 (J.Appl. Phys; Phys. Chem. Chem.Phys.) and several others will be submitted.

III. Energy transfer processes in coordination polymers with lanthanides. This research theme was started in 2009 in collaboration with Prof. M. Andruh from the University of Bucharest and includes investigation of (i) linear and non-linear photophysical properties and (ii) sensitization processes in several heterodinuclear complexes with lanthanides and transition metals. We found that the relative energetic position of the triplet levels and ligand-

to metal charge-transfer band to the europium emissive levels are responsible for the lack of the antenna effects reported for most of its complexes with bi- compartmental Schiff-bases. Also, we evidenced for the first time two-photon emission in Zn- lanthanides heterodinuclear complexes.
Dissemination: Four papers were published during 2010- 2011 (Inorg. Chem; Cryst. Cryst. Growth. Des., Polyhedron).
IV. Structure-luminescence relationships in micro/mesoporous compounds. This research theme was started in 2004 in collaboration with Prof. V. I. Parvulescu from the University of Bucharest. Several novel zeolites and double hierarchical micro - mesoporous materials with lanthanides were investigated with focus on the hydrophobization and surface modification with organic ligands and ionic liquids on the surface/ pore distribution as well as emission and excited states dynamics of the lanthanides. Due to the highly heterogeneous nature of these materials, a more complex modeling of the typical non-exponential excited- states dynamics of lanthanides, different from that based on discrete emissive species was proposed. Our approach may be applied to the comprehensive description of *species-related* luminescence-structure relationships in lanthanide –doped materials with heterogeneous distribution.
Dissemination: A number of 13 papers were published during 2007- 2010 (J. Appl. Phys.; J. Phys. Chem. B(C); Phys. Chem. Chem. Phys, Langmuir. J. Nanosci. Nanotech., etc.).
IV. Infrastructure. The current infrastructure and its extension approved for 2012 enable the foundation of unique laboratory at the national scale, dedicated to the temporally and spectrally resolved UV/Vis to NIR luminescence of multifunctional inorganic or/and organic compounds.

Interdisciplinary research. The research conducted by us during 2007- 2011 has a strongly interdisciplinary character as it covers up-to-date fundamental and experimental research topics related to the structural and electronic effects induced by doping, surface and confinement phenomena, optically and X-ray induced luminescence mechanisms, excited-states dynamics modeling, (intramolecular) energy transfer processes and emission quenching mechanisms. As the investigated compounds encompass a wide range of complex organic and/or inorganic materials, our team initiated several research collaborations with chemists from Romania, US and Europe.

Evolution of human resources
The one - member team will be extended thanks to the funding of our in - going project PCE Ideas 305/ 2011- 2014. One full- time assistant researcher will be employed whereas one PhD will work part time on the whole period of the project. If the project we proposed within the recent call “Joint Applied Research Projects” will be selected for funding, the team will be further expanded with one temporary research assistant position.

International cooperation. Our team conducted collaborative research with groups affiliated to research institutes and universities from US (Columbia University), Spain (Universitat Autonoma de Barcelona and CIBER en Biotecnología, Biomateriales y Nanomedicina), Germany (Institute of Physical Chemistry, Potsdam University), Belgium (Katholieke Universiteit Leuven), Mexico (Centro de Investigación en Materiales Avanzados) and Sweden (Kungliga Tekniska Högskolan, KTH, School of Chemistry). Within collaboration between our team and Potsdam University, Andre Gessner completed in 2010 his PhD thesis entitled “Neuartige Lanthanoid-dotierte mikro- und mesoporöse Feststoffe”. Finally, Dr. Carmen Tiseanu is member of the management committee of COST project EUFEN:European F-Element Network (2011-2015).

Team: E15 (http://pse.inflpr.ro/) Plasma Surface Engineering
Team Leader: Dr. Cristian RUSET

<u>Team structure</u>

The team is composed of 5 researchers (1 senior researcher Ist rank, 2 senior researchers IInd rank, 1 senior researcher IIInd rank and 1 scientific researcher), 1 engineer, 2 technicians and one worker.

<u>Dynamic of research topics and objectives</u>

During the reporting period, the activity of Plasma Surface Engineering (PSE) team was focused on the following main subjects:

a) Investigation on the physical and chemical processes occurring during the Combined Magnetron Sputtering and Ion Implantation (CMSII) deposition technique.
b) Development of a tungsten coating technology of carbon based materials for the first wall in nuclear fusion devices
c) Development of a combined laser alloying and plasma nitriding treatment for service lifetime increase of the forging dies
d) Tokamak neutron diagnostics based on the superheated fluid detectors (SHFD's).

A brief report on these activities and on the results obtained is given below.

a) During the last years CMSII technique was developed from laboratory to industrial scale and it proved its superiority over the conventional deposition techniques in a few particular applications. This method involves superposing of three low pressure electric discharges, namely: (i) the magnetron discharge which produces the metallic atoms (and ions) used in deposition process, (ii) the DC discharge induced by substrate bias (-70V ÷ - 800V) and (iii) the high voltage pulse discharge between the substrate and the ground electrode (-30 kV ÷ -70 kV; $\tau \approx 20$ μs; f = 25 Hz). This complex plasma has been investigated using electrical probes, emission spectroscopy and a retarding field analyzer. A special attention is been paid to the interaction between the plasmas produced by two adjacent magnetrons. It is clear that the ions striking the coating during its growth have energies near to that corresponding to the bias potential applied to the substrate; little energy is lost by collisions. Another important result of this investigation concerns the internal stress induced in the coatings during their growth. It seems that this stress is higher in front of the magnetrons and lower between magnetrons. A way to reduce the high internal stress in the coatings has been found and this is very important from the application point of view of this technique,

The influence of magnetron target on plasma and coating characteristics have been investigated as well. In this respect, various coatings such as VN, VNC, VC, ZrCN, N-alloyed stainless steel, nc-WC_{1-x}/a-C have been produced and characterized. Special attention was given to the nano-crystalline tungsten carbide imbedded in an amorphous carbon matrix. This kind of coatings has a large potential for application in automotive industry to reduce the fuel consumption and toxic emissions and to increase the engines efficiency. The metal carbide crystallites ensure the wear resistance while the amorphous carbon provides a low coefficient of friction.

b) In a plasma fusion device with magnetic confinement the temperature in the core plasma is in the range of 50-100 millions Celsius degrees. Under these conditions the surface temperature of the first wall can reach in some areas 2,000 °C. There are not too many materials which can be used for such application. Currently, the primary ITER (International Thermonuclear Experimental Reactor) materials choice is a full beryllium main wall and tungsten at divertor, but this combination was never tested on a tokamak. In order to do this, a big project entitled "ITER like Wall - ILW" was lunched at JET (Joint European Torus) with the objective to replace the CFC (Carbon Fiber Composite) wall with a new one similar to that designed for ITER. JET is the biggest operational tokamak in the world. In the R&D phase of the ILW project, **as a result of a tough**

competition between five EURATOM Associations from Germany, Italy, France, Finland and Romania accompanied by European companies specialized in W coating of carbon materials, Combined Magnetron Sputtering and Ion Implantation **(CMSII) technology proposed by MEdC (Romanian EURATOM Association) was chosen for W coating with layers of 10 μm of about 1,000 CFC tiles for the ILW.** Tungsten coatings of 10 μm deposited on CFC reference samples by CMSII **were the only ones which survived without delamination to high heat flux tests** (HHF) (T≤2,000°C) carried out at Max-Planck Institute for Plasma Physics (IPP) from Garching, Germany.

The reference samples were coated by CMSII method using a small experimental unit (Φ300x420 mm) with one magnetron. The task for JET was to coat about 1,000 CFC tiles of different shapes and dimensions during one year. This could not be done with the small unit.

In two years (2007, 2008) an Industrial CMSII coating unit was designed, manufactured and commissioned. The deposition chamber (Φ0.8 x 0.75 m) is equipped with 24 magnetrons with a total power of 25 kW. A picture of the unit is shown in Fig.1.

The transfer of the CMSII technology from a small chamber with one magnetron to a chamber with 24 magnetrons was a very difficult task mainly due to the interaction of the plasmas produced by two adjacent magnetrons. At the beginning of 2009, due to serious technical problems associated with the production of 200 μm of W on real CFC tiles by Vacuum Plasma Spray technology, CMSII technique was extended to 20-25 μm. This thickness was designed for divertor tiles where the erosion rate is higher than in the main chamber of the tokamak. After passing the qualification tests, a number of about 800 tiles was added to those 1,000 tiles which had to be coated with W.

A quality management system in accordance with ISO 9001:2001 standard and additional JET requirements was developed and implemented in PSE laboratory. In 2009 and 2010 about 1,800 CFC tiles were coated with W layers of 10-15 μm and 20-25 μm for the ILW project and delivered to JET. The biggest tile was G7 divertor tile with approx. dimensions 370 x 170 x 50 mm (Fig.1). The project is finished.


Fig.1 CMSII industrial coating unit and a load of CFC divertor tiles coated with 20 μm of tungsten

The above mentioned activity was carried out between 2007 and 2010 in the framework of the EURATOM program. The partners were MEdC, IPP Garching, and FZ Juelich from Germany and JET from UK. The value of the works for INFLPR was **EUR 846.680**.

This was a very complex project involving research, development and production activities in one project.

c) During the operation of a forging die its active surface is subjected to intense mechanical, thermal and chemical stresses. This leads to a limited service lifetime. The current surface treatment for the forging dies is nitriding (gaseous or plasma) or salt bath nitrocarburising. In both cases the diffusion, zone which is responsible for fatigue resistance, has a depth of 50-300 μm depending on the type of steel and on the treatment parameters. A combined laser alloying and plasma nitriding was developed in the framework of the project "Computer-aided laser surface treatment and combined nitriding of forging dies with the objective of a lifetime increase – CURARE" financed by the European Community in the FP7 Specific Programme "Capacities" – Research for the benefit of SMEs. The consortium included two research organizations (Fraunhofer Institute for Production Technology – IPT Aachen, Germany and INFLPR) and 7 SMEs from Germany, Italy, Portugal and Slovakia. The laser treatment was carried out at IPT and the nitriding in Romania and Italy. The analysis of the samples treated by laser alloying with WC-Co-Cr powder followed by plasma nitriding was performed at INFLPR. The laser treatment parameters were optimized in accordance with these results. *The main innovation of the project was producing below the nitriding layer of a laser alloyed zone of 0.6-0.8 mm with a hardness of 700-800 HV. This zone significantly increases the fatigue resistance of the surface layer and consequently the die lifetime.* The tests of the treated dies carried out by the companies from the project under industrial conditions have shown an increase of the service lifetime by 50-100% in comparison with that of the same dies treated by standard nitriding.

d) A 36-detector neutron spectrometer based on small superheated fluid detectors was designed, manufactured and successfully tested on JET tokamak in high performance (high neutron yield) discharges. It provided valuable data (absolute calibrated) on the spatial distribution of the neutron fluence (resolution of the order of one cm) and on the energy distribution of the neutron emission over a broad energy range (10 keV to 20 MeV).

Interdisciplinary research

Almost all the activity carried out by the team involves an interdisciplinary character by combining plasma physics with material science particularly physical metallurgy. The CMSII technology developed in the group during the last 10 years is a result of the interdisciplinary research of plasma physics and material science. The combined laser alloying and plasma nitriding technology is also a result of the research in the field of laser and plasma applications.

Evolution of human resources

The main achevment of the team concerning development **of CMSII technology from laboratory to industrial scale** and **succesful application of this technology for the biggest tokamak in the world** was possible by a very hard work and dedication of the team members. This project was carried out by 7 persons with complementary qualification as follows: 1 scientist, team leader (plasma physics), 1 scientist (material science), 1 engineer specialized in electronics, 1 mechanical engineer, 2 research technicians (mechanical and electronics) and 1 worker. In 2010 the team was increased with 3 persons, a senior scientist 2nd degree and a young scientist specialized in plasma diagnostics and a senior scientist 3nd degree specialized in image aquisition and processing. There were two promotions (from CS3 to CS2 and from AC to CS) and one member started PhD sdudies. Unfortunately the mechanical engineer died in 2011 at the age of 54.

International cooperation

The main activity of the team is carried out in the framework of FP7-EURATOM program in cooperation with CCFE (Culham Center for Fusion Energy), UK, IPP (Max-Plank Institute for Plasma Physics, Garching, Germany, FZ Jülich, Germany, CEA France, ENEA Italy, TARTU Estonia, etc. Five projects were finalized and three projects are ongoing in this program.

At the same time a very good cooperation was carried out with the Fraunhofer Institute for Production Technology IPT, Aachen, Germany in the framework of FP7-Research for SME Program.

Entrepreneurial initiatives

In addition to the research activity, some activities on commercial bases are carried out by the PSE team. These concern W coating of fine grain graphite tiles for ASDEX Upgrade tokamak, Garching, Germany (over EUR 150,000) and plasma nitriding of various mechanical components mainly for plastic industry (about EUR 10,000/year).

Team E16: Plasma Chemistry and Advanced Functional Materials (http://ped.inflpr.ro)
Team Leader: Dr. Nicolae Bogdan Mandache

Team structure

The team is composed of 5 researchers (3 senior researchers Ist rank, 1 senior researcher IIIrd rank, 1 scientific researcher) and 1 technician.

The team is active in the following two main research directions:

1. Advanced functional materials
2. Non-thermal plasma for environmental applications.

Dynamic of research directions and subjects

1. Advanced Functional Materials

This research activity started with the design, build-up and optimization of a pulsed electron beam source for the growth of thin films (the pulsed electron beam deposition method, PED). This growth technique was built-up for the first time in Romania and has features similar with the pulsed laser deposition (PLD) but uses a pulsed electron beam instead of a laser beam.

The aim of this research direction is to explore and develop an original approach for the growth of advanced functional oxide thin films with physical properties which could give rise to potential applications. Thus, the scientific activities of the team were focused on the use of the PED method for oxide thin films growth with a good control of the surface morphology, cationic composition, oxygen stoichiometry and crystalline structure of the films. In particularly, the growth of complex oxide thin films with different functional physical properties was performed, with special attention paid to the epitaxial growth of oxide thin films on single crystal substrates. Interesting results were obtained for ZnO and ITO films on c-cut sapphire and MgO single crystal substrates.

Recently, nanocomposite oxide thin films were grown by PED method. Also, transparent thin film transistors were developed by PED using various oxide thin films

2. Non-thermal plasma for environmental applications

Regarding this research direction, the team was involved in studies related to the decomposition of various pollutants in air and water using non-thermal plasma. Recent results are related to electrical discharges generated at the interface between gas and liquid, aimed at the degradation of organic pollutants in water. The studies have been recently extended to the degradation of pharmaceutical compounds in water. Pharmaceuticals are of special concern due to their large variety and high consumption over the past years and to their persistence in the environment, since their presence in water can have potential health effects on humans and may also affect aquatic organisms in an unpredictable way. Several beta-lactam antibiotics and pentoxifylline have been investigated.

The other topic of interest is related to the combination between non-thermal plasma and heterogeneous catalysis aimed at the total oxidation of volatile organic compounds (VOC) in air. Dielectric barrier discharge reactors and packed-bed reactors have been used with various catalysts placed either directly in the plasma region (in-plasma configuration) or downstream of the reactor (post-plasma configuration). High values of the VOC conversion can be obtained in plasma, however the process is rather unselective and other harmful by-products may be formed. The addition of catalysts was found to improve the conversion and especially the selectivity towards total oxidation, even at low temperature, below the threshold for thermal activation of the catalysts. The study of the reaction mechanism provided new insight into the processes responsible for VOC decomposition in plasma-catalytic hybrid systems.

Most important achievements

1. Advanced Functional Materials

One of the most interesting results obtained during this period was to put in evidence a metal-semiconductor transition (MST) in epitaxial un-doped ZnO thin films grown by PED on c-cut and MgO single crystal substrates. The interpretation of this MST in the frame of the quantum corrections to conductivity in disordered oxides was addressed and correlated to the growth mechanism by PED. A better understanding of these mechanisms was obtained by the *in situ* diagnostics (fast imaging, optical emission spectroscopy, Langmuir probes) of ablation plasma produced at the pulsed electron beam interaction with the target.

Largely oxygen deficient indium tin oxide thin films (more than 20% oxygen missing) grown by PED lead to the synthesis of nanocomposite films, i.e. metallic (In, Sn) clusters embedded in a stoichiometric and crystalline oxide matrix. The presence of these metallic clusters induces specific transport properties, i.e. a metallic conductivity via percolation with a superconducting transition at low temperature (about 6 K) and the melting and freezing of the In-Sn clusters in the room temperature to 450 K range evidenced by large changes in resistivity and a hysteresis cycle.

Field effect transparent thin film transistors (TTFT) were developed using Y_2O_3 or Al_2O_3 as gate insulators. Depending on the growth parameters, ZnO and In_2O_3 transparent films, with controlled electrical properties, either semiconductor for the channel or conductive for the electrodes of the TTFTs were grown by PED. The electrical characteristics of these transistors are comparable to the results reported in the literature.

In this period, we published 12 articles in ISI journals on this research direction and attended international conferences with 10 posters, 6 oral presentations and 2 invited talks. Four seminars were presented at foreign universities.

- Co-organization of the Symposium R "Laser processing and diagnostics for micro and nano applications" at European Materials Research Society (EMRS) Spring Meeting 2010 (M.Nistor).

- Special Issue Guest Editor of the Proceedings of the EMRS 2010 Spring Meeting Symposium R "Laser Processing and Diagnostics for Micro and Nano Applications", Applied Surface Science (Elsevier), Vol. 257, Issue 12, Pages 5125-5470 (2011), Edited by R. W. Eason, M. Nistor, J. Perriere, J. Solis and I. Zergioti

- Co-organization of the French-Romanian Workshop: „Growth and functional properties of thin films and nanostructures" during the EMRS Spring Meeting 2009, Strasbourg, organizers: INFLPR (M.Nistor) and Universite Paris 6, France (Dr. J.Perriere), with the financial support of E-MRS and French Embassy in Romania.

2. Non-thermal plasma for environmental applications

Promising results regarding the abatement of water pollutants have been obtained using an optimized discharge reactor with the purpose of decomposing organic dyes in water: the degradation efficiency achieved is higher by an order of magnitude than the values previously reported in the literature. It should be also mentioned that the results reported by the team are among the first publications addressing the degradation of pharmaceutical compounds using plasma. During 2007-2011 the team published 5 articles in ISI journals on this subject, which accumulated 17 citations and presented 11 contributions at international conferences.

The combination between non-thermal plasma and appropriate catalysts was found to improve significantly the decomposition of organic pollutants in air and especially the selectivity of the process towards total oxidation, particularly at low catalyst temperature. During 2007-2011 the team published 5 articles in ISI journals on this subject, which accumulated 50 citations and presented 9 contributions at international conferences. A book chapter "Plasma-assisted NOx abatement processes: A new promising technology for lean conditions?" (M. Magureanu, V. Parvulescu) was published in "Past and Present of DeNOx Catalysis" (editors P. Granger, V.I. Parvulescu – Elsevier, 2007). Another book chapter "VOC removal from air by plasma-assisted catalysis – experimental work" is presently in the production process and will appear in 2012 in "Plasma Chemistry and Catalysis in Gases and Liquids" (editors V. Parvulescu, M. Magureanu, P. Lukes – Wiley).

During 2007-2011 a total of 22 ISI articles were published by the team on the two main research directions.

Interdisciplinary research

1. Advanced Functional Materials

This research is multidisciplinary covering topics in physics, material science, chemistry and nanoscience. As a result the team developed a long-standing collaboration with researchers experienced in material science and nanoscience (INSP, Universite Paris 6), chemistry (ICMCB-CNRS, Bordeaux) and laser and plasma engineering (GREMI, Universite d'Orleans).

2. Non-thermal plasma for environmental applications

The character of this research is inherently interdisciplinary, being situated at the border between physics and chemistry. Therefore, the team developed a long-standing collaboration with researchers experienced in analytical chemistry and catalysis from the Faculty of Chemistry of the University of Bucharest. The team also benefited from a cooperation with the Group of Catalytic Reaction Engineering from EPFL Lausanne during a joint research project (SCOPES) on this topic.

Evolution of human resources

A student was employed in the research team in 2007 after graduating the Faculty of Physics. She finished her master degree classes in 2009 (title of dissertation: "Decomposition of organic pollutants in water and air using a dielectric barrier discharge") and is now PhD student (title of PhD thesis: "Study of non-equilibrium plasma in combination with heterogeneous catalysis for the decomposition of organic pollutants in air and water").

M. Nistor was CNRS associated researcher for 3 months in 2007 and since 2008 as invited researcher at INSP, Université Pierre et Marie Curie (Paris 6).

During this period three members of the team became scientific researcher I.

International cooperation

- Scientific collaboration with Dr. J. Perriere within a French-Romanian project Brancusi (2007-2008) and a scientific cooperation agreement (2010-2015) in nanoscience and materials between NILPRP and INSP, Université Pierre et Marie Curie-Paris 6
- Scientific collaborations with Dr. A.Rougier (ICMCB-CNRS, Bordeaux) and Prof. E.Millon (GREMI, Universite d'Orleans)
- Group of Catalytic Reaction Engineering, EPFL Lausanne (joint research project SCOPES "Innovative Reactor Combining Plasma and Structured Catalysts for the Destruction of Industrial Pollutants", 2005-2008)

Team: E17: **Microtomography and Image Processing** (http://tomography.inflpr.ro/)

Team Leader: Dr. Ion TISEANU

Team structure

The team is composed of 2 researcher (1 senior researchers Ist rank, 1 senior researcher IInd rank, 1 scientific researcher, 1 research assistant) and 1 technician.

Dynamic of research directions and subjects

Since 2000 our group has been responsible for the design and fabrication of a prototype of an X-ray microtomography facility suitable for operation in the (*International Fusion Materials Irradiation Facility)* IFMIF test cell environment. This task was successfully accomplished: *(*EFDA Fusion Newsletter*, 3-D X-ray Microtomography at MEC Romania, Vol. 2003/6, December 15, 2003).*

Currently the microtomography group operate two X-ray imaging facilities which were completely designed and constructed within our laboratory:

A. **NanoCT** – an X-ray submicron resolution computer tomograph

Upgraded and commissioned during 2007-2008, the system is equipped with a high performance Nanofocus X-Ray source for non-destructive inspection. The source is operational in micro- or nano-focus regime in which case it is capable of sub-micron feature recognition, at a tube voltage up to 225 kV and a maximum power of 10÷20 W. X-Ray images can be acquired by using three different high resolution detector types: Image Intensifier (768x576 pixels of 132x132 µm2) for rapid non-destructive examinations and two CMOS flat panels (pitch size 48 and 75 µm) as very high resolution 2D imaging detectors. A high energy, line detector (pitch size 400 µm) is employed for the slice by slice scanning of high density samples. Positioning and turning around of the sample are ensured by a set of seven high precision motorized micrometric manipulators. Automation, control and data acquisition were obtained by means of an in-house software package. The tomographic reconstruction for the cone-beam scanning is based on an optimized implementation of the modified cone beam filtered back-projection algorithm. Using a parallelization technique on multiprocessors workstations, experimental data consisting of several hundreds of large radiographic images (1220x1216 pixels) are processed for building the 3D reconstructions of typically 1024x1024x1024 voxels in less than 10 min.

B. **Tomo-Analytic** – a combined X-ray microbeam transmission/fluorescence system for 3D morphology characterization and composition mapping

Tomo-Analytic (commissioned in 2008) is an innovative concept of 3D morphology and composition mapping instrument completely developed by our group. The 3D-CT component is configured to take several hundred highly resolved (48 µm) radiographic views of the object in order to build a 3D model of its internal structure. 2D slices through this volume can be viewed as images, or the 3D volume may be rendered, sliced, and measured directly. For the NDT inspection of miniaturized samples the microtomography analysis is guaranteed for feature recognition better than 15 µm. The key element of the XRF component is a policapillary lens which provides a focal spot size around 15-20 micrometers. Also a significant increase of X-ray intensity (up to three orders of magnitudes) is obtained. This guaranties higher detection sensitivity and shorter measurement time. The main limitation consists in the possibility to investigate relatively thin samples. The implementation of a confocal geometry realized with the attachment of a polycapillary conic collimator to the X-ray detector further allows the extension of capabilities of the instrument towards fluorescence tomography (3D composition mapping).

Main applications of our X-ray imaging techniques

I. Non-destructive analysis in fusion technology

- Assessment of the structural integrity of a prototypical instrumented IFMIF high flux test module rig. 3-D tomography is accepted as the official inspection procedure.

- Tomography measurements with very high space resolution (up to 2.5 microns/voxel) on relatively large sample volumes (up to 5x5x5 mm3) were performed at the NanoCT facility
- A new procedure for the quantitative evaluation of the CFC porosity factor by post-processing of the 3-D computed tomography images has been applied. Porosity factors for all fusion technology relevant CFC materials and multilayer SiC were evaluated.
- Non-destructive analysis of bonding technologies for CFC and SiC/SiC materials to heat sink components (ex. brazing of N11 CFC to Cu in the Tore Supra tokamak)
- Non-destructive analysis of metal coated/impregnated composite materials. The 3D reconstructed model of the infiltrated metal can be used as input data for the evaluation of the thermal properties of the CFC – heat sink assembly.
- Our combined absorption/fluorescence X-ray technique offers a fast and nondestructive method which allows the quantitative determination of the thickness of a tungsten coating on a carbon material on large areas. The method is currently used to determine 2D erosion mapping of metal coated graphite/CFC tiles from ASDEX Upgrade and JET tokamaks.

II. Microtomography on superconductor materials: bulk, wires and cables

Another relevant topic concerns the tomographic analysis of superconducting wire and cables (Nb3Sn, NbTi and MgB2).

- We proved that X-ray micro-tomography permit the non-destructive reconstruction of the 3D image of the Nb3Sn ITER-type multifilamentary wire enabling the determination of the number of inter-filament contacts on unite lengths well as the twist-pitch parameter.
- We applied microtomography visualization to MgB_2 bulks, tapes and wires. This provides powerful and unmatched information by the conventional microscopy techniques on the local 3D density uniformity and distribution, connectivity, search and identification of the macrodefects, 3D-shape details of the macro defects and of the components from the composite MgB_2 wires or tapes, on the roughness and perfection of the interfaces between the components.
- Our group has won a Fusion for Energy cotract to perform the quality control monitoring of NbTi strands and conductors for JT 60 SA tokamak.

Image reconstruction and processing for fusion plasma diagnosis

Gamma and neutron tomography for JET plasma diagnostic: A package of tomographic reconstruction methods were developed for JET plasma diagnosis. The methods are able to deal to severe limited data sets provided by JET neutron cameras, a unique instrument among similar diagnostics available at large fusion research facilities. The reconstructions are useful for the study the thermal and beam-induced sources of neutron emission and to analyze the evolution of fast ion populations.

Image processing methods for fusion plasma diagnosis: An optical flow method was developed for and is applied of several fusion plasma relevant issues, including plasma wall interactions. The method is able to provide good results for JET fast-visible camera images which can be affected by saturation, discontinuous movement, reshaping of image objects, low gray-level in-depth resolution. Significant experimental cases concerning pellet injection, plasma filaments and MARFEs are analysed. The method is able to provide the real velocity for objects moving close to structures.

Most important achievements

- Development of the X-ray advanced imaging instruments operated in our laboratory.
- Development of the official inspection procedure for the assessment of the structural integrity of an instrumented IFMIF high flux test module rig.
- Consistent evaluation of porosity factors for all fusion technology relevant CFC materials and multilayer SiC.
- Development and application of a high productivity method for the 2D erosion mapping of metal coated graphite/CFC tiles from ASDEX Upgrade and JET tokamaks.
- Novel image processing methods for fusion plasma diagnosis: An optical flow method was developed for and is applied of several fusion plasma relevant issues, including plasma wall interactions.

Interdisciplinary research

Our work involves close cooperation with material scientists, surface engineering experts as well as geologists or more recently medical engineering and biology specialists.
A short list of interdisciplinary topics:

- Complete morphology and mineral composition characterization of granite samples of the candidate nuclear waste repository by X-ray tomography and microbeam fluorescence.
- Reverse Engineering of Cardiovascular Devices: mechanical valves and carotid stents were scanned by X-ray microtomography in order to provide the accurate 3D CAD model necessary in numerical modeling and simulations
- Treatment of Acid Mine Drainage: Column experiments and X-ray microtomography for determination of variation in porosity and secondary mineral precipitation.

Our strategy is to introduce X-ray imaging methods to new fields like chemical engineering, geology of biomedical. In this regard we have combined our forces with a leading institute of biology in order to construct a "*High-resolution, small animal radiation research platform with fully 3D X-ray tomographic and microbeam fluorescence/luminescence guidance capabilities*". The main objective is to deliver to the Romanian biomedical community involved in oncology and radiobiology research, an open access platform for in vivo 3D investigation of tumors in animal models and nanoparticles (NPs) enhanced radiation therapy. Irradiation of high-Z NPs targeted and delivered to tumor cells results in physical and biological processes that may be exploited efficiently for both imaging and therapy (theranostics).

Evolution of human resources

The core members of our team have an experience of almost 30 years between them in the field of tomography algorithms, scaning configurations and image processing. Recently, we've hired two young engineers to support the continuous upgrading activity but also to offer high value added services to research and industry. We estimate the need for an additional physicist in the next years.

International cooperation

Collaborations with research institutes and universities

- Max-Planck-Institut fuer Plasmaphysik, Garching, Germany
- Institut fuer Energie und Klimaforschung – Plasmaphysik, Forschungszentrum Juelich GmbH, Germany
- JET Culham, UK
- Forschungszentrum Karlsruhe, Germany
- National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan
- ENEA - Frascati Research Center, Italy
- CEA Cadarache, France
- Institute of Nuclear Technology and Radiation Protection, N.C.S.R. "Demokritos", Athens, Greece
- Institute of Environmental Assessment and Water Research, IDAEA, CSIC, Barcelona, Spain

Collaboration with industry

- Hans Wälischmiller GmbH (HWM), Germany: as scientific advisor I. Tiseanu has assisted the company in all areas related to radiation physics, tomography scanning configurations, reconstruction software design and implementation. Among numerous projects implemented are the X-ray tomographs of : Audi AG Neckarsulm, Eurocopter and EADS Munechen, Toyota Poland, Kytek Corea and FH Wels, Austria.
- Uni-Hite System Corporation, (UHS) Japan: in UHS I. Tiseanu have participated at the development of a new image reconstruction method and device by oblique view cone beam tomography (OVCB-CT). Based on these inovations protected by two patents, tens of eucentric OVCB systems were sold to major japanese companies: Japan Texus Instruments, Toshiba, Mitsubishi Electric, Kawasaki Electronics, Hitachi, Pioneer, Pentax, Mitsubishi Motors, Nissan, Sony, Fuji Electrics, Yazaki, Canon, Matsushita AVC, Matsushita Kotobuki, Senju Metalics.
- RayScan GmbH, Germany is the succesor of HWM company. One of the main project I. Tiseanu have participated in RayScan was the design and construction of a mobile CT-System for in-situ

inspection in the LHC at CERN. The key role is played by the limited angle scanning and tomography reconstruction.

Entrepreneurial initiatives

- Recently, we have hired two young engineers to support our offer of high value added services to research and industry.
- We conduct a service contract with Fusion for Energy for the performance of quality controls in support of an in-dept monitoring of the NbTi TF strand and TF conductor production for JT-60SA.
- We offer training services for laboratory CT.

Team E18: Atomic Particle Trapping and Frequency Standards Group (APTFS) (http://aptfs.inflpr.ro/)

Team Leader: Dr. Ovidiu Stoican

Team structure

The team is composed of 4 researchers (1 senior researcher IInd rank, 2 senior researchers IIIrd rank, 1 scientific researcher), 1 technician.

Dynamic of research directions and subjects

Within the APTFS group, new technologies and fundamental theoretical approaches in this area are being pursued, focused on three main areas of research:

1. Trapped Ion Physics and its emerging technologies (quantum physics, quantum optics and high resolution spectroscopy with ion traps, electrodynamic traps operating in standard temperature and pressure conditions)
2. Plasma Physics (plasma sources operating at atmospheric pressure, interaction between plasma and electromagnetic field)
3. Intense Laser Pulse Physics (obtaining micrometer and sub micrometer sized granular targets by using quadrupole trap technology and study their interaction with intense laser pulses).

In the future, based on the results already obtained, we intend to extend our research by adding the following topics:

- Investigations on trapping and cooling of charged particles on different scales and development of new methods and techniques for ion detection. Studies performed together with the National Institute For Materials Physics (INFM-NIMP) for realization of planar (2 D traps), using the state of the art facilities located in NIMP, such as the existing clean room Spectroscopy with Ba+ ions. Preliminary tests towards the realization of a stabilized laser for high resolution spectroscopy, using a Fabry-Perot resonator.
- Time evolution of the particles (one or two particles) in the ion trap, in the framework of the theory of open quantum systems. The interaction with the thermal bath will be taken into account by considering environment operators linear in the canonical variables of the open system. Estimation of the decoherence time for different ion species. Investigation on ion quantum separability in the presence of a Markovian environment.
- Numerical algorithms and software development regarding simulation of the charged particles motion in quadrupole traps and their interaction with external electromagnetic fields
- The study of the electrodynamic traps as a tool used in environment protection, material and solid state physics.
-In the next three years the team will carry out research activities under the project PN09-II-PCE-2011-3-0958 related to the interaction of plasma formed in capillary tubes with high intensity laser radiation.
-Obtaining micrometer and sub micrometer sized granular targets by using quadrupole trap technology and study their interaction with intense laser pulses. Realization of electrodynamic traps able to confine micrometer sized solid particles and liquid drops, in ultrahigh vacuum conditions, used as targets for intense laser radiation.
-Study of the intense laser radiation effect on the micrometer sized granular solid and liquid targets. Both mechanical and electromagnetic effects will be considered. As laser sources we intend to use the existing facility TEWLAS or the facilities to be realized in the near future (CETAL and ELI). The team was already involved in such kind of researches in the framework of the projects ELI 37N/P1. Also, team members have been involved in the elaboration of the project proposal: *Acceleration of particles using femtosecond multi-terawatt laser pulses and their interaction with solid, gaseous and plasma targets* which has been submitted at projects call COMPLEX EXPLORATORY RESEARCH PROJECTS - PN-II-ID-PCCE-2011-2
-Development of the plasma sources operating at atmospheric pressure, for various practical applications (medicine, environment protection and material processing). Development of novel diagnosis methods for plasma at atmospheric pressure, based on the interaction between plasma and electromagnetic field.

Most important achievements

A. **Trapping of charged particles in quadrupole traps**

The novel concepts of quantum physics and quantum engineering promise to achieve unprecedented levels of precision in metrology as well as testing fundamental physical laws. Late results in trapped ion physics led to unprecedented accuracy in high resolution spectroscopy and mass spectrometry of atomic particles, as well to the most accurate measurements on fundamental constants in physics. There is a constant and large scientific interest towards probing variation of fundamental constants. New and very accurate frequency standards based on trapped ions and atomic ions are the most suited tools for such investigations. The APTFS group is performing researches on issues of large world scientific interest related to the ion traps physics. Group achievements in the field of the charged particles trapping, are internationally recognized and allowed it to join at COST project: Action MP 1001 "*Ion Traps for Tomorrow Applications*". The most important achievements in this filed are:

A1. A method was investigated which enables the construction of an invariant operator based on the Lewis and Riesenfeld approach. The method was applied to the case of an ion confined in a Paul trap, treated as a quantum harmonic oscillator. An invariant operator was associated with the system. The spectrum of the quasienergy operator finally resulted. The eigenvectors of the system were found using the Fock state basis. The result is original.

A2. The quantum Hamiltonian for a boson confined in a nonlinear ion trap was investigated. The expected value of the quantum Hamiltonian on coherent states is obtained. We showed that the equation of motion for the boson results using the time-dependent variational principle (TDVP) and the Hamilton equations of motion. The resulting equation of motion is equivalent to the one describing a perturbed classical oscillator, which is an original result.

A3. We have investigated the axial dynamics of an ion confined in a nonlinear Paul trap. The equation of motion for the ion was shown to be consistent with the equation describing a damped, forced Duffing oscillator. All perturbing factors were taken into consideration in our approach. Moreover, the ion was considered to undergo interaction with an external electromagnetic field. The method is based on numerical integration of the equation of motion, as the system under investigation is highly nonlinear. Phase portraits and Poincaré sections show that chaos is present in the associated dynamics. The system of interest exhibits fractal properties and strange attractors. The bifurcation diagrams emphasize qualitative changes of the dynamics and the onset of chaos. It was our intention to emphasize the fact that trapped and laser cooled ions can be used for studies of integrability and classical, as well as quantum chaos.

A4. We investigated the spectral properties of the Hamiltonian function that describes an ion confined within a nonlinear trap. The Hamiltonian was then particularized to the case of dynamic traps and we introduced algebraic models with the aim to characterize the associated dynamics. The coherent states formalism for dynamic groups and the TDVP are applied in order to study the semiclassical behavior of the confined ion. We deal with the fermionic realization of the Lie algebra of the SU(1,1) group, which we particularized for the case of an ion confined in a combined (Paul and Penning) trap. We inferred the equations of motion for the ion in a semiclassical approach. We suggested an algorithm by means of which we could associate a classical Hamiltonian to the quantum Hamiltonian describing the ion. The classical Hamiltonian implicitly contains spectral information on the quantum system, which means we can dequantify the system using this algorithm, an original contribution.

The original results have been published in: B. M. Mihalcea, *Quantum parametric oscillator in a radiofrequency trap*, Physica Scripta, Vol T 135, 014006 (2009); B. M. Mihalcea, *Nonlinear harmonic boson oscillator*, Physica Scripta, Vol. T140, 014056 (2010); B. M. Mihalcea, Gina Vişan, *Nonlinear ion trap stability analysis*, Physica Scripta, Vol. T140, 014057(2010), B. M. Mihalcea, *Semiclassical dynamics for an ion confined within a nonlinear electromagnetic trap,* Physica Scripta, Vol. T143, 014018 (2011).

A5. Another direction of research was trapping micrometer sized charged particles in electrodynamic traps (quadrupole traps operating at low frequency). Depending on the size and nature of the charged microparticles witch are to be stored, various types of quadrupole traps have been successfully used as a part of the experimental setups aimed to study different materials, liquid drops or microorganisms. Within this field, extensive studies regarding the effect of a low frequency acoustic wave on a microparticles cloud which levitate at normal temperature and atmospheric pressure within an electrodynamic trap. The aim of this experimental approach is evaluating the possibility to manipulate the stored microparticles by using an acoustic wave. That means both controlling their position in space and performing a further selection of the stored microparticles. In the case of a conventional quadrupole trap where electrical forces act, particle dynamic depends on its charge-to-mass ratio Q/M. Because the action of the acoustic wave is purely mechanical, it is possible to decouple the mass M and the electric charge Q, respectively, from the equation of motion. An acoustic wave can be considered as a force field which acts remotely on stored microparticles. The experiments have been focused on the acoustic frequency range around the frequency of the ac voltage applied to the trap electrodes, where resonance effects are expected. Comparisons between experimental results and numerical simulations have been done. The original results have been published in: O. S. Stoican, L. C. Dinca, G. Visan, S. Radan, *Acoustic detection of the parametrical resonance effect for a one-component microplasma consisting of the charged microparticles stored in the electrodynamic trap*, Journal of Optoelectronics and Advanced Materials, 10, 1988 (2008) and O. S. Stoican, *Studies on the Interaction Between an Acoustic Wave and Levitated Microparticles*, in Waves in Fluids and Solids, ed. InTech, ISBN: 978-953-307-285-2.

B. **Plasma source at atmospheric pressure and interaction between plasma and the electromagnetic field**

In the past two years the group has turned his interest to the development of plasma sources operating at atmospheric pressure. Work in this area has resulted in achieving a plasma source supplied by an electrical circuit consisting of two voltage sources parallel connected. The circuit topology enables an easy control of the discharge current and a high efficiency of the electrical energy to plasma energy conversion. By using argon as a working gas, a stable plasma plume up to 8 mm long can be obtained either in a transferred or nontransferred arc mode. The plasma source has been described in the paper: O.S. Stoican, *An atmospheric pressure plasma source driven by a train of monopolar high voltage pulses superimposed to a dc voltage*, The European Physical Journal Applied Physics, 55 , 30801 (2011). Another, scientific results obtained by the group are related to the plasma antenna technology and to the study of the interaction plasma-RF electromagnetic field applied to the plasma diagnose. Plasma antenna technology is interesting for various applications, especially in the areas of the radar technology or digital communication. The researches regarding plasma antennas had three main objectives, namely, RF pulses forming, study of RF radiation due to the discharge switch and the effect of the excitation circuit on the plasma properties. A simple, cheap and reliable method to obtain RF pulses is by inserting the discharge tube in a relaxation oscillator circuit. Thus, discharge tube operates simultaneously as plasma antenna, dc voltage switch and RF switch (O. S. Stoican, *Study of a switched dc electrical discharge operating as plasma antenna*, 18th International Conference on Phenomena in Ionized Gases, ICPIG 2007, July 15-20, 2007, Prague). Also, we studied the influence of the excitation RF field on the dc discharge properties. It was investigated the drift of a discharge tube relaxation oscillator period placed in a low intensity microwave field. A significant variation of the relaxation oscillator period has been observed. The experiments led to the conclusion that even RF fields much smaller than dc field can modify the discharge breakdown voltage. A simple method to detect the microwave fields using discharge tube represents a side application of this work. This method is described in: O. S. Stoican, *Period shift of a discharge tube relaxation oscillator due to a weak microwave field*, Japanese Journal of Applied Physics, 48, 070218 (2009).

Interdisciplinary research

1. Experimental and theoretical research performed by the group, in recent years, related to the interaction between stored ions and laser radiation in order to achieve laser cooling and/or optical pumping requires a comprehensive approach in the areas of the quantum physics, laser physics and ion trap technology. Laser-cooled ions in Paul traps form the basis of one of the most promising and advanced experimental realizations of a quantum information processor.
2. Trapped atomic or molecular ions allow the study of individual quantum systems (or controlled ensembles of them) in a quasi-perturbation-free environment. These highly controlled samples constitute the quantum sensors which are at the basis of tomorrow's most advanced technology. Applications with enormous impact include frequency metrology, the development of new frequency and time standards, high-accuracy measurements of fundamental constants, quantum information, atomic and molecular spectroscopy, high-precision determination of atomic ground state properties (mass, life-time, spin, etc.), study of non-neutral plasma, cavity QED experiments as well as the production and reaction dynamics of cold molecules.
3. The objectives of the ion trapping research are spread over a large range of topics throughout atomic and molecular physics, nuclear physics, plasma physics, and chemistry for various applications including ultrahigh-resolution spectroscopy.

4. Nonlinear phenomena associated to the action of an acoustic wave on the charged particles stored in an electrodynamic trap
5. During above described research it was necessary to build certain equipments and devices related to the applied electronics field which cannot be acquired from commercial providers. The most important were: various gate dip meter and autodyne circuits, system for the RF pulses frequency measurement, system based on optical and laser beams used to isolate galvanically the various equipment stages, high voltage power supplies. The original results have been published in O. S. Stoican, *Galvanic isolated voltage source using a single photodiode*, Review of Scientific Instruments, 81, 046102 (2010).

Evolution of human resources

-Dr. Ovidiu Stoican, who was involved in the research projects mainly targeted to the field of the electromagnetism, especially, related to the interaction between the electromagnetic field and charged particles. Research topics approached by Dr. O. Stoican during his career include: low pressure radiofrequency gas discharges obtained by an inductive coupling between RF generators and plasma, hollow cathode arc discharge used as an intense optical radiation source, plasma sources at atmospheric pressure, Paul trap operating in ultrahigh vacuum conditions and trapping of Ba+ ions, electrodynamic traps operating at atmospheric pressure aimed to store macroscopic particles (powders), record of NQR spectra using superregenerative receiver and marginal oscillators, and various applied electronics projects related to the detection of the low level RF signals in noisy environments and development of high voltage power supplies.

-Dr. Bogdan Mihalcea is basically a physics engineer, with experience in the domains of trapped ion physics, electronic physics, plasma physics, quantum optics and quantum physics. His research activity was targeted on the following main directions: ion trapping in ultrahigh vacuum conditions of Ba+ ions in quadrupole Paul traps, microplasma generation in electromagnetic fields (new trap geometries, design and realization of d.c and high voltage a.c. power supplies; design and production of miniaturized setups, both quadrupole and linear multipole geometry for charged microparticle trapping in air), classical and semiclassical study of the dynamics of trapped ions and microparticles generated in electromagnetic fields and of the chaotic and regular motion regimes, both analytically and numerically (computer simulation), preliminary researches aimed on realizing an atomic time-frequency standard based on laser-cooled trapped ions, hydrogen maser and various applied electronics projects.

-Dr. Cipriana Mandache. Her field of expertise lies in all domains connected to the opto-kinetical manipulation of atoms, in particular quantum and classical optics using solid state diode lasers and optical fiber technology. More precisely, her work was concerned with the design of optical benches used in the characterization of laser diodes, their spectral width, their frequency and intensity noise; atom laser cooling; trapping of atoms in magneto-optical traps; study of static Stark effect in atomic fountains; characterization of atomic ensembles cooled by laser radiation (atomic molasses). She has also supported these experimental studies by means of several theoretical analyses.

- PhD student Gina Visan, mathematician, is specialized in computer simulation of the phenomena related to the ion traps, laser and plasma physics.

-Stefan Radan, technician, who is able to perform both electrical and mechanical works.

The group members are highly skilled in key domains of physics and interdisciplinary research such as: ion trapping physics, magneto-optical traps, plasma physics and processes, analog and digital electronic design (including RF and low microwave range), time and frequency standards, programming and numerical simulation languages (C++, VisualBasic, Mathematica, Maple, SciLab), network administration (CCNA), etc. Based on current scientific interests and existing cooperations the group is aiming towards a better European integration and an enhanced scientific impact, a work which is undergoing. Our interest is also centered on professional training, while trying to attract students and form specialists in one of the hottest domains of physics.

International cooperation

The group is involved in COST Action MP1001, *Ion Traps for Tomorrow Applications* (06.12.2010 - 05.12.2014). Dr. B. Mihalcea is the Project Director for the Romanian part and member of the Management Committee of the Action, while Dr. O. Stoican is also a member of the Management Committee. Another very important argument is the cooperation between the APTFS group and the QUEST group form PTB, Braunschweig, Germany, on "Sympathetic Cooling of Coulomb Crystals for Optical Clocks", a cooperation which started in Nov. 2011 by a 3 week workstage of Dr. B. Mihalcea in Braunschweig. An outcome of this visit would be the project entitled "*Advances in atomic particle trapping, cooling and detection techniques. Applications in modern quantum physics, ultrahigh resolution spectroscopy, metrology, nanoelectronics and nanotechnology*", written in cooperation with the QUEST group from PTB, and submitted at the Competition Funding Application for Joint Applied Research Projects PN-II-PT-PCCA-2011-3.

Entrepreneurial initiatives

Fundamental research

-Team members have been involved in the elaboration of the project proposal: *Acceleration of particles using femtosecond multi-terawatt laser pulses and their interaction with solid, gaseous and plasma targets* which has been submitted at projects call COMPLEX EXPLORATORY RESEARCH PROJECTS - PN-II-ID-PCCE-2011-2.

Applications

- Metrology applications of the ion trap technology. A project proposal entitled *"Advances in atomic particle trapping, cooling and detection techniques. Applications in modern quantum physics, ultrahigh resolution spectroscopy, metrology, nanoelectronics and nanotechnology*", project director: Dr. Bogdan Mihalcea, written in cooperation with the QUEST group from PTB, has been submitted at the competition Funding Application for Joint Applied Research Projects PN-II-PT-PCCA-2011-3.

-Development of plasma sources operating at atmospheric pressure, for various practical applications (medicine, environment protection and material processing). For this purpose a project proposal entitled *Mobile system generating a plasma jet at atmospheric pressure* has been submitted at the competition: Funding Application for Joint Applied Research Projects PN-II-PT-PCCA-2011-3.

Team E19: Plasma Theory Group (http://plasma-theory-group.inflpr.ro/)

Team Leader: Dr. F. Spineanu

Team structure

The team is composed of three persons : two senior researchers 1st rank, one research assistant.

Dynamic of research directions and subjects

The main activity of the Plasma Theory Group is ellaboration of phenomenological explanations, analytical models and numerical instruments adequate to analyse available experimental data in plasma physics. The purpose of the activity is the advancement of the understanding of physical processes in view of applications in particular fields of research.

The main field of work in the interval 2008 – 2011 was plasma physics for controlled thermonuclear fusion research with special emphasis on the toroidally confined plasma in tokamak geometry. This field of research is of highest importance for the possible realisation of a source of energy: clean, safe and sustainable. The Tokamak experimental reactor is actually the major objective of the scientific research, worldwide.

The Group has covered several areas of research which are specific to the hot plasma and in particular to the confined plasma:

- Numerical simulations of transport processes in tokamak plasma
- Theory of instabilities and of the generated turbulence, calculation of rates of transport of density and of energy in magnetically confined plasmas
- Statistical physics of test particle motion in random fields
- Large scale flows and coherent structures in plasmas
- Self-organization of vorticity in two-dimensional Euler fluid and in plasmas

Most important achievements

In recent time the Group had notable contributions in the domains:

- Statistical description of plasma turbulence and application to the problem of energy and particle transport in plasma in toroidal geometry.
- Coherent structures, organized flows and achievement of regimes of high confinement in tokamak plasma.
- Two-dimensional Fluid flows organized in asymptotic states into long-lived vortical structures.
- Application of results of two-dimensional organized Euler fluid flow to planetary atmosphere, including quantitative description of tropical cyclone and tornados.

In the field of description of plasma turbulence using methods of statistical mechanics of test particles, there has been a continuous accumulation of results regarding the diffusion regimes of particles, with application to the characterization of the confinement. The results are based

on the method, originally developed by the Group of Plasma Theory, called “Decorrelation Trajectory Method”, one of the successes of the recent years in the activity of the Group.
In the field of cuasi-coherent structures in magnetized plasma we have recently offered several original explicative models for important issues in the physics of tokamak

- The Edge Localised Modes, (ELM) a detrimental instability in the H-(high) confinement regime, the Group has proposed a physical picture and has developed an analytical description based the theory of filamentation of the current and vorticity layer, based on the “anomalous polytropic” gas analogy. The explanation correctly identifies the time scale for the process, compatible with the experimental observations.
- The reversal of the toroidal rotation at the transition from low to high confinement regimes. The explanation is based on generation of convection rolls and neoclassical polarization.

In the field of asymptotic organized states of the two-dimensional Euler fluids the Group has developed an original approach and appropriate analytical technics that allow identification of stationary states. The theoretical method is based on a field theoretical formulation. Two new elements have been developed within this area of work, and represent original findings:

- Axial anomaly, a characteristic of the system consisting of a string, a fermion field and a gauge field (via the triangle diagram) is actually a mirror of a very classical process in planetary atmosphere and in plasma: vorticity concentration
- The discretization of the Euler 2D fluid into the discrete system of point-like vortices is a similar process as the generation of the mass of the pion in the Nambu-Jona-Lasinio fermion theory.

In the field of applications of the originally developed models to the physics of the planetary atmosphere, the description of the general characteristics of the tropical cyclone has been continued with the identification of new relationships, in particular the equality between the Rossby radius and the radial extension of the cyclone.

Interdisciplinary research

The Group has been invited to participate to the COST collaboration on Parametrization of Cumulus convection. It involves groups of several European countries collaborating in this field of the science of the atmosphere. In particular, the expertize of the Group in the field of Self Organization at Criticality has been at the origin of the invitation to make a presentation and to initiate a series of developments based on this concept (Meeting of Cambridge 2011 and following works).
This collaboration becomes more and more extended, with exchenges of visits and projects of diversifying the subjects, to include renormalization transport due to atmosphere’s turbulence.

An interdisciplinary research is carried out by the Group in two distinct fields: stability of asymptotic Euler flows and Constant Mean Curvature surfaces in Euclidean 3-space. The group has offered a clear solution to the stability problem by proving the connection mentioned above and next exploiting the theorems on the embedding/immersion of surfaces.

The group has started an organised effort of extending its area of activity in the problems of plasma generated by high intensity laser, in view of future contribution to the exploitation of laser facilities.
Other applications of the Group's expertize are : astrophysical plasma (protoplanetary accretion via entropy-sustained instabilities); and quantum plasma.

The publications will still be mainly related with the Fusion domain. However the interdisciplinary activities will become a substantial part of the preoccupations in the Group.

<u>Evolution of human resources</u>

The Plasma Theory Group has evolved with few permanent members (between three and five over the interval) but with numerous collaborations within the European structure of research in plasma fusion.
The extension strictly depends on the resources that are allocated for theoretical research. The suppression of financement of one Project (Idei) in 2008 has led to a loss of an opportunity of hiring a young researcher, the latter leaving for postdoctoral position in USA.

The success of obtaining resources from the proposed interdisciplinary project will allow extension of the resources and hiring new members.

<u>International cooperation</u>

The Group has constant contributions to the Association EURATOM – MEdC Romania, proving over the years the capacity to respond to the challenges rised in the European integrated research for fusion. The subjects of work are exclusively chosen from the Work Plan established by the European Fusion Development Agreement (EFDA). It reflects the priorities of the European research in the field and the integration with the international research within the Project ITER (International Thermonuclear Experimental Reactor). The subjects of work of the Plasma Theory Group are obtained competitionally under the Calls of Project Proposal organized by EFDA and they are confirmed by the signature of Task Agreements between the Romanian EURATOM Association and EFDA. The work is done in collaboration with Topical Groups and Task Forces which represent the structure of EFDA. The results must be presented at the Reporting Meetings of the Topical Groups and are subject of evaluation by experts with the same area of preoccupation.

The Plasma Theory Group has collaborations within the integrated European fusion research: with groups from France, Italy, Belgium and also participation to JET experiments. Beyond the field of fusion the collaborations are with France. Permanent contacts of professional works exist with groups from Japan and United States.
In the next period the activities of the Group will be oriented to the better integration in the international ITER activities, via the European structures.
Members of the Group have received responsabilities in the participation of Romania to the fusion research:

- Representative of Romania to the Consultative Committee of EURATOM for Fusion
- Representative of the Association EURATOM – MEdC Romania to the Steering Committee of the European Fusion Development Agreement

Member of the Board of Fusion for Energy, the domestic ITER Agency of Europe.

Entrepreneurial initiatives

Team **E20**: **Mathematical Modelling for Fusion Plasma Group**

Team Leader: Dr. Calin-Vlad Atanasiu

Team structure

The team is composed of 2 researchers (1 senior researcher I[st] rank, 1 research assistant)

Dynamic of research directions and subjects

Our research activity is focalized on the “MHD interpretation and control of helical perturbations in tokamaks”, with Resistive wall modes (RWMs) stabilization and Construction of ITER tokamak pertinent equilibria with flow of arbitrary direction as main tasks. Our activity takes place under the EURATOM-Fusion programme, and is based mainly on the cooperation with the Theory Department of the Max-Planck-Institute for Plasmaphysics in Garching, Germany.

2007

we have continued to develop our real 2D equilibrium model (with axisymmetrical geometry) for a 3D perturbation of the RWM, and have achieved the following tasks:

a) description of the vacuum field given the normal component of the perturbed field on the plasma boundary for a 2D axisymmetrical diverted tokamak;
b) calculation of the surface current corresponding to a given plasma mode (instability).

2008

a) we have calculated relevant parameters to check the tearing mode stability criteria for some specific ASDEX Upgrade discharges, by using our tearing mode routines,

b) we have developed further our 2D numerical code for RWM calculation in an axisymmetrical tokamak configuration with the following specific objectives:

b1) improving of our method to calculate the wall response to an external kink perturbation, by developing a matrix formulation in place of an iterative scheme to solve the parabolic equation with boundary and initial conditions function of the unknown function itself;
b2) improving of the accuracy of calculation the wall response by removing the singularity appearing around the re-entry corners of the holes in the wall;

2009

a) we have investigated some ASDEX Upgrade discharges by using our tearing mode routines, the single ones, after our knowledge, being able to calculate tearing modes in a diverted tokamak configuration.

b) we have optimised the calculation of the wall response (for a realistic 2D geometry, with holes) to external kink mode perturbations with the following specific tasks:

b1) further improving of our scalar potential formulation (in place of the magnetic vector potential to be defined in the whole space used by others) which is necessary to be determined in the volume of the wall only, and not in the whole space like in the case where the magnetic vector potential is used,

b2) better understanding of the plasma-wall interaction by using our concept of surface currents.

2010

we have applied our numerical model in the calculation of the wall response (for a real 3D geometry with holes) to the external kink mode perturbations of diverted tokamak configurations, by using our very accurate and extreme fast scalar potential formulation to the ASDEX Upgrade wall and internal coil future structure, still maintaining the thin wall approximation, and have compared our approach with the alternative development made by our IPP colleagues with the help of the magnetic vector potential.

2011

a) we have started the implementation of our numerical code to calculate the wall response (for a real 3D geometry with holes) to the external kink mode perturbations of ITER on the ITM Gateway Platform – the EURATOM-Fusion computing facility (under the EFDA task forces TF-ITM WP11 ITM-11-IMP12),

b) we have performed analytical equilibrium calculations with flow (parallel with the magnetic field),

c) we have started to define a mathematical model to optimize the equilibrium system in a stellarator.

Most important achievements

- development of a new approach to treat the singularity in MHD calculations (equilibrium and stability) due to a tokamak separatrix,
- development of a new very efficient approach to calculate the response of a 3D resistive wall with holes to an external kink mode instability in a tokamak.

Future research activity

For the next years, our activity will continue to be focalized on the Fusion plasma research under the frame of the EURATOM-Fusion programme. Our project: **“Interpretation and control of helical perturbations in tokamaks”** will be focalized on the following two tasks:

I. Resistive wall modes (RWMs) stabilization

under the **European fusion tasks priorities “1 Provision of support to the advancement of the ITER and DEMO Physics Basis”, 1.3 MHD stability and plasma control,** under the EFDA TASK FORCE: ITM (Integrated Tokamak Modelling) IMP12

Motivation: the target of this research is to advance the physics understanding of RWMs stability, including the dependence on plasma rotation, wall/plasma distance, and active feedback control, with the ultimate goal of achieving sustained operation at beta values close to the ideal-wall beta limit through passive and active stabilization of the RWMs. Such

objective has its justification in the fact that the stabilization of RWM in ITER, where it is probably not possible to maintain a very fast plasma rotation is still an open problem.
The following **milestone** will be considered:

- ***M1*** Finalization of the implementation of our numerical code to calculate the wall response (for a real 3D geometry with holes) to the external kink mode perturbations of ITER on the ITM Gateway Platform (TF-ITM WP11 ITM-11-IMP12)

After improving of our model to calculate the eddy currents in a 3D thin wall for the rotating plasma case [1] and application of our approach to the wall geometry of the ASDEX Upgrade structure [2], we intend to continue to implement these improvements on the Gateway Platform and to run our code. This task consists in continuing a collaborative work between us and the Max-Planck Institute for Plasma Physics (IPP), Garching, Germany.

II. Construction of ITER pertinent equilibria with flow of arbitrary direction
under the **European fusion tasks priorities "1 Provision of support to the advancement of the ITER Physics Basis", 1.7 Theory and modelling for ITER and DEMO,** under the EFDA Task Force TG MHD (Topical Groups MHD)

Motivation: the increasing need for self consistent equilibria with flow as starting points for stability and transport investigations of ITER relevant plasmas. In fact the proposal consists in continuing a collaborative work between the National Institute for Laser Plasma and Radiation Physics (MEdC-EURATOM Association), the University of Ioannina (EURATOM-Hellenic Republic Association), and the Max-Planck Institute for Plasma Physics, Garching, Germany. Specifically, the proposed work aims to extend the equilibria with field aligned flows being constructed within the framework of 2011 Physics MHD Topical Group (Activity: WP11-MHD) to at least one of the following **milestones:**

- ***M1.*** Further extension of solutions to a generalized Grad-Shafranov equation [3], based on the static analytic equilibrium of Ref. [4] or other linear equilibrium solutions, for non-parallel flows associated with radial electric fields which play a role in the transition to improved confinement regimes in tokamaks;
- ***M2.*** Derivation of novel equilibrium solutions with flow by applying the Bogoyavlenskij transformation [5].

Expected results: The solutions to be constructed could be used to derive configurations with ITER shaping characteristics and confinement figures of merit, i.e. single lower *x*-point diverted configurations with appropriate values of poloidal beta, plasma current, safety factor on axis and internal inductance. In particular, the impact of the electric field on the equilibrium characteristics will be examined. In addition to the aforementioned importance as starting points for stability and transport studies the equilibria to be constructed could be used for benchmarking equilibrium codes with flow.

References:
[1] C.V. Atanasiu et al. Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **54**, 2, (2011).
[2] C.V. Atanasiu et al. *MHD modelling in diverted tokamak configurations*, The 7th International Symposium on ATEE, May 12-14, 2011, Bucharest, Romania.
[3] G. N. Throumoulopoulos et al. Phys. Plasmas **17**, 122104 (2010).
[4] C. V. Atanasiu et al. Phys. Plasmas **11**, 3510 (2004).
[5] O. I. Bogoyavlenskij, Phys. Review E **66**, 056410 (2002).

Interdisciplinary research -

Evolution of human resources

- one of our team member, associated assitent, started his PhD preparation activity in 2011.
- if possible, we intend to increase our team by one member each 3 years.

International cooperation

Our research activity takes place under the following cooperation frame:

- Prof. S. Günter, Prof. K. Lackner (1994-present) : MP-IPP Garching, Tokamakphysics Department (Theory 3)
- Prof. A.H.Boozer (1998), Applied Physics Department of Columbia U, USA
- Dr. L.E. Zakharov(1999-present): PPPL, Theory Department, USA
- Dr. V.D. Pustovitov (2007, 2010): I.V. Kurchatov, Theory Department, Moscow, Russia
- Dr. S. Gerasimov (2003-2008), Dr. M.Gryaznevich (2008): JET, Culham, UK

and is centred on MHD analytical and numerical modelling of tokamak plasmas.

Entrepreneurial initiatives -

Team E21 **Generation of repetitive electromagnetic pulses of high voltage and high power; applications in plasma physics (team leader Dr. N. Georgescu)**

Activity report 2007-2011

The team has an experience of approximately 10 years in the field of the production and use of cold atmospheric plasmas, obtained by using high voltage pulses. Its researches have been synchronous with the international research.

Between 2007 – 2011 the great accomplishments regarding the obtaining and the applications of cold atmospheric plasma jets have been exploited scientifically. The Team Leader managed an IDEI project: *"New high-voltage pulsed structures, generating cold atmospheric plasma jets, with bio-medical applications"*. He also worked as the Person in charge from Partner 1 in the project PARTENERIATE 2007: *"Microbial decontamination of the termosensitive food using pulsed cold plasmas, in the frame of food safety objectives"*. The both projects have had a strong interdisciplinary character.

In 2010 and 2011, the Team Leader published, as main author, four articles in ISI journals, three of which in IEEE Transactions on Plasma Science, one of these three articles as a single author. The articles discusse the generation of cold atmospheric plasma jets and their application in ecology, biomedicine and the decontamination of thermo-sensitive food surface. One of these articles (N. Georgescu and A. R. Lupu "Tumoral and normal cells treatment with high-voltage pulsed cold atmospheric plasma jets" *IEEE Trans. on Plasma Science* **38** 8 part 2 1949 – 1955 **2010**) has already been cited in scientific journals with great impact factor (IF): *Small* (IF = 7.333); *Stem cells* (IF = 7.871); *Biosensors & Bioelectronics* (IF = 5,397).

(L22-E7) Generation of repetitive electromagnetic pulses, of high voltage and high power. Applications in plasma physics

Future Research

*Using of pulsed cold atmospheric plasmas to destroy the microorganisms from the egg surface, in order to increase the food safety***.**

Immersing the eggs in cold plasma at atmospheric pressure is proposed. By the action of the plasma on a set period of time, the surface microorganisms are destroyed, while the organoleptic qualities of the treated eggs are not affected.

The other known methods for eggs decontamination (chemical, thermal and radiation) are not sustainable. Chemical products can be absorbed by the egg shell. Thermal processes affect egg content. Irradiation of eggs is not permitted in the EU.

Cold plasma at atmospheric pressure will be produced in a closed parallelipipedal chamber with a volume in litres, to allow for the introduction of as many eggs as possible. Inside the chamber an inert gas will be introduced (helium, argon), and small quantities of oxygen, water vapours, hydrogen peroxide, etc. to provide for the generation of chemically active species, with a strong bactericidal effect. For plasma obtaining, the gas mixture will be excited with repetitive pulsed, high voltages (25 – 30 kV amplitude).

We would also focus on obtaining experimental conditions favourable to air use in the chamber. This achievement will be a big advantage in terms of cost and simplicity of the installation.

The eggs, contaminated under controlled conditions with several microorganisms (*Salmonella spp.*, *Escherichia coli*, *Staphylococcus aureus*, etc.) will be treated under experimental conditions ensuring a high bactericidal potential. Later on, the quantity of the destroyed microorganisms will be measured. We want to obtain a decontamination degree of over 99.5%, for treatment times as short as possible.

Finally, a pilot installation for eggs treatment with cold atmospheric plasma will be implemented at one small entreprise, which will be our research partner. In order to apply the new technology at a larger scale, the industrial scaling possibilities will be analysed.

This project will provide a highly effective system to sterilise eggs using a plasma source, a simple and safe microbial sterilisation technique, and contribute to reducing the high number of zoonotic infections. The commercial objective is to increase the competitiveness of small/medium entreprises egg producers and packers by providing them with a low cost, rapid and effective system that will be suitable for simple insertion into modern production or packing lines, facilitating installation and maintenance, thus saving time and associated costs.

Team **E22**: Theoretical Modeling of Fusion Plasmas

Team Leader: Dr. Iulian Gabriel Miron

Team structure

The team is composed of 1 researcher (1 scientific researcher IIInd rank)

Dynamic of research directions and subjects

Our research objectives reside in the theoretical modeling of the plasma instabilities behavior, error fields penetration phenomenon and neoclassical toroidal viscosity (NTV) non-resonant magnetic braking effects in tokamak plasmas.

The magnetic error fields are small static deviations from the equilibrium magnetic field structure due to the field coil misalignments. The phenomenological mechanism assumes that, at marginal stability, the plasma unstable harmonic resonates with the corresponding error field harmonic which exerts an electromagnetic torque at the level of corresponding magnetic surface. The pattern of the error field penetration lies on the joint effect of the electromagnetic and viscous torques (due to neoclassical toroidal viscosity, NTV) by finally braking the plasma rotation, followed by the resonant internal modes and resistive wall mode (RWM, at plasma boundary) destabilization. Therefore, the above phenomena is very important in order to prevent major tokamak plasmas disruptions.

Most important achievements

The first achievement consisted of the development of a cylindrical model for the influence of the error field penetration on the stability of the RWM that contains non-resonant error field effects. A multimode analytic cylindrical model has been developed starting from plasma equations that includes neoclassical, sound wave and dissipative particle collisions charge exchange effects. The present model is able to extend the investigation to the toroidal case. Due to the calculus that includes both poloidal and toroidal mode coupling, the optimal error field spectrum can be determined. Finally, although NTV has a stabilizing dissipative effect as long as RWM in far from marginal stability (where small error fields have practically no effect on RWM stabilization), its global destabilizing aspect under error fields action as marginal stability is approached has been proved. The plasma toroidal angular equation of motion has been solved, an explicit analytic time-dependent solution being provided. We have showed that the error field penetration process is responsible for the increased destabilizing influence of the neoclassical toroidal viscosity on external and internal magnetohydrodynamic perturbations, caused by the global deceleration of the toroidal rotation of the plasma. The clear and explicit analytic obtained solution makes it possible to find the optimal less destabilizing error field spectrum as well as the optimal choice for the feedback parameters in order to provide stability.

The next step in our study was to the previously derived cylindrical mathematical model to an axisymmetric 3-dimensional perturbative analytic model (within 2-dimensional axisymmetric geometry) capable to illustrate the involved physical phenomena. As a first step, a 3-dimensional, analytic RWM dispersion relation has been obtained. As a second step, a dynamic theoretical model that proves the phenomena of global tokamak plasma deceleration and neoclassical toroidal viscosity braking of the plasma toroidal rotation has been built. A 3-

dimensional model provides a more realistic description of the phenomena involved by taking into account realistic plasma shape parameters like the Shafranov shift, toroidicity, ellipticity and triangularity that cannot be considered within a cylindrical model description. A compact dispersion relation of the RWM has been obtained. It has been demonstrated that the error field modes coupling effect prevails and the single mode theory is unable to provide realistic results. The influence of toroidicity, ellipticity and triangularity parameters in finding the less destabilizing configuration has been showed.
The next step was to develop a more reliable theoretical model, based on a quantitative NTV term, within the frame of a *kinetic* (particle) description. The NTV term is no longer considered constant inside the internal plasma inertial layers (IL), but dependent on nonlinear influence of the perturbed magnetic fluxes and their radial (flux coordinate) derivatives jump across the inertial layers. The mode coupling and, consequently, the non-resonant error field influence become intrinsically linked with the NTV torque action. The IL toroidal angular equation of motion assumes the new NTV term nonlinearity, becoming more difficult to be analytically solved. The NTV torque expressions have been derived for different collisionality regimes: the plateau and collisional transport regimes versus the collisionless transport regime. The 3-dimensional kinetic model assumed the same conditions as the 3-dimensional fluid model. The 2-dimensional axisymmetric geometry is embedded in the analytic expressions of the NTV torques through the presence of the toroidicity, Shafranov shift, ellipticity and triangularity parameters. Again, unlike the fluid model, the kinetic model has been able to provide realistic, time dependent expressions of the NTV torques from the analytically derived time dependent expressions of the flux magnetic perturbations. We have derived clear and explicit expressions for the neoclassical toroidal viscosity torques for different collisionality regimes.

Our future research proposal consists of the derivation of a semianalytic theoretical model that describes the effect of the resonance between the resistive wall mode (RWM) frequency and the magnetic precession drift or bounce frequency of the thermal trapped particles on the RWM stabilization.
The above mentioned resonance is considered as an important dissipation channel for the RWM instability. The proposed model does not follow the kinetic MHD energy principle, but starts from the perturbed MHD equations with the kinetically derived pressure tensor term. The bounce and precession motions of the thermal trapped particles are considered. The trapped particles influence the RWM through their resonant and non-resonant contributions. The multimode approach of the proposed theoretical model allows us to compare the latter contributions.
Recent theoretical damping models and experimental results suggest that the RWM resonance with the thermal ions at their bouncing (or passing) frequencies does not significantly affect the RWM behavior. On the other hand, at lower frequencies, such as the precession drift frequencies of the trapped particles, the RWM resonance is higher; therefore the RWM behavior seems to be significantly affected by the latter kinetic effects. The proposed theoretical model will evaluate the above dissipative effects.
The proposed model includes a three-dimensional description of the magnetic perturbations (due to the nonaxisymmetric feedback system) for a two-dimensional, axisymmetric equilibrium magnetic field geometry (toroidicity, Shafranov shift, ellipticity and triangularity parameters are considered). General natural (flux) coordinates will be used.
The perturbed pressure tensor will be analytically derived. A semianalytic RWM dispersion relation that includes explicitly derived kinetic terms will be obtained. The RWM and the particle bounce/ precession drift frequency resonance phenomenon will be investigated to calculate the RWM damping efficiency. The influence of the plasma rotation and the effect of

the passive and active feedback systems action will be investigated within the frame of the above kinetic scenario (at bounce/ precession drift frequency resonance).

Interdisciplinary research

Evolution of human resources

During the period 2007-2011 a PhD has been presented: I.G.Miron, "The analytic and numerical study of the resistive wall modes instabilities in tokamak plasmas" (2008)

International cooperation

2009-2011 : Participation to the MHD Topical Group Activities under the EFDA Work Programme (Euratom FP7).

Entrepreneurial initiatives

Team 23 Plasma and Laser Accelerators
Team Leader: Dr. Catalin Ticos

Team "Plasma and laser accelerators"

The "Plasma and laser accelerators" team is a newly created team during 2011 with experienced researchers, the team leader Dr Catalin M Ticos, CS I and Dr Mihai Oane, CSIII, three young physicists hired very recently among whom two are doctoral students and one is a master student, and one technician. The team has varied interests in fundamental problems of experimental and theoretical physics, ranging from acceleration of dust particles in plasma to tuning of THZ radiation using plasma crystals, and the interaction of lasers beams with surfaces. Part of the experimental work of the team is carried out on a system equipped with a modern vacuum system (Leybold) which produces rf or dc plasmas and low energy (of a few Joules) pulsed plasma jets. The diagnostics include a high-speed Fastcam 1024 PCI Photron CCD camera with frame rate capabilities up to 10^5 fps, a Nikon Micro-Nikkor lens and two teleconverters. Our tem has demonstrated dust removal trapped in a rf pasma by a short burst of plasma jet propagating at a few km/s, with potential applications in the semiconductor industry. It is well known that during wafer etching dust particles formed inside the plasma and floating above the wafer can ruin its surface when the process ends and the plasma is turned off. Over the last 4 years the team produced about 15 publications in high-profile journals such as Applied Physics Letters, Physics of Plasmas, Review of Scientific Instruments, etc on experimental topics in plasma and laser physics. On the theory side, over 25 papers have been focused on developing and improving models for heat propagation during laser irradiation of materials. Some representative works have been published in Optics and Laser Technology, Lasers in Engineering, Infrared Physics & Technology, etc. A strong participation at international conferences has been a main objective of our team members, resulting in a large number of conference proceedings papers. Furthermore, Dr CM Ticos has been recognized with 2 international prizes, one at ICPDP08 in Azores, Portugal, and one at the summer school in plasma physics which took place at the International Center for Theoretical Physics, in Trieste, Italy. The acceleration of particles to relativistic speed using high-power laser pulses is a research direction which will be undertaken in the near future. We are now ready to embark on a new and exciting scientific adventure, which will involve the use of a 20 Terawatt (TW) laser called TEWALAS which is a unique facility of its kind in Romania. TW laser pulses interacting with gaseous targets produce a dense plasma which can sustain gigantic electric fields. By properly synchronizing these fields with the separation of electrical charges within the plasma, monoenergetic electrons can be accelerated to several hundred MeV over distances of a few millimeters.

Team E24: "Electron beam and microwaves applications for environment, biomedicine and new materials" (http://ale.inflpr.ro)

The team consists of 6 researchers (1 senior researcher Ist rank, 4 senior researchers IIIrd rank, 1 scientific researcher - PhD student), 1 sub-engineer and 3 technicians. The experimental research activities of the team involve the use of electron beams obtained from linear accelerators and the application of irradiation techniques to materials processing, environmental protection, biomedicine and food preservation. Two electron linear accelerators ALIN-10 and ALID-7 were built at our institute several years ago and are fully functional and currently used by the team. Both are traveling-wave accelerators, driven by a 2 MW peak power tunable magnetrons operating in the S-band. The electron energy of the beam is in the range 5 to 7 MeV for currents up to 130 mA. The beam power is about 160 W and 650 W, respectively, for the two accelerators. X-ray beams can be obtained from the electron beam with a good conversion rate. Small linear accelerators can provide sufficient high irradiation power for the type of experiments performed by the team, and have several advantages such as easy beam deflection, flexibility in adjustment of the electron beam current and no subsequent radiation contamination when the beam is stopped. A major benefit which recommends the use of linear accelerators as a safe tool instead of highly radioactive sources is the absence of radioactive waste at the end of an experimental campaign. An important task of our team was the control of the beam and the maintenance of the accelerators to operate at optimal parameters.

The team has proposed in the last few years a new approach to irradiation of samples by combining the ionization effects of accelerated electron beam (EB) with the thermal and non-thermal effects of microwaves (MW), which led to new promising results in the field of material sciences. The main idea was to combine the advantages of both, EB and MW, i.e. the very high efficiency of EB processing with MW high selectivity and volumetric effects, in order to reduce the required absorbed dose level and irradiation time, and thus decrease the processing costs of a sample by improving productivity.

The team participated in the last 5 years in several projects within the National Program for Research, Development and Innovation. The outcome included the development of equipments (demonstrative setups and semi-pilot facilities) for application of innovative technologies based on synergistic effect of combined electron beam and microwave irradiation with applications spanning from materials processing to environmental protection and biology. The achievements within the projects are as follows:

- the development of treatment therapies of some types of cancer by synergistic action of bioactive compounds, accelerated electrons and microwave - CEEX-VIASAN, 2005-2008;
- the creation of rubber materials obtained by crosslinking and grafting of the elastomers through irradiation with electron beam and microwave in the presence of multifunctional monomers - CEEX CALIST, 2005-2008;
- the removal of volatile organic compounds from industrial gases by the combined treatment with accelerated electrons and microwave (CEEX RELANSIN, 2005-2008);
- the development of a biotechnology for specific prophylaxis of infectious pododermatite to ruminants, caused by Fusobacterium necrophorum, by the simultaneous use of accelerated electrons and microwaves (CEEX BIOTECH, 2005-2008);
- the development of a technology for simultaneous retention of sulfur and nitrogen oxides from flue gases using microwave and electron beam (PNCDI-2, 2007-2010);
- the development of an innovative diagnosis method for staging and immunological monitoring of skin-melanoma (PNCDI-2, 2007-2010);
- the development of a remote system with tele-transmission capability for monitoring the irradiation levels of X, gamma, neutron and alpha-beta contamination, in areas with radiological risks (PNCDI-2, 2007-2010).

The team was involved in international cooperation in the frame of IAEA project 13138 “VOC removal by combined electron beam and microwave treatment”, part of the Agency’s Coordinated Research Project "Electron beam treatment of organic pollutants contained in gaseous streams", 2005-2008.

The team was also involved in calculations and evaluations of radiation source terms (high energy electrons, X-rays, protons) for the future Integrated Center for Advanced Laser Technologies (CETAL) which hosts a 1 Petawatt pulsed laser, and in the design of radiological shielding of this facility.

Moreover, technical and scientific support related to the physics of particle acceleration in general and nuclear physics with electron beams in particular obtained using the FLUKA code has been provided during 2010-2011 to the feasibility study of the Extreme Light Infrastructure (ELI-NP) project. The ELI-NP facility is a 280 mil Euros European laser facility which will be built starting 2012 at Magurele, in Romania. The ELI-NP includes also a particle accelerator for generating high-intensity and high brightness gamma beams at 600 MeV. The team has been heavily involved in all aspects, from design to handling of electron beams, of this facility.

Other activities of the team included the design and construction of control and dosimetric systems for the electron beams of ALIN-10 and ALID-7 accelerators, the development of new dosimetry methods for fluorescence measurements in vitro during exposure to 2.45 GHz microwave and for electron beam dosimetry at low temperature, and the development of a new method and design of an innovative setup for submicrometer-size particles collection by combined DC or short pulsed corona discharge, and soft x-ray irradiation. The applied research in life sciences of the team is represented by the development of an innovative bio-medical method based on the simultaneous use of electron beam and microwave irradiation of cancer cells. The technique could be implemented in vitro and in vivo with or without cytostatics administration, on human blood and on cellular membrane electroporation.

Team **E25**: **E**lectron **B**eam **A**pplications (EBA) (http://ale.inflpr.ro/)

Team Leader: Dr. Monica R. Nemțanu

Team structure

The team is composed of 4 researchers (1 senior researcher Ist rank – Dr. Constantin Oproiu, 1 senior researcher IInd rank – Dr. Monica Nemțanu, 1 senior researcher IIIrd rank – Dr. Mirela Brașoveanu and 1 scientific researcher – Dorina Toader) and 1 technician – Marian Stoicu. The team was founded in February 2008 under supervision of Dr. C. Oproiu and had one more senior researcher IIInd rank – Dr. Mihai Oane. Since November 2011, the new team leader is Dr. M.R. Nemțanu.

Dynamic of research directions and subjects

The team focused on studies concerning:

1. The accelerated electrons interaction with complex materials and biological structures for:
   - Modification of biopolymers and for grafting/crosslinking of polymeric materials
   - Microbial decontamination/sterilization of food, phytoterapeutic products and cereal seeds
   - Development of new dosimetry methods and systems for absorbed dose and distribution measurement
2. Development of an electron-optic system DYADIN for non-destructive characterization of intense electron sources of low energy (10 to 50 keV)
3. Thermal effects in radiation-matter interaction

Most important achievements

The main results of the team in the last years are:

1. New materials with modified structure and improved functional properties: electron beam modified starches and combined electron beam-microwave modified corn starch for food applications
2. Combined treatment of corn starch with electron beam and microwave
3. Demonstration of fundamental difference for the "dose-effect" relation between electron beam irradiation and microwave exposure of corn starch
4. Identification of "window effect" for corn starch exposed to microwaves
5. Setting of specific parameters of electron beam and luminescent low temperature plasma to control some seed-borne pathogens causing diseases on cereal crops
6. Small size quasi-adiabatic calorimeter for electron beam dosimetry
7. Calorimetric dosimeter with optical fiber
8. Obtaining of cracks and micro- and nano-penetrations in inorganic systems
9. Absorbed dose increase using electron back-scattering effect for technological irradiations
10. Optimizations of DYADIN installation: electron beam diagnosis and dynamics on DIADYN equipped with hot filament source/a new plasma source; adjustment of the installation in order to extract the electrons from a plasma source; optimization of the electron beam channel to increase the beam current transmission
11. General model of the thermal fields distributions in solid under multiple laser beam irradiation
12. Design and implementation of the *Laboratory of Physico-chemical Analyses*

The research activity has been performed within 2 research *projects managed by the EBA team* (Project PN II-PARTNERSHIPS in Strategic Fields 51-007/18.09.2007 and Project PN II-CAPACITIES 376/26.04.2010 – Bilateral Cooperation Romania – Turkey) and other 2 *collaborative projects* (Project PN II-PARTNERSHIPS in Strategic Fields 71-007/2007 and CEEX 308/19.09.2006).

The scientific results can be found in 38 publications in scientific journals (22 ISI and 16 non-ISI), 6 chapters in different books, 1 edited book, 14 papers in Proceedings of scientific meetings, symposia, workshops or conferences and 2 patent applications registered at the State Office for Inventions and Trademarks – Romania (A/00771 from August 02, 2011 and A/00984 from October 18, 2010).

During the reported period, three members of the team successfully defended their *PhD thesis*: Mirela Braşoveanu (2007), Mihai Oane (2009) and Monica Nemțanu (2009).

Interdisciplinary research

The strong multidisciplinary researches of the team were at the frontiers of physics, chemistry, mathematics, electronics and engineering. Interaction of radiation with matter generally involves interdisciplinary activities related to different fields of research: charged particle beams physics, beam instrumentation and diagnostics, dosimetry, plasma physics, surface physics, chemistry and chemical engineering, biochemistry, biology, mathematics electronics and electrical engineering, etc. In this regard, we carried out research studies together experienced researchers from other prestigious research institutes and universities such as University of Bucharest, National Institute of Food Bioresources – Bucharest, National Institute for Microtechnologies – Bucharest, National Institute of Physics and Nuclear Engineering “Horia Hulubei” Bucharest, “Politehnica” University of Bucharest, Süleyman Demirel University, Turkey – Faculty of Agriculture – Plant Protection Department, University of Sao Paulo, Brazil – Faculty of Pharmaceutical Sciences, Hacetteppe University, Ankara, Turkey – Food Engineering Department, etc.

Evolution of human resources

The team members have evolved in last years so that three of them have obtained *doctor’s degree*, M. Braşoveanu in Physics (2007), M. Oane in Physics (2009) and M.R. Nemțanu in Engineering Sciences – Chemical Engineering (2010), and one of them enrolled in a doctoral school (D. Toader in 2010).

Also, three members were *promoted by competition*: Mihai Oane as a senior researcher IIIrd rank in 2008, Monica R. Nemțanu as a senior researcher IIIrd rank in 2008 and then as a senior researcher IInd rank in 2011, and Dorina Toader as a scientific researcher in 2011.

For a continuous improvement of their scientific knowledge, the team members attended different courses of specialization:

1. *Specialization Program: “Project Manager”*, Experts Body in Accessing European Structural and Cohesion Funds, Bucharest, Romania, July 25 – August 28, 2011 – **Monica Nemțanu** and **Mirela Braşoveanu**
2. *Radiological security in practices with ionizing radiation sources* - Level 2, National Institute of Research-Development for Nuclear Physics and Engineering “Horia Hulubei”, Bucharest, Romania, November 02 – 11, 2009 – **Mirela Braşoveanu**
3. *Validation and Process Control for Electron Beam Sterilization* (course and training on electron beam dosimetry using dosimetric systems as calorimeters, radiochromic

films and alanine), Riso High Dose Reference Laboratory, Riso-DTU and Technical University of Denmark, Riso, Denmark, 08-15 June, 2008 – **Dorina Toader**

4. *Fundamentals of Environmental Chemistry*, "Politehnica" University of Bucharest, Faculty of Applied Chemistry and Material Science, Romania, June 25 – 28, 2007 – **Monica Nemțanu**

Dr. Monica R. Nemțanu is the Chairman of Scientific Seminar of the Electron Accelerators Laboratory since 2009 and the EBA team leader since 2011.

A student has been *employed* in the project PN II-PARTNERSHIPS in Strategic Fields 51-007/18.09.2007 for 2 months (in 2008).

Dr. Mihai Oane became part of a newly created team in the Electron Accelerators Laboratory since November 2011.

International cooperation

At international level, several collaborations have been initiated and developed with foreign universities such as **Süleyman Demirel University**, Isparta, Turkey – Faculty of Agriculture – Plant Protection Department in the Project PN II-CAPACITIES 376/26.04.2010, **University of Sao Paulo**, Brazil – Faculty of Pharmaceutical Sciences (*Lat. Am. J. Pharm.* 29(2), 293-297, 2010; *Acta Horticult.* 826, 205-212, 2009; *Nucl. Instrum. Meth. Phys. Res. B* 266(10), 2520-2523, 2008; Expert Commentary in *"Radiation Physics Research Progress"* (ed. Aidan N. Camilleri), ISBN 978-1-60021-988-7, Nova Science Publishers, Inc., New York, 2008) and **Hacetteppe University**, Ankara, Turkey – Food Engineering Department (*Nucl. Instrum. Meth. Phys. Res. A* 580(1), 795-798, 2007).
Also, Dr. Monica R. Nemțanu has been an invited professor at the Faculty of Pharmaceutical Sciences of University of Sao Paulo, Brazil (July 31 – September 1, 2007).

Entrepreneurial initiatives

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Team E26: Laser Metrology and Standardization Laboratory – LMSL

Team Leader: Dr. Dan Sporea

1. Mission

LMSL (http://metrology.inflpr.ro/) was established in 1996 by the Institute Management decision with the mission to run research programs and develop methods/ procedures related to laser metrology, optical fiber metrology as well as metrology using laser radiation.

In 2003 the Laboratory was evaluated by RENAR, the national accreditation body for testing and calibration laboratories and was accredited for four years (licence no.294-L/30.08.2004) as the first laser metrology laboratory in the field of lasers and optical fiber systems. The Laboratory applied for the reaccredidation as both a testing and a calibration laboratory. The re-accreditation process will be continued in the frame of CETAL project (see CETAL project below).

In 2007, the Laboratory established another entity in the Institute: the Center for Science Education and Training - CSET (http://education.inflpr.ro), with the mission to support science education at pre-university level and to develop outreach activities.

The LMSL team is running projects under two umbrellas: LMSL and CSET.

2. LMSL staff

From 2003 to 2007 the Laboratory was a small entity, formed by two senior researchers, which run for several years a research project in the frame of the EU's Fusion Program, by testing optoelectronic components and optical fibers degradation and different irradiation conditions (gamma-ray, electron beam, neutron, and proton).

In 2007, a young researcher (Adriana Puiu) who was hired by the Laboratory started her PhD studies at TorVergata University of Rome, Italy. She returned to the Laboratory in November 2010, after finishing her thesis on "Techniques of Laser Photoacoustic Spectroscopy applied for measuring ethylene emission from biological samples"

In January 2008, the Laboratory hired a graduate of the Faculty of Physics, University of Bucharest, Miss Laura Mihai. In 2009 she started her PhD at the University of Bucharest, in the filed of atmospheric physics and left the Laboratory in 2010 to pursue her studies at Joint Research Center in Ispra.

The Laboratory made efforts to develop its personnel staff and in October 2010, a graduate of the Faculty of Electronics "Politehnica" University of Bucharest was hired as research assistant, Mr. Andrei Stancalie.

In supporting our continuous concern on staff qualification, the LMSL personnel attended different courses and training sessions in: Biomedical application of high resolution laser spectroscopy, Principles and applications of time-resolved fluorescence Spectroscopy, Radiation protection for charged particle accelerator facilities, Auditors of the Quality Management System in an Accredited Laboratory according to ISO 17025. The younger members of the team attended also several on-line web seminars/ courses on: Motion Control and NI LabVIEW Web User Interface, data acquisition and processing, oscilloscope modules for the PXI platform.

3. Projects and achievements

In the last four years the Laboratory continued its policy to improve the research infrastructure and run until 2008 the Capacity project "MIDAS-Maintenance, improvement, development of apparata and systems". In the frame for this project, several advanced equipments were purchased: a 3D scanning laser vibrometer; a time-resolved fluorescence spectrophotometer with excitation time of around 150 ps; a complete system for optical fiber systems development and testing; two optical fiber near-IR spectrometers operating in the 900 nm – 1700 nm and 1600 nm –

2300 nm spectral ranges. The investment policy continued in 2009 and a solar simulator class "ABA" was acquired.

Year 2007 was the last year LMSL participated to the EU's Fusion program by investigating gamma-ray and electron beam radiation effects on Peltier thermoelectric coolers and the degradation of polarization characteristics of optical fibers.

In 2007, on a competition bases, the Laboratory was awarded a research contract for the development of set-ups to assess the optical fibers and optical fiber sensors degradation under different ionizing radiation conditions. This project will finish in 2011. Some of the research tasks of this project were performed in collaboration with University of Palermo, the Faculty of Physics and Astronomy. Comparative studies on radiation induced color centers in UV enhanced transmission, solarization resistant and H_2-loaded optical fibers were done in Bucharest and Palermo, through EPR (electron-paramagnetic resonance) and luminescence analysis. In the mean time, different types of silica glasses were investigated under gamma-ray and electron beam irradiation in order to evaluate the build-up of color centers depending on the samples composition, structure and preparation methods. The results of these investigations on radiation effects were finalised as journal or conference papers and a book chapter on irradiation effects in optical fibers in the UV spectral range was published in collaboration with the Italian team. According to our knowledge, this is the first published book chapter devoted to radiation effects on optical fibers operating in the UV range. Some other results are subjects of two patent applications. Another journal paper is under evaluation. It is worth to mention that the two journal papers under discussion were published in prestigious international journals with a relative index factor higher than 3. Until 2009, the Laboratory was an associated participant to COST Action 299 "Optical Fibres for New Challenges Facing the Information Society". Some of the previous mentioned results were included also in this European project. For irradiation tests, LMSL cooperated with the Linear Accelerator Laboratory form our Institute, with the National Institute for Nuclear Physics and Engineering – "Horia Hulubei", the National Institute for Materials Research, the Institute for Nuclear Research in Pitesti.

Continuing its policy towards the development of a first class research infrastructure, LMSL staff participated to another national project competition by proposing the expansion of its activities to cover a much broader spectrum of optical radiation applications, both coherent and non-coherent, from UV to THz. The new laboratory proposed to be developed was the Photonics Investigations Laboratory. As the LMSL team won the competition, the decision of the Institute management at its highest level decided to include this new Laboratory into a larger infrastructure "Center for Advanced Laser Technologies". The goal of the CETAL project was to achieve the first integrated center for research in the domain of photonics in Romania and in South-Eastern Europe, being a consequence of the increasing implication of NILPRP in national and international research projects, mostly at a European level. The center will be structured into three major compartments:

- *Laboratory for frontier research on hyperintense laser beam-matter interaction*
- *Laboratory for advanced and frontier technologies based on laser photonic processing*
- *Laboratory for investigations in the field of photonics*

Dr. Sporea, head of LMSL, acts also as Deputy Technical Director for the CETAL project. The equipments procured previously and mentioned above will be relocated at the Photonics Investigations Laboratory premises, in specially designed clean rooms and the 3D laser vibrometer will be installed in a dedicated vibration free laboratory.

During the reported period, the CETAL team supervised the tenders for the design of the building project, the acquisition of the PW laser, the designation of the constructor for the new facilities. Thales Optronique was designated as the manufacturer of the PW laser, while the project of the buildings was commissioned to SITON. The construction of the building was started and the first milestone was accepted for the laser system. By the middle of 2012 it is expected the finalization of the building and in April 2013 it is planned the full operation of the PW laser.

In 2008 and 2009 the Laboratory was involved in the EUROMET project 156-Part 1 dealing with an international intercomparison on high power laser at the wavelengths of λ = 488 nm and λ =

1.06 μm. The nine worldwide participants were: National Institute for Standards and Technology (USA); Physikalisch-Technische Bundesanstalt - PTB (Germany); the National Research and Testing Institute (Sweden); Laboratoire National de Métrologie et d'Essais –France, National Measurement Institute - Australia, National Metrology Institute of Japan, National Metrology Institute of South Africa, National Physical Laboratory-United Kingdom and National Institute for Laser, Plasma and Radiation Physics -Romania. For the four tests the Laboratory participated, it reached among the highest marks as it was ranked the second for two of the tests and the first for other two tests, as it concerns the correction factors for the spectral responsivity of the detectors used as standard detectors in the intercomparison. The final report certifying our results is available on the BIPM web site at http://iopscience.iop.org/0026-1394/47/1A/02003.

In 2010, the Laboratory jointed the COST Action TD1001 "Novel and Reliable Optical Fibre Sensor Systems for Future Security and Safety Applications" and now leads the Romanian team participating to this project. In the frame of this COST action the Laboratory has bilateral collaborations with University of Limerick (the coordinator of this TD1001) and the French Agency for the Management of Nuclear Wastes - ANDRA. The cooperation with the Irish team refers to the development of new radiation dosimeters for medical use, based on extrinsic optical sensors, while the common work run with ANDRA addresses the employment of Raman intrinsic optical fiber sensors for nuclear waste repositories. With both parties the Laboratory has results ready for publications and together with members of the Limerick team, the Laboratory staff published a book chapter (in print) on the use of optical fibers and optical fiber sensors in radiation monitoring. In our opinion, this book chapter is he most updated and compressive study on the use of optical fiber and optical fiber sensors for radiation dosimetry and radiation fileds mapping. The cooperation with Univestity of Limerick was complemented with our collaboration with the X-ray microtomography Laboratory from our Institute.

In the frame of the "Nucleu" program, LMSL team work on the development of new procedures for the use of the newly acquired equipment (i.e. 3D laser vibrometer, the time-resolved fluorescence unit) and started several collaborations at national level (Faculty of Pharmacy, the "I. Cantacuzino" Institute, Faculty of Mechanical Engineering at "Politehnica" University, National Authority for Meteorology) to prepare the ground for participation to national research grants. Some of the investigations were performed in cooperation with the Faculty of Applied Sciences at the "Politehnica" University, by involving four graduate students, one graduate thesis was prepared in this frame, based on 3D vibration investigations. As the student involved into these studies attends now a master degree at University of Copenhagen, the collaboration continued within this new frame. These young researchers contributed with their results to four papers at international conferences.

Based on the infrastructure it has and the international cooperation, the Laboratory team took part to six project proposals in the frame of the last call for the "Parteneriate" program, the spectrum of the partnership the Laboratory undertook for this call range from monitoring of secure operation of critical installations; drought monitoring and forecasting; science education; evaluation of UV radiation hazards; the use of nanotechnology in life sciences.

As it concerns the outreach activities and educational support for science teaching, the Centre for Science Education and Training- CSET won a project ("Discover!") funded by the European Structural Fund, to support school science teachers training according to the inquiry-based approach. The outcomes of this project are: an e-learning platform to support science teachers' continuum professional development (CPD) at primary and lower secondary school levels, over 35 learning units for science teaching, more than 20 educational videos. The modules are either original or translations from European projects and are available on the e-learning platform. Within this project, CSET organized two international conferences and numerous courses across the country. Over 1000 school teachers were trained and a Science Day is organized each school year, in cooperation with the French School in Bucharest. In 2010 for example, the event was attended by more than 500 school students and was supported by the French Embassy in Bucharest, the Romanian Ministry of Education and the French Agency for Education Abroad (http://www.aefe.fr/sciences/chercheurs-en-herbe-un-projet-de-cooperation-educative-autour-des-sciences-initie-par-le-ly). During he reported period, CSET run collaborative projects and educational activities (contests, demo sessions, science fairs, etc.) with over 85 schools and cooperated with school inspectorates from 12 counties. CSET e-mail list and database encounter more than 1500 school teachers across the country. CSET web site was visited by over 15,500 visitors and the "Discover!" project site was used by 5000 school teachers.

In the last four years, CSET applied in various consortia to European funded projects. Some of them were successful, so, for now CSET coordinates at national level two FP7 project in the context of Science in Society funding scheme: the "Fibonacci" project and "Creative Little Scientists" project.

According to its mission, the Laboratory offered also consultancy and testing services to industry and academic partners.

Team E27 Plasma Processes for Materials and Surfaces (http://plasmat.inflpr.ro)
Team leader- Gheorghe Dinescu

Team structure

The group was organized 10 years ago and has in the present a total number of 14 permanent employees, from which 2 Senior Scientist 1st degree, one of them being PhD supervisor at University of Bucharest, Physics Faculty, 2 Scientific Researchers 3rd degree, 5 Scientific researchers, 4 Research assistants and 1 technician. The average age of the research staff is below 37 years.

Dynamic of the research subjects and directions and the **most important achievements** are the following:

1. **Development of plasma sources**

According to the hot topics in the fields, one of the approached research directions was the development of new, innovative types of atmospheric pressure, cold (nonthermal) plasma jet sources operating in various gases for applications in nanotechnology, biomedicine, environment, fusion technology.
A compact plasma source (850 g), of small size (17 cm length and 2 cm diameter at the nozzle), but capable of functioning at RF powers up to 500 W in Argon and nitrogen, has been realized in the group (2007). We demonstrated that this plasma source is suitable for cleaning the codeposited-like layers in Tokamak devices. In 2010 the plasma source has been redesigned for enhancing its functionality in reactive gas atmosphere and we proved its capability of operation in pure oxygen or Ar/oxygen mixture, air, mixture Ar/ammonia, Ar/hydrogen (EURATOM contracts). At the same time, a low power miniaturized RF plasma source having 0nly 99 mm length and 8.2 mm diameter, able to operate up to 25 W, was designed for processing of temperature-sensitive materials, like polymers (2008-2009, Partnership contracts), appropriate for biomedical applications. These plasma sources are based on an original design in which the electrodes are in direct contact with plasma; therefore we called them generically “Discharge with Bare Electrodes” – DBE. We have been published 3 ISI papers and 1 PhD degree has been obtained in this topic in the reported period. In addition, various configurations of dielectric barrier discharges (DBDs) have been tested (2009-2011) in conjunction with the generation of a RF plasma jet, namely in plan-parallel, cylindrical or trapezoidal configurations (IDEAS contract, 1 PhD degree obtained).
In the same field of innovative discharge configurations, low pressure plasma systems have been developed. An Inside-Gap Plasma Generator which allows the discharge penetration inside gaps with dimensions similar to those of Tokamak walls (2007, EURATOM contracts, 1 ISI paper, 1 PhD in course) was demonstrated. A low pressure sequential deposition system in which the substrate is alternatively exposed, in a controlled manner, to a PECVD plasma source for amorphous carbon synthesis and to a magnetron sputtering plasma source for metal inclusion has been set-up for obtaining composite materials (1 ISI paper, Euratom projects, including collaboration with CEA Saclay, France and Tekes/VTT, Finland, CIEMAT Spain). In a similar approach, a combined deposition using a plasma polymerization source and a magnetron sputtering source has been set-up for metal-polymer composites (Young team research project).

2. **Plasma synthesis of nanomaterials and process characterization**

We succeeded to synthesize carbon nanowalls (CNW), carbon nanofibers, core-shell metal nanoparticles coated with graphite layers, by using low pressure radiofrequency plasma jets. We focused on carbon nanowalls: we have shown that they consists from small graphene domains assembled together in veils of tens of nm thickness, and length, heights of a few microns (SEM, TEM, Raman spectroscopy). We have developed methods of controlling their size and surface density. The results were published in 5 ISI papers and led to the the defense of 1 PhD thesis in the group, while another PhD thesis is in course. Functionalization of the CNWs by plasma post-processing in various gases (SF_6, O_2, N_2) has proved to be efficient for controlling the wettability, without important modification of morphology. These new materials, based on graphene, are very promising for applications in biology, nanotechnology, catalysis, fuell cell. A cell-repellent behaviour of CNWs was evidenced (1 ISI paper), and both superhydrophyilicity and superhidrophobicity were shown (1 ISI paper). Collaborations with research groups from Germany, Spain, and France are in course on this topic. In addition, we collaborate with a number of Romanian research and education institutions. The research was was funded in the frame of Ceex, Partnership, Young researcher team contracts.

3. **Materials processing by low and atmospheric plasmas**

In the field of surface modification, we have proved that the atmospheric pressure plasma sources developed for functioning at low RF powers, both in DBE and DBD discharge configurations, are capable of increasing wettability (contact angle measurements) of polymeric materials (2 ISI papers), including the case of Teflon, and may promote the cell adhesion on the treated surfaces (Partnership, Ideas contracts, 1 PhD thesis defended, 1 PhD thesis in course).

By using the high RF power plasma sources at atmospheric pressure and the Inside-Gap Plasma Generator, we demonstrated (Spectroscopic Ellipsometry, AFM) the removal of carbon layers and composite materials similar to those encountered upon fusion machines functioning, both from flat surfaces and from castellated surfaces with dimension of the castellation as low as 0.5 mm width and deepness down to 23 mm (2008-2010, 1 ISI paper, Euratom contract, in collaboration with CEA, France, 1 PhD thesis in course).

Preliminary results showed Si and Fe nitridation may proceed in the ambient upon exposure to atmospheric pressure RF nitrogen plasma. Hydrogen defects were induced in silicon at controlled deepness from the surface (TEM), upon exposure to hydrogen plasma generated at low pressure (2 ISI papers). This approach may facilitate the lift-off of single crystal Si layers thinner than 50 nm (1 patent).

Polymeric nuclear track membranes have been submitted to various plasma treatments at low pressure, in order to modify their pore size (SEM) and transport characteristics (collaboration with JINR, Russia). The possibility of tuning the transport properties of gases and in solution have been proved upon exposure to plasma generated both in polymerizing and non-polymerizing atmosphere. The formation of bi-layered membranes (FTIR, XPS) led to asymmetry of conductivity in solution (6 ISI papers).

Metal-carbon composite materials have been obtained by using the sequential method, the ratio between the carbon and metal content being controllable through sequences timing (1 ISI paper). Plasma polymers have been synthesized starting from precursors with conjugated bonds for obtaining conductive polymers, in various plasma configuration, while in-situ and ex-situ doping with iodine was considered for improving conductivity (2 ISI papers,1 PhD Thesis, Partnership contract).

4. **Processes in plasmas and their diagnostics**

For the development of plasma sources and configurations, as well as for the understanding of the processes responsible for the material synthesis or surface modification, plasma diagnostics was essential. Such as, the operation of RF plasma jets in DBE configuration during has been investigated by imagistic, optical emission spectroscopy and electrical measurements (IDEAS contract, 1 PhD Thesis, 2 ISI papers). Similar measurements have been implemented for DBD RF plasmas, which, in conjunction with simulation of OES spectra (collaboration with University of Bucharest, Physics Faculty) provided valuable information regarding the operation regimes (1 PhD student, 1 paper to be submitted).

A complete diagnostics of the low pressure expanding RF plasma generated in argon and injected with acetylene and hydrogen during carbon nanowalls synthesis has been performed. The formation of high mass carbon clusters (up to C8) and the existence of high energy ions were evidenced; at the same time, a maximum of the C2 and CH radicals could be observed in the optical emission spectra in respect to Ar lines. The results, correlated to those devoted to material characterization, pointed out toward the existence of an optimal distance from the injection point, in which the maximum of high mass ionic species densities were determined, but still enough hydrogen is present. Therefore, a balance between the depositing and etching species could be evidenced (1 ISI paper, a PhD thesis in course).

In the topic related to plasma polymerization, mass spectrometry and OES allowed the determination of main species present in plasma and the existence of polymerization reaction in plasma volume, which lead to formation of large mass oligomers (Partnership, Young Research Team projects).

Important achievements were obtained regarding the OES monitoring of the sequential process of metal-carbon nanocomposites synthesis, which offered information on the process stability and reproducibility (Euratom project, 1 ISI paper) during deposition of mixed layers with controlled ratio of metal to carbon

Evolution of human resources

Over the reported period the staff evolved significantly regarding the scientific positions: 1 member became PhD supervisor, one promoted from Scientific researcher 3rd degree to Senior Scientist 1st degree and most of the other promoted 1 position on the scientific hierarchy. 6 persons defended their PhD, one of them abroad and 3 in 2011 under the supervision of the team leader. Other 5 PhD students are in the final year of doctoral studies.

The team members have given more than 10 invited lectures at International Conferences in the field of plasma physics, plasma chemistry and material synthesis and characterization, with over 300 participants, several seminaries at Institutes from abroad. They are official referees of more than 12 international ISI Journals, most of them with impact factors exceeding 2. The team leader is member in Board of Directors of International Plasma Chemistry Society (IPCS) and President of Plasma Physics Division of the Romanian Physical Society, was member of the International scientific committees of more than 6 conferences, co-chair of the 14th and 15th International Conference of Plasma Physics and Applications and Co-organizer of the E-MRS Spring meeting 2009 of Symposium Q.

Interdisciplinary or entrepreneurial initiatives refer to applications in various fields, from microelectronics to biomedicine and from environmental pollution to nuclear safety. In the last period the group registered 3 inventions at OSIM, 1 of them being already granted.

International cooperation

- CEA Cadarache, CEA Saclay, France, Tekes/VTT Finland, CIEMAT Madrid, Spain and MHest Ljubliana, Slovenia: Euratom topics on co-deposited materials and fuel removal
- JINR Russia on polymeric nuclear track membrane treatment for filtration
- Hacettepe University, Turkey, in the field of biomedical applications
- Technical University Eindhoven, The Nederlands, - on plasma diagnostics
- Leibniz-Institut für Plasmaforschung und Technologie, Greiswald, Germany – synthesis and applications of nanocomposite materials
- Hasselt University, Belgium- diamond based materials -synthesis and applications in electronic devices, Ph D student
- Fundazione Bruno Kessler, Trento, Italy – synthesis of transparent and conductive materials, PhD student

Team E28: "Pulsed Transient Plasma" Team Leader Dr. M. Ganciu

1. In the frame of the EU-FP6 STREP project EMDPA (www.emdpa.eu) we have optimized the discharge modes in GD-OES and GD-MS systems so that the sputtering the excitation and ionization would be controlled avoiding the surface damage, a very benefic aspect for sensitive surfaces. The discharge mode developed was an original one and assured an increase in atomic and ionic metastable density a real suplementary energy source for exitation and ionization processes occuring in analytical plasmas. Direct and fast chemical analysis of solid material is of major interest for trace elements analysis and layer characterization, particular in thin film technologies which is a rapidly owing market in modern industrial application and thus of permanent interest in material research. Determination of the chemical composition of solid material as well as characterization of thin films is achieved by several different spectroscopic techniques using bulk (elemental) analysis or depth profiling methods. For this purpose, several techniques are commonly used including inorganic Mass Spectroscopy methods (MS), Auger Electron spectroscopy (AES), X-ray Phoelectron Spectroscopy (XPS) and Glow Discharge Optical Emission Spectroscopy (GD-OES). These methods are based on different physical principles and characterized by specific advantages and disadvantages. Speed and ease of use are also crucial to keep pace with new materials development and these necessary requirements are not possible with classical surface techniques (XPS, AES etc) that are very slow and also operate over very small zones of analysis. GD-OES has the speed of analysis required, but could not provide any valid molecular information and the lack of sensitivity inherent to OES make it steel inappropriate for the needs of new materials. GD MS could be a valid concept but in order to develop a new instrument fulfilling advanced materials' requirements, fundamental breakthroughs, must be overcome.

2. We identified new reactive excitation and ionization processes involving atoms and ions of analyte samples, conductive layers and multilayers. Also we evidenced the analytical plasma optimum parameters for the new identified processes and established the role of each new identified process in the elemental analysis in order to make the analytical process more efficient.

3. We studied and we identified new reactive excitation and ionization processes of molecules and molecular fragments sputtered from organic and anorganic samples in analytical plasmas and evidence the optimum parameters for each of them. These parameters were correlated with the IR spectroscopic results of the organic and anorganic surfaces. The IR spectroscopic measurements provided information about the severe physical-chemical modifications such as cross-linking, bond breaking, radical formation, etc., that radically change the nature of the investigated sample. An optimum between sputtering conditions and ionization conditions for molecular fragments were established

Due to the high complexity of the research, the experimental and theoretical studies favourized the development and strengthen the international collaboration (EUproject EMDPA and a collaboration agreement between LPGP, Univerisite Paris-Sud, CNRS Franta and INFLPR Bucuresti Romania).

4. We identified a new control method of GD plasmas by a magnetic field at the surface of the analyzed material, favouring efficient ionization in GD-TOF-MS systems studied by us

within the EMDPA project. This method has been patented by NILPRP and HJY (WO/2009/130424A1, WO/2010/092301) and is commercialized by HJY (http://www.bulletins-electroniques.com/actualites/59514.htm).

5. GD Grimm lamp, used in GD-OES and GD-TOF-MS analytical surface diagnostic techniques, was improved by enhancement of ionization processes using an original method of micro-modulation of RF plasma inside the anode of the lamp by using a supplementary adapted fast high voltage discharge.

6. Another research field of our team members was to develop a physical polymerization method in order to obtain organic, anorganic and nanocomposite layers with thermal and chemical stability used as protective coating layers or adhesivity promoters. The method had a high degree of originality and complexity because it offered the possibility to use a wide range of organic and polydymetylsiloxane liquid precursors with different polymerization mechanisms. Thus it will be avoided the precursors evaporation and their mixture with the working gas and consequently the contamination of the polymeric layers generated in the plasma.
To ensure this objective we needed fundamental studies concerning the nonequilibrum discharges at atmospheric pressure in short pulses regimes, the interaction between active species and dielectric liquids, the convective liquids movement occurred in order to establish the best conditions for the polymerization processes for polymeric layers deposition on different type of surfaces. The researches were also concentrated on the establishment of the polymerization steps of the liquids precursors generated by the active species from the electrical discharge. There were identified of the proper discharge regime at atmospheric pressure, in correlation with the proper liquid precursor the irradiation time for the generation of a certain polymer.

7. We developed researches in the field of Surface Modification by Immersion Ion Implantation (PIII)

"Surface Modification" is a well known term in surface science and technology defining the act of improving the surface properties of materials. Surface modification is used in the automotive, aerospace, missile, power, electronic, biomedical, textile, petroleum, petrochemical, chemical, steel, power, cement, machine tools, and construction industries. Surface engineering techniques can be used to develop a wide range of functional properties, including physical, chemical, electrical, electronic, magnetic, mechanical, wear-resistant and corrosion-resistant properties at the required substrate surfaces.
Ion implantation is one important process of Surface modification, which can improve mechanical properties of surfaces (hardness, adhesion, wear, friction, fatigue, etc.), chemical properties (electrochemistry, catalysis, oxidation resistence, corrosion resistence, etc), optical (refractive index, reflectance, etc) and electronic (magnetic properties, conductivity). Ion implantation is a process in which the ions are accelerated at sufficiently high energy to penetrate the material of a target.
There are two main methods of ion implantation: Ion Beam Implantation and Plasma Immersion Ion Implantation (PIII).
In this context, our group focused on Surface Modification by Immersion Ion Implantation (PIII) method, in which the object to be implanted is immersed in low pressure and low temperature plasma and high voltage pulses are applied to the object holder in order accelerate the ions from the plasma sheath. As the ion dose implanted, the main characteristic of the ion implantation

process, increases with background plasma density, raising the plasma density while keeping the pressure as low as possible is desirable. For example plasma produced by a filament or RF discharge, the density can be enhanced by confining electrons in a magnetic multipole ‘‘bucket’’geometry. In the case of capacitively coupled sources, significant increase of plasma densities can be obtained from when higher frequencies are used (e.g., VHF, up to 300 MHz, or 500 MHz in a large-area ribbon beam source (UHF frequency region)).

In this context, one of the high level and complex research direction concerns the development of a high performance ion source, which will be capable to generate high-density plasma (10^{13} cm^{-3}) by choosing optimum discharge configurations and operating regimes, so that a large amount of ions will be accelerated towards the target when negative high voltage pulses are applied. For this purpose, we proposed and developed an original method to modulate the preexistent plasma around the substrate by superimposing supplementary high voltage pulsed discharges before applying the short accelerating pulses on the target. Geometrical, electrical and spectral parameters were adapted to the requirements appropriate to different thin layer type, which will subject ion implantation.

8. We identified a new operation mode of magnetron discharges for the deposition of thin films in short and ultrashort pulses by effective ionisation of the sputtered vapours http://www.fist.fr/en/manufacture-devices/high-power-pulsed-magnetron-without-arc-formation.html. This patented technique, has led to an intense and fruitful technological French - Romanian cooperation comprising: more than 10 invited conferences of the inventors group; 12 articles in ISI journals with more than 150 citations; 3 already finalized Ph.D. theses and 3 ongoing Ph.D. theses at IMN-Nantes in collaboration with Thales and CEA and a US patent granted in 2011 (7927466 B2/Apr.19, 2011)

9. We developed a new method for atomic nitrogen generation at atmospheric pressure by employing a new principle of non-equilibrium plasma ignition. A first application of this discovery - the decontamination of thermo-sensitive materials – has been patented. (US Patent: 7229582 B2 / June 12, 2007, European Patent EP 1638616 B1, 10/03/2010) The European Patent granted in 2010 is at the core of the creation of a start-up company (www.plasmabiotics.com) which is, to the best of my knowledge, the first start-up created in France as a result of a scientific French-Romanian collaboration.

10. In collaboration with Prof. Marian Apostol from IFIN-HH we developed a new model and a new theory of polaritonic transport, under specific conditions of relativistic electron packets spatially and temporarily synchronized with intense laser pulses. This theory opens a new direction for the generation of coherent gamma sources by Compton Backscattering on polaritonic structures. It has been presented in seminars on ELI thematic (http://www.ifa-mg.ro/eli_seminars.php) and a recently published article in JAP (doi:10.1063/1.3530599) was selected as research highlight (http://jap.aip.org/research_highlight_archive). These achievements allowed us to start scientific collaborations in plasma and laser assisted high field physics with Thales-Optronique (France), Thales-Ro and Strathclyde Electron and Terahertz to Optical Pulse Source (TOPS), University of Strathclyde, Glasgow, UK. For the developing of these objectives a new project (PN-II-PCE-2011-3-0958) was recently granted for the period 2011-2014: “Electron acceleration and polaritonic transport by laser-plasma interaction in new capillary configurations”.

Team: Plasma Coatings (http://www.plasmacoatings.ro/)

Team Leader: Dr. Cristina Surdu-Bob

Team structure

The team is composed of 5 researchers (1 senior researcher I[st] rank – PhD in medicine, 1 senior researcher II[nd] rank – PhD in veterinary medicine, 1 senior researcher III[rd] PhD in physics, 2 scientific researchers – a PhD and a PhD Student in physics).

Dynamic of research directions and subjects

The Group was established in October 2008 within the Low Temperature Plasma Laboratory of INFLPR [www.plasmacoatings.ro]. Since establishment, the Plasma Coatings group has been active on plasma diagnostics, deposition of thin films, the synthesis of medical implants and in vivo and in vitro experimental work.

The first research activities were based on diagnosis and development of the Thermoionic Vacuum Arc (TVA) plasma source. An in-house computer-controlled ion energy analyzer was built and used to determine ion energy distributions in the TVA plasma. The results allowed a better knowledge and control of the plasma.

Further work focused on development of the plasma source for the deposition of metallic and non-metallic thin films, pure or in combinations, for different applications. Correlations of film characteristics with plasma parameters were obtained. Special attention was given to finding optimal plasma conditions for the deposition of quality, adherent films. A series of coatings on mechanical parts were realised for different companies interested from Romania and abroad (Acree Technologies – USA, Amplo srl. - Romania, Gera GmbH – Germany, Horologium srl. - Romania).

A new research subject emerged on the occasion of funding of a Partnership project (no. 42-129). A deposition process on textiles was developed. The deposition technology was applied for antimicrobial coatings for studies concerning prevention of infections in hospitals at the Clinical Institute and Hospital Fundeni (collaboration agreement No. 5846/29.11.2010).

The research area of the Group was further enlarged since the success obtained in a pilot study for a new cancer therapy concept based on the controlled release of engineered implants.

A post-doctoral research fellowship of the Group Leader on *Materials to be used in medicine* (between June 2010 and July 2011) added more knowledge via courses, lab work and contacts with researchers in the medical field. This offered new perspectives in terms of collaboration on applied physics in medicine interdisciplinary field.
The new funding within the Ideas framework (Project No. 3-0953/2011) offers the opportunity to study plasma based functional materials on osteomyelitis treatment.

Most important achievements

- The development of a dual plasma source which opens up new perspectives in the field of thin film deposition. Using this source, thin films of any combination of materials and chemical compounds can be obtained (Issued patent No.123002-RO/30.06.2010).
- Construction of a large scale deposition system for antibacterial coatings on textiles (Patent application No. A/01267/02.12.2010).
- The development of a method to synthesize spherical particles in the sub-millimetric range made of different materials (Patent application No.A/00754 / 22.12.2009).
- The development of a new therapy concept based on the controlled release of plasma synthesised implants. The therapy was tested on cancer-bearing mice and the results were recently published. The concept is currently being tested on osteomyelitis.

Interdisciplinary research

The Plasma Coatings Group has conducted research on plasma physics (plasma diagnosis), materials physics (film and surface analysis), microbiology (material effects on bacteria) and medicine (efficiency of implant-based therapy).

Evolution of human resources

When the Plasma Coatings Research Group was established, on October 2008, it was composed of two researchers on Physics and a part-time chemist. The Group Leader has background on Plasma Physics and Surface Science obtained at Aston University (Birmingham) – UK. The other physicist is a PhD student. In 2010 the group acquired a new member, an MSc on Physics and in 2011 another three members: a PhD in physics, a PhD in medicine and another PhD in veterinary medicine.

International cooperation

An international cooperation on research was established within the framework of a project funded by AvH Humboldt Foundation V - 1050696. A large series of unfunded collaborations on sample analysis and preparation have been conducted.
Other international cooperation was mainly focused on applied research. Companies like Acree Technologies Ltd. – USA and Gera GmbH – Germany have used our solutions for coating of machine parts and further collaboration is envisaged.

Entrepreneurial initiatives

The activities undertaken since 2008 of the Plasma Coatings Group included applied research in industry in Romania and abroad. The Group has undertaken research for industrial applications on performance improvement of machine parts by protective coatings to be evaluated by companies interested. This is the first activity towards entrepreneurial initiatives.

Team: 28 Elementary Processes in Plasma and Applications(http://eppa.inflpr.ro/)
Team Leader: Dr. Cristian P. LUNGU
Team structure
The team is composed of 6 researchers (1 senior researcher I[st] rank, 2 senior researchers III[rd] rank, 3 scientific researchers) and 4 technicians

Dynamic of research directions and subjects

1. Magnetorezistive materials

In the frame of the project "Spin structure with applications in magnetoelectronics" the team developed granular type magnetoresitive materials. The granular metallic thin films consisting of single domain ferromagnetic clusters embedded in a non-magnetic metallic matrix and presenting giant magnetoresistance (GMR), acquired in the last years a great interest, in challenge to the typical multilayer systems. The research team studied Fe-Cu and Co-Cu nano-globular thin films presenting GMR effects and obtained by a new procedure (thermionic vacuum arc method). The obtained films were characterized in respect to both the magneto-transport properties and local magnetic interactions. The influence of subsequent thermal treatments on the magnetoresistive effects was also studied.

2. Coatings resistant to high temperature oxidation

In the frame of the project "High temperature and oxidation super-resistant coatings metallic coatings, nanostructured Re–Cr–Ni multiple component film was chosen as a diffusion barrier layer and was prepared by the original thermionic vacuum arc (TVA) method. The electron beam evaporates the anode materials as much as to create a dense gaseous metal atmosphere between the cathode and anode in which the electrons build up dense pure plasma which expands out in the surrounding vacuum space toward the substrates. The Re and Re–Cr–Ni films were deposited using: (i) a single discharge in Re vapors and (ii) two independent discharges in Re and Ni/Cr vapors, running in the same vacuum vessel. The appropriate Cr/Ni raw composition of 25/75 at.% was found in order to obtain the desired Re30Cr10Ni composition.

3. Low friction coatings

The metal–containing amorphous carbon (a-C:Me) or tetrahedral (diamondlike) amorphous carbon (ta-C:Me) films have been intensely studied, specially due to their applications as extremely low-friction coefficients and very good wear-resistant surfaces (up to 10,000 times greater than polysilicon). The corrosion properties of DLC-coated metals are also outstanding; The study promotes the thermionic vacuum arc method for deposition of smooth, low-friction, continuous and high sp3 content metal-carbon nanostructured coatings. The structure and composition of the Ag-containing amorphous carbon composite films deposited by TVA method was correlated with the morphological and structural features (Ag grain size and sp3 content of the a-C matrix) with the mechanical properties (the friction coefficient) by variation of the Ag atomic percent in the films.

4. Protective Diamond Like Carbon (DLC) coatings

DLC thin films have a wide range of applications in nanoelectronics, novel optical devices, integrated digital circuits and protective coatings. From all of these, DLC thin films used as protective coatings cause a growing interest for many areas as: compact disks, optical windows (glasses), optical fibers, magnetic storage disks, micro-electromechanical devices (MEMs), and biomedical coatings. Were studied DLC films prepared using thermionic vacuum arc method in different working conditions. TVA method generates hydrogen-free DLC thin films. Comparing with hydrogenated DLC, hydrogen free DLC films show advantages such as higher hardness and elastic modulus, lower coefficient of friction in humid environment and also higher thermal stability

5. Research and production of the "marker tiles" for the FUSION program

The ITER-like wall (ILW) project is a very important part of the JET programme in support of ITER. The main aim of ILW is to implement a full metal first wall in JET and to demonstrate tokamak operation with beryllium (Be) components in the main chamber and tungsten (W) in the divertor. Therefore, the R&D programme also includes activities to facilitate: (i) the coverage of the inner wall Inconel cladding with Be coatings to reduce the influx of high-Z metals to the plasma ; (ii) measurements of Be erosion from limiters by means of so-called marker tiles. These tiles will be distributed in areas of particular interest, such as outer poloidal limiters (OPL) and inner wall guard limiters (IWGL). The 'marker' is a Be tile coated first with a thin (2–3μm) film of an easily detected heavy metal (e.g., W, Re, Ni acting as an interlayer) and then coated with a few micrometers (7–9μm) of bulk-like Be on top of that. The major effort related to markers has been to select and optimize the most appropriate production process of dense, uniform and high purity Be films on a high-Z metal interlayer deposited on bulk Be limiters. The optimization (i.e., layer thickness, structure and purity) must ensure good adhesion and thermomechanical compatibility of the system. The thermionic vacuum arc (TVA) deposition process has been chosen in order to obtain high density films for the production of markers.

6. Hydrogen retention in ITER relevant mixed material layers

Based on observations in present fusion devices, it is expected that the wall material will be eroded due to the interaction with plasma particles and subsequently deposited on other material surfaces. This leads to the formation of mixed material layers on the wall surface. Material mixing can change not only the thermo-mechanical properties, such as thermal conductivity or melting point, but also fuel retention properties of the plasma facing wall. Fuel retention influences the hydrogen recycling on the plasma facing surface and the tritium inventory in the vacuum vessel. In ITER, for safety reasons, periodic tritium removal will be required before the invessel tritium inventory reaches its administrative limit, meaning that tritium retention rate strongly affects ITER operation program in the D–T phase.

From these considerations, hydrogen uptake and retention in mixed material systems is an important issue for reliable extrapolation of in-vessel tritium retention in ITER. Although various investigations have been done to clarify the hydrogen retention properties of each pure material, there are only a few available data for mixed materials at present. In this study, representative mixed material layers of Be, C and W, prepared using thermionic vacuum arc were prepared, and hydrogen retention in those layers was investigated under controlled laboratory conditions.

Most important achievements

- Contribution to the discovery of the "monochromatization" radiation effect of plasma displays emitted radiation using a triple, convenient mixture of gases including an important contribution to the first plasma display accomplishment.
- Contribution to the development of the thermionic vacuum arc method with applications in multifunctional, nanostructured films preparation

- Contribution to the preparation and characterization of the granular and multilayer magnetoresistive films (GMR, CMR and TMR)
- Contribution to the preparation and characterization of carbon based low friction coatings
- Contribution to the preparation and characterization of the films resistant to oxidation at high temperature (Re based composites)
- Contribution to the preparation of the pure beryllium and beryllium based composites for thermonuclear applications. Be coatings of the “smart” marker tiles and Inconel tiles for the ITER-like wall of the JET devices from Culham, UK.
- Basic studies on the Be-C-W films formation in fusion devices and fuel retention.

Interdisciplinary research

Evolution of human resources

During the analized period of time, 3 members of the team graduated the doctoral school and defended the PhD thesis in 2011. One member is enrolled on a PhD course at the University of Lile, France.

International cooperation

The research team cooperated successfully with specialists from the following laboratories:

- Max-Planck-Institut für Plasmaphysik, Garching, Germany
- Jozef Stefan Institute (JSI), Ljubljana,Slovenia
- Forschungszentrum J¨ulich, J¨ulich, Germany
- Alfv´en Laboratory, Sweden
- Culham Science Centre, Abingdon, UK
- VTT, Association Euratom-Tekes, Finland

Entrepreneurial initiatives

Team E31: STARDOOR

Team Leader : Dr. A. Scarisoreanu

Between 2007 and 2011 the staff of the STARDOOR laboratory has been involved in the following research projects:

- CEEX – CERES 2006 – 2008, Module IV, Project title: "Laboratory designated by the competent authority for nuclear activity as Secondary Standard Dosimetry for high-energy (STARDOOR)", contract nr. 225 / 10.08.2006;
- CEEX – CERES 2006 – 2008, Module I, Project title: "The study of the Process for generating laser radiation with free electrons in the range 1 MeV - 50 MeV (GENERAL), contract nr. 35 / 25.07.2006;
- CEEX – CERES 2005 – 2008, Module I, Project title: "Computational methods for high-efficiency of current physical problems (COMPUT)", contract nr. 56 / 10.10.2005;
- CEEX – CERES 2005 – 2008, Module I, Project title: "Integrated Microsystems for Real-time monitoring of drilling parameters to optimize the exploitation of oil (MICROSYSOIL)", contract nr. 30/ 10.10. 2005;
- CEEX – CERES 2006 – 2008, Module I, Project title: "The study of cumulative generation of particles in high energy interactions", GECPEI, contract nr. 17 / 25.07.2006;
- CEEX – CERES 2006 – 2008, Module I, Project title: "Study by unconventional methods (microwave absorption and micro-tomography) of superconductor YBa2Cu3O7-x system: BaZrO3 irradiated with high energy electrons (ATYB)", ATYB;
- CEEX – CERES 2006 – 2008, Module I, Project title: "The behavior of emerging states in heavily correlated electronic systems; COSTEMSEC, contract nr. 98 / 19.09.2006;
- CEEX – RELANSIN 2006 – 2008, Module I, Project title: "Low energy electron beams: generation, nondestructive analysis, dynamic and testing in the application plan", contract nr. 308 / 19.09.2006;
- CEEX-BIOTECH 2006-2008, Project title: "Application of electron beam treatment for microbial decontamination of sea buckthorn supplements", CATI, contract 86/31.07.2006;
- PNCDI 2 2007 -2010, Project title: "Natural dietary supplement with anti-stress properties", BLOCSTRES, contract 51-101/14.09.2007;
- PNCDI 2 2007-2010, Project title: "Uncontaminated plant extracts used in phytotherapy obtained by unconventional technologies", FITODEC contract 31-061/14.09.2007.

The team of the STARDOOR laboratory is comprised of the following grades of scientific researchers: 1-CS I, 1-CS II, 1-CS, 4-ACS, 1-IDT, 3-TI. In the period reported utilizing part of the infrastructure from the STARDOOR laboratory and of INFLPR one of the researches has obtained a doctor degree in physics, and 2 other have started doctoral studies at the University of Bucharest.

The results obtained in the above mentioned projects have been quantified in the participation at different national and international scientific events (symposiums, conferences, workshops), by publishing scientific papers in ISI journals, in CNCSIS journals, proceedings etc. The most significant results are as follows:

- Organization of the international symposium "1st Secondary Standard Dosimetry Symposium" SSD07 on the 12 November 2007 in Magurele;
- The acquisition of modern equipments and dosimetric systems;

- Elaboration of the quality assurance manual (MMC- STARDOOR-06) and of the organizational, technical, system and work procedures specific to the STARDOOR laboratory;
- Obtaining accreditation for calibration and testing;
- Obtaining from CNCAN the notification for “ Secondary Standard Laboratory at high energy”- STARDOOR and the signing of a contract between RENAR and INFLPR for the accreditation of this laboratory;
- Organization of the international symposium “1st Free Electron Laser National Symposium” – FEL – 08NS between the 26 and 27 of September 2008 at the Ramada Majestic Hotel , Bucharest;
- Acquisition of a nanosecond laser that is going to be used for researching the quantum efficiency of photocathodes;
- Elaboration of a precise method for measuring the energy absorbed by materials exposed to accelerated electron beams, method that can be utilized both in technology related irradiation and in calibrating dosimetric equipment;
- Determining the doses necessary for treatment of underbrush oil (2,5 kGy) and juice (2 kGy) with accelerated electron beams that do not cause significant changes to the chemical and nutritional properties of these products; outfitting the physico-chemical laboratory;
- Creating the bloc diagram of the free electron laser RO-FEL;
- Creation of a bloc diagram for a synchrotron radiation source with applications in research and industry;
- Study of Thompson scattering of spontaneous or stimulated of intense radiation waves from relativistic electron beams;
- Study of the methods and devices capable of generating spontaneous and stimulated emission in the energy range of the free electrons produced by the INFLPR particle accelerators;
- Tests done in the electron beam of the NUCLOTRON from IUCN-Dubna with the SFERA multi-detector;
- Elaboration of the necessary documentation for patenting the obtained results from project51-101/2007;
- Publication in ISI journals of 19 scientific papers;
- Publishing on 56 papers in non ISI journals and in proceedings edited after conferences symposiums and workshops;
- 5 awarded articles in the Human Resources program project Awarding of Research Results.

The STARDOOR laboratory from INFLPR has come into existence from the CEEX – Module, IV Nr. 225/10.08.2006 programmed, named “Laboratory designated by the competent authority for nuclear activity as Secondary Standard Dosimetry for high-energy” (abbreviated STARDOOR).

Following the conditions of the above mentioned contract the STARDOOR laboratory was evaluated by RENAR for accreditation, as a standalone calibration and testing laboratory for ionizing radiation of high energies. After the evaluation by RENAR, the STARDOOR laboratory obtained the accreditation certificate for calibration and testing, LE 020 respectively LI 906 from 10.01.2011, valid until 09.15.2015. At the present time the STARDOOR laboratory is the only

RENAR accredited facility from Romania for dosimetry in the field of high energy ionizing radiation.

Concerning the impartiality, independence and transparence of SR EN ISO 17025:2005 standard requirements respect and based on the INFLPR general manager declaration, STARDOOR laboratory is direct dependent of general manager in conformity with the INFLPR organizational structure approved by Ministry Order no. 4130 / 09.05.2011.

STARDOOR appeared behind the requirements and the absence of traceability to international standards, primary standard in special. Laboratory assures primary standard traceability at Physikalisch-Technische Bundesanstalt (PTB), recognized to international level by Bureau International des Poids et Mesures (BIPM).

By accreditation obtaining, the laboratory certify the personnel competence in the ionizing radiations domain, the interaction of the radiation with matter, the development of method and procedures that respect the following international standard requirements: ISO, IEC, IAEA, NCPR, ICRP, etc.

STARDOOR laboratory foundation going to new working places creating and engaging young faculty graduated people (Ph. D. student and M. Sc. student) in the laboratory activity domain, respecting the requirements of Excellence Research Program and Research, Development and Innovation National Plan 2007-2013.

By approach problems, the obtained results during the above mentioned projects are enrolled in present line of the world wide researches in the public health and alimentary security domains. The obtained results has an major impact in increasing of the life quality by improving the quality assurance procedures in clinical dosimetry and in radiotherapy practices using the clinical equipments, traceable to secondary standards, from STARDOOR laboratory.

Also, in conformity with present lows, the calibration and verification of the dosimetric control equipments is needed to optimize and assurance of the radioprotection in nuclear, industrial and medical domains. For that purpose, the STARDOOR laboratory endowment permits high energy experiments realization in the ELI-NP project and protection shielding optimization needed for the professional exposed personnel.

Team 32: Theoretical Physics and Astrophysics Group
Self Evaluation Report
(http://www.spacescience.ro/gft/)
Team leader: Dr. Cecil Pompiliu Grunfeld

I. Team structure

The team is composed of 13 researchers: 4 CS1 ("1st rank senior researcher") - *Dr. I. Baldea, Dr. D. Baleanu, Dr. G. Buica, Dr. C. P. Grunfeld* , 1 CS2 ("2nd rank senior researcher") - *Dr. M. Vatasescu*, 6 CS3 ("3rd rank senior researcher") - *Dr. P. Ghenuche, Dr. C. S. Ionescu, Dr. O. I. Patu, Dr. F. C. Popa, Dr. P. Stefanescu, Dr. O. C. Tintareanu-Mircea*, 1 researcher - *Dr. R. S. Bundaru*, and 1 research assistant - *L. B. Popescu*. The average age in the group is ***42*** years. The team is structured into three sub-groups, joining members with similar scientific affinities: *A) Atomic and molecular processes*; *B) Kinetic theory of complex systems, exactly solvable models*; *C) Space-time structures and symmetries in General Relativity.*

II. 2007- 2011 dynamics of research directions & subjects, main achievements, interdisciplinarity

In the period 2007-2011, the scientific activity of the team ranged over the landscape of analytical modeling and numerical calculations along researches on atomic and molecular quantum processes, equilibrium and non-equilibrium aspects of some classical/quantum complex systems, up to studies of the space-time structures and symmetries in general relativity. Some of the group's results are of interest in several theoretical and experimental areas of astrophysics and space research, and in other domains of physics, mathematics, chemistry, biology. The above activity resulted in ***58 papers published in valuable ISI journals with good relative AIS*** (Article Influence Score), ***2 monographs, 3 book chapters,*** contributions in collective volumes (published by reputed international and national publishers), conference proceedings and presentations at national and international conferences, etc. In the period 2007-2011, our team publications received over **600** citations in ISI journals, **229** of these citations referring to works published between 2007 and 2011.

Below, we summarize, *very selectively*, the scientific activities of the group and a few of its important achievements in the period 2007-2011.

A. Atomic and molecular processes (*Dr. G. Buica, Dr. M. Vatasescu*)

Goals. Quantum control of dynamics in cold atomic and molecular gases using shaped laser pulses. Accurate description of multiphoton atomic ionization by ultrashort laser pulses allowing precise calculation of atomic parameters, transition probabilities and photoionization cross sections.

Motivation. Cold atoms physics provides various precision measurements and also models for astrophysics: the physics of Bose-Einstein condensates (BEC's) is used to model black-hole radiation and to mimic properties of collapsing and exploding stars; there are new experiments searching for the presence of dark content of the vacuum using cold atom interferometry. There is an increased demand of more precise radiative data for light astrophysical abundant elements, in order to improve the analysis of spectral observations from space missions.

Main achievements:

• We achieved a theoretical description for a new regime of cold molecules formation, by modeling the photoassociation of cold atoms at small/intermediate interatomic distances using strong laser pulses. This strong non-impulsive regime of coupling brought to light a vibrational dynamics steered by the topology of the light-induced potentials, showing new phenomena in the momentum transfer and the molecular dynamics, which could be useful to design new experiments *[Nucl. Instrum. Meth. B 267, 390 (2008); J. Phys. B: At. Mol. Opt. Phys. 42, 165303 (2009)]*.

• We have investigated the quantum preparation of localized vibrational wave packets in cold molecules with light-induced molecular potentials by chirped laser pulses *[Nucl. Instrum. Meth. B 2011 doi: 10.1016/j.nimb.2011.10.037]* .

• We obtained a nonperturbative description of the two-valence electron atoms Mg and Ca interacting with LP and CP ultrashort laser pulses in the domain of moderate and high laser intensities. We clarified for the first time the source of the intermediate peaks in the above threshold ionization spectra. We made new calculations of atomic parameters for Mg (both singlet and triplet states) and Ca atoms, by means of a frozen-core Hartree-Fock potential and a model potential *[J. Quant. Spectrosc. Radiat. Transfer., 109 (1), 107 (2008); Phys. Rev. A, 79, 013419 (2009);Phys. Rev. A, 81, 043418 (2010)]*. The last results are also of interest in the analysis of the spectra from a wide range of astrophysical sources observed by spatial missions.

B. Kinetic theory of complex systems, exactly solvable models (*Dr. I. Baldea, Dr. R. S. Bundaru, Dr. P. Ghenuche, Dr. C. P. Grunfeld, Dr. C. S. Ionescu, Dr. O.I. Patu, L. B. Popescu*)

Goals. Developments of the kinetic theory and thermodynamics of conservative and dissipative complex systems; analytical and numerical solutions of kinetic models for reactive fluids; exact thermodynamical description of quantum low-dimensional multicomponent systems, quantum transport; interaction between nanostructures and external electromagnetic fields.

Motivation. More precise analytical and numerical methods for solving nonlinear kinetic models of reacting flows are needed in realistic computational combustion theories, description of astrophysical processes, and in space vehicle engineering (modeling of the space shuttle re-entry into the upper atmosphere). The kinetics of dissipative flows is important in understanding phenomena based on spontaneous aggregation, like complex organic structure formation or cosmic dust aggregation. There is an increased interest in exactly solvable models, as a result of the recent advances in optical and magnetical trapping of cold atoms which opened the way for the experimental realization of low-dimensional physical systems which can be well approximated by integrable models. These experimental realizations allowed testing various theoretical predictions of importance for condensed matter, field theory.

Main achievements:

• We have obtained a very general, unified theory of global existence and uniqueness of solutions for a large class of kinetic models, both conservative and dissipative. This includes, in particular, space-inhomogeneous Povzner-like equations, space-homogeneous Boltzmann-like equations, and quantum kinetic models *[e.g., Commun. Contemp. Math., 9 , 217 (2007)]*

• We have elaborated a model which proved that the microphase formation in colloidal suspensions based on competing interactions is in a tight relationship with spontaneous aggregation and pattern formation phenomena *[e.g., J. Phys.: Condens. Matter 20, 415106 (2008)]*. This has a potential impact in applications where micro-cluster morphology can be controlled by the macroscopic physical parameters.

• We obtained the first efficient thermodynamic description for the two-component one-dimensional repulsive Bose gas, valid for all values of the relevant parameters (temperature, coupling constant and chemical potentials) *[Phys. Rev A 84, 051604(R), 2011]*. The crucial advantage of our description with respect to other methods (like direct application of the Thermodynamic Bethe Ansatz) is that it relies on a finite number of coupled non-linear integral equations. Such a description allows for efficient numerical implementations and, ultimately, comparison with prospective experimental data.

• We calculated analytically the asymptotic behavior of the space and time dependent correlation functions in the anionic Lieb-Liniger model using the Riemann-Hilbert problem associated with a generalized sine-kernel, infirming the conformal field theory predictions *[EPL-Europhys Lett. 86, 40001 (2009)]*.

• Numerical investigations were performed demonstrating the existence of hidden dynamical quasisymmetry in the optical absorption of a distinguished class of finite nanorings. A critical analysis of a variational method used to describe molecular electron transport was achieved. Numerical investigations applying the so called "extended molecule approach" to correlated electron transport were carried out for an extended molecule described by the interacting resonant level model *[Phys. Rev. B 75, 125323 (2007); B 77, 165339 (2008); B 80, 165301 (2009)]*.

C. Space-time structures and symmetries in General Relativity *(Dr. D. Baleanu, Dr. F. C. Popa, Dr. P. Stefanescu, Dr. O. C. Tintareanu-Mircea).*

Goals. Investigation of hidden space–time symmetries and superenergy type geometrical structures; investigation of the variation of fundamental physical constants at cosmological time-scale; development of fractional dynamics.

Motivation. Although General Relativity (GR) is a well tested theory, its geometrical nature makes apparently impossible covariant descriptions of important quantities like energy-momentum (e-m) tensors. One approach to the e-m problem involves the super-energy (s-e) tensor. Working with Caputo derivatives is a very appealing technique to obtain new classes of fractional dynamical systems, in particular in GR.

Main achievements:

• We have obtained a nontrivial connection between s-e and geometrical structures related to space-time hidden symmetries. We provided a generalization of the s-e tensor, relating it to the problem of determining geodesic quadratic first integrals. We also obtained new higher rank hidden symmetries based on rank three Killing-Yano tensors, and proved that these tensors lead to physically interesting Dirac-type operators and to a theory free of quantum anomalies *[Mod. Phys. Lett. A 22, 1309 (2007); A 22, 711 (2011); A 26, 337 (2011)]*.

• By using the Cosmic Microwave Background (CMB) 3-year data from WMAP space mission, we obtained a 30% improvement (as compared with the results from WMAP 1-year data) on the values of the fine structure constant at the recombination epoch of the Universe. The corresponding recombination redshift shows a delayed recombination epoch**,** compared with the results from WMAP 1-year data *[e.g.,New Astronomy, 12(8), 635, (2007)]*.

• A systematic investigation was performed on fractional variational principles in the presence of delay. A generalization of the Euler-Lagrange and Hamiltonian approaches to quantum mechanics and GR by using fractional calculus was obtained *[J Vib Control 13, 1239 (2007); 14, 1301 (2008); Rep Math Phys 61, 199 (2008)]*.

III. Projects and perspectives, entrepreneurial initiatives

We intend further ***developments in our domains of expertise*** and envisage ***new subjects*** as follows:

• Developments in the theory of laser assisted processes: investigation of the space-time dynamics for trains of ultrashort laser pulses in an optical thick absorbing medium under the electromagnetically induced transparency conditions.

• The problem of decoherence for specific vibrational wave packets prepared in cold molecules; new strategies of coherent control and vibrational purification in cold molecules.

• Developments in kinetic theory of complex systems and exactly solvable models: elaboration of fast converging numerical schemes for nonlinear Boltzmann kinetic models with chemical reactions.

• Applications of the new and powerful transseries theory to the asymptotic analysis of nonlinear Boltzmann and Vlasov models.

• Investigation of the thermodynamic behavior of multi-component fermionic gases and study of the asymptotic behavior of temperature dependent correlation functions in a Bose gas.

• Developments in the theory of space-time superenergy type structures and hidden symmetries for new metrics and alternative theories of gravity (ATG). In the same context of ATG we will investigate the possible time dependence of some fundamental physical constants by using CMB and large scale structure data.

• We envisage a collaboration of the members of our group with expertise in kinetic theory and the theories of special and general relativity, in order to develop research activities related to Boltzmann and Vlasov kinetic modeling of flows in backgrounds characterized by strongly deformed space-time metrics.

• The members of our group with expertise in the physics of cold atoms and exactly solvable models intend to initiate and develop analytical and numerical calculations for physical quantities (entanglement entropies, spectra) relevant to the fields of quantum information and quantum computation.

IV. Evolution of the human resources

The average age in the group is ***42*** years, ranging from 60 years (two senior researchers) to 31 years (the three youngest members of the group). In the period 2007-2011, six researchers have obtained their PhD degrees. Notably, three PhDs were awarded by prestigious foreign institutions (two in EU and one in US). Two members of our group were promoted CS1 and CS2, respectively. Moreover, other three members were promoted CS3. Our team benefited from the experience of the members that studied and worked in foreign institutions. Presently, three members of our group occupy temporary senior research positions abroad.

V. Recognition

We have an associate editor at two ISI journals (Cent. Eur. J. Phys. and Adv. Differ. Equ.) and an AMS Math. Rev. invited reviewer. These are also book (co)editors (at World Scientific, Springer, and Romanian Academy Printing House). Our group includes referees of reputed ISI journals, participations in international scientific committees, invited lecturers, etc.

VI. Collaborations

In the period 2007-2011 we had two cooperation agreements with Cankaya and Cergy Pontoise Universities. These agreements will be renewed. There are strong personal scientific collaborations with research teams from EU, USA, Japan, and Turkey. Under 2 CEEX and 4 PN contracts, we had collaborations with the Romanian Space Agency, Horia Hulubei National Institute of Physics and Nuclear Engineering, Institute of Statistical Mathematics and Applied Mathematics of the Romanian Academy, University of Bucharest, and the Research Center for Aeronautics and Space of the Polytechnic University of Bucharest.

VII. Exploitation of the infrastructure

Solving some of the problems outlined in our development plan requires strong computational facilities. We will supply the lack of conventional high performance computing hardware by using the GRID-cluster and GPU infrastructure of the Institute for Space Sciences.

VIII. Funding

Our research was performed under two contracts won in the CEEX 2005 national project competition and two contracts won in the PN 2 -2007 and PN 2-2008 competitions. Several members were supported under the PN 2-"IDEI" grants. In addition, two members of our group were awarded postdoctoral fellowships abroad. Partial support was ensured by the national "Nucleu" program.

TEAM 33: Cosmology and Astroparticle Physics Group - ISS

Self-evaluation Report

I. Team structure

The team consists of ten researchers: Dr. Lucia Aurelia Popa –LP, Dr. Vlad Popa –VP (first degree senior researchers), Dr. Ovidiu Maris –OM (second degree senior researcher) , Ana Caramete -AC, Laurentiu Caramete -LC, Dr. Octavian Micu - OcM, Gabriela Emilia Pavalas -GP, Dr. Aurelian Andrei Radu -AR, Dr. Marius Rujoiu -MR (third degree senior researchers) and Daniel Tonoiu - DT(researcher).

The team activity covers research in complementary fields like: Cosmology, Neutrino Astrophysics, Very High Energy Gamma Ray Astronomy, Ultra High Energy Cosmic Rays and Theoretical Astrophysics.

II. 2007- 2011 Activity and main results

The group is involved in activities included in the European Space Agency (ESA) "Cosmic Vision" and in the ASPERA (Astroparticle Physics European Research Area) roadmaps. Most of its members joined after stages in prestigious research institutes and universities abroad. In the last 4 years the group produced 21 research papers published in international ISI quoted journals, participated to various international conferences and co-authored two scientific books published by prestigious international publishers. In 2007 we became members of the KM3NeT Consortium (aiming to build a very large volume neutrino telescope in the Mediterranean Sea) and in 2011 we was recognized as members of the EUCLID Consortium, that successfully proposed the ESA EUCLID mission (aimed to investigate the topology of the Universe and to identify the origin of the "dark energy").

A. Cosmology

Goals: ***I)*** Improved understanding of dark sector of the universe by exploiting complementary observables and experimental techniques. ***II)*** Strengthen cooperation on problems as nature, interactions and decay of Dark Matter (DM) and Dark Energy (DE) through the synergies between space and ground-based cosmological and astrophysical measurements. ***III)*** Add value to present and future space missions and ground-based experiments by the detailed study of the expansion history of the universe and the growth rate of cosmological structures. ***IV)*** Testable link between cosmology and particle physics consistent with both unified field theory and astrophysical and cosmological measurements. ***V***) Optimization of the observing strategies of the future European space missions dedicated to probe the dark energy (e.g. EUCLID) or to study the primordial gravitational waves (e.g. CoRE and CMBpol). The paths to achieve these goals are related to: ***1)*** Characterization of the Cosmic Microwave Background (CMB) anisotropies; ***2)*** Investigation of the mechanisms generating the primordial gravitational waves production; ***3)*** Study of the DE perturbation properties; ***4)*** Cosmological tests of the General Relativity ; **5)** Probing the DM and DE interactions; **6)** Cosmological implications of particle properties.

Motivations: Members of the research group (LP, AC, DT, VP) are actively involved in ESA/Planck mission (presently mapping the microwave sky with very high accuracy) and recently approved ESA/EUCLID mission (dedicated to study the DE properties and to test the GR at cosmological scales), taking advantage of previously experience in the scientific analysis of CMB measurements from COBE and WMAP satellites and other astrophysical measurements (e.g. astrophysical foregrounds, supernovae, X-ray clusters, Ly-alpha forest).

Main achievements: ***(i)*** Study of non-thermal Dark Matter production from Planck lensing extraction (**A825**); ***(ii)*** Constraints on lepton asymmetry and radiation energy density: implications for Planck (**A859**); ***(iii)*** Reconstruction of inflationary potential from high-precision CMB measurements (**A891**); ***(iv)*** Proposal approved by ESA for EUCLID mission within Cosmic Vision Program (**A892**); ***(v)*** Cosmological constraints on the Higgs mass (**A935**); ***(vi)*** the Planck-LFI scientific program (**A937**); ***(vii)*** Observational consequences of the Higgs inflation variants (**A1011**); ***(viii)*** Cosmics Origins Explorer (CoRE) mission: proposal selected by ESA.

B. Neutrino telescopes

Goals: Neutrino astronomy is the missing component of the newly developed "multi-messenger astronomy". Due to their properties (weak interactions and very low masses), neutrinos are an ideal probe in investigating the features of the "violent Universe". Cosmic neutrinos are produced in cores of massive astrophysical objects and propagate virtually without perturbations, reaching the Earth. The very large volume neutrino telescopes are the only tools allowing the reach of this goal; their discovery potential goes far beyond the neutrino astronomy.

Motivations. Members of the group (VP, GP, MR) are involved in the ANTARES experiment; it is a neutrino telescope operated by an international cooperation in the Mediterranean Sea. ANTARES is the only undersea successful project of the kind (**A1017**), and is the most important precursor for the future KM3NeT. Neutrino telescopes in the Northern hemisphere have the advantage to access the Galactic Plane (**A1019)**, only marginally seen by similar experiments in the Southern hemisphere (IceCube), Furthermore, they could take the advantage of the common sky coverage with the Auger Southern observatory. The future deployment of KM3NeT offers opportunities to develop highly performing technological activities and to imply the Romanian industry in the effort (OM and AR are participating also in the KM3NeT related activities).

Main achievements: ***(i)*** the inclusion of the search for super-massive exotic particles in the ANTARES scientific program (and consequently in the KM3NeT scientific motivation), **A1016**; ***(ii)*** the completion of the nuclearite search in the 2007-2008 ANTARES data; no candidate was found, so a 90% confidence level flux limit was obtained, that improves by an order of magnitude the previous best limit in the literature (the MACRO limit). The results were presented at the International Cosmic Ray Conference 2011 (Beijing, China) and at the Very Large Volume Neutrino Telescopes 2011, (Erlangen, Germany). A dedicated research paper is under preparation; ***(iii)*** the successful completion of the FP6 KM3NeT-DS project; ***(iv)*** we coordinate a sub-project in KM3NeT, aiming to deploy a test multi – PMT optical module on the ANTARES site; this will allow understanding the coincidence background counting rates as a function of the angular distance between photomultipliers, information of interest for the future development of Monte Carlo simulations and KM3NeT acquisition and reconstruction software. (This project was presented at the ICRC 2011, Beijing, China. The deployment of the test device is foreseen for early spring 2012.)

C. Very high energy gamma ray astronomy

Goals: The best way to detect very high-energy γ-rays of cosmic origin, from the ground, is by imaging the Cherenkov light produced by the secondary particles. This method employs Imaging Atmospheric Cherenkov Telescopes (IACTs). The major IACT experiments currently in operation have demonstrated their discovery potential with consequences for astrophysics, cosmology and particle physics. A new era of outstanding precision will begin with the future Cherenkov Telescope Array (CTA).

Motivations. The major IACT experiments are performing observations at their sensitivity limit or in multi-wavelength campaigns for most of their operation time. Due to the importance of the observational data, a global network of several small Cherenkov telescopes was proposed to be operated in a coordinated way for long-term monitoring the brightest blazars - the DWARF (Dedicated Worldwide AGN Research Facility) Network. It will be distributed around the globe for 24/7 monitoring, with redundancy to account for weather and duty cycle constraints, as well as for muon background reduction. We intend (AR, VP) to install a small VHE γ-ray telescope in Romania, as a component of the DWARF network.

Main achievements: ***(i)*** various possible sites for the future IACT have been characterized from astroclimatic, existing infrastructure, accessibility and socio-economic points of view; ***(ii)*** a device dedicated to measure the light of the night sky in different locations have been constructed; observation campaigns will follow; ***(iii)*** a Memorandum of Understanding concerning the future collaboration in the DWARF network has been signed with the Dortmund Technical University.

D. Ultra high energy cosmic rays, theoretical astrophysics

Goals. Understanding of the origin and properties of the Ultra High Energy Cosmic Rays (UHECR) is among the most challenging aspects of astroparticle physics. If an extragalactic component found, questions on the validity of the relativity in extreme conditions would arise. UHECR could be produced by exotic mechanisms, and extreme objects (as micro black holes) could be present in their composition. The physics of super-massive black holes is also a goal of this research field.

Motivations. Group members involved in this activity (LC, OcM) have experience in the data analysis from the Pierre Auger Southern Observatory and in the COST European project.

Main achievements: ***(i)*** original results on the physics of the black holes have been published (**A940, A941**); ***(ii)*** a PhD thesis in to the Pierre Auger experiment is in the final stage.

E. Neutrino astrophysics

Goals. Neutrinos are the first elementary particles that shown behavior beyond the standard model. We intend to pursue research concerning the neutrino sector, based on the accumulated experience and the significant discovery potential. Important questions are still seeking answers, as the mass hierarchy and the possible Lorentz invariance violation by ultra-energetic neutrinos.

Motivations. Neutrino astrophysics (and physics) has significant impact on all fields of interest for our group. fr

Main achievements: ***{i}*** the completion of the analysis of data collected during the 2006 total solar eclipse and the results, representing the best lower limits for the neutrino radiative decay lifetimes obtainable from such data were published (**A938**). A generalization was presented at the 2010 European Cosmic Ray Symposium, Turku, Finland (VP); ***(ii)*** co-authorship (OcM) of the MicroBooNE White Bock. MicroBooNE will be the next step at FERMILAB after the MiniBooNE experiment, justified by the OPERA results on possible tachionic neutrinos.

F. Related accelerator experiments

Goals. Accelerator experiments offer precise values of tparameters of interest for cosmology and astroparticle physics. The Large Hadron Collider at CERN is the ultimate such a facility, due its capacity to reach the energy Very High Energy Cosmic Rays (VHECR).

Motivations. The experience in the search for exotic particles with passive detectors (VP) allowed us to propose the MoEDAL project, an experiment at LHCb, looking for exotics as light magnetic monopoles and micro black holes. It was approved by the CERN Council, and will be operated by an international collaboration.
Main achievements. MoEDAL test modules have already been deployed in the hall of LHCb at CERN, and will be recovered for analysis during the next accelerator shutdown.

G. Outreach and Education

Goals. The outreach is realized trough public dissemination of knowledge and to educational actions, dedicated to high school and undergraduate students (as well as their teachers). The goals are twofold: to improve the public perception of the fundamental research, and to attire gifted youngsters to the scientific world.
Motivations. Cosmology and astroparticle physics have an important potentiality to attire the general public attention. As main financial contributors, citizens are entitled to have access to scientific achievements, trough media adapted to the general level of understanding. The future development of the field requires a significant amount of highly qualified manpower , that could be insured on the long term only by motivating young people.
Main achievements: ***(i)*** two prototype cosmic shower stations designed for the use in high schools, one of them included in a demonstrative European network; ***(ii)*** dissemination actions ("Science Fest" or "Open Days") special lessons in high schools, papers published in public media, radio and TV shows; ***(iii)*** The presence in the EuroCosmics initiative, aiming to apply for a educational project in the FP7 "Science and Society" program.

III. Projects and perspectives

The group will concentrate on the scientific exploitation of data from the major active experiments in which we are members (PLANCK and ANTARES) and the preparation of the future large projects indorsed by ESA (EUCLID) and ESFRI (KM3NeT). This assumes not only scientific contributions, but also technical issues. In EUCLID we will contribute to the ground segment effort, while in KM3NeT in the integration of telescope elements, and the involvement of Romanian industrial actors in component manufacturing. All activities referred to in the previous section will be pursued and developed. The group will constantly participate in future competitions (European and national) in order to ensure its proper funding and sustainable development. The perspectives to achieve our goals are good: the recent evolutions in fundamental physics indicate the imminence of significant breakthroughs beyond the standard models of particle physics and cosmology. The Romanian adhesion to ESA and CERN, and the Romanian participation in ASPERA through the ROASTROPART consortium (cofounded by members of the group) represent strong arguments supporting our strategy.

IV. Evolution of the human resources

Three of the younger group members were promoted and one was assumed, on contest basis, during the last year. The three PhD students are due to defend their thesis before the end of the next year. The foreseen increase of our activity asks for the group extension in the next years. We will hire new young researchers, graduate students and more qualified personnel as scientists returning from different formation or research stages abroad. The admission of new group members will be made respecting high performance criteria.

V. Recognition

Senior members of the group act in the coordination bodies of the international collaborations we are involved in (PLANCK, EUCLID, ANTARES, KM3NeT and MoEDAL). We have one expert evaluator for the ESA research proposal, one for the Bulgarian National Research program and two for the Romanian National Research and Development program. Two senior members are also referees for international and national research journals.

VI. Collaborations

International collaborations: PLANCK, EUCLID, COrE, ANTARES, KM3NeT, DWARF, MoEDAL, participation in Auger and COST. National collaborations with: Romanian Space Agency, Bucharest University, Bucharest "Politehnica" University, National Meteorological Authority, Civil Engineering Academy, Fine Mechanics National Institute, S.C. OPTOELECTRONICA-2001.

VII. Exploitation of the infrastructure

The group has its own computing cluster. Members have personal work stations. The access to the computing and experimental facilities of the collaboration partners is granted. Stack holders of the ANTARES deep sea neutrino telescope.

VIII. Funding

The funding is ensured exclusively trough competition won projects. Internationally funded projects: one ESA-PECS, one FP6 (completed), one FP7. National projects: 2 "Exploratory research – Ideas" (one completed), 3 "Collaborative grants" (2 completed), and projects in the "Capacities" program: one support project (Mod. III), one representation project (Mod. IV), one "Post Doctoral" project, one "Young Teams" project. One FP7 and one "Collaborative grant" projects are in the evaluation process.

TEAM 34: High Energy Astrophysics and Advanced Technologies – HEAT

Introduction:

The main research activities of HEAT Group are focused on relativistic heavy ion physics, reactions with relativistic radioactive beams, hadronic physics, nuclear astrophysics, astroparticle physics, computational physics and high performance computing. These research topics are related to our long stand international collaborations such as: **ALICE** (**A** **L**arge **I**on **C**ollider **E**xperiment) from LHC-CERN (Switzerland), **R^{3}B** (**R**eactions with **R**elativistic **R**adioactive **B**eams) from FAIR-GSI (Germany), **Becquerel** (**Be**ryllium **C**lustering **Que**st in **Rel**ativistic Multifragmentation) from JINR-Dubna (Russia), **WLCG** (**W**orld **L**HC **C**omputing **G**RID). In the last years our group started new collaborations with **FCAL** (**F**orward **Cal**orimeter) at ILC, **MPD/NICA** (**M**ulti-**P**urpose **D**etector / **N**uclotron-based **I**on **C**ollider F**a**cility) from JINR-Dubna, and started the initiative to join the **Pierre Auger Collaboration**.

Scientific objectives of HEAT Group in the frame of international collaborations:

As we stated above our group comprise researchers from many fields of expertise; therefore a concise presentation of the activity of our group for the last 4 years has to follow the description of the activities carried out within international collaborations that our group members are involved:

1. ***ALICE Collaboration at CERN-Geneve***: ISS was involved in ALICE experiment activities since 2000 through collaboration with the long-standing science partner - Joint Institute of Nuclear Research, Dubna. Contributions to ALICE activities started with Offline software development and continued later with data analysis activities for Forward Muon Spectrometer. In 2006 ISS became full member of ALICE Collaboration by signing the Memorandum of Understanding. Since then, the contributions are as follows: 1. Contributions to ALICE offline computing - Maintenance and support for the geometry package used for describing ALICE geometry, tools used for misalignment representation and usage within simulation and reconstruction; Development of the data analysis framework based on a data-driven model, leading to higher modularity and possibility of serializing several analysis tasks for the same event. 2. Contributions to ALICE physics: The physics activities are integrated into the ALICE Physics Working Group 4 (*Jets*). The planned activities are related to physics of particle correlations, jet reconstructions and analysis; 3. Grid Computing resources: ISS provides to ALICE collaboration 400 cores for computing, 140 TB data storage and 10 GigE Ethernet connectivity to European educational and scientific network (GEANT).
2. ***R^{3}B Collaboration at FAIR-Darmstadt***: Our Group is entrusted exclusively with the simulation of the entire ensemble of detectors that make up the high-resolution neutron time-of-flight spectrometer – NeuLAND (New Large Area Neutron Detector). The group has contributed to the development of software that brought together the latest simulation techniques and resulted in the general system software - *R3Broot* - which is the simulation and analysis framework of the experiment. This includes studies on the interaction of high-energetic neutrons with matter, determination of operation principle of the NeuLAND device, geometry and design studies with respect to the detector type to be chosen and mainly Monte Carlo simulations that lead to the final scheme. To determine the geometric configuration of the detection system GEANT4 and FLUKA simulation packages has been used and for data analysis and histograming we used ROOT utilitary. HEAT Group is also involved in nuclear astrophysics studies where it is expected that results will shed new light on stellar processes, on what happens in nucleosynthesis processes of explosive events like novae or supernovae.
3. ***Becquerel Collaboration at JINR-Dubna***: Our group is interested in observation of the fragmentation of light relativistic nuclei in emulsion exposed to stable and radioactive nuclei with energy of the order of few GeV per nucleon in the JINR Nuclotron beams in order to explore highly excited nuclear states near multiparticle decay thresholds. A principal experimental task consists in provision of a complete spectroscopy of final fragments - observation of dissociation events, determination of various channel probabilities (branchings) and fragment identification and velocity measurement.
4. ***WLCG Collaboration at CERN-Geneve***: The *Worldwide LHC Computing Grid (WLCG)* is a global collaboration of more than 140 computing centres in 35 countries, the 4 LHC experiments, and several national and international grid projects. The mission of the *WLCG* project is to build and maintain a data storage and analysis infrastructure for the entire high energy physics community that will use the Large

Hadron Collider at CERN. The ISS main tasks are to ensure computing power and storage capacity in GRID for the ALICE Collaboration

The dynamic of the research activities of our group is also focused on continuous development in accordance with the evolution of our research topics at international level. This means that our group has expressed interest to contribute to new collaborations such as: FCAL/LC, Pierre Auger Observatory, MPD/NICA.

FCAL is a worldwide detector Research & Development collaboration. About 40 physicists join their effort to develop the technologies of special calorimeters in the very forward region of future detectors at an e+e- collider for energies from 500 GeV to 3 TeV. The instrumentation of the very forward region comprises three subdetectors: At small polar angles, adjacend to the beam-pipe, the Pair Monitor and BeamCal measure remnants of beamstrahlung to assist beam tuning. BeamCal in addition will measure high energy single electrons. LumiCal, at larger polar angles, will be the luminometer of the experiment using Bhabha scattering as the gauge process. The ISS main tasks are: experimental and Monte Carlo simulation studies of the FCAL calorimeters.

The ***Pierre Auger Observatory*** is the world largest cosmic ray air shower experiment located in Argentina. Romania became associated member since March 2011, through the KIT, Germany. Since summer of 2011, the ISS has started the procedure to join the Auger collaboration. The ISS contributions on Auger are on data analysis of radio data recorded from cosmic ray air showers, theory of ultra high energy cosmic rays, and computational resources.

The global scientific goal of the ***NICA/MPD*** Project is to explore the phase diagram of strongly interacting matter in the region of highly compressed and hot baryonic matter. Such matter exists in neutron stars and in the core of supernova explosions, while in the early Universe we meet the opposite conditions of very high temperature and vanishing baryonic density. In terrestrial experiments, high-density nuclear matter can transiently be created in a finite reaction volume in relativistic heavy ion collisions. The ISS main task is to make Monte Carlo simulations of the MPD detectors.

Summary of the main scientific results obtained during the last 4 years:

The scientific results follows the contributions to the international experiments that we are committed:

1. ***ALICE Collaboration:*** The contributions of ISS to the ALICE experiment are: developments to the main analysis and simulation framework (AliRoot) - The geometrical modeller developed by our group are currently used in ALICE for the offline description of the detector geometry. The frameworks for simulation, reconstruction and event display are all based on this modeler. The detector misalignment information used by the alignment framework is also accessible at this level. In order to avoid the problems regarding the overlaps between the real volumes and the virtual containers, one can assemble in TGeo modeler real volumes without virtual ones. Another contribution to the experiment is the development and implementation of a cone based algorithm for the detection and characterization of hadronic jets. Also, we have developed a GRID infrastructure for the experiment and a PROOF (Parallel ROOT Facility) cluster for fast, online data analysis. **This results in 16 ISI scientific papers.**
2. ***R^3B Collaboration***: Results obtained during the last years was concentrated on simulations and analysis to establish the design for the new neutron detector (NeuLAND) and followed the next steps: validation of physics lists from Geant4 simulation code by comparison with results represented by Fluka simulation code; check the validity of the two codes (Geant4, Fluka) for neutrons, due to large discrepancies observed between them, by comparing with data obtained in the Saturne experiment; development and implementation in simulations of a new physics list which corresponds our requirements: the results predicted by this are in a better match with experimental data; implementation of the entire detector geometry of the old LAND in Geant4 and runinng activities to include this in the R3B specifically designed framework namely *R3Bsim*; development of independent macros for signal analysis of R3B experiment and currently working on a similar structure for the whole LAND; a detailed analysis of individual channels for neutron interaction by checking the output from Geant4, Fluka and MCNPX; simulations to establish the total production of neutrons, protons, pions and photons in the reaction n+Fe at various energies of incident neutrons (200, 500 and 850 MeV); detection efficiency calculations with Fluka and Geant 4, implementation of light output functions using Birk & Wright formula, establish of contribution of various particles (n, p, π, γ) to efficiency; calculated the total cross section of neutron interaction on various targets (Pb, Zr, Ca, O) using FLUKA code and compared with experimental results; studies of existing structures and components of LAND, studies of test experiments that led to the current structure of LAND; performed a geometric reconstruction of LAND current structure in various simulation codes and has been studied the possibility of designing structures used in detection of neutrons

("tower" and "paddles" type structures) to incorporate resistive plate detectors. We now continue focusing on Monte Carlo studies evaluating the full LAND detector and on development of a track recognition algorithm using the details of showers induced by neutrons (average length of showers, opening angle, deposited energy, etc..) for a more accurate detection of multiple hits. **This results in 2 scientific papers and 12 presentations to international meetings.**

3. ***Becquerel Collaboration:*** In the last few years within HEAT Group have been carried out studies of: a) general characteristics of inelastic interactions of 1A GeV/c of ^{3}He projectiles with emulsion nuclei: the mean free path was measured and found to agree with the different theoretical parameterizations, the multiplicity characteristics for interactions were studied and separated into (H), (CNO) and (AgBr) groups; b) reaction of coherent multifragmentation: we studied such reactions and considered the coherent break-up of ^{10}B-> 2 α at 1 A Gev and we investigated the azimuthal correlations in angles between types of charged secondary particles, the invariant energy, transvers momentum distribution; c) studies of peripheral collisions of ^{56}Fe at 1 A GeV/c in nuclear emulsion: we measured the charge and the angular distributions of single and multiple charged relativistic particles emitted from peripheral interactions, we investigated a possible new method of separating interactions of electromagnetic origin, we provided the values of several parameters evaluated in a sample selected using the classical method; d) diffraction dissociation interactions of ^{16}O, ^{22}Ne, ^{28}Si, ^{32}S, ^{56}Fe nuclei accelerated at the JINR Synchrophasotron in the energy range 1 – 3.7 A GeV: we used criteria which separate electromagnetic dissociation events among the nuclear collisions, we described their topology and studied their characteristic parameters, relative rates of nuclear fragmentation, average multiplicities and the angular distributions of fragments as a function of the energy and the nature of primary nuclei. **This results in 10 ISI scientific papers and 2 presentations to international conferences.**
4. ***WLCG Collaboration:*** In the last few years the ISS computing grid group had an important role in WLCG. The two ISS grid clusters, ISS-ALICE cluster and gLite RO-13-ISS, provide support for computing power about 420 CPUs and storage capacity 145 TB for the ALICE experiment.

National / international projects through which cooperation was achieved:

The results presented above were obtained within activities carried out in several national (CeEx, PNII) and international projects (FP7, PECS, etc.); here should be mentioned that each subgroups wich is a part of a international collaboration had or has financial suport from national research projects (competition based!). Over the last 4 years there were **3 international projects** and **17 national projects** which assured the support needed for our participation in international collaborations.

Among international projects one of the most important project is ***"Romanian GRID middleware repository for Space Science Applications - RoSpaceGRID"*** which is a PECS support project for GRID infrastructure in ISS (a project of 700.800€ leaded by Dr. Sorin Zgura). There are also two FP7 projects namely ***„High-Performance computing infrastructure for South East Europe's Research Communities - HP-SEE"*** and ***"Simulations for Nuclear Reactions and Structure in Europe – SiNuRSE***", projects based on work developed together with WLCG and R^{3}B Collaborations.

National competitions were also an important source for projects which supported our work in international experiments; from these we should strength the ***3 projects*** which support our participation in ALICE and WLCG Collaborations (payment of ISS contribution to CERN, participation to technical shifts, continuous monitoring GRID clusters): *"National contribution at the GRID development LCG computing for elementary physical particle - WLCG"*, *"Simulations of detection in the ALICE experiment using realistic conditions – SIDERALIS"* and *"Preparing simulation and preliminary analysis of data from ALICE experiment - IMOTEP"*. There were also 10 projects in national competitions that are already finalized: we had ***4 projects in CeEx Program***: *"Type of quark-gluon plasmas in relativistic nuclear collisions and in Universe evolution after Big-Bang –QGPBB"*, *"Relativistic radioactive beams with applications in astrophysics – FARRA"*, *"Top researchers in charm quark physics - FQC"*, *"National development and exploitation system of the GRID for LCG computing for elementary physical particle - SINDEGRID"; **5 projects in PNII Program, Subprogram Partnerships***: *"New experimental results concerning HUBBLE evolution in relativistic nuclear collisions"*, *"Method for data management and communication using GRID infrastructure based on technologies and digital certificates - GRIDCERT*", *"Explosive nucleosynthesis studies using radioactive ion beams – NUFAR"*, *"Laboratory study of processes from primary cosmic rays: digital reconstruction and medicine applications – CORA"*, *"Processing of experimental data obtained at ultrarelativistic energies through clusterization and distributed computing technologies – PROCEEX",*; ***1 project at PNII Program, Subprogram Ideas***: *"Detalied simulations of a new functional structure of resistive plate detectors for fast neutron detection – SERAND"*, At this moment there are 4 projects that are implemented in our group within PNII Program: ***1 project in "Young independent research team" Subprogram*** namely *"Study of anysotropical flow in relativistic nuclear physics using GPU"*, ***1 project of "Postdoctoral research" type*** namely *"Advance studies for radion signals from atmospherical shower induce by the cosmic rays at ultra-high energy"* and ***1 project of "Exploratory research project PCE" type*** namely *"Study of diffractive processes in interactions of 1-4 GeV ions with nuclear emulsion and applications in astrophysics – DIPNE"*.

Evolution of human resources:

The HEAT Group comprises a total of 25 researchers with different scientific degrees and functions and is headed by Dr. Sorin Zgura. Depending on professional degree obtained we have 1 CSI, 2 CSII, 9 CSIII, 12 CS, 1 ACS (CS – Scientific Researcher, ACS, Assistant of Scientific Researcher) and depending on the scientific title obtained we have 13 Doctors, 9 PhD students, a master student and 2 Licensed students. Due to the excellent work in the collaborations that they were included some of our members are detached for a shorter or longer period of time to research institutes abroad: Andrei Gheata, Mihaela Gheata and Mihai Niculescu at CERN-Geneve, Mihaela Paraipan at JINR-Dubna, Ionut Arsene at GSI-Darmstadt. Also, in the past years our researchers participated to many working stages at high level institutes abroad (JINR-Dubna, GSI-Darmstadt, CERN-Geneve etc.). On one hand, we should mention that in the last 2 years our group managed to attract new researchers both experienced researchers from other Romanian institutes or from institutes abroad and young researchers who just finished their educational program. On the other hand, due to their implications in the international and national projects some of our group members successfully defended their PhD. thesis.

ALICE team from ISS is made of 6 senior researchers (Dumitru Hasegan, Maria Haiduc, Sorin I. Zgura, Mihaela Gheata, Andrei Gheata and Daniel Felea) and 5 PhD students (Ionel Stan, Adrian Sevcenco, Andrea Danu , Ciprian Mitu and Mihai Niculescu). The contribution to the ALICE experiment started at JINR,Dubna , where several members made working stages there (Mihaela and Andrei Gheata-2000-2002, Ciprian Mitu and Adrian Sevcenco: 2003-2005). Mihaela Gheata and Andrei Gheata are working at CERN since 2002, and Mihai Niculescu started a three year working stage, also at CERN, in late 2011. Since 2010 we are contributing to ALICE experiment with technical shifts (Offline and Data Quality Monitoring-136 days at CERN).

Simulation group which is part of ***R3B Collaboration*** is composed of 3 young physicists (Madalin Cherciu, Emil Stan and Mihai Potlog) under the guidance of Dr. Maria Haiduc, whose main activity was focused until now on *NeuLAND* detector design studies. During the last years we participated in two working stages at GSI-Darmstadt (Germany) where we concentrated on development of simulation framework for NeuLAND and as result, Madalin Cherciu has sucessfully defended his PhD. thesis.

WLCG group has six members (Ion Sorin Zgura, Ionel Stan, Adrian Sevcenco, Titi Preda, Mihai Niculescu, Ciprian Mitu) leaded by Dr. Ion Sorin Zgura. The main activity of the group is to ensure a very good functionality of the GRID clusters: ISS-ALICE and RO-13-ISS in gLite. That means to provide very good hardware for computing and storage, the last GRID software packages in excelent security conditions, an unterrupted functionality and a continuous monitoring and comunication with the EGI staff.

The leader of the ISS concerning the ***Auger Collaboration*** is Dr. Paula Gina Isar. She is the leader of the Auger group of ISS formed by 5 people (Gina Isar, Laurentiu Caramete, Octavian Micu, Sorin Zgura, Mihai Niculescu). The ISS contributions on Auger are on data analysis of radio data recorded from cosmic ray air showers, theory of ultra high energy cosmic rays, and computational resources.

TEAM 35: Space Plasma and Magnetometry Group

http://gpsm.spacescience.ro

The Space Plasma and Magnetometry Group (in Romanian Grupul de Plasmă Spațială şi Magnetometrie, GPSM) at the Institute for Space Sciences (ISS), Bucharest, started to develop in the early 1990's. Several Romanian fluxgate magnetometers, with the electronics realized by Dr. Mircea Ciobanu, were launched on Intercosmos and later Interball–Magion satellites, providing valuable data for both navigation and science. The initial goal of GPSM was the processing and interpretation of the magnetic field data measured *in-situ* by the Romanian instruments. Later on, the scientific activity of GPSM diversified. The members of the group were involved in doctoral projects and post-doc collaborations with Max Planck Institute for Extraterrestrial Physics (MPE) Garching, Belgian Institute for Space Aeronomy (BISA) Bruxelles, Institute for Geophysics and Extraterrestrial Physics (IGEP) Braunschweig. Since early 2000's new young scientists joined GPSM, now pursuing PhD projects themselves, and the visibility of the group increased, by workshop and summer school events organized in Romania, as well as visits of colleagues from abroad. During the last decade GPSM played a prominent role in the Romanian space research, and since 2007 was at the forefront of the collaboration with the European Space Agency (ESA), under the Plan for European Cooperating States (PECS). At present GPSM contributes to the analysis of data from several missions, including Cluster (ESA), THEMIS (NASA), FAST (NASA), and Venus Express (ESA), at the same time with numerical simulation and theoretical modelling projects. The group is well prepared to strengthen its involvement in international space research projects, in the new framework created by the accession of Romania to ESA as full member state.

Team

GPSM includes at present 12 people: *6 research scientists*, out of which 5 doctors in physics and 1 senior engineer, doctor in applied electronics; *5 young scientists*, 4 of which are PhD students in physics and 1 has a master degree in computing sciences; *1 technician*, skilled in mechanical work and machine tools.

Research themes and scientific achievements

The research themes addressed by GPSM can be broadly classified as follows: (i) *Solar-terrestrial interactions*, with emphasis on magnetospheric physics and the coupling of the magnetosphere with the solar wind and the ionosphere–thermosphere; (ii) *Fundamental processes in collisionless plasmas*, including shocks, reconnection, turbulence, parallel electric fields, MHD and kinetic waves, instabilities. Relationship to astrophysical and laboratory plasmas; (iii) *Disturbances in geospace and connections to the Earth*, for example space weather or electromagnetic phenomena associated with earthquakes; (iv) *Hardware development and software tools*, including particle and magnetic field sensors, in-flight calibration, advanced data analysis and numerical simulation techniques.

From 2007–2011 the members of GPSM authored or co-authored 65 papers in major international journals (relative article influence score > 1), contributed papers to 3 monographs, and presented about 150 communications at international conferences, workshops, and seminars, more than 10 invited. The space plasma dimension of the GPSM activity is illustrated with a few selected papers on the solar wind – magnetosphere (*Blăgău et al, 2010; Comişel et al., 2011; Constantinescu et al., 2007; Echim et al., 2011a, b; Voitcu et al., 2008*), and magnetosphere – ionosphere (*Constantinescu et al., 2009; Echim et al., 2007, 2008, 2009; Marghitu et al., 2009, 2011*) components of the Sun–Earth system. An astrophysical perspective on a nuclear physics problem is provided by *Comişel et al (2007)*, while results in micro-electronics and detector physics that may support future GPSM involvement in space hardware projects are reported by *Ciobanu et al. (2007, 2011)*.

Blăgău, A., B. Klecker, G. Paschmann, S. Haaland, O. Marghitu, and M. Scholer, A new technique for determining orientation and motion of a 2-D, non-planar magnetopause, *Ann. Geophys., 28*, 753–778, 2010.

Ciobanu, M., A. Schuttauf, E. Cordier, N. Herrmann; K. D. Hildenbrand, et al., A front-end electronics card comprising a high gain/high bandwidth amplifier and a fast discriminator for time-of-flight measurements, *IEEE Trans. Nucl. Sci.*, 54, 1201–1206, 2007.

Ciobanu, M., E. Berdermann, N. Herrmann, K.D. Hildenbrand, M. Kis, W. Koenig, J. Pietraszko, M. Pomorski, M. Rebisz-Pomorska, A. Schuettauf; In-beam diamond start detectors, *IEEE Trans. Nucl. Sci., 58 (4)*, 2073–2083, 2011.

Comişel, H., C. Hategan, G. Graw, H. H. Wolter, Proton threshold states in the Na-22 (p, γ) Mg-23 reaction and astrophysical implications, *Phys. Rev. C*, 75, 045807, 2007.

Comişel, H., M. Scholer, J. Soucek, S. Matsukiyo, Non-sationarity of the quasi-perpendicular bow-shock: comparison between Cluster observations and simulations, *Ann. Geophys., 29*, 263–274, 2011.

Constantinescu, O. D., K.-H. Glassmeier, P. M. E. Décréau, M. Fränz,, K.-H. Fornaçon, Low frequency wave sources in the outer magnetosphere, magnetosheath, and near Earth solar wind, *Ann. Geophys., 25*, 2217–2228, 2007.

Constantinescu, O. D., K.-H. Glassmeier, F. Plaschke, U. Auster, V. Angelopoulos, W. Baumjohann, K.-H. Fornaçon, E. Georgescu, D. Larson, W. Magnes, J. P. McFadden, R. Nakamura, Y. Narita, THEMIS observations of duskside compressional Pc5 waves, *J. Geophys. Res., 114*, A00C25, 2009.

Echim, M., M. Roth, J. De Keyser, Sheared magnetospheric plasma flows and discrete auroral arcs: a quasi-static coupling model, *Ann. Geophys., 25*, 317–330, 2007.

Echim, M., M. Roth, J. De Keyser, Ionospheric feedback effects on the quasi-stationary coupling between low latitude boundary layer and postnoon/evening discrete auroral arcs, *Ann. Geophys., 26*, 913–928, 2008.

Echim, M., R. Maggiolo, Ml Roth, J. De Keyser, A magnetospheric generator driving ion and electron acceleration and electric currents in a discrete auroral arc observed by Cluster and DMSP, *Geophy. Res. Lett., 36(12)*, CiteID L12111, 2009.

Echim, M., J. Lemaire, O. Lie-Svendsen, A review on solar wind modeling: Kinetic and fluid aspects, *Surv. Geophys., 32 (1)*, 1–70, doi:10.1007/s107120109106y, 2011a.

Echim, M., R. Maggiolo, J. De Keyser, T.L. Zhang, G. Voitcu, S. Barabash, R. Lundin, Comparative investigation of the terrestrial and Venusian magnetopause: Kinetic modeling and experimental observations by Cluster and Venus Express, *Planet. Space Sci., 59*, 1028–1038, doi:10.1016/j.pss.2010.04.019, 2011b.

Marghitu, O., T. Karlsson, B. Klecker, G. Haerendel, J. McFadden, Auroral arc and oval electrodynamics in the Harang region, *J. Geophys. Res., 114*, A03214, doi:10.1029/2008JA, 2009.

Marghitu, O., C. Bunescu, T. Karlsson, B. Klecker, H. C. Stenbaek-Nielsen, On the divergence of the auroral electrojets, *J. Geophys. Res., 116*, A00K17, doi:10.1029/2010JA016789, 2011.

Voitcu, G., C. Bunescu, M. Echim, Investigation of anisotropic velocity distribution functions using numerical solutions of the stationary Vlasov equation, *Young Scientist Outstanding Poster Presentation* at European Geosciences Union General Assembly, Vienna, Austria, 2008.

Institutional support

Since 2001, when Romania moved toward project oriented research, GPSM submitted several proposals, in response to national Calls. Most of these proposals transformed into funded research grants, as listed on the group site. From 2007–2011, GPSM was involved in 4 national projects: Plasma physics applications in geophysics. Auroral phenomena (*ALEGRO*, 2006–2008, PI_{ISS}: Octav Marghitu); Multidisciplinary system to investigate precursor phenomena of earthquakes in the Vrancea region (*MEMFIS*, 2006–2008, Co-I_{ISS}: Marius Echim); Boundary layers and charge structures in planetary plasmas (*SAFIR*, 2007–2010, PI_{ISS}: Marius Echim); Proton threshold states in stellar nuclear cycles: Mg-Al (*PTSMgAl*, 2007–2010, Co-I_{ISS}: Horia Comişel). National funding for a new project on Magnetosphere–ionosphere coupling in the auroral region (*M–ICAR*, 2011–2014, PI_{ISS}: Octav Marghitu) was recently granted to GPSM.

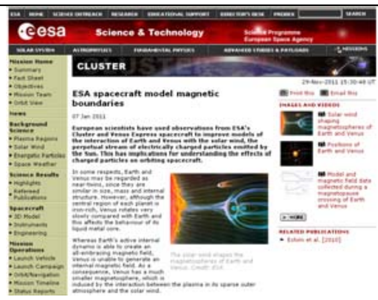
As soon as the PECS framework became available in 2007, GPSM submitted two proposals that received funding from ESA: Energy conversion and transfer in the solar wind – magnetosphere – ionosphere system (*ECSTRA*, 2007–2011, PI: Octav Marghitu, Co-Is: Horia Comişel, Dragoş Constantinescu) and Kinetic and experimental investigation of the Earth and Venus plasma layers (*KEEV*, 2007–2011, PI: Marius Echim, Co-I: Adrian Blăgău).

National and international collaborations

Collaboration in Romania: National Institute for Physics and Nuclear Engineering, Bucharest – Măgurele (PI PTSMgAl); National Institue for Earth Physics, Bucharest–Măgurele (PI MEMFIS); Dunărea de Jos University, Galați (Co-I SAFIR); University of Iassy (Co-I SAFIR).

Ongoing international collaborations: Belgian Institute for Space Aeronomy, Bruxelles, Belgium (kinetic models and simulations, M–I coupling); University of Alberta, Edmonton, Canada (Liouville mapping); University of Oulu, Finland (space weather); Centre d'Etude Spatiale des Rayonnements, Toulouse, France (PI Cluster/CIS); Max Planck Institute for Extraterrestrial Physics, Garching, Germany (Cluster/CIS, FAST); Institute for Geophysics and Extraterrestrial Physics Braunschweig, Germany (Cluster/FGM, THEMIS); Jacobs University Bremen, Germany (Cluster, Swarm); Royal Institute of Technology, Stockholm, Sweden (auroral electrodynamics); Swedish Institute of Space Physics, Kiruna, Sweden (Cluster, Venus Express); Physics Department of the Umeå University, Sweden (magnetotail physics); Space Sciences Lab., UC Berkeley, USA (FAST, THEMIS); JHU/APL, USA (neural networks).

Former international collaborations related to Aktivnyi, Apex, and Interball missions: Institute of Atmospheric Physics, Prague, Czech Republic (SG-R magnetomeres for the Magion-2, 3, 4, 5 satellites); Space Research Institute, Moscow, Russia; Institute of Experimental Physics, Kosice, Slovakia.



International recognition: EGU Award 2008 (left), Cluster Award 2010 (middle), ESA highlight 2011 (right)

International visibility and recognition

Workshops, http://gpsm.spacescience.ro/workshops: Solar–terrestrial interactions from micro-scale to global models (STIMM-1 2005, STIMM-2 2007); 6th COSPAR Capacity Building Workshop, Solar–terrestrial interactions: Instrumentation and techniques (STIINTE 2007); 19th Cluster Workshop, Multi-point investigations of magnetosphere–ionosphere coupling and aurora (2010).

Participation in team projects at the International Space Science Institute (ISSI), Bern: Dragoş Constantinescu (Conjugate response of the dayside magnetopause and dawn/dusk flanks using Cluster-THEMIS conjunctions and ground based observations, selected in 2008), Marius Echim (Plasma entry and transport in the plasma sheet, selected in 2010), Octav Marghitu (Co-chair, Plasma coupling in the auroral magnetosphere–ionosphere system, selected in 2010, http://gpsm.spacescience.ro/polaris).

Participation in proposal consortia: ESA Cosmic Vision (Cross Scale and Alfvén mission proposals); FP7–Space; ERASMUS Mundus Joint Doctorates.

Awards: Gabriel Voitcu, 2008: Young Scientist Outstanding Poster Paper Award (Voitcu et al., 2008); Octav Marghitu, 2010: Individual Achievement Award – Cluster mission; Marius Echim, 2011, ESA highlight (Echim et al., 2011b, http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=48190).

Cluster Co-Ivestigators: Adrian Blăgău (Cluster Ion Spectrometer, CIS, in-flight calibration); Dragoş Constantinescu (FluxGate Magnetometer, FGM, in-flight calibration); Octav Marghitu (CIS).

Referee assignments: Octav Marghitu (Ann. Geophys., 2005; NASA, 2006; J. Geophys. Res., 2010, 2011; Research Council of Norway, 2011).

SOC assignments: Octav Marghitu (11th International Conference on Substorms, September 2012).

Young scientists

Costel Bunescu, PhD project at Jacobs University Bremen on *Investigation of magnetosphere–ionosphere coupling by multi-point satellite and ground data*.

Vlad Constantinescu, preliminary PhD work on using neural networks to identify 'events' in time series satellite data.

Costel Munteanu, PhD project at University of Bucharest (UB) on *Turbulent fluctuations and discontinuities in the solar wind: Properties and possible effects on planetary plasmas*. Collab. with Oulu Univ., Finland.

Cătălin Negrea, PhD project to be defined at University of Colorado, Boulder, USA.

Gabriel Voitcu, PhD project at UB on *Kinetic simulations of magnetized plasma dynamics in discontinuity regions: Applications to physics of planetary magnetospheres*. Collaboration with Univ. of Alberta, Canada.

Infrastructure

Dell High Performance Computing cluster, 128 cores, 3GB memory per core, QDR Infiniband networking. Provides computing power for space plasma simulations (PIC, hybride, MHD codes).

Prospects

The accession of Romania to ESA as full member state is expected to have a positive influence on the future development of GPSM. The strong involvement in the multi-spacecraft ESA Cluster mission is expected to continue, together with contributions to NASA multi-spacecraft missions, like THEMIS (launched in 2007) and MMS (to be launched in 2014). The group is also involved in data validation and exploitation proposals for the 3-satellite ESA Swarm mission, to be launched in 2012. In the longer run, missions like Solar Orbiter, to be launched in 2017, as well as participation in hardware projects and laboratory experiments, may support as well the further development of GPSM.

TEAM 36: Application of Space and COmmunication Technologies in the Social Benefit – ASCOT

ASCOT Overview:

The group of Applications of Space and Communication Technologies has the roots in the electronics and general engineering support for space research and application carried in the Laboratory of Space Engineering from ISS.

The space activities development in Romania, with the extension of international cooperation as well as the emerging new opportunities of cooperation with the international space community (e.g. ESA - Plan for European Cooperating States and the recent adhesion of Romania as full Member State to ESA), forced the group to define some directions of activity and project development as follows:

- telemedicine, in-field, mobile, portable-by-foot;
    - emergency, critical telemedicine;
    - medical assistance in remote, disadvantaged areas;
    - health screening and epidemic surveys;
- human security and safety:
    - search and rescue;
    - civil protection;
    - disaster management;
- environment survey and prediction:
    - Earth observation data protection data processing:
    - satellite image advanced treatment for predictions;
    - complex mathematical models for feature and patterns recognition;
- human performance assessment, and training for:
    - countermeasures to adverse bio, mental and physiological effects of long human space flights:
    - neuro-muscular countermeasures for microgravity related human physiology affectation;
    - psycho-neuro-mental countermeasures to human prolonged reclusion;
    - spin-off of space flight related countermeasures for training of professional exposed to stress and demanding environments, extreme and high performance sportsmen, practitioners of exercises for life quality enhancement.

and, as general support for research,

- engineering and applied physics technological research and solutions for:
    - experimental setup's for researches of other groups in ISS;
    - technologic solutions for group's specific activities.

It is to be fostered that all the mentioned directions and sub-domains have a strong interdisciplinary character and the projects, researches and application models were developed in cooperation with other groups in ISS, as well as with Institutions and Companies outside the institutional frame of ISS, in national and international context.

Although ASCOT had, at beginning, a strongly application-oriented profile, together with the challenges and the increasing complexity of tasks, the fundamental and theoretical research dimension of activity has dramatically increased, as support for the above mentioned applications. It is to be mentioned, in this respect the works on:

- Information Management in Bio-systems;
- bio motility and neuro-muscular control;
- mental flexibility and resilience to stress;
- personal and group interaction psychology;
- some specific populations sociology;
- psychological and sociological response of groups in peculiar conditions to media and globalization-related stimuli;
- Brain Computer Interaction (BCI);

etc.

It is also to be mentioned, in context of the theoretic/application research support, with notable personal contributions of some group's members as well as of cooperators from outside the ISS, the emergence of cutting-edge, original, research domains defined by authors as:

- Virtual Milieus Simulation;

- Information Management in Bio-systems;
- Information Anthropology.

These domains are part of doctoral work of some of our group members.

National Cooperation and Scientific and Technological Objectives of ASCOT Group:

Institutions, Organizations and Companies:

- Ministry of Health;
- General Inspectorate for Emergency Situations, Ministry of Administration and Interior;
- SMURD - Emergency, Resuscitation and Extrication Mobile Service (Targu Mures, Bihor, Brasov);
- Mountain and Cave Rescue Services - SALVAMONT&SALVASPEO - (Bihor);
- ANSMR - Romanian National Association of Mountain Rescuers;
- "Politechnica University", Bucharest, Romania;
- Fundeni Clinical Institute, Bucharest, Romania;
- Constanta County Emergency Clinical Hospital, Constanta, Romania;
- Timis County Emergency Clinical Hospital, Timosoara, Romania;
- "Bagdasar - Arseni" Clinical Hospital, Bucharest, Romania;
- National Institute for Sports Research, Bucharest, Romania;
- UTI Group, Bucharest, Romania;
- ASRC - Advanced Studies and Research Center, Bucharest, Romania;
- OnlineSolutions Media srl, Bucharest, Romania;
- Common Technic Group srl, Bucharest, Romania;
- PROCARDIA Romania, Targu Mures, Romania;
- Global Communications Services Romania S.A., Bucharest, Romania

The scientific and technological objectives ongoing and in perspective:

1. Finalization of Portable telemedicine Workstation PTW;
2. Passing to prototyping and inclusion in SMURD service of the Portable Telemedicine Workstation;
3. Development of the "Spaceborne Multiple Aperture Interferometry and Sequential Patterns Extraction Techniques for Accurate Directional Ground and Infrastructure Stability Measurements" Project (in cooperation);
4. Exploitation of results and continuation of cooperation on virtual milieus and space flight countermeasures with MEDES (Centre de Medicine et Physiologie Spatiale - Toulouse) under CNES (Centre National d'Etudes Spatiales - France) (in cooperation);
5. Exploitation of results and continuation of researches on mental flexibility and BCI in benefit of space flight countermeasures and curative medicine (in cooperation);
6. Continuation of theoretical studies on virtual milieus, information management in bio-systems.

International Cooperation and Scientific and Technological Objectives of ASCOT Group:

Institutions, Organizations and Companies:

- ESA - ESTEC (European Space Research and Technology Centre), Noordwijk, Netherlands;
- ESA - IAP Integrated Application Promotions), Noordwijk, Netherlands, Viena, Austria;
- DLR (German Aerospace Center), Köln, Stuttgart, Germany;
- CNES - MEDES (Centre de Medicine et Physiologie Spatiale) - Toulouse, France;
- CNES (Centre National d'Etudes Spatiales) - Paris, Toulouse, France;
- Universite de Savoie, France;
- Laboratoire d'Informatique, Systemes, Traitement de l'Information et de la Connaissance, Annecy, France;
- Italian Association for Telemedicine and Medical Informatics, Milan, Italy;
- AstroBionix GmbH, Innsbruck, Austria.

The scientific and technological objectives ongoing and in perspective:

1. Extension of PTW application in Alpine Region for Search and Rescue through ESA- IAP mechanisms (in cooperation);
2. Exploitation of results and continuation of cooperation on virtual milieus and space flight countermeasures with MEDES (Centre de Medicine et Physiologie Spatiale - Toulouse) under CNES (Centre National d'Etudes Spatiales - France) (in cooperation);
3. Continuation and further development of satellite image processing techniques for GMES, Safety&Security and Disaster Prevention and Management (in cooperation).

Summary of the main scientific publications and dissemination:

The scientific results where disseminate trough publications and conference contributions (selection):

- E. Trouvé, G. Vasile, M. Gay, L. Bombrun, P. Grussenmeyer, T. Landes, J.-M. Nicolas, Ph. Bolon, I. Petillot, A. Julea, L. Valet, J. Chanussot, and M. Koehl, Combining airborne photographs and spaceborne SAR data to monitor temperate glaciers - Potentials and limits, IEEE Transactions on Geoscience and Remote Sensing (TGRS), 45(4): 905–923, 2007;
- Văleanu V, Telea A, Marin M, de Hillerin P, Vizitiu A, Automatic Warning for Abnormal Vital Parameters Evolution in Tele-Care and Home-Care Applications, Proceedings of Space Application Days SPACEAPPLI08, April 22-25, 2008, Toulouse, France.
- Văleanu V, de Hillerin P, Haşegan D, Marin M, Vasiliu V, Costache C, Vizitiu A, Using Virtual Milieu Modeling for Astronauts Training, International Conference e-Health and Bioengineering - EHB 2009 17-18 Septembrie 2009, Constanța, publicat în: Advancements of Medical Bioengineering and Informatics, p. 59, "Gr. T. Popa" University of Medicine and Pharmacy Publishing House, Iaşi, Romania, 2009.
- Marin M, Vizitiu A, Ciurea C, Botezatu C, Factori de Influență în Măsurători cu Platforma de Echilibru în Domeniul Performanței Umane, A X-a Conferință de Bioinginerie Medicală - INGIMED 2009, Bucureşti 12-13 Noiembrie 2009, publicată în "Progrese în Ingineria Biomedicală", editori Radu Negoescu şi Florina Rădulescu, Editura ICPE-CA, Bucureşti, 2009, pag. 49-55.
- I. Petillot, E. Trouvé, Ph. Bolon, A. Julea, Y. Yan, M. Gay, and J.-M. Vanpé; Radar-Coding and Geocoding Lookup Tables for the Fusion of GIS and SAR Data in Mountain Areas, IEEE Geoscience and Remote Sensing Letters (GRSL), 7(2): 309–313, 2010;
- Văleanu V. Cabibbe G M, Arafat R, Csillag P B, Gabella F, Marin M, Haşegan D, Vasiliu V, Vizitiu A, Critical Telemedicine Vector in Response to Emergencies and Crises, Proceedings of Toulouse Space Show 2010, Space Applications Workshop SPACEAPPLI10, June 7-11, Toulouse, France.
- A. Julea, N. Méger, Ph. Bolon, C. Rigotti, M.-P. Doin, C. Lasserre, E. Trouvé, and V. Lăzărescu, Unsupervised Spatiotemporal Mining of Satellite Image Time Series Using Grouped Frequent Sequential Patterns, IEEE Transactions on Geoscience and Remote Sensing, 49(4): 1417–1430, 2011;
- Văleanu V, Unitatea Portabilă de Telemedicină cu Comunicație Satelitară în Beneficiul Asistenței Medicale de Urgență, publicată în Jurnalul de Medicină de Urgență şi Salvări în Situații Speciale, Supliment Nr.1/2011, pag. 23. (supliment editat cu ocazia celei de-a treia ediții a Conferinței Naționale de Medicină de Urgență şi Salvări în Situații Speciale „Search and Rescue 2011", 9-12 noiembrie 2011, la Băile Felix, Oradea).
- Văleanu, V., Hillerin P-J, Ciurea J., Vizitiu A., Marin M., Researches on a Novel Method for Computer-Aided Training of Mental Flexibility, published in Proceedings of the International Conference on e-Health and Bioengineering, EHB 2011, Gr. T Popa University of Medicine and Pharmacy Publishing House, Iaşi, Romania, 2011, ISBN 978-606-544-078-4 (indexed in IEEE Xplore®, ISI-Proceedings, SCOPUS, INSPEC IET and EI Engineering Information data bases).
- Ciurea J., Vizitiu C., Hillerin P-J, Văleanu V., Bălănescu B., Chronaxie and Deep Brain Neuromodulation in Connection with the Information Management in Biosystems, published in Proceedings of the International Conference on e-Health and Bioengineering, EHB 2011, Gr. T Popa University of Medicine and Pharmacy Publishing House, Iaşi, Romania, 2011, ISBN 978-606-544-078-4 (indexed in IEEE Xplore®, ISI-Proceedings, SCOPUS, INSPEC IET and EI Engineering Information data bases).

Evolution and future needs of human resources:

The ASCOT group of ISS plays the role of ideas and solutions provider as well as activity management for the use of space assets and knowledge in applications for domains with high impact in the social life. This position of the group allowed to develop activities and to have notable achievements with a rather restrained group of specialists with highly mix competences ranging from electronics and mechanical engineering, applied physics, till data processing and project management (with a growth from 2 to 5 persons in the last 4 years).

The growth of tasks dimensions and challenge, present and expected, together with the increasing complexity of societal demands and new available technologies and methods seem foster a personnel growth and completion in the very next period. The close future personnel growth necessity range from young specialists in the *traditional space-related* fields (e.g. engineering, physics, mathematics, etc.) to specialists in complementary, *non-space-traditional* fields (e.g. sociology, psychology, human safety, neuro- and bio-sciences, complexity science, etc.).

TEAM 37: Gravitation and nanosatellites research team

General description

The gravity and nanosatellites team of the institute focuses on the research for the development of applicative small satellite missions for scientific measurements and earth observation objectives. Advanced celestial mechanics and space dynamics research expertise exists and one of its applications is the fuel minimization for scenarios of nanosatellites in close orbital formations and constellations. Objectives as data mining, artificial intelligence, satellite image processing and mathematical modeling are derived from the applied nature of the space research being conducted.

The team's activities have been financed from national grants proposed on the subjects of interest in partnership with key members from the aerospace and science domains in Romania: GOLIAT (the development of the first Romanian nanosatellite), PLURIBUS (identical nanosatellites for formation flying missions), FORMUAV (autonomous UAVs for formation flying missions), VECSS (telemetry and data module on board a privately financed Romanian rocket), COMPOSAT (individual subsystems for nanosatellites), Nucleu: ”*Cercetarea si dezvoltarea de tehnologii si aplicatii spatiale prin valorificarea sistemelor de achizitie si procesare distribuita la bordul nanosatelitilor aflati in zbor in formatie stransa*” (developing and identifying applications for formation flying and constellation missions of nanosatellites), Nucleu: ”*Efecte gravitationale in Sistemul Solar si la scara mare cu implicatii observationale si experimentale*” (research on gravity effects in the Solar System with experimental implications), Aerospatial: „*Efectul radiatiilor ionizate (cosmice) asupra proprietatilor structurale electrice si optice ale straturilor subtiri din compusii semiconductori* A^{II}-B^{VI} *folosite la realizarea celulelor solare pentru aplicatii spatiale*” (research on the effects of cosmic radiation on thin layer semiconductors used in space applications), PTDNS (national technological platform for space dynamics), MARKS (coordination system for space activities using advanced research and knowledge management), TERASCAN (research on the emission, modulation, scaning and detection of THz electromagnetic waves; experimental model for a detection and imaging instalation of objects for security purposes).

The results of the research group include Goliat, the first Romanian satellite, the ground station infrastructure for satellite communications, numerous subsystems developed, papers and conferences were the results were presented.

Objectives and activities:

Nanosatellites are a new class of spacecrafts characterized by a mass between 1 and 10 kg. They represent one of the fastest developing sector of aerospace research driven by cost minimization and rapid development cycles from the drawing board to launch and operations. The research conducted in the team is focused on space applications for LEO missions (Low Earth Orbit). The research group closely collaborates with the Romanian Space Agency for a joint long term program that focuses on enabling the utilization of nanosatellites for complex scientific investigations and commercial applications through multiple satellite missions.

The long term plan was kicked-off with the development of GOLIAT, a CubeSat class nanosatellite, developed by an interdisciplinary consortium in which the Institute for Space Sciences had an important contribution. The satellite is currently at the launch base in Kourou, French Guyana, scheduled to be launched in January 2012. The natural continuation of GOLIAT is the development of generic standard nanosatellite components designed for reuse on multiple missions and the development of a standardized satellite for formation flying scenarios. These objectives were the focus of the research in the PLURIBUS and

COMPOSAT projects, when important advancements were met through the development of vital nanosatellites subsystems. Future research and financial efforts will be directed to the development of a standardized satellite platform offering a fully functional bus and capable of accommodating various types of missions (MOSOM project). With these goals we focus on providing generic tools for space research to scientist working in research fields from biology to physics and to other potential end users (mainly applications in GIS – Geographic Information System).

The group also used its experience outside the nanosatellite domain, in developing a data and telemetry module designed to fly on board a private rocket (VECSS project) and for developing autonomous UAVs (Unmanned Aerial Vehicles) for formation flying missions (FORMUAV project).

Corresponding to these objectives, the main activities of the research team are: mechanical and electrical design and development of subsystems for nanosatellites, mechanical and electrical design and development of payload instruments for nanosatellites missions, nanosatellite development and space based missions, mechanical and electrical design and development of aeronautics systems, development of applications for small satellite missions, near Earth radiation environment analysis and instrumentation, Earth's gravity field investigations and orbit propagation for low Earth orbit mission scenarios, the study of the Glyden problem, the study of the chaotic movement, orbital design and space debris studies, applying the artificial intelligence method to specific problems, automatic information extraction from images, temporal series, etc., developing image processing techniques for satellite images, developing mathematical models and algorithms for a great range of problems, mathematical studies on project specific problems.

The team maintains a close collaboration with international teams working on nanosatellites and a common FP7 project was proposed. A strong international collaboration opportunity is for another FP7 project (QB50) and pending a Call for Proposal announcement. For this collaboration the research group wants to develop a single satellite whose launch will be partially financed by the FP7 project and, during the flight to gather data on the performance of the custom developed nanosatellite hardware.

The applied research conducted by the group has the potential of being utilized through spin-offs and start-ups for the commercial exploitation of the subsystems, satellites and systems of satellites developed. At this moment the market for products designed for nanosatellites is constantly growing. These commercial exploitation paths are currently being investigated together with the institute's partners as means for further financing the research in the field.

The team's future research will focus on meeting the proposed long term objective of close orbital formation flying missions for nanosatellites. In this way, low cost space instruments can be implemented on innovative missions for augmenting the in situ data on near Earth phenomena and for providing rapid re-visitation in Earth observation applications, complementary to the limited number of high resolution satellites.

Human resources

The structure of the research group has evolved during the last 4 years, with two main goals in mind: to maintain its multidisciplinary composition and to extend its qualifications. As such, an important objective is to identify valorous young persons that could be integrated in the multidisciplinary team. An important example in this regard is the addition of students from University of Bucharest and University Politehnica of Bucharest to the research group recommended by their important work conducted for the development of the Goliat satellite. The augmentation of the team does not only focus on the addition of new members but also on developing the professional expertise of the existing personnel through postgraduate studies and training courses in the proposed fields of research.

Together with the Romanian Space Agency we try to identify potential hands-on projects for students, in which they become accustomed to the MO of space research. Such an opportunity has been identified for ESEO (European Student Earth Orbiter) and ESMO (European Student Moon Orbiter), two projects coordinated by the European Space Agency, where three groups of students work on various subsystems for the two spacecrafts. Through its members the institute's research team is actively supporting these participations with scientific and technological guidance.

Results

The most visible result of the research team is the realization of the first Romanian nanosatellite in a joint consortium with the financing support through the GOLIAT project. The flight ready satellite was delivered to the launcher and is scheduled for launch in January 2012 on board the maiden flight of the new European rocket: VEGA.

Goliat is a single unit CubeSat-type nanosatellite that will be launched on an elliptical low Earth orbit having the apogee at 1450 km, the perigee at 300 km and the inclination at 69.5^{o}. The satellite has three payloads: a 57 mm focal length digital camera capable of taking pictures with a resolution of up to 3 megapixels, a total dose radiation detector based on a scintillator and a photodiode and a piezoelectric film impact detector for estimating the flux of micrometeoroids on LEO. Additionally to the payload, bus subsystems had to be developed and integrated: a low noise electronic power supply, autonomous on board computer, radio transceiver module, attitude determination and control subsystem. All this subsystems feature custom developed software embedded on each microcontroller.

Of great importance to the mission is the ground segment that was implemented at two locations. The main ground station was equipped at the Institute for Space Sciences in Magurele and it includes: two stacked Yagi antennas, a 3 m dish, azimuth and elevation rotators for the two antenna assemblies, automated tracking control units, automated tracking software, radio transceivers for the two bands used in communicating with Goliat (UHF and S-band) and modems.

The research activity has also materialized in the design and development of numerous engineering models of nanosatellites, nanosatellite subsystems, UAVs and UAV subsystems.

The research is disseminated internationally in publications and conferences dedicated to the utilization of small satellites for in situ measurements, Earth observation or other types of space applications. The subsystems' models have also been part of the institute's participation at the exhibition areas at the International Astronautical Congress and other science and technology fairs. These participations have facilitated the good connection with teams from all over the world working on nanosatellite research.