

Evaluation of the Research and Professional Activity of the Institutes of the Czech Academy of Sciences (CAS) for the period 2010–2014

Final Report on the Evaluation of the Institute

Name of the Institute: Institute of Plasma Physics of the CAS, v. v. i.

Fields, in which the Institute registered its teams:

Physical sciences

Observer representing the Academy Council of the CAS: Tomáš Kruml

Observer representing the Institute: Pavel Chráska

Commission No. 3: Physical sciences

Chair: Prof. John Dainton

Date(s) of the visit of the Institute: October 15 - October 23, 2015

Programme of the visit of the Institute: see attached Minutes from the visit

Evaluated research teams:

No. 1 - Tokamak; No. 2 - Pulse Plasma Systems; No. 3 - Centre TOPTEC; No. 5 - Thermal Plasma; No. 6 - Laser Plasma

A. Evaluation of the Institute as a whole

1. Introduction

The Institute of Plasma Physics of the Czech Academy of Sciences (IPP CAS) is by far the largest institution in the Czech Republic working on different fields of plasma physics and applications. It is located at three sites: CAS campus at Prague 8, Letňany (Prague 18), and Turnov. In several fields it has been a driving force for other new EU countries in Central and Eastern Europe through multiple high level bilateral and EU-coordinated collaborations. At the national level its partners are (i) major universities (Charles, CTU and Chemistry & Technology in Prague, Masaryk in Brno, West Bohemia in Pilsen, and TU in Liberec) where employees of IPP CAS are teaching specialized courses and from where most of the master PhD students trained at IPP CAS come from; (ii) research institutes (CAS Institutes of Physics and Physics of Materials, and Research Centre Řež); and (iii) industrial partners.

2. Strengths and Opportunities

The origin of IPP CAS goes back to 1959 when the Institute of Vacuum Electronics was established. Major milestones were the installation of the first tokamak in Central and Eastern Europe in 1977, the arrival of the plasma torch group in 1981 and of the materials group (outside the present evaluation) in 1985, the treatment of kidney stones (and recently of cancer) with focused shock waves in 1989, the fundamental restructuring of IPP in 1990-1992, the contract of Association EURATOM/IPP.CR in 1999, the start of PALS in 2000, the successful testing of plasma gasification of waste (starting in 2004), the start of COMPASS in 2009, and the establishment of the Regional Centre for Specialized Optical and Optoelectronic Systems in Turnov in 2010. IPP.CAS owns and operates two large national research infrastructures (COMPASS and PALS).

Decades of high level fundamental experimental, theoretical as well as applied research constitute the major (world recognized) strengths of IPP CAS in a variety of fields such as magnetic fusion, non-equilibrium discharges, thermal plasmas, materials connected with plasmas, laser-produced and lasing plasmas, and special optics and optoelectronics. The institute uses all opportunities to introduce new promising cutting-edge research topics. The committee considers the International Board of Advisors for the fusion programme as best practice.

Between 2010 and 2015 the personnel grew from 150 people (127 FTE) to 220 people (178 FTE). For historical reasons there is a gap in the age range between 40 and 50, but a successful exchange of generations has been realized in most departments, holding promise for the future. The funding situation of IPP.CR is sound and stable.

3. Weaknesses and Threats

No particular weaknesses nor threats have to be reported. However, for the Thermal Plasma Department strengths and opportunities are seriously jeopardized by the age structure.

4. Recommendations

A sound motivation is required for the planned upgrade of COMPASS to make it attractive for the different funding agencies. Cooperation with the International Board of Advisors could be very useful. The Pulse Plasma Systems Department is advised to focus on the most promising fields. The committee advises the Centre TOPTEC to pursue in the direction of more basic scientific activities and more high level publications. If a short term remediation of the age structure of the Thermal Plasma department is not feasible, it is

recommended to maintain at least the research on steam plasma treatment of biomass and organic waste and on reforming of gas. To maintain the unique expertise localized in the Czech Republic it is mandatory to keep the operation of the PALS facility possible for a time-span that warrants a continuation to serve the Czech interests at ELI-Beamlines.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

Several teams are world-leading in their specific fields of expertise. The overall quality of the scientific results is high and internationally recognized. However, the ratio between publications in peer review journals to conference contributions could be enhanced. For the vast majority of the publications the main authors are from IPP. PALS was up to last year organized mostly as a large research infrastructure providing open access, where the staff was mostly responsible for operation of the experiment infrastructure and preparation and running the experiment; the physics papers were mostly written by external users (foreign and Czech), partly within the Laser Lab Consortium.

Declaration on the involvement of students in research

In collaboration with major universities in the Czech Republic (co-accreditation) as well as with several foreign institutions (such as the Erasmus Mundus master FUSION-EP), there is an intensive involvement of researchers in teaching specialized courses and seminars and in supervising a large number of students (BSc, MSc and PhD). The total number of PhD students was 31 and the total number of defended PhD theses was 21.

Declaration on societal relevance

IPP CAS is quite active in outreach activities (school on-site visits, open door days, public lectures, radio and TV programmes, articles in newspapers, books and brochures) The institute is regularly visited by Czech and foreign politicians, and by representatives of leading companies. Involvement in standpoint papers for the Czech government.

Declaration on the position in the international and national context

IPP CAS is nationally and internationally respected for its high level research in a variety of plasma-related fields. Multiple collaborations have been established inside and outside Europe, with many members of the institute visiting institutions abroad and many foreign researchers visiting the institute.

Declaration on the vitality and sustainability

During the evaluated period the institute underwent some important changes regarding the experimental possibilities and capabilities, as well as regarding human resources (many promising young scientists and students joined the institute), holding promise for the future of IPP CAS has been very successful in obtaining funding which enabled an impressive growth.

Declaration on the strategy and plans for the future

The clearly outlined strategy and plans for the future are quite ambitious and based on the successful present activities. Proper attention is paid to collaboration with foreign and in particular European institutions.

B. Evaluation of the individual teams

Evaluation of the Team No. 1: Tokamak

1. Introduction

The scientific work has been focused on several main topics directly linked to the international long-term efforts to master thermonuclear magnetic fusion. In the period 2010 – 2013 most of the effort has been devoted to putting the tokamak COMPASS transferred from the UK (the only tokamak in Central Europe, and supported by the MEYES programme for Czech large national research infrastructures) into full operation including commissioning of all the auxiliary systems and many new advanced diagnostics. Afterwards, the main emphasis was put on the successful development of (ITER-) relevant operational scenarios. In parallel and with an increasing emphasis, the focus has been on ITER relevant problems. The new programme benefits from the existing tokamak edge plasma expertise of the team acquired already on the previous tokamak CASTOR. Many new topics and key problems identified within the EURATOM and EUROfusion programme have been addressed.

2. Strengths and Opportunities

The scientific research plan is specified in more details in cooperation with the International Board of Advisors of IPP as well as with the management of the EUROfusion consortium on an annual basis.

3. Weaknesses and Threats

The committee sees no particular weaknesses or threats

4. Recommendations

- In some research areas (including theory and modelling) the programmatic or scientific aims should be further developed, while other activities are clearly top-class research. A task force structure would help working out a scientific rationale for an upgrade of COMPASS as well as for optimizing international collaboration. The integration of the research on COMPASS should be further integrated into the EUROfusion program, stressing the programmatic aspects aligned with the EU fusion roadmap.
- Concerning the plans for an upgrade of COMPASS, it is very important that there is a sound motivation that makes this upgrade attractive for the different funding agencies, i.e. a combination of programmatic and scientific issues that can be addressed in a unique manner on COMPASS Upgrade, complementary to existing devices. Cooperation with the International Board of Advisors could be very useful.
- The Tokamak Department makes several important contributions to ITER physics and technology questions. It is now possible to obtain direct ITER contracts, and IPP.CR should explore if this can be a significant stable funding source for the future.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

The COMPASS scientific program addresses timely issues for the EU and the worldwide fusion program and the majority of the publications is excellent.

Declaration on the involvement of students in research

The education & training program is outstanding and highly appreciated with the EU fusion programme, with many unique features such as hands-on (and remote) tokamak operation for Czech and foreign students.

Declaration on societal relevance

Czech and foreign politicians, as well as representatives of leading companies visited COMPASS. Scientists have been involved in the preparation of papers for the government. Intensive PR activities (newspapers, TV, press conferences, public presentations). Strong interaction with schools and with the general public (1000-1500 visitors per year).

Declaration on the position in the international and national context

The EU fusion programme is international par excellence. There is an intensive collaboration with Czech universities as well as an intensive participation in experimental work at several European facilities, in particular at the European tokamak JET (UK) and the tokamak ASDEX-Upgrade (Germany), in the framework of the EUROfusion Consortium.

Declaration on the vitality and sustainability

The high quality of the team which is young and motivated is impressive. Concerning funding stability, the group is well embedded in the EU fusion lab network as well as in the Czech research world

Declaration on the strategy and plans for the future

The strategy and plans for the future are quite ambitious.

- The research activities will be focused on the further exploitation of the COMPASS tokamak, participation in related experiments on other European fusion devices (mainly JET and ASDEX-Upgrade) as well as on development of theory and modelling of the fusion plasma within the EUROfusion consortium.
- Ongoing ITER & DEMO projects and activities will be continued. Upgrades of diagnostic systems and of the COMPASS tokamak are either ongoing or planned, reflecting the gradual development of fusion research as well as needs of the ITER and DEMO projects.
- An upgrade of COMPASS is envisaged (subject to availability of funding from CR and from the EU Structural Fund); it could include a new central solenoid to increase significantly the duration of the discharge; a higher toroidal magnetic field, a new vacuum vessel (increase of plasma size, and thus, plasma performance; improvement of diagnostics access); a closed differentially pumped divertor; and modification of existing plasma-facing components)
- In addition, the following feasibility studies will be performed: installation of a lithium divertor; upgrading of the systems for additional plasma heating (increase of the power of the Neutral Beam Injectors to ~MW level ; installation of a novel multi-strap antenna for ion heating in the range of ion cyclotron frequencies relevant for DEMO); High Temperature Superconductors on COMPASS for the generation of the poloidal magnetic fields; and advanced divertor concepts for DEMO

Evaluation of the Team No. 2: Pulse Plasma Systems

1. Introduction

The team has a worldwide reputation in fundamental and applied research of-equilibrium (low-temperature) plasmas generated by various types of pulse high-voltage electrical discharges in gases, liquids and gas/liquid environments. Four main topics were studied in the period 2010-2014 with a view to the utilization of electrical discharge plasma in different applications (environmental, biological, medical): (1) Plasma chemistry induced by electrical discharges in liquids and gas/liquid environments, (2) Physics and biological effects of focused shock waves in water, (3) Physics, kinetics and diagnostics of streamer discharges in gas phase, (4) Soft X-ray emission of fast high-current capillary discharges.

2. Strengths and Opportunities

In the fields of plasma chemistry induced by electrical discharges in liquids and research of non-equilibrium streamer kinetics in atmospheric gases, the team belongs to the top. In these fields there exist a wide range of opportunities for environmental, biological, medical applications.

3. Weaknesses and Threats

If the team wants to focus on the above mentioned promising fields, the other research fields will have to be downscaled.

4. Recommendations

Focus the research activities on promising environmental, biological, and medical applications.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

The team is very successful and achieved significant results with high level recognition in the low-temperature plasma community. The team is very well internationally established, integrated in the several international research programs with several bilateral collaborations. In the fields of plasma chemistry induced by electrical discharges in liquids and research of non-equilibrium streamer kinetics in atmospheric gases, the team belongs to the top.

Declaration on the involvement of students in research

The number of students involved in research is appropriate.

Declaration on societal relevance

The research activities have been presented in two Czech TV programs focused on the popularization of science and technology. Each year during the "Week of Science" the Department also opens its doors and organizes presentations and demonstrations for students as well as for the general public.

Declaration on the position in the international and national context

The team is very well internationally established, integrated in several international research programs with several bilateral collaborations. Since 2013 the team is also a member of the new European network project COST Action TD1208. In 2012, the head of the Department was 6 months as Visiting Professor at Kumamoto University, Kumamoto, Japan. Since 2011, the team also became a member of prestigious International

Bioelectrics Consortium (IBC). The investigation of shock wave propagation in tumor tissue is performed in collaboration with the Institute of Animal Physiology and Genetics AS CR and the First Faculty of Medicine of Charles University in Prague. In the field of streamer discharges there are bilateral cooperations with Istituto de Astrofisica de Andalusia, (IAA-CSIC Granada, Spain) and with the Istituto di Metodologie Inorganiche e dei Plasmi (CNR, Bari, Italy). The Soft X-ray research team is a branch of the UNESCO International Centre for Dense Magnetized Plasma (ICDMP) and is integrated into the COST activity MP 1203.

Declaration on the vitality and sustainability

Recently there has been a generation change in the leadership. The age structure of the team is good, but could still be improved.

Declaration on the strategy and plans for the future

In the period 2015-2019 it is planned to focus the scientific program on the two most successful and promising research topics, i.e. plasma chemistry induced by electrical discharges in liquids and research of non-equilibrium streamer kinetics in atmospheric gases

Evaluation of the Team No. 3: Centre TOPTEC

1. Introduction

The Regional Centre for special optics and optoelectronic systems in Turnov was formerly a small independent academic laboratory which has been integrated in IPP in 2006. They have been awarded substantial grants from the Czech government and the EU. Recently they acquired new laboratory rooms and cutting edge technologies for machining and measurements, as well as software for simulations & design in the fields of special optics and optoelectronics.

2. Strengths and Opportunities

TOPTEC has been awarded substantial grants from the Czech government and the EU. Recently they acquired new laboratory rooms and cutting edge technologies for machining and measurements, as well as software for simulations & design.

3. Weaknesses and Threats

No manifest weaknesses nor threats have been observed, although the R&D activities are rather “market”-than science-driven.

4. Recommendations

Compared to the situation before the evaluated period, there are more basic scientific activities and more high level publications. The committee advises to pursue in this direction.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

Most of the research is contractual (national and international customers). The quality of the evaluated results is good. However, the ratio between publications in peer review journals to conference contributions is rather low.

Declaration on the involvement of students in research

The involvement of students is quite good. The general aim is to promote the education and training of talented R&D employees. This is a process that begins when potential new employees of the Centre are still studying. The teaching work of employees at the Centre, mainly at the Technical University of Liberec and the Czech Technical

University in Prague allows to monitor talented students and encourage them to become employees of the Centre in the future. Furthermore, the Centre is educating many master students, who work on their projects and thesis there. The Centre provides the students with the opportunity of short-term internships and practical trainings. It is anticipated that the students participate in the research activities and focus on the topics specified in the research objectives.

Declaration on societal relevance

Regular visits to TOPTEC are organized for the Faculty of Science of the Palacký University Olomouc-Joint laboratory of Optics, the Czech Technical University in Prague, the CAS - Czech Astronomical Society, the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague, and the Technical University of Liberec (study track nanomaterials).

Declaration on the position in the international and national context

Involvement in research projects of ESA and CERN. Collaboration with Czech universities, in particular with the Technical University of Liberec and the Czech Technical University in Prague. Contractual research for national and international customers.

Declaration on the vitality and sustainability

The age profile of the team and the current successful contract R&D activities guarantee a continuation and further development of these activities.

Declaration on the strategy and plans for the future

On the basis of the very successful current activities ambitious R&D activities are planned in the fields of fine mechanics, thin films, aspherical optics, optoelectronic systems and detectors, metrology, adaptive optics and vibration control, crystal optics and electro-optic systems based on nonlinear optical materials.

Evaluation of the Team No. 5: Thermal Plasma

1. Introduction

The research activities are concentrated on the investigation of generators of thermal plasmas, diagnostics of electrical discharges producing thermal plasma, study of interaction of thermal plasma with gas, liquid and solid materials, and investigation of physical and chemical processes in plasma processing of materials. Special attention is devoted to study of plasma and plasma jets generated in a world-unique type of plasma generator with water stabilized electric arc (for which IPP is worldwide renowned) and its applications (plasma pyrolysis and gasification of organic materials and waste, plasma spraying, plasma cutting of materials, and removal of organic pollutants from water). Steam plasma generated in water stabilized torches and hybrid water/argon plasma torches is characterized by extreme parameters, especially high temperature, high plasma enthalpy, and high exit plasma jet flow velocity. The investigation of sources of steam plasma with the water stabilized arc recently resulted in the design and realization of an optimized type of the plasma torch for industrial applications. Given the expertise and the infrastructure of the team, the research topics are well chosen.

2. Strengths and Opportunities

The Department has a world-unique and very extensive experience in water stabilized torches, the industrial potential of which is huge (in particular in the field of plasma treatment of waste streams in which the department has been quite successful). The hybrid gas/water plasma torch has been commercialized.

3. Weaknesses and Threats

However, the above mentioned strengths and opportunities are seriously jeopardized by the age structure.

4. Recommendations

If a short term remediation of the age structure of the department is not feasible, it is recommended to maintain at least the research on steam plasma treatment of biomass and organic waste and on reforming of gas which holds the highest promise from the point of view of applied as well as basic research, and of societal relevance. The new cylindrical plasma reactor with direct flow where plasma/reactants input and reaction products output are on the opposite ends of the cylinder, will allow the study of mixing of reactants with plasma along the jet, the evolution of the chemical composition along the reactor, the process rates and kinetics, as well as exact the determination of the energy balance of the process.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

Although the emphasis is more on optimization than on basic science, the quality of the evaluated results is good. However, the ratio between publications in peer review journals to conference contributions should be enhanced.

Declaration on the involvement of students in research

The involvement of students (in particular of foreign students) is appropriate, but in view of the sustainability of the department more Czech students should be attracted.

The head of the department is a member of Boards for doctoral studies at the Faculty of Electrical Engineering of the Czech Technical University Prague and the Faculty of Applied Sciences of the University of West Bohemia in Pilsen, a member of the examination doctoral committee at the Faculty of Mathematics and Physics of the Charles University in Prague.

Declaration on societal relevance

The research field of plasma treatment of waste and gas reforming has a high societal relevance. Two papers about research activities of the Department in the field of plasma gasification of waste materials and international cooperation were published in the Academic Bulletin of ASCR (2013, 2014). A lecture on Pyrolysis and gasification of waste in plasma (in Czech) has been given at the exhibition FOR WASTE2010 (Symposium „Possibilities of utilization of waste“) in Prague.

Declaration on the position in the international and national context

The department has several well established collaborations with foreign research institutions and universities, as well as with Czech universities and national and international industrial partners. The head of the department has been a member of the Board of Directors of the International Plasma Chemistry Society, Fellow of International Union of Pure and Applied Chemistry, Fellow of the Engineering Academy of the Czech Republic, member of the Executive Committee of the European Society of High Temperature Materials Processing, member of the Council for International Affairs of the ASCR.

Declaration on the vitality and sustainability

A more sound age structure of the department is mandatory to improve the vitality and to maintain the expertise and the key R&D activities.

Declaration on the strategy and plans for the future

The research plans are sound and based on the successful present activities. The principal goals of the investigation of plasma systems with water stabilized arcs are an optimization of steam plasma generation and improvement of the performance of plasma processing applications. The research results should lead to a better control of the plasma jet parameters, a reduction of erosion in parts of the generators and hence an increase of their lifetime, and increase of stability of plasma flow in the jet. The new plasma reactor will allow the basic investigation of steam plasma treatment of biomass and organic waste and of gas reforming. As the characteristic time constants of the phenomena are in the microsecond and submicrosecond range, special diagnostic systems are necessary.

Evaluation of the Team No. 6: Laser Plasma

1. Introduction

During the evaluation period the Laser Plasma team was the operator and a main contributor, together with a team from IOP and in collaboration with universities, to the PALS project. This project operates a world leading laser facility intensely integrated into international collaborations (e.g. Laserlab Europe) with other leading facilities in the world. The team “Laser Plasma” in this context was one of the driving forces and providing the national educational and technological background for the installation of the ELI pillar “ELI-Beamlines” and the HILASE facility at Prague.

2. Strengths and Opportunities

Building on the world-wide connection at the forefront of laser science, the team has produced a rich and recognized scientific outputs as well as technological developments. The opportunity to proceed along these lines will be enhanced by the upcoming ELI-Beamlines facility.

3. Weaknesses and Threats

There is no weakness in the performance of this team. However there exists a threat do to the positioning in the future. PALS facility is an internationally leading facility offering Terawatt pulses of several 100 J. For this sector the upcoming ELI facility will not offer a replacement for the near future.

4. Recommendations

To maintain the unique expertise localized in the Czech Republic it is mandatory to keep the operation of the PALS facility possible for a time-span that warrants a continuation to serve the Czech interests at ELI-Beamlines.

5. Detailed evaluations

Declaration on the quality of the results and share in their acquisition

The output of the team represents outstanding quality on the international level. Within the fields of laser induced cavity pressure acceleration, shock generation, and plasma jets, and the fast time resolved and spatial diagnostics of these, articles in the top-most relevant journals were published. Members of the team are important co-authors. The international collaborations performing the research were mostly lead by members of the tea.

Declaration on the involvement of students in research

The team has a large numbers of results where graduate students had a leading role. In addition to national students, students from the international collaborations participated. Several of them are now part of the ELI project.

Declaration on societal relevance

Members of the team were very actively teaching at surrounding universities. Workshops and summer schools were initiated. International connections were enhanced. Team members were active in particular in the boards of European networks like Laserlab Europe and Hiper.

Declaration on the position in the international and national context

The internationally operating PALS facility and the research of the team have high visibility both inside of the Czech Republic as world-wide. Strong links exist to research groups in particular in France, Germany, Poland and Great Britain, and also in the USA (Colorado University).

Declaration on the vitality and sustainability

There is no doubt on the vitality of the team, which combines experienced and young researchers in a well-balanced way. This will also guarantee a sustainability to perform leading research in the field making ultimate use of the new opportunities between ELI-Beamlines and HILASE. Care should be taken that there will be no unnecessary break by reducing the capabilities of the PALS system before an adequate research possibility will be exist.

Declaration on the strategy and plans for the future

The most important aims of the strategy are named directly in the report:

- promote, in a coordinated way and on a European scale, the use of advanced lasers and laser-based technologies for research and innovation,
- serve a cross-disciplinary user community, from academia as well as from industry, by providing access to our laser research installations,
- increase the human resources in the field of lasers,
- improve human and technical resources through technology exchange and sharing of expertise among laser experts and operators from the LASERLAB-Europe consortium

The way to reach this is presented in going on providing leading research in the fields of laser plasma interaction, also in the direction of secondary sources and contribution to both laser- and magnetic- fusion developments. This is well based on the important expertise owned by the team.

Date: January 13, 2016

Commission Chair: Prof. John Dainton