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:

Materials engineering, materials science and nanotechnology

Observer representing the Academy Council of the CAS: Jiří Chýla
Observer representing the Institute: Pavel Chráska

Commission No. 8: Engineering and technology
Chair: em Prof.DI.Dr.Dr.hc. Hans Peter Nachtnebel

Date(s) of the visit of the Institute: October 12 - October 21, 2015
Programme of the visit of the Institute: see attached Minutes from the visit

Evaluated research teams:
No. 4 - Materials Engineering

EVALUATION OF THE INSTITUTE OF PLASMA PHYSICS (IPP)

This report refers to the evaluation of the Institute of Plasma Physics (IPP) of the Academy of Sciences of the Czech Republic (CAS), 2010-2014, and is written according the to the guidelines reported in the Appendix 6.1 and 7.1 as well as the Recommendation for Elaboration of the Final Report drawn by the CAS.

1. INTRODUCTION

1.1 Location of the institute and its dept., labs. & sub units.

IPP is mainly located in Prague 8, at the Campus of the Academy of Sciences, Za Slovankou 1782/3 - 182 00 Prague 8 - Libeň. In two detached sites are located the Laboratory of Plasma Technologies of the Material Engineering Department (in Hala No. 6, Areal VZLU, a.s. - Beranových 130 - 19900 Prague 8) and, respectively, the Regional Centre for Special Optics and Optoelectronic Systems - Turnov OPToElectronic Centre - TOPTEC (in Sobotecká 1660, Turnov 51101).

IPP consists of five research departments (Tokamak, Laser Plasma, Pulse Plasma Systems, Materials Engineering, Thermal Plasma), the Regional Centre TOPTEC in Turnov, and several support units. During the evaluation this commission visited the institute and the research team *No. 4 - Materials Engineering.*

1.2 Brief history of the institute

The Institute of Plasma Physics was founded in 1959 by the then Czechoslovak Academy of Sciences. It originates from the Institute of Vacuum Electronics (IVE) of the Czechoslovak Academy of Sciences, established from a group of 50 former employees of the Research Institute of Vacuum Electrical Technology, leaded by Ing. Jan Váňa. The new Institute was commissioned to coordinate thermonuclear fusion research in Czechoslovakia, after the Second Conference on Peaceful Uses of Atomic Energy in Geneva (1958), where the capabilities of controlled thermonuclear fusion was for the first time discussed. In 1963, after the visit of the Russian scientist L.A Artsimovich, started a period of fruitful collaboration with Russian scientists, lasting almost thirty years. Staring from '90s, IPP broadened its collaboration to European countries, joining a range of international activities, including the EURATOM project in 1999. Today the IPP extends its activities to many of the main research areas related to the plasma technologies and their applications.

1.3 Mission and research topics

IPP is the only entity of the Czech Republic specialized in the research and applications of plasma. The studies range from relatively cold discharge plasma with temperatures below

40,000 K, to very hot laser plasma with temperatures in tens of millions K. The range of densities of the plasma studied is also very wide. It spans from plasma density of several orders of magnitude lower than atmospheric pressure, to density comparable with one of solid phase.

In the field of plasma generation and confinement, IPP carries out studies about plasma properties and its interaction with matter, including the applications of this interaction (an example is given by the development of materials able to withstand long-term exposure to hot plasma in tokamaks). The materials are prepared by plasma spraying, analyzed and optimized in the materials engineering department, and then tested in real working conditions in the tokamak facility.

IPP main research topics are about:

- Fusion-relevant research of magnetized plasmas in Tokamaks.
- Non-equilibrium discharges (discharges in gas and liquids, focused shock-waves, chemically active non-equilibrium plasma).
- Thermal plasmas (water-stabilized arc discharges, thermal plasma as a basis for plasma technologies).
- Material research connected to plasma (interaction of plasma with solids and liquids, material for fusion devices, plasma spraying of tailored materials).
- Experimental and theoretical research about laser produced and lasing plasmas (in Prague Asterix Laser System - PALS)
- Special optics and optoelectronics (at TOPTEC in Turnov).
- Moreover, IPP owns and operates two large national research infrastructures operating in open access regime:
- COMPASS tokamak
- PALS laser system

1.4 Staff size and full time equivalents age distribution

IPP has 222 employees (as of 1 September 2015), the full-time employees equivalent (FTE) is 182.4, with a significant prevalence of employees aged below 45 years. The number of researchers is 94, including 34 PhD students. It is worth noting that the age structure of the Institute's employees has been improved in the period 2010– 2014, with a significant increase from about 150 to 220 people, and combined to a strong generational change (mainly related to the Tokamak, TOPTEC and Material Engineering Departments). The age structure of the Institute related to the 31 December 2014 is reported in the Tab. and Fig. below.

Age category	< 25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	≥ 70
Number of members	2	39	34	35	22	7	13	20	10	16	20

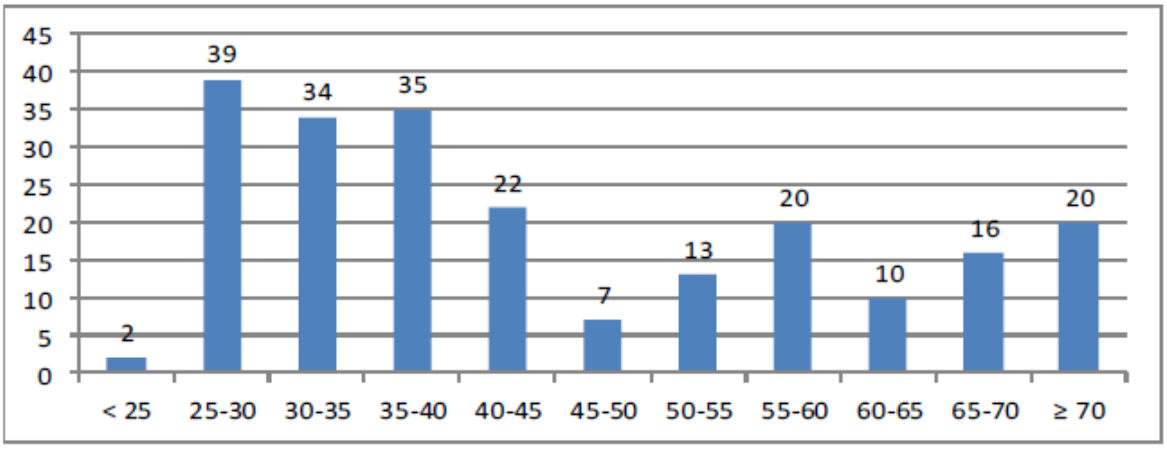


Figure 1: The age structure of the Institute related to the 31 December 2014

2. STRENGTHS AND OPPORTUNITIES

2.1 Timeliness of research topics

The timelines of research topics is good.

2.2 Budget: Ratio of institutional budget, grants and contractual resources, international funds

In the period 2010-14, the total operating subsidy amount was about 650,840,000 CZK (the total of the personnel expenses was about 494,516,000 CZK), and external funds coming from projects and grants were about 652,670,000 CZK. The external funds deriving from international projects are about the 13% of the total external funds (national and international). On this basis we can consider good the level of the project activity.

2.3 Intensity of collaboration among teams and among institutes, national collaboration and international involvement

Thanks to the two Research Infrastructures COMPASS and PALS, and to the TOPTEC Regional Centre, the institute has a crucial role within a national network of public research laboratories and universities, with many scientific contacts also at international level. The intensity of national and international collaborations is very good.

2.4 Position of the institute within the Czech scientific community and its international position

The Institute position at national level is very good. At international level is good.

2.5 The overall capacity of staff

Given the quality of publication, the capability to get external funds on projects and grants, and the personnel age structure with a prevalence of young scientists, the overall capacity of the staff can be considered good.

2.6 Reasonability of the structure of the institute and the departments

The Institute structure sounds good and adequate to its aims.

2.7 Comments on the age structure

The number of researchers is 94, including 34 PhD students, representing more than 35% of the scientific staff. The age structure of the Institute's employees has been improved in the period 2010– 2014, with a strong increase from about 150 to 220 people, combined to a generational change (mainly related to the Tokamak, TOPTEC and Material Engineering Departments) that resulted in a significant prevalence of employees aged below 45 years.
In conclusion, the age structure is good.

2.8 Frequency and quality of publications

The overall quality of publications is good, with more than 40% of the outputs that is world-leading or internationally excellent, and with the highest percentage of publications in the first quartile in terms of AIS of the Journals.

The number of impacted journal articles published each year in the period 2010-2014 has been growing , from about 50 published in 2010 up to about 70 in the 2014. This means about 1 impacted publication for researcher (excluding PhD students) a year. It is not a high rate of scientific outputs, but the frequency of publications should improve now that the efforts to set up the new infrastructures and laboratories are terminated and the positive effects of these useful and promising transformations will be available.

2.9 Patents and role in contractual work

In the period 2010-14, IPP produced 7 patents. This is acceptable but reflects some limits in the exploitation of competence and infrastructures for industry oriented researches. The data is confirmed by the poor percentage (lower than 2%) of non-public external funds deriving from technological transfer activities or contracts with respect to the total amount of external funds (see table in sec 5.5).

3. WEAKNESSES AND THREATS

3.1 Patents and role in contractual work

In the period 2010-14, IPP produced 7 patents. This is acceptable but reflects some limits in the exploitation of competence and infrastructures for industry oriented researches. The data is confirmed by the poor percentage (lower than 2%) of non-public external funds deriving from technological transfer activities or contracts with respect to the total amount of external funds (see table in sec 5.5).

The patent productions and the capability of acquiring external funds related to technology transfer activities and contracts by private companies should be improved. This can be done by a better exploitation of the capabilities of the OPTOTEC Regional Centre, the PALS RI and the Laboratory of Plasma Technologies of the Materials Engineering Dept..

4. RECOMMENDATIONS

4.1 Re-organisation of the internal structure of the institute and departments, laboratories, teams and groups considering the critical mass of each unit, the overlap of units

IPP does not require any major re-organization.

4.2 Internal programs to stimulate actions to enforce strengths and to reduce weaknesses

It is important to continue on the line recently traced: improve the participations of PhD students, postdocs and young scientists to the research activities, and push the capabilities of the facilities and laboratories of the Institute. Moreover, it could be extremely useful to stimulate and intensify with specific programs (as already done by the two research infrastructures of the Institute) the cooperation and scientist exchange with leading international laboratories in order to improve the impact of research activities in the international community. Programs for the equal opportunity of gender should be promoted.

5. DETAILED EVALUATION

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

Characterisation of the main research activities (experiments, theoretical areas)

As already reported in section 1.3, the IPP carries out both theoretical and experimental studies concerning plasma physics, as well as the main applications of plasma technologies. A large effort is spent to own and operate, in open access mode, the two large scale national facilities "COMPASS Tokamak" and "PALS Laser System".

Relevance in the national and international context

The quality of activities, and the presence of the COMPASS and PALS facilities put the Institute in a relevant position at national and international level.

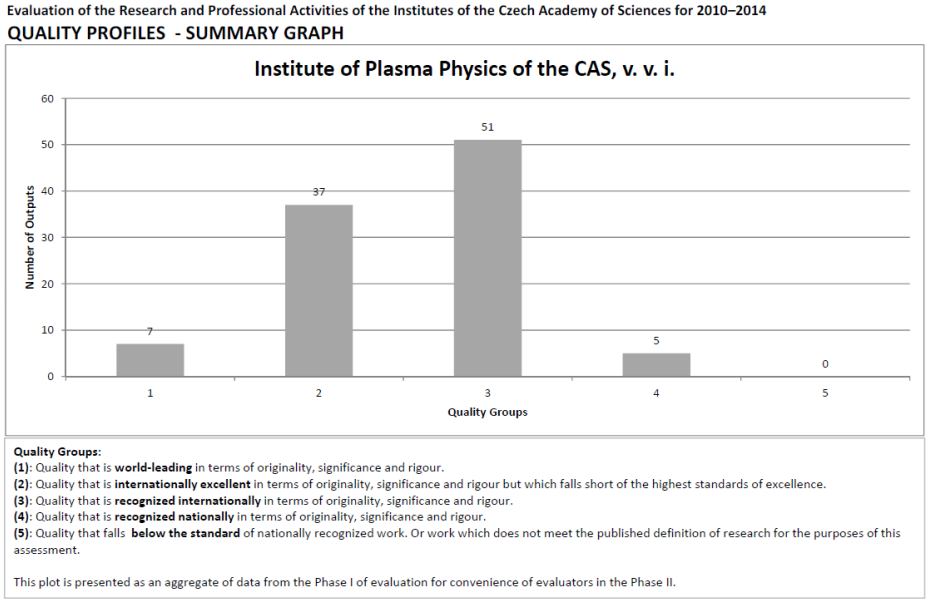
In fact, experimental use of the COMPASS infrastructure is carried out in collaboration with the leading European and world-class research infrastructures in the field of thermonuclear fusion. Due to change of the organization of the fusion research within EURATOM in the framework programme H2020, the collaboration was carried out mainly within the newly established consortium EUROfusion. Scientists from these (approx. 15) institutes were directly involved in an experimental exploitation of the COMPASS-RI infrastructure, in the development of specific diagnostic methods and systems for the COMPASS tokamak, and

collaborated with the scientists of the Tokamak department on the exploitation of other European fusion infrastructures. Infrastructure also collaborates with seven institutions outside the European research area (ITER Organization, St. Paul-Lez-Durance, France; Princeton Plasma Physic Laboratory, USA; Kurchatov Institute, Moscow, Russian Federation; Ioffe Institute, St. Petersburg, Russian Federation, etc.). Almost every year in period 2012-4 the three international experimental schools (approx. 50 foreign students) and the IAEA Joint Experiment (18 foreign participants) are organized.

PALS RI is also intensively exploited by the European scientific community both in the framework of the European research consortium LASERLAB-Europe and in the EURATOM activities in the areas of inertial fusion. As a provider of international Access and participant in Joint Research Activities, the PALS RI is collaborating with other 22 members of the Consortium. It was the PALS RI who paved the Czech way into the community of the large-scale European laser research infrastructures, which has finally resulted in the plans to build one of the big ESFRI infrastructures, the ELI-Beamlines facility, in the Czech Republic. The current main tasks of the PALS infrastructure include ensuring the training of young scientists, and implementation of preparatory experiments for the ELI-Beamlines project.

Overall quality of publications

From the summary graphs reported below we evince that the overall quality of publications is good, with more than 40% of the outputs that is world-leading or internationally excellent. In terms of Article Influence Score (AIS) of the Journals, the highest percentage of publications is in the first quartile.



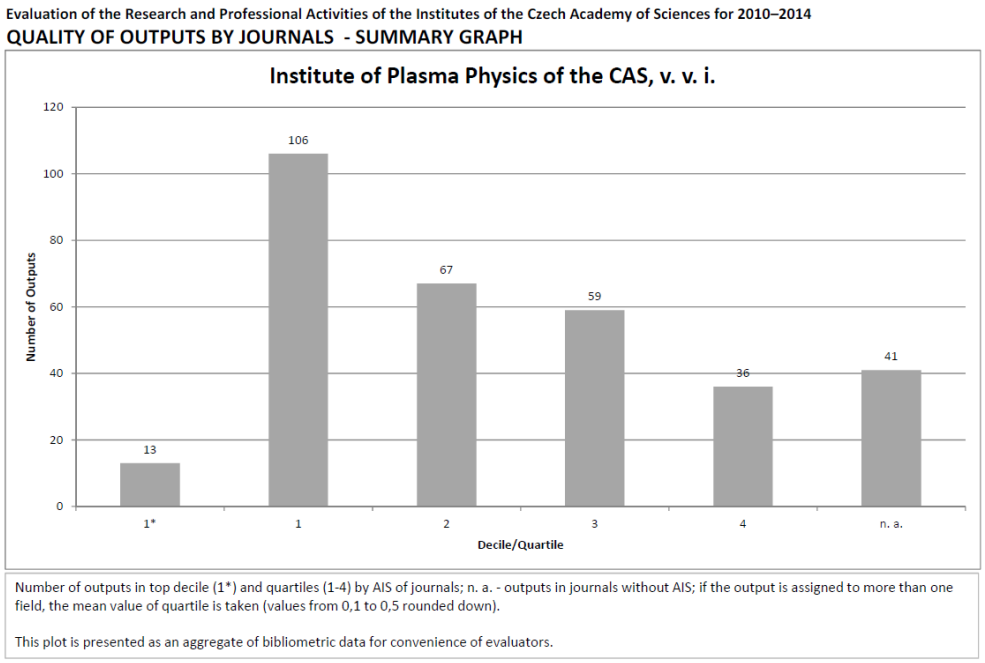


Figure 2: Quality Profile of Inst. of Plasma Physics

5.2 Declaration on the involvement of students in research

Involvement of students (doctoral, undergraduate) into research

The institute's researchers supervise bachelor and diploma theses and work as tutors or specialised tutors for doctoral students. In the evaluated period, the IPP had co-accreditations for doctoral programmes (6 – 8 valid co-accreditations a year on the average). IPP also cooperates in the organisation of bachelor and master study programmes. The number of students (at any level) supervised by IPP researchers is therefore significant, with about 120 theses defended in the reference period, as can be evinced from the table below. The number of PhD students in the research staff is 34 (as of 1 September 2015). In general, the involvement of students in research activity can be extrapolated by the Institute age structure plot reported in sec. 1.4, where we see the greatest percentage of research staff with an age in the range 25-30 years, mainly due to PhD students and post-docs.

Table 1: Involvement of the staff of the IPP in supervision of bac-, MSc and PhD students

Type of study	No. of supervisors (theses, dissertations)	No. of consultants or co-supervisors	Theses defended in 2010-2014
Bachelor	35	18	51
Master	47	22	48
Doctoral	48	17	21

Particular contributions of students to research

IPP runs two large infrastructures - tokamak COMPASS and PALS. The PALS Research Infrastructure operates one of the largest laser facilities in Europe, a kilojoule-class sub-nanosecond iodine photodissociation laser system. The research programmes of the COMPASS and PALS involve participation of PhD students and/or postdoc fellows in the projects. According to the user statistics kept since 2000 for the PALS facility, external Czech users represented 37%, foreign users 43 %, and members of the PALS own research teams 20% of all users. Out of this number, 12% of users are from Czech universities and 22.7 % from foreign universities, the rest from non-profit or governmental organizations.

Number of defended PhD students in relation to students involved (success rate)

The number of defended PhD theses in the evaluation period is 21, representing about the 17% of the total theses defended (bachelor, master and doctoral).

Employment of former PhD students (career options)

The recruitment of new researchers with adequate qualifications focuses mainly on cooperation with universities and direct contacts with their students. There is a clear policy aimed at attracting young, qualified and motivated students with potential for further professional growth. For instance, in the COMPASS research infrastructure, thanks to an active recruitment policy, the middle-aged and young researchers already prevail and gradually replace the previously dominant group of researchers at the retirement age. To provide future generations of scientists and users of the infrastructures, the IPP scientists are very active in teaching at universities, which secures a high influx of students into the Institute.

5.3 Declaration on societal relevance

Impacts of the results and other activities on economy

Plasma is an important topic of scientific research due to its unique properties and wide-ranging utilization of its technology, ranging from the clean production of thermo-nuclear energy to various biomedical and environmental application, up to the fabrication of new materials. In particular, IPP coordinates the thermonuclear fusion research in Czechoslovakia, and hosts a unique facility (COMPASS tokamak) on the national level, as well as in the Central and Eastern Europe, for studying the confinement of plasma for nuclear fusion

research and for the development of related technologies. Thanks to this facility, Czech Republic plays an important role in the field of nuclear fusion research in Europe as member of the EUROfusion consortium and as partner of important European projects (such as EURATOM).

Moreover, the Institute hosts the PALS Research Infrastructure, one of the largest laser facilities in Europe, offering a highly demanded instrument for basic and applied studies of laser light interaction with matter. PALS RI and its partners from the LASERLAB-Europe consortium develop enabling laser technologies facilitating cross-disciplinary research with a broad range of scientific applications. They operate in strict synergy with ESFRI projects such as ELI and HiPER in terms of both strategic laser technology development and training of new generations of laser physics experts.

Particularly devoted to industrial research application are also the activities carried out in the Regional Centre TOPTEC in Turnov. At present, the Centre is the only R&D facility that focuses on ultra-precision and special optics in the Czech Republic, with the perspective of becoming one of the five best R&D centres for ultra-precision optics in Europe.

For all this reasons, the results of the IPP research and activities could strong impact the Czech and the European economy if well addressed.

Impacts of the results and other activities on education

IPP collaborates with the following higher education institutions

- Czech Technical University in Prague (Faculty of Nuclear Sciences and Physical Engineering, Faculty of Eletrical Engineering);
- Charles University in Prague (Faculty of Mathematics and Physics)
- Masaryk University (Faculty of Science)
- Technical University of Liberec (Faculty of \Mechanical Engineering, Faculty of Mechatronics and Interdisciplinary Engineering Studies)
- Brno University of Technology (Faculty of Chemistry)
- University of West Bohemia (Faculty of Applied Sciences)
- Comenius University of Bratislava (Faculty of Mathematics, Physics and informatics)
- University of Chemistry and Technology, Prague.

The long-term cooperation with Czech universities mainly concerns the support of bachelor, master, doctoral and post-doctoral studies by providing lectures and exercises, supervising theses, working as tutors or specialised tutors for doctoral students, and producing study materials. The Institute's researchers work in final state examination committees, study programme boards and contribute to experimental activities. In cooperation with universities, IPP carries out a number of research projects, particularly in the area of basic and applied research. On the average, the Institute carries out 8–10 projects in cooperation with universities each year. The funds for these projects are most often provided by the Grant agency of the CR and the Technological Agency.

IPP also cooperates with a number foreign universities on the basis of joint projects, formal and informal cooperation agreements or individual cooperation. Main collaborations are activated with: University of Gent, Belgium; Gramme Institute, Lieges, Belgium; University of Orleans and University of Lyon, France, University of Messina, Italy, Sorbonne University

Pierre et Marie Curie, Paris; University in Rome, Bologna University, University of Seville, Department of Applied Physics, Kumamoto University, Japan.

The construction and operation of the COMPASS research infrastructure has had also significant effect on the educational and training activities in the nuclear fusion energy in the Czech Republic. In 2014, approx. 36 students worked on their theses using the infrastructure, and 6 foreign students actively participated in the experiments under various schemes and programmes (Master and Doctoral Erasmus Mundus programme, direct collaboration with foreign laboratories). In addition, the scientists of the Tokamak Department (COMPASS RI) teach extensively at universities - 11 courses in 2014 (326 given lectures in total).

Impacts of the results and other activities on culture

IPP has a rich editorial activity. The following publications with ISBN assigned to the Institute were released in 2010-2014:
2011- Controlled Thermonuclear Fusion for Everyone
2012 - OaM/2012, Optics and Measurement International Conference
2013 - Czech Republic and the ITER project of the EU.

In the period 2010-2014, 1025 publications with affiliation to the IPP were recorded in the database. Namely: 7 patents, 6 monographic books, 14 chapters in books, 289 articles in periodicals with impact factors, 367 articles in other scientific periodicals and 299 contributions in proceedings from conferences, and other types of publications such as research reports, applied research results. Most of the records from 2010-2014 are connected to the WOS and SCOPUS databases.

Outputs providing information relevant for public policy decisions in all fields of life

The CAS document AV21 "New strategy of the Czech Academy of Sciences" states that "*Top research in the public interest* is the motto of the new strategy of the Czech Academy of Sciences, which presents itself more strongly as an institution whose primary mission is high quality research focused on the problems and challenges faced by contemporary society.The past twenty years have shown that the Czech Academy of Sciences is an important part of the research, development and innovation system in the Czech Republic. It must continue to remain a guarantor of research quality, but for its further development it is necessary that it be able to identify important scientific and social issues, define problems, and propose their solutions based on the current level of knowledge. The Czech Academy of Sciences is ready to act not only as a renowned center of science and national culture, but also as an increasingly important economic factor. Topics such as the future of energy in the Czech Republic, public health or the quality of public policies involve complex sets of problems, the solution of which requires broad-based interdisciplinary research. The Czech Academy of Sciences has therefore adopted Strategy AV21 based on a set of coordinated Research Programmes utilizing interdisciplinary and inter-institutional synergies in order to identify the problems and challenges of our time and to harmonize the efforts of research institutes of the Czech Academy of Sciences towards their solutions.". "...Czech Republic in its long-term plan for energy supply security counts on nuclear energy as an essential component of the energy mix and defines the need for research in both advanced fission generation IV reactors, as well as in the field of controlled thermonuclear fusion." The IPP Director Radomir Panek coordinates the Research Programme "Systems for Nuclear Power Industry" of the CAS,

whose activities are expected to be relevant for public policy decision in the energy supply field.

Services for research (libraries, data bases, collections,..)

IPP has a Library whose publications and services are available on its website (http://www.ipp.cas.cz/cz). In 2010-2014 the library registered 223 new publications (books and journals), and lent 875 publications.

Popularisation and similar activities

IPP develops many activities aimed at promotion of thermonuclear fusion and presents the results of its work to experts and general public. The yearly report of IPP's activities provides an overview of popularization activities. A list of some of them in reported hereafter:

- Articles (about 100) in press media, internet news reports.
- Lectures for high school and university students and general public, in addition to the lectures given within Open Door Days (57 lectures).
- Presentations in TV and radio (11 presentations).
- Expositions and trade fairs.
- Short videos: 8 videos on thermonuclear fusion on DVD for the New Millennium, 2013.
- Books: M. Řípa and col.,*Controlled Thermonuclear Fusion for Everyone,* 3rd (2011) and 4th (2014) volume; M. Řípa and col., *Czech Republic and the ITER EU Project* (2013); M. Řípa: *History of Research on Controlled Thermonuclear Fusion,* (2014) (for a total of 4 books).
- Website:http://www.ipp.cas.cz/Tokamak/index?m=articles;http://www.materialy21.cz
- Puzzle: ITER – On the Way towards New Energy, Tokamak COMPASS.
- Open doors days: in the evaluation period, the IPP received 1000 students from 27 schools and approximately the same number of individual visitors.
- Participation to the "Week of science and technology".
- Materials for the New Millennium (MAT21): Science popularization project receiving support from the Education for Competitiveness Operational Project. It included visiting days (13 schools and 450 students). The outcome were unique study materials for school clubs.

5.4 Declaration on the position in the international and national context

Comparison of the position, recognition, outputs and impacts with leading and international teams

From the summary graphs reported in sec.5.1 concerning the IPP scientific publications, we evince that the Institute position in an international context is good, with more than 40% of the outputs that is world-leading or internationally excellent. In terms of Article Influence Score (AIS) of the Journals, the highest percentage of publications is in the first quartile.

Role and position in international collaboration

The quality of activities, and the presence of the COMPASS and PALS facilities, active at European level, put the Institute in a good position in international collaboration.

Ability to attract foreign researchers at different levels

IPP hosts the COMPASS tokamak facility very active in the studies of the plasma confinement for nuclear fusion research and for the development of related technologies. The facility plays an important role in the Central and Eastern Europe being part of the initiatives developed within the EUROfusion consortium and the EURATOM project.

Moreover, the Institute hosts the PALS Research Infrastructure, one of the largest laser facilities in Europe, offering a highly demanded instrument for basic and applied studies of laser light interaction with matter. PALS RI, and its partners from the LASERLAB-Europe consortium, operates in strict synergy with ESFRI projects such as ELI and HiPER in terms of both strategic laser technology development and training of new generations of laser physics experts.

Both facilities attract foreign students and researchers.

Position of the team in the national context

The position of the IPP teams in the national context is very good.

5.5 Declaration on the vitality and sustainability

Composition of staff with respect to age and gender, qualification, international experience

IPP has 94 researchers including 34 PhD students (more than 36 %). The age structure of the Institute's employees has been improved in the period 2010– 2014, with a significant increase of the total staff from about 150 to 220 people due to a strong generational change (mainly had in the COMPASS RI, the TOPTEC Regional Centre and the Material Engineering Departments), with the consequent prevalence of employees aged below 45 years. The age structure of the Institute related to the 31 December 2014 is reported in the table in sec 1.4. Information about gender composition is not available. The presence of two facilities (COMPASS and PALS) active at international levels also guarantees a good exchange of competence within an international context.

Attraction of research programmes for young people

The research activities of IPP attracts many young people. Due to presence of active recruitment policy, the middle-aged and young researchers already prevail. IPP's HR policy for recruitment of new employees with corresponding adequate qualifications focuses mainly on cooperation with universities and direct contacts with their students. All activities already described in sec. 5.2 "Declaration on the involvement of students in research" reflect the Institute's intention to attract young, qualified and motivated students with potential for further professional growth.

In particular, COMPASS RI operation has significant effect on the educational and trainning activities. In 2014, approx. 36 students worked on their theses using the infrastructure, and 6

foreign students actively participated in the experiments under various schemes and programmes (Master and Doctoral Erasmus Mundus programme, direct collaboration with foreign laboratories). Moreover, almost every year in period 2012-2014 three international experimental schools (approx. 50 foreign students) and the IAEA Joint Experiment (18 foreign participants) are organized. Operation in open Access mode is applied mostly for the EUROFUSION projects and as such the IPR strategy is governed by the EUROFUSION Consortium Agreement and REGULATION (EU) No 1290/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013.

Similar considerations can be done for the PALS RI, where the evaluation of the research projects to be conducted at the facility is carried out through an independent peer review by a panel of international experts of the LASERLAB consortium according to the following mandatory criteria: (i) originality and scientific significance of the project, (ii) partnership with other laboratories, (iii) participation of PhD students and/or post-doc fellows in the project. Of the Czech institutions profiting from using the PALS RI facilities for experiments and training of young scientists let us mention in the first places the Institutes of the Academy of Sciences of the Czech Republic, in particular the Institute of Physics (including the ELI Beamlines Project Division), and Jaroslav Heyrovsky Institute of Physical Chemistry. The most of Czech university users come from the Czech Technical University in Prague. The current main tasks of the PALS infrastructure include ensuring the training of young scientists.

Funding (structure of the resources and its comparison with the outputs, grants and project activity

In the period 2010-14, the total of the personnel expenses was about 494,516,000 CZK, representing about the 75% of the total operating subsidy of about 650,840,000 CZK. A significant project activity is carried out by the IPP researchers which results in a total amount of about 652,670,000 CZK deriving from external funds. A simplified table of the external funding resources structure in the evaluation period is reported in the table below.

Table 2: Funding of IPP

Funding type	**Total in 1,000 CZK**	**Total in 1,000 Euro**
Public **national** grants and projects	557,522	20,649
Public **international** grants and projects	82,836	3,068
Non-public sources (technology transfer, contracts, etc.)	12,312	456
TOTAL	**652,670**	**24,173**

Effectiveness of research (based on comparing size of groups, funding and output)

The number of impacted journal articles published each year in the period 2010-2014 has been growing , from about 50 published in 2010 up to about 70 in the 2014. This means about 1 impacted publication for researcher (excluding PhD students) a year. It is not a high rate of scientific outputs. Anyway, as already discussed in sec. 5.1, the overall quality of publications

is good, with more than 40% of the outputs that is world-leading or internationally excellent. In fact, in terms of AIS of the Journals, the highest percentage of publications is in the first quartile. The quality of outputs seems to be adequate to funding resources.

5.6 Declaration on the strategy and plans for the future

Relevance of the out lined strategy and research plans

The IPP out lined strategy and research plans are interesting and adequate to the actual Institute situation. In fact, in the reference period, IPP underwent important development stages, for instance completing the COMPASS facility and the TOPTEC Regional Centre, and performing a generational change in its staff. Also the external founding is adequate to the IPP aims, which look at

1) having a central role in international fusion research programs by participating to the international project of the fusion reactor ITER.
2) applying its technologies in research activities aimed at improving the environment, at positive influence the food-chain, and at obtaining results in the health-care field.
3) exploiting the TOPTEC Regional Centre activities in the field of optics and photonics, one of the fastest developing areas in the world,
4) using the capabilities of PALS RI to take part in ESA projects, to get involved in the ELI, HiPER and in other high-tech projects that will be further developed at international level;
5) following the world wide trend to exploit plasma technology for the preparation of new special materials, hardly constructible through other procedures (such as composite materials, functionally graded materials and surface/substrate systems including plasma facing materials for the fusion projects).
6) investigating and developing new plasma sources with optimized plasma parameters for specific plasma technologies aimed at (i) the treatment of waste materials, (ii) pyrolysis and gasification of biomass and organic substances for fuel gas production, (iii) plasma cutting and cleaning of surfaces, and (iv) for surface coatings and modifications.

Adequacy of available means and human resources to achieve these plans

IPP hosts two important facilities - tokamak COMPAS and Laser laboratory PALS which are listed in the strategic document Czech Roadmap of large research Infrastructures. Further on IPP disposes of exceptionally large portfolio of equipment for broad spectrum of plasma types as e.g. world unique plasma jets WSP® / WSPH®, Unique plasmochemical reactor PLASGAS, the Spark Plasma Sintering facility“ or generators of focused shock waves in liquids. IPP also finished the building up the Regional Optoelectronic Centre in Turnov which is equipped with state-of-the-art technologies. The last years have brought to a significant personal generation exchange of researchers, especially in the Tokamak and Material Engineering Departments. IPP is now involved in many European programs, especially in EURATOM and works on many research projects with EU countries, and sometimes with USA, Japan etc. IPP has many joint accreditations of study programmes with Czech universities.

Starting for this point, the available means and human resources seem to be adequate to the future plans of the Institute.

EVALUATION OF THE INSTITUTE OF PLASMA PHYSICS (IPP)

Dept. of Materials Engineering (DME)

This report refers to the evaluation of the Department of Materials Engineering of the Institute of Plasma Physics (ME-IPP) of the Academy of Sciences of the Czech Republic (CAS), 2010-2014, and is written according the to the guidelines reported in the Appendix 6.1 and 7.1 as well as the Recommendation for Elaboration of the Final Report drawn by the CAS.

1. INTRODUCTION

1.1 Location of the institute and its dept., labs. & sub units.

ME-IPP is located in Prague 8, at the Campus of the Academy of Sciences, Za Slovankou 1782/3 - 182 00 Prague 8 - Libeň. In a detached sites is located the Laboratory of Plasma Technologies of the Material Engineering Department (in Hala No. 6, Areal VZLU, a.s. - Beranových 130 - 19900 Prague 8). ME-IPP is one of the five departments of the Institute of Plasma Physics.

1.2 Brief history of the de Department.

In the beginning of 1980's, utilization of plasma for coatings and thin layers preparation gained interest also at the Institute of Plasma Physics in Prague. The focus was pointed to plasma spraying using unique, in-house developed water stabilized plasma (WSP) torch whose principle and construction philosophy were different to those of conventional gas stabilized torches. Various issues including thermal plasma generation, i.e. construction of plasma torch, and development of powder feedstock materials were also addressed. In January 1985 Prague subsidiary of Institute of Physical Metallurgy (headquartered in Brno) moved to IPP. The transition, including personnel and experimental equipment, lead to the formation of a new department (Materials Structure Department) that was soon equipped with high-end X-ray powder diffractometer and scanning electron microscope with electron probe analyser. Other scientists joined the department. However, the topic of plasma spraying still remained distributed among several departments and research groups. After 1990's, materials research was concentrated into one department, Materials Engineering Department, where both the materials and plasma spraying researches were carried out cooperatively. Since 2000, a gradual modernization of experimental facilities occurred. A new generation of researchers also joined the team. In 2012, newly built "Laboratory of Plasma Technologies – LPT" was

opened in Prague-Letňany and in the same year, Spark Plasma Sintering technology (located also in LPT) was installed as the first system in the Czech Republic.

1.3 Mission and research topics

The research is focused primarily on a special field of materials engineering –interaction of plasma with solid and liquid phase. The Department hosts one of the few laboratories in the world engaged in plasma-material interaction at both major levels: interaction of materials with high-temperature plasma (for example in fusion devices, such as tokamaks), as well as plasma technologies for preparation of new materials, using so called low-temperature (thermal) plasma. The activities can be divided in three main research topics:

Fusion applications.

During their interaction with plasma, materials undergo various surface and volumetric changes, which may complicate the operation of construction parts under long-term exposure to plasma. These issues are highly relevant in current or planned high-power fusion devices, such as tokamaks. To increase the lifetime of plasma facing components, for instance, the ME Department develops so-called functionally graded materials (FGMs), which are generally layered structures combining for example refractory properties of tungsten with the mechanical strength of steel or the thermal conductivity of copper. For testing the behavior of these materials in tokamak plasma, a special port of tokamak COMPASS at IPP is used. Simulated loading, e.g. by laser or electron beams, is performed in collaboration with domestic (Research Centre Rez, UJV Rez, Brno University of Technology,…) and foreign (Forschungszentrum Juelich - Germany, Dutch Institute for Fundamental Energy Research - Netherlands, ...) partners.

Plasma spraying

Plasma is utilized to deposit various materials by plasma spraying technique. Materials in the form of powder, suspension, or solution are injected into a thermal plasma jet generated by a plasma torch. Once the material particles enter the plasma jet, they are subjected to various interactions with the plasma that raises their temperature, velocity and may also lead to chemical changes. A so-called “plasma sprayed coating” with typical thickness of 0.1 to 1 mm is formed after many of the particles deposit onto the component surface. Such coatings then improve the functional surface properties of the coated component, e.g. abrasion resistance, corrosion resistance, thermal and electrical conductivity etc. Patented fabrication of thin-walled free-standing ceramic shells or parts is a specialty of the laboratory. Plasma spraying at ME Dept. is carried out by a unique Water Stabilized Plasma (WSP) torch technology, or by a newly developed Hybrid Water (WSP®H) torch. Both of these torches were developed in cooperation with ProjectSoft HK company that is in charge of their commercial sales to end users.

Spark Plasma Sintering of powder materials

The ME Dept was the first one in the Czech Republic that started using Spark Plasma Sintering (SPS) technique to fabricate bulk materials from powders. This technique is also called Field Assisted Sintering Technique (FAST). It uses pulsed electric current and increased pressure to sinter metallic and non-metallic powders in graphite dies. The sintering can be done at temperatures of up to 2400°C using very high heating rates and thus in considerably short times. SPS technique is remarkably suited for fabrication of pure ultrafine-grained materials and special composites.

1.4 Staff size and full time equivalents age distribution

In the ME-IPP activities are involved 12 researchers, 4 PhD students and 6 technicians (as of 1 September 2015). A table with the full-time employees equivalent (FTE) in the evaluation period is reported below, together with a plot with the age structure of the ME Dept. (as of 31 Dec. 2014).

Table 3: Avergae aggregate FTEs of DME

Average aggregate FTE of the team's members

	2010	2011	2012	2013	2014
Researchers	5,82	6,60	5,90	7,23	7,70
Other Workers	1,99	2,00	5,39	5,61	6,17

Age category	< 25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	≥ 70
Number of members	0	6	4	1	5	1	0	1	0	1	3

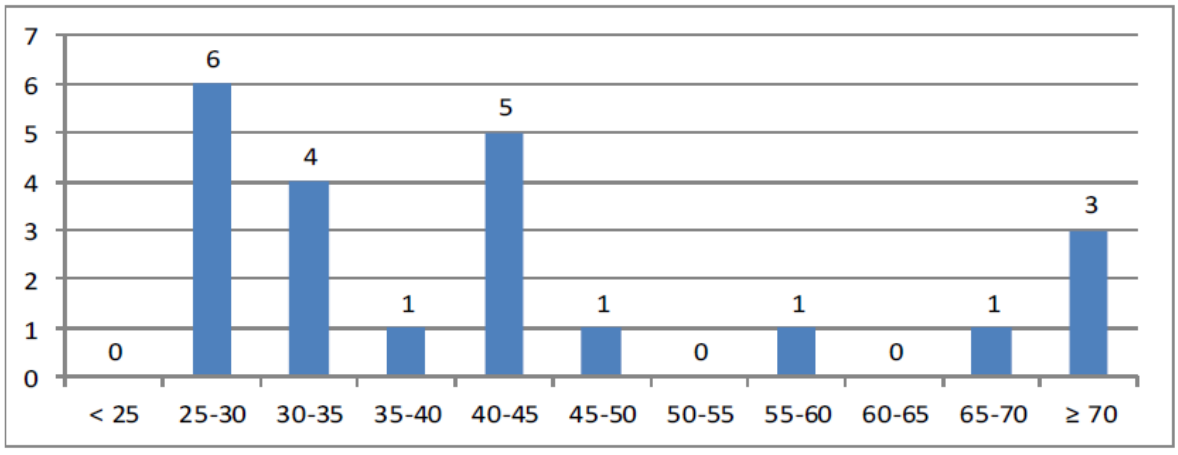


Figure 3: FTEs and Age Structure of the DME-IPP

The data shows a significant prevalence of employees aged below 45 years. It is worth noting that the age structure of the Institute's employees has been improved in the period 2010–2014, due to a gradual generational change. Three team members retired and young researches joined the ME department as full time employees. Some of them came from the Czech Technical University (CTU) in Prague, with which close ties are maintained. A number of doctoral and PhD students from CTU and other universities spend several years within the ME team as they worked toward the fulfilment of their degree. Three current team members received their PhD in the 2010-2014 period, within the IPP-CTU collaboration. Since summer 2012, there is also a new head of the ME department and a new head of the Laboratory of Plasma Technology.

2. STRENGTHS AND OPPORTUNITIES

2.1 Timeliness of research topics

The timelines of research topics is good.

2.2 Budget: Ratio of institutional budget, grants and contractual resources, international funds

The institutional budget for the ME Dept. is not available, so it is not possible to compare it with the budget deriving from external grants and projects (public and non-public)**.** The amount of ME external budget is good.

2.3 Intensity of collaboration among teams and among institutes, national collaboration and international involvement

The intensity of national collaborations is good.

2.4 Position of the institute within the Czech scientific community and its international position

The ME Dept. position at national and international level is good.

2.5 The overall capacity of staff

Good

2.6 Reasonability of the structure of the department

Good

2.7 Comments on the age structure

The Dept. age structure is very good, with a significant prevalence of employees aged below 45 years thanks to a recent gradual generational change. Moreover, three current team members received their PhD in the 2010-2014 period.

2.8 Frequency and quality of publications

The publication frequency of impacted journal articles is acceptable being slightly more than one (1.15) per year per researcher. The overall quality of the 13 selected outputs in the 2010-14 period (from the 147 total) is quite good, with 9 outputs "internationally recognized", and the highest percentage of the selected publications in the first quartile in terms of Article Influence Score (AIS) of the journals where they are published.

2.9 Patents and role in contractual work

The number of deposited patents (3 in the reference period) is acceptable. The role in contractual work is expected to increase now that the Laboratory of Plasma Technologies of the Dept., developed in collaboration with the Project Soft HK company and mainly dedicated to industrial applications, is completed and normally running.

3. WEAKNESSES AND THREATS

3.1 Frequency and quality of publications

The frequency and overall quality of publications could improve.

3.2 Patents and role in contractual work

The number of deposited patents (3 in the reference period) is just acceptable. This could be a weakness point for a Dept. whose activities are oriented to industrial applications. The role in contractual work should increase, too. At the moment, the ME Dept. has a little income (25,000 Euro in the reference period) from contractual activities (practice and transfer technology) with non-public companies. This income, not sufficient at the moment, is expected to increase now that the Laboratory of Plasma Technologies of the Dept., developed in collaboration with the ProjectSoft HK company, is completed and normally running.

4. RECOMMENDATIONS

4.1 Re-organisation of the internal structure of the institute and departments, laboratories, teams and groups considering the critical mass of each unit, the overlap of units

ME Dept. does not require any major re-organization.

4.2 Internal programs to stimulate actions to enforce strengths and to reduce weaknesses

It is important to continue on the line recently traced: improve the participations of PhD students, postdocs and young scientists to the research activities, and push the capabilities of the Laboratory of Plasma Technologies of the Dept., developed in collaboration with the ProjectSoft HK company, now that is completed and normally running. Moreover, it could be extremely useful to further stimulate with specific programs the cooperation and scientist exchange with leading international laboratories in order to improve the overall impact of research activities in the international community. Programs for the equal opportunity of gender should be promoted.

5. DETAILED EVALUATION

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

Characterisation of the main research activities (experiments, theoretical areas)

The research activities, strongly experimental, deals with the interaction of plasma with solid and liquid phase. The Department hosts one of the few laboratories in the world engaged in-plasma-material interaction at both major levels: interaction of materials with high-temperature plasma (for example in fusion devices, such as tokamaks), as well as plasma technologies for preparation of new materials, using so called low-temperature (thermal) plasma. Two unique torch technologies – Water-Stabilized-Plasma (WSP) and Hybrid-Water-Stabilized-Plasma (WSP®H) - were developed in cooperation with ProjectSoft HK company that is in charge of their commercial sales to end users. ME-IPP participates in the Center of Excellence “Multidisciplinary research centre for advanced materials” and the Center of Competence “Research center of surface treatment”. It also designs and fabricates special plasma coatings for specific applications for a number of Czech companies, and carries out contractual material analyses and consultations.

Relevance in the national and international context

The ME team cooperates with many domestic and international universities and research institutions. There are contacts with Czech Technical University in Prague, Institute of

Chemical Technology in Prague, University of West Bohemia in Pilsen, Research Center Rez, Nuclear Physics Institute ASCR and Brno University of Technology. The ME team participates in one Project for promotion of excellence in basic research (Centre of excellence) supported by Czech Science Foundation. The project (2014-2018) brings together six departments from four Institutes of ASCR and two Universities to form Multidisciplinary research centre for advanced materials. The centre focuses on complex investigation of ultrafine-grained (UFG) materials, functionally graded materials, coated light metal-based composites, and functional materials. Several members of the team also participate in the Competence Centre (2014-2019) called "Research center of surface treatment" supported by Technology Agency of the Czech Republic. One work package of this centre focuses on the development of novel thermal barrier coatings for jet engines and the main partners are Brno University of Technology and Honeywell International s.r.o. There are several running bilateral projects as well. Both the Centre of Excellence as well the Centre of Competence are quite prestigious in the Czech Republic.

Internationally, the ME Department collaborates with several research institutions, and in particular: Center for Thermal Spray Research (Stony Brook, NY, USA), University of Limoges (France), Forschungszentrum Juelich (Germany), Argonne National Laboratory (IL, USA), Tampere University of Technology (Finland), and Fraunhofer Institute in Dresden (Germany), University West (Trollhattan, Sweden). Within the last five years, the ME team has become a strong partner in European Fusion Development Agreement (EFDA) and EuroFusion programmes that are related to materials for fusion applications (e.g. plasma facing components). Several recently published papers are a positive outcome of this cooperation.

The activities are therefore relevant at national and international level.

Overall quality of publications

Table 4: Number of scientific outputs of DME

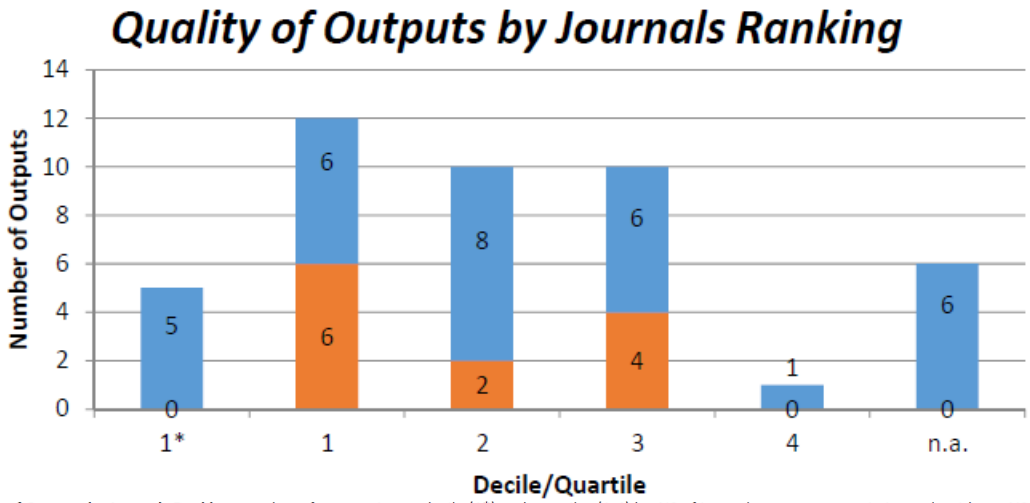
The number of all scientific outputs according to the individual types during the period under evaluation (2010-2014), whose authors or co-authors were members of the Team.

Articles in journals with impact factor	38
Articles in other journals	22
Professional books	1
Chapters in professional books	1
Contributions to proceedings	80
Patents	3
Applied results	2

The data in the table above puts in evidence a frequency of publication of impacted journal articles lower than 1 per year per researcher, and therefore quite low. Anyway, from the summary graphs (results from the evaluation phase I) reported below we evince that the overall quality of the 13 selected outputs in the 2010-14 period (from the 147 total) is quite good, with 9 outputs "internationally recognized", and the highest percentage of the selected publications in the first quartile in terms of Article Influence Score (AIS) of the journals where they are published.

Quality Groups:
(1): Quality that is **world-leading** in terms of originality, significance and rigour.
(2): Quality that is **internationally excellent** in terms of originality, significance and rigour but which falls short of the highest standards of excellence.
(3): Quality that is **recognized internationally** in terms of originality, significance and rigour.
(4): Quality that is **recognized nationally** in terms of originality, significance and rigour.
(5): Quality that falls **below the standard** of nationally recognized work. Or work which does not meet the published definition of research for the purposes of this assessment.

Figure 4: Quality profile of the selected outputs of DME.



Quality of Outputs by Journals Ranking: number of outputs in top decile (1*) and quartiles (1-4) by AIS of journals; n. a. - outputs in journals without AIS; if the output is assigned to more than one field, the mean value of quartile is taken (values from 0,1 to 0,5 rounded down); orange: outputs submitted by the team to the Evaluation, blue: other outputs by the team.

Figure 5: Quality profile of the publications of DME by journal ranking.

Specification of the main achievements

Main research achievements have been obtained in three major topics. One topic, which is becoming more and more important within the ME team, concerns the study of materials for fusion applications. The other two topics focus on fundamental research and development of materials prepared by the unique materials processing equipment (H-WSP and SPS) that is operated by ME team members. These two processing techniques are utilized to develop new classes of usually multicomponent materials that are tailored for specific application (*e.g.*, functionally graded materials and dielectric coatings). These three major topics are interrelated.

5.2 Declaration on the involvement of students in research

Involvement of students (doctoral, undergraduate) into research

From the ME Dept. web site we see that the team is made of 12 researchers, 6 technicians, 4 PhD students and 7 students. This seems to be a good percentage of students with respect to the research staff. This is also the result of a gradual generational change that brought young researches as full time employees. In particular, three current team members received their PhD in the 2010-2014 period.

Number of defended PhD students in relation to students involved (success rate)

In the table below, the number of theses followed by the scientist staff is reported. The percentage of the defended theses with respect to the total supervised ones is high.

Table 5: Supervision of Bac, MSc and PhDs students at DME

Type of study	No. of supervisors (theses, dissertations)	No. of consultants and co-supervisors	Theses defended in 2010-2014
Bachelor	2	1	3
Master	4	2	5
Doctoral	4	3	4

Employment of former Phd students (career options)

In the 2010-2014 period, three PhD students became members of the research team. Therefore, the Department seems to offer excellent careers opportunities.

5.3 Declaration on societal relevance

Impacts of the results and other activities on economy

See comments about the whole Institute.

Impacts of the results and other activities on education

Several members of the ME department take part in pedagogical activities at various Prague universities. The ME department obtained official accreditations for education of students given by the State Accreditation Board. Prominent contacts are with the Czech Technical University in Prague, with five members of the ME team involved in teaching and supervising undergraduate or doctoral thesis. Other members of ME also act as supervisors or as members of the State examination boards, or other scientific committees. Similar activities are carried out in the Prague Institute of Chemical Technology and the Charles University in Prague. Cooperation activities (like seminars and student visits) are carried out with other universities, such as West Bohemia University, Charles University, and Brno University of Technology.

Impacts of the results and other activities on culture

See comments about the whole Institute.

Outputs providing information relevant for public policy decisions in all fields of life

See comments about the whole Institute.

Services for research (libraries, data bases, collections,..)

See comments about the whole Institute.

Popularisation and similar activities

Various members of the Department give lectures, participate to the educational project for high school students, and to the publication of popularization booklets. Another activity for high school students is the "open house day" of the Institute, involving also the Department labs. Moreover, groups of university students throughout the year visit the Laboratory of Plasma Technology as a field trip.

5.4 Declaration on the position in the international and national context

Comparison of the position, recognition, outputs and impacts with leading and international teams

From the summary graphs reported in sec.5.1 concerning the ME Dept. scientific outputs in the 2010-14 period, we evince that the overall quality of the 13 selected publications (from the 147 total) is quite good, with 9 outputs "internationally recognized", and the highest percentage of the selected publications in the first quartile in terms of Article Influence Score (AIS) of the Journals where they are published.

Role and position in international collaboration

As already stated in sec. 5.1, the Dept. has significant international collaborations.

Ability to attract foreign researchers at different levels

There is not enough information on this point.

Position of the team in the national context

The Dept has a relevant position at national level.

5.5 Declaration on the vitality and sustainability

Composition of staff with respect to age and gender, qualification, international experience

Concerning the age structure of the Dept. see Sec. 1.4. The gender structure puts in evidence the presence of only one female researcher among the 12 scientists active as permanent staff.

Attraction of research programmes for young people

See considerations for the whole Institute.
During the visit at the ME Dept., the recent internships of students from the University of Limoges and Ecole National (France) and Stony Brook University (USA) were pointed out.

Funding (structure of the resources and its comparison with the outputs, grants and project activity

Funding structure is in line with that of the whole Institute, and consistent with the outputs. Moreover, the ME Dept. has a little income (25,000 Euro in the reference period) from contractual activities (practice and transfer technology) with non-public companies. This income, not sufficient at the moment, is expected to increase now that the Laboratory of Plasma Technologies of the Dept., developed in collaboration with the ProjectSoft HK company, is completed and normally running.

Effectiveness of research (based on comparing size of groups, funding and output)

The research effectiveness seems to be coherent with size group and funding.

5.6 Declaration on the strategy and plans for the future

Relevance of the out lined strategy and research plans
The research plans for the future are relevant. They concerns three main research areas: (1) employment of water stabilized plasma torch for thermal spraying, (2) preparation of materials by SPS, (3) materials for fusion applications. There is also a general interest in exploring the capabilities of other plasma technologies. While a priority will be the education of the new generation of engineers and researchers in the field of thermal spraying and fusion materials.

Adequacy of available means and human resources to achieve these plans

The human and instrumental resources are adequate to achieve the research plans.

Date: March 2, 2016

Commission Chair: em Prof.DI.Dr.Dr.hc. Hans Peter Nachtnebel