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 Photonics and Electronics of the CAS, v. v. i.

Fields, in which the Institute registered its teams:

Electrical engineering, electronic engineering, information engineering,Materials engineering, materials science and nanotechnology

Observer representing the Academy Council of the CAS: Jiří Chýla
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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. 3 - Bioelectrodynamics; No. 4 - Synthesis and Characterization of Nanomaterials

EVALUATION OF THE INSTITUTE OF PHOTONICS AND ELECTRONICS

This report refers to the evaluation of the Institute of Photonics and Electronics (IPE) 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.

The Institute of Photonics and electronics (IPE) has facilities in two locations in Prague. The main campus of IPE is located in Prague-Kobylisy and provides home to all the five research units – four research teams (*Optical Biosensors, Fiber Lasers* and *Non-Linear Optics, Synthesis and Characterization of Nanomaterials, Bioelectrodynamics)* and one specialized laboratory *(Laboratory of the National Time and Frequency Standard).* It also contains all the supporting units (*e.g.*, accounting, services and supplies, IT, and a mechanical workshop). The second IPE's facility located in Prague-Lysolaje accommodates *Laboratory of Optical Fibers* - a sub-unit of *Fiber Lasers and Non-linear Optics* research team (this laboratory was originally a part of another research institute and joined IPE in 1993). The vast majority of employees perform their jobs in Prague-Kobylisy (the staff of the Laboratory in Prague-Lysolaje presents less than 1/10 of the staff of the Institute) and the communication among the main campus and the Lab in Prague-Lysolaje is organized through shared resources, staff meetings, etc.

1.2 Brief history of the institute

The Institute of Photonics and Electronics (formerly the Institute of Radio Engineering and Electronics) was established in 1950s to pursue mainly applied research in the field of electronics. During the following five decades, research activities of the Institute have been expanded to include fundamental and applied research in the fields of optoelectronics and photonics. Over the last twenty years the center of gravity of research activities of the Institute has shifted to photonics which has become a key research area of IPE. This shift resulted in a change of the name of the Institute in 2007 when the institute changed its name to the Institute of Photonics and Electronics. In 2012 management of the Institute implemented restructuring of research units to reflect conclusions of the previous research evaluation exercise, enable sustainable development of the main research programs and create more efficient management structure. This restructuring has given rise to a flat organizational structure with four research teams (*Optical Biosensors, Fiber Lasers* and *Non-Linear Optics, Synthesis and Characterization of Nanomaterials, Bioelectrodynamics)* and a specialized laboratory *(Laboratory of the National Time and Frequency Standard).* In addition to research units IPE has had six supporting units.

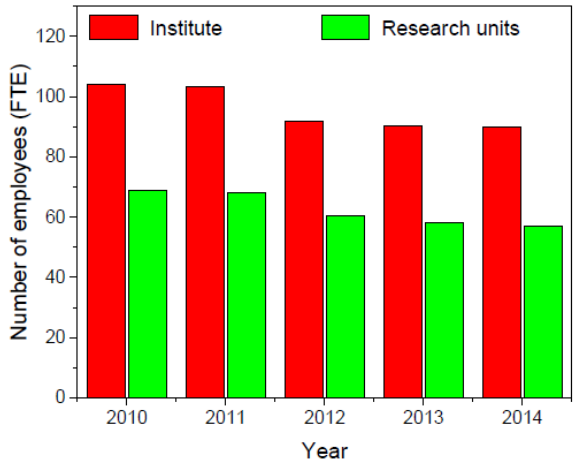
1.3 Mission and research topics

IPE carries out fundamental and applied research in the scientific fields of photonics, optoelectronics and electronics. In these fields, IPE generates new knowledge and develops new technologies.
The research submitted for the evaluation has been carried out in five research units consisting of four research teams - Optical Biosensors (senior team), Fiber Lasers and Non-Linear Optics (senior team), Bioelectrodynamics (junior team), and Synthesis and Characterization of Nanomaterials (senior team) and one specialized laboratory - Laboratory of the National Time and Frequency Standard.

The activity of the *Optical Biosensors* research team has been focused on research and development of optical affinity biosensors that combine very sensitive optical techniques with special biomolecules, which are able to recognize and capture other molecules. The result of this combination of optics and biology is a technology that enables the study of (bio)molecules and their interactions as well as a determination of their concentrations. This is a highly multidisciplinary research that encompassed research effort in the following areas: plasmonic and photonic (nano)structures and phenomena, optical platforms, microfluidic effects and devices, functional biomolecular coatings, biosensor-based methodologies for biomolecular interaction analysis, and biosensor-based methodologies for detection of chemical and biological species.
The research program *Fiber lasers and non-linear optics* has been focused mainly on high-power fiber lasers and their applications. The properties of these high-power fiber lasers have been tailored to meet specific needs of material processing and medical applications. Specifically, the main research topics included fiber lasers, high power ytterbium-, erbium-, thulium- and holmium-doped fiber lasers, nonlinear optical parametric generators, and numerical methods for the investigation of light propagation in fibers and planar lightwave circuits.
The activity of the *Bioelectrodynamics* research team has been focused on the electromagnetic properties of biomaterials: from the level of single molecules to that of cells. These research activities covered both experimental and theoretical aspects that involve the characterization of the electromagnetic properties of biomaterials. Specifically, this research has been focused on the electrodynamic properties of biological protein nanostructures with a focus on cellular fibers (microtubules), and endogenous radiofrequency and optical electromagnetic biosignals generated on the cellular level.
The research activities of program *Synthesis and Characterization of Nanomaterials* have been directed towards a wide range of topics related to the preparation and characterization of electronic and photonic materials. Specifically, the team's research efforts have been concentrated on six main topics: the investigation of electrical contacts on compound semiconductors, studies of the optical properties of semiconductors and special glasses; nanodiagnostics of semiconductor and photonic materials using scanning ion and electron beams, the electrochemical preparation of porous III-V semiconductors and their application in lattice-mismatched epitaxial growth, the characterization of thermoelectric materials, and the preparation of high-purity epitaxial layers of III-V semiconductors with rare-earth elements admixtures and their application in radiation detectors.
The specialized *Laboratory of the National Time and Frequency Standard* is entrusted with the management of the National Time and Frequency Standard. The main activities of the laboratory are the physical realization of the unit of time (the SI second) and furthermore, the generation of the national time scale. Furthermore, the laboratory performs demanding calibrations of primary and secondary time and frequency standards (atomic clocks), ultra-stable frequency sources, and equipment for comparing time scales.

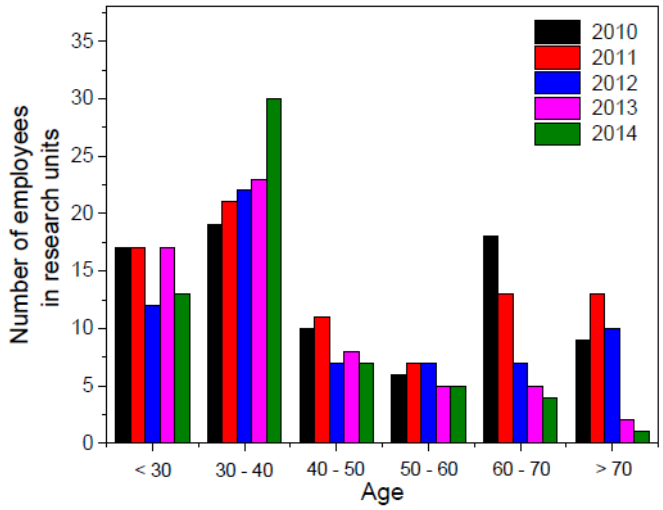
1.4 Staff size and full time equivalents age distribution

At the end of the evaluation period (31 December, 2014) IPE was employing 102 researchers and staff members in 5 research units and 6 support units. The total FTE was 89.1 from which 57.6 FTE belonged to research units (scientists & postdocs 25.4 FTE, graduate students 13.9 FTE, research staff 18.4 FTE). The employment figures in 2014 were lower by about 15% than those in the beginning of the evaluation period, mainly due to the restructuring of research units in 2012 (see fig. below).



Evolution of the number of employees during 2010-2014.

In principle, the number of employees and their professional distribution match well the type and size of the IPE's activities. It should be noted that the restructuring has substantially improved age structure (and therefore sustainability of the main activities pursued by IPE) with a constant increase (in the years 2010-14) of employees in the range 30-40 years of age, and a general decrease in the range above 40 years of age (see fig. below).



Evolution of age structure of employees in research units.

The age distribution plot (see fig below), as given for the end of the year 2014, shows that the majority of the employees (more than 55%) were below 40 years of age, large group of employees (33%) fell between 40 and 65 years, and less than 12% of employees were above 65 years.

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	9	19	19	12	4	7	4	12	4	10	2

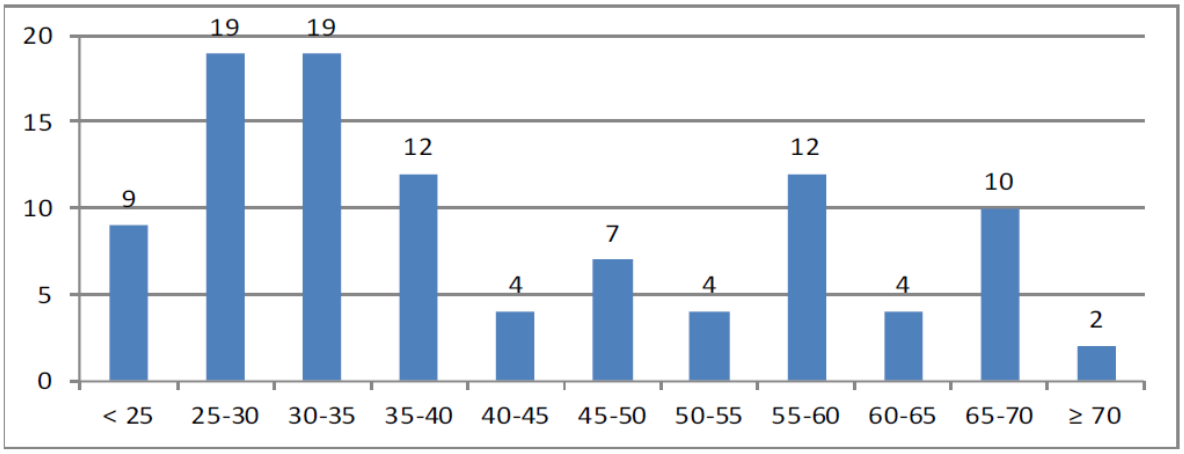


Figure 1: Age structure of the Institute (as of 31 Dec. 2014)

2. STRENGTHS AND OPPORTUNITIES

2.1 Timeliness of research topics

IPE strives to identify and pursue timely and significant research topics. This has been demonstrated by the restructuring of research units in 2012 during which several research programs that were no longer deemed relevant and competitive were substantially reduced or closed (*e.g.*, speech synthesis) and new research topics were opened. For instance, research program in the field of *Bioelectrodynamics* was upgraded, expanded by recruiting several young researchers, and established as a new junior research team. The current research topics pursued by IPE research units appear to be timely and relevant as evidenced by over 200 publications in scientific journals and citations generated by these publications. In particular, publications by the *Optical Biosensors* research team has attracted a high number of citations demonstrating their strong impact on the field. Timeliness and uniqueness of research activities in the field of high-power lasers is evidenced by growing collaboration of the *Fiber Lasers* and *Non-Linear Optics* research team with industry and increasing number of collaborative research projects. The *Synthesis and Characterization of Nanomaterials* team was upgraded in 2013 with a strong generational change that resulted in the individuation of 3 key members of the team below 40 years of age, therefore with a long perspective of scientific career. Anyway, the number of planned research activities by the team seems too wide with respect to its current staff size.

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

During the evaluation period, IPE was operating with an annual budget ranging from 81 to 91 MCZK (3.3 -3.6M€) (excluding capital equipment); the share of institutional funding was about 70% while the share of competitive funding was about 30%. Majority of the competitive funding was sponsored by domestic governmental agencies; research funding from sources outside the Czech Republic did not exceed 5%. Contractual research funding was rather limited and insignificant compared to the funding from other funding sources.
In conclusion, the budget is adequate to the planned activities. Efforts could be done to improve the external (competitive) research funding, also looking at international projects and non public (industrial) contractual research and technological transfer activities.

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

There is a good flow of communication and a very good degree of collaboration among research teams at IPE. This collaboration is manifested mainly by teams sharing special equipments, facilities and expertise. The evaluation documents submitted by IPE suggest that all the research teams have had a good level of national and international collaborations, resulting in joint research activities and publications. Main collaborating institutions included *Charles University in Prague*, *Prague, Czech Technical University*, Prague, Palacky University, Olomouc, *Institute of Macromolecular Chemistry of the CAS, Institute of Molecular Genetics of the CAS, Austrian Institute of Technology, Vienna (Austria), Imperial College, London (United Kingdom), University of Washington, Seattle (USA), University of Chicago (USA), Ewha Womans University, Seoul (Korea), Université de Rennes, Université Claude Bernard in Lyon.*

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

IPE is one of the key institutes of the Applied Physics Section of the Czech Academy of Sciences (CAS). The position of the *Optical Biosensors* team in the Czech scientific community is excellent. Due to its breadth and depth, the multidisciplinary effort carried out by the *Optical Biosensors* is unique and highly regarded even on an international level. This is evidenced by a high number of publications in leading scientific journals (66 during the evaluation period) in multiple fields and a high number of citations (~1,000 citations/year). Although the main focus of this research is clearly on cutting-edge research, the team has also been granted 5 patents (including 2 US patents) and has developed several unique biosensor platforms that are in use at universities and research institutions situated in the USA, Europe, and Asia.A good position is also held by the *Fiber Laser and Non-Linear Optics* team, whose uniqueness of research activities in the field of high-power lasers is evidenced by growing collaboration with industry and increasing number of collaborative research projects.
The specialized Laboratory of the National Time and Frequency Standard holds a special position in the Czech Republic. The Lab, entrusted with the management of the National Time and Frequency Standard, carries out the physical realization of the unit of time and the generation of the national time scale. It also performs demanding calibrations of primary and secondary time and frequency standards (atomic clocks), ultra-stable frequency sources, and equipment for comparing time scales.
The *Bioelectrodynamics* team and the *Synthesis and Characterization of Nanomaterials* team are too young to already have a leading reputation at national and international level. Anyway, their activities are in perspective very promising.

2.5 The overall capacity of staff

The overall capacity of staff is good. Its internationalization should be improved.

2.6 Reasonability of the structure of the institute and the departments

The recent restructuring dating back to 2012-2013 has substantially improved the age structure and sustainability of the main activities pursued by IPE. In particular, some teams have been grouped and their research activities have been reorganized to answer to the main limits that the previous Institute organization had shown. Thus, two new teams (*Bioelectrodynamics*, respectively *Synthesis and Characterization of Nanomaterials*) started their new activities in 2013, and a new one team (*Nano optics*) will start in 2016. The result of this new organization seems to answer to a more competitive approach that relies on the capabilities of young team leaders and research groups. The current Institute structure is very good. The age distribution at the end of 2014 was very good, too. Anyway, concerning the Dept. of Synthesis and Characterization of Nanomaterials, a mid-term analysis of the adequacy of its staff dimension to the numbers of its research lines is desirable.

2.7 Comments on the age structure

The current age distribution is very good.

2.8 Frequency and quality of publications

The total quality profile of the selected publications for the 1st evaluation phase shows that more than 90% of them belongs to the "internationally excellent" (41%) and "internationally recognized" (51%) quality groups. The frequency and quality of publications is between good and very good.

2.9 Patents and role in contractual work

The *Optical Biosensors* has granted 5 patents (of the 6 in total), including 2 US patents, and has developed unique biosensor platforms that are in use at universities and research institutions situated in the USA, Europe, and Asia. The impact of its activity in terms of patents and contractual work is very high.
A good position in term of contractual work is held by the *Fiber Laser and Non-Linear Optics* team as a consequence of its collaborations with industry and increasing number of collaborative research projects.

3. WEAKNESSES AND THREATS

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

Some activities are underfunded. Efforts could be done to improve the external (competitive) research funding, also looking at international projects and non public (industrial) contractual research and technological transfer activities.

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

The overall capability of attracting young foreign scientists, such as doctoral students and postdocs, has to be increased.

3.3 The overall capacity of staff

A greater internationalization of the research staff is desirable.

3.4 Reasonability of the structure of the institute and the departments

Concerning the *Dept. of Synthesis and Characterization of Nanomaterials*, the involvement of graduate and PhD students in the team staff should be increased. Moreover, the capability of acquiring new human resources is a crucial point to be addressed in the next future.

3.5 Patents and role in contractual work

In the evaluation period, the *Optical Biosensors* team alone has granted 5 patents, while the other 4 teams together only 1 patent. This last data puts in evidence a weakness point that could be overcome by the creation of a more efficient unit supporting the development of the intellectual property and technology transfer.

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

The human and instrumentation resources currently available to the Dept. of Synthesis and Characterization of Nanomaterials (DSCN) represents an adequate starting point to achieve the team plans. Anyway , the team is young and with a limited critical mass. Therefore, the capability of acquiring new human resources is a crucial point to be confirmed in the next future, to avoid also the risk of an inadequate critical mass to carry out all the planned activities in depth. Finally, a mid-term analysis of the adequacy of its staff dimension to the numbers of its research lines is recommended.

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

Internal programs and actions are desirable:

to improve the external (competitive) research funding, also looking at international projects and non public (industrial) contractual research and technological transfer activities;

to support the development of the intellectual property and technology transfer;

to increase the overall capability of attracting young foreign scientists, such as doctoral students and postdocs;

to foster the internationalization of the research staff.

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)

IPE carries out fundamental and applied research in the scientific fields of photonics, optoelectronics and electronics. In these fields, IPE generates new knowledge and develops new technologies.

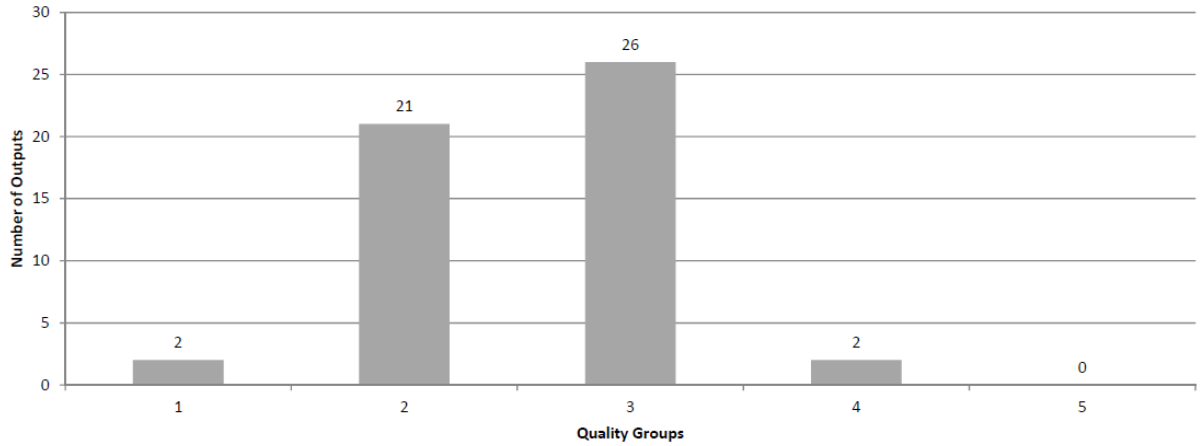
Relevance in the national and international context

IPE is one of the key institutes of the Applied Physics Section of the Czech Academy of Sciences (CAS). Although there may be some overlap among research programs of IPE and other Czech institutions, the quality, scope and extent of research activities make IPE a highly visible player in the field of photonics, optoelectronics and electronics. The strongest positions in the Czech scientific community are held by the two largest research teams of IPE - *Optical Biosensors* and *Fiber Laser and Non-Linear Optics*. Due to its breadth and depth, the multidisciplinary effort carried out by the *Optical Biosensors* is unique and highly regarded even on an international level. This is evidenced by a high number of publications in leading scientific journals (66 during the evaluation period) in multiple fields and a high number of citations (~1,000 citations/year). Although the main focus of this research is clearly on cutting-edge research, the team has also been granted 5 patents (including 2 US patents) and has developed several unique biosensor platforms that are in use at universities and research institutions situated in the USA, Europe, and Asia. The multidisciplinary research carried out by the *Bioelectrodynamics* research team also shows a high degree of uniqueness on a national level and holds promise for future. The specialized Laboratory of the National Time and Frequency Standard holds a special position in the Czech Republic. The Lab has been entrusted with the

management of the National Time and Frequency Standard. It carries out the physical realization of the unit of time and the generation of the national time scale. The Lab also performs demanding calibrations of primary and secondary time and frequency standards (atomic clocks), ultra-stable frequency sources, and equipment for comparing time scales.

Overall quality of publications

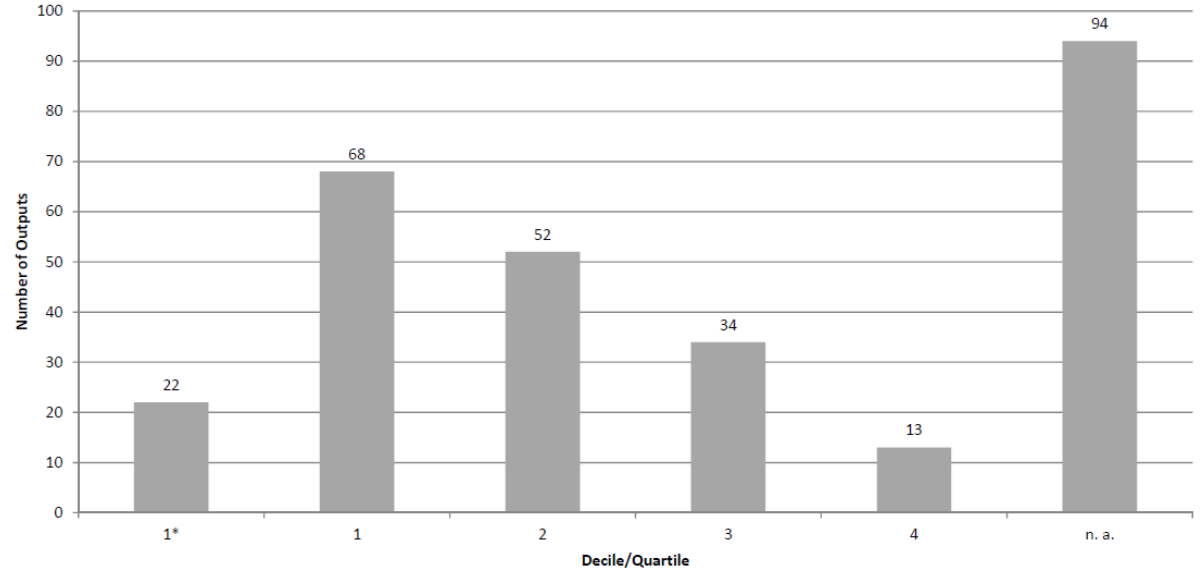
During the period of evaluation, the IPE has generated a total of 205 publications in scientific journals with an impact factor. The total quality profile of the selected publications for the 1st evaluation phase shows that more than 90% of them belongs to the "internationally excellent" (41%) and "internationally recognized" (51%) quality groups (see fig. below).



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 2: Total quality profile of selected outputs

The quality of outputs by Article Influence Score (AIS) of the journals where they are published (see fig. below) shows the highest percentage (more than 40%) in the first quartile.



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).

Figure 3: The quality of outputs by AIS of journals

In particular, the research program Optical Biosensors has generated 66 publications; many of these publications were in highly-ranked journals in the field of biosensors (*Analytical Chemistry, Analytical Chimica Acta, Biosensors and Bioelectronics*), nanoscience and nanotechnology (*ACS Nano, Small*), photonics (*Optics Letters, Optics Express, Plasmonics*), microfluidics (*Lab on a Chip*), and molecular biology (*Nucleic Acids Research*). Publications produces by the team generate about 1,000 citations/year (according to WOS, includes also publications before the evaluation period). The research program *Fiber lasers and non-linear optics* has generated 48 publications; many of these publications were published in highly-ranked journals in the field of optics (*Optics Express, Optics Letters, IEEE J. of Quantum Electronics, J. of Lightwave Technology, Laser Physics Letters*), physics (*Physical Review A and B*), analytical chemistry (*Analytical and Bioanalytical Chemistry, Sensors and Actuators B*), and material science (*J. of Physical Chemistry C, J. of Alloys and Compounds*).The research team *Bioelectrodynamics* has produced 22 papers in highly reputable journals such as *Applied Physics Letters*, *PLoS ONE*, *Cell Communication and Signaling*, and *Integrative Biology*. During the evaluation period, the research team *Synthesis and Characterization of Nanomaterials* has generated 69 scientific journals with an impact factor, many of which appeared in highly-ranked journals in the field of materials science (*Carbon, Journal of Alloys and Compounds*), applied physics (*Applied Physics Letters, Physical Review B*), and chemistry (*Sensors and Actuators B: Chemical*).

Specification of the main achievements

The following main achievements have been reached by the Institute in the reference period:

- *Optical Biosensors research team*
  - Biosensor based on localized surface plasmons on an array of gold nanoparticles, and a contribution to discussion on the relative merits of plasmonic sensors based on continuous and nanostructured metal films.
  - Compact biosensor based on a novel approach to spectroscopy of surface plasmons for the detection of microRNA biomarkers.
  - Enhancing sensitivity of SPR biosensors by functionalized gold nanoparticles.
- *Fiber lasers and non-linear optics research team (in collaboration with high-tech companies)*
  - Efficient optical fibers for fiber lasers
  - High power ytterbium-, erbium-, thulium- and holmium-doped fiber lasers
  - Nonlinear optical parametric generators
  - Numerical methods for the investigation of light propagation in fibers and planar lightwave circuits.
- *Bioelectrodynamics research team*
  - Unique electrodynamic/vibrational models of bionanostructures (microtubules) and high frequency sensors for their verification
  - B.Biological ultra-weak photon emission and its role in cell signaling
- *Synthesis and Characterization of Nanomaterials research team*
  - High quality graphite Schottky contacts on bulk compound semiconductors and on ZnO nanorods and their application in highly sensitive hydrogen sensing elements.
  - Discovery of the method of non-destructive quantification of Fe doping levels in GaN, which pushes forward the technology of high electron mobility transistors.
  - Development of extremely stable ballistic electron emission microscope and its use for the mapping of the density of states of buried semiconductor quantum dots.

- Development of the technology of pore etching of compound semiconductors for epitaxial growth.

5.2 Declaration on the involvement of students in research

Involvement of students (doctoral, undergraduate) into research

From the data reported in Sec. 1.4 we evince that the students represent about the 25% (13.9 FTE) of the total research staff (57.6 FTE).

Particular contributions of students to research

In sec. 1.4, we pointed out that the recent Institute restructuring has substantially improved the age structure (and therefore sustainability of the main activities pursued by IPE) with a constant increase (in the years 2010-14) of employees in the range 30-40 years of age, and a general decrease in the range above 40 years of age. This generational change has been often combined to a greater involvements of PhD students and post docs in the research teams. In particular, this is the case of the "Bioelectrodynamics“ team whose current staff consts of 1 team leader, 2 postdocs, 5 PhD students, 1 research engineer (all below 35 years of age). The same involvement of graduated students in the research activity is expected in the“Synthesis and characterization of nanomaterials”to overcome one of the main weakness in this recently restructured area.

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

The Institute cooperates with Czech universities both for teaching activities and for supervising undergraduate, graduate and doctoral theses. For this reason, it also shares co-accredited doctoral programs. The success rate of PhD students is not available. Anyway, a table with the supervised and defended theses in the reference period is reported in the next section.

Employment of former PhD students (career options)

The Institute, after the required generational change advocated by the last evaluation report relative to the years 2005-09, seems to look at the PhD students working in its research teams with greater interest, trying to offer them concrete career options. An example is given by the Bioelectrodynamics research team founded in 2013. During the evaluation period 2010 – 2014, five of the seven team members retired. They were replaced by two postdoctoral fellows (former PhD students of the team that had successfully defended their thesis in that period) and by three new PhD students.

5.3 Declaration on societal relevance

Impacts of the results and other activities on education

An important educational activity is developed in collaboration with the Charles University in Prague and the Czech Technical University in Prague by means of co-accredited doctoral programs, supervision of undergraduate, graduate and doctoral students, participations in

doctoral and scientific boards. Members of the Institute have been engaged in regular pedagogical activity in bachelors, masters, and doctoral programs at the following Czech universities: Czech Technical University in Prague, Charles University in Prague, University of South Bohemia in České Budějovice, University of Chemistry and Technology in Prague, and Jan Evangelista Purkyně University in Ústí nad Labem. Institute members annually delivered over 450 teaching hours in two bachelors, 8 masters, and 8 doctoral regular semester courses. In addition, members of the Institute provided several one-time thematic courses at other universities in both the Czech Republic (Palacký University in Olomouc, Ostrava University, and Tomáš Bata University in Zlín) and abroad (University of Padova, Italy, University of Oulu, Finland, Instituto Technologico, Zacatepec, Mexico, and the International Centre for Theoretical Physics in Trieste, Italy, within the Winter School of Optics). They are also members of the committees for final state examinations and PhD defenses at a number of Czech as well as foreign universities. These included Charles University in Prague, Czech Technical University, Brno University of Technology, Ostrava University, Jan Evangelista Purkyně University in Ústí nad Labem, and University of Malaga in Spain.
A table with the supervised and defended theses in the reference period is reported below.

Table 1: Supervised and defended theses in the evaluation period.

Type of study	No. of supervisors (theses, dissertations)	No. of consultants or co-supervisors	Theses defended in 2010-2014
Bachelor	1	5	6
Master	11	13	20
Doctoral	13	9	6

Impacts of the results and other activities on culture

The Institute has not published or edited any book or periodical within the period of evaluation.

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

The Institute has operated a scientific library. The library has provided a variety of services to both employees of the Institute and the general public. The book stock of the library comprises around 17 thousands book and journal volumes mainly in English, Russian, and Czech. It includes a collection of leading foreign magazines in the fields of electronics, optoelectronics, physics of solids, radio engineering and computer technology. Some of the titles are unique in the Czech Republic. In addition to the printed sources, it has provided users with access to online journals and magazines, scientific databases and search services. It has also kept records of the works published by the employees of the Institute (ASEP).

Popularisation and similar activities

Every year, the Institute organizes the Open Doors Days event, during which a few hundred of interested visitors – mainly students of secondary schools – can visit the research labs of

the Institute and meet with young staff members and PhD students. Members of the Institute also actively participate in the annual "Week of Science and Technology" organized by the Czech Academy of Sciences, during which they present lectures popularizing their research field. In order to disseminate information about the Institute and its activities on the internet, the Institute has created and regularly updates its website as well as its profiles on the social networks Facebook and LinkedIn. Within the period of evaluation, members of the Institute participated in 8 programs on national TV and 4 programs on national radio, published 7 popularization papers in newspapers and journals, and edited two booklets popularizing research progress in the field of optical fiber lasers and in the generation and detection of electromagnetic fields in living organisms.

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

See sec. 5.1, sub-section "Relevance in the national and international context".

Role and position in international collaboration

The evaluation documents submitted by IPE suggest that all its research teams have had a large network of national and international collaborations, resulting in joint research activities and publications. Main collaborating international institutions included *Austrian Institute of Technology, Vienna (Austria), Imperial College, London (United Kingdom), University of Washington, Seattle (USA), University of Chicago (USA), Ewha Womans University, Seoul (Korea), Université de Rennes, Université Claude Bernard in Lyon.* In summary, it is clear that IPE researchers appreciates an international dimension of science that they pursue collaborative opportunities and are (or make effort to be) an integral part of an international scientific community in their respective field.

Breadth/completeness of the research activities compared to world leading teams of comparable size

There is a natural flow of communication and high degree of collaboration among research teams at IPE. This collaboration is manifested mainly by teams sharing special equipments, facilities and expertise. This approach strongly helps in competing with world leadind teams of comparable size. The *Optical biosensor* team has a world leading role and reputation in its field of activity. The *Bioelectrodynamics* team and the *Synthesis and Characterization of Nanomaterials* team are too young to already have a leading reputation at international level. Anyway, their activities are in perspective promising.

Ability to attract foreign researchers at different levels

The limited internationalization is reported by the Institute as a weakness point, and although the share of foreign researchers working in the Institute has been growing, there is no doubt that the ability to attract foreign researchers has to be improved.

Possible missing research directions

The teams and relative research activities have been recently reorganized to answer to the main limits that the previous Institute organization had shown. Two teams (*Bioelectrodynamics*, respectively

Synthesis and Characterization of Nanomaterials) started their new activities in 2013, and a new one team (*Nano optics*) will start in 2016. The result of this new organization seems to answer to a more competitive approach that relies on the capabilities of young team leaders and research groups. Before looking at possible missing research directions, it would be useful to give time at these new groups to develop their activities and show their actual capabilities.

Position of the team in the national context

All the teams have a relevant position in the national context. They also actively cooperate with Czech industries.

5.5 Declaration on the vitality and sustainability

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

The recent restructuring of the Institute has substantially improved the age structure (and therefore sustainability of the main activities pursued by IPE) with a constant increase (in the years 2010-14) of employees in the range 30-40 years of age, and a general decrease in the range above 40 years of age. The age distribution plot (see fig below), as given for the end of the year 2014, shows that the majority of the employees (more than 55%) were below 40 years of age, large group of employees (33%) fell between 40 and 65 years, and less than 12% of employees were above 65 years. The presence of female researchers is significant; the qualification and international experience of the whole research staff sound good.

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

During the evaluation period, IPE was operating with an annual budget ranging from 81 to 91 MCZK (3.3 -3.6M€) (excluding capital equipment); the share of institutional funding was about 70% while the share of competitive funding was about 30%. Majority of the competitive funding was sponsored by domestic governmental agencies; research funding from sources outside the Czech Republic did not exceed 5%. Contractual research funding was rather limited and insignificant compared to the funding from other funding sources.

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

In general, the number of employees and their professional distribution match well the type and size of the IPE's activities. Concerning the Dept. of Synthesis and Characterization of Nanomaterials, a mid-term analysis of the adequacy of its staff dimension to the numbers of its research lines is desirable.

Organisational structure, recruitment methods, career system, incentives for females, young researchers, international researchers

The organizational structures is effective.
The review of scientific merit of each research team is performed by the Board of the Institute and takes place every year. The evaluation is performed on the basis of merit review materials prepared by the head of each unit. The Board also may solicit a meeting with the head of a research unit. The evaluation criteria include scientific output (expressed in terms of scientific publications), competitive funding, educational activities, services to the Institute and the scientific community, public outreach activities, and the use of resources. The outcome of the merit review is used by the management to

determine the distribution of research and equipment funding within the Institute. The outcome of the Merit review is communicated to each research unit to provide them with feedback on their performance and enable them to improve their operations.
Concerning recruitment, researcher positions in existing research units are opened based on requests made by the head of a unit and approval by the management of the Institute. Strategic research positions (positions of leading scientists who are expected to form a new research unit in the Institute) are opened based on the approval of the management and the Board of the Institute. All the research positions are filled through a public competition. The public competition is announced on the website of the Institute, the website of the Czech Academy of Sciences, and also distributed through other channels. Non-research positions are opened based on requests made by the head of a unit and approval by the management of the Institute. Once the position is opened, it is advertised on the website of the Institute as well as other appropriate media (e.g., online job portals). An appropriate candidate is identified by a committee appointed by the director of the institute.
Information about incentives for females, young and international researcher is not available.

5.6 Declaration on the strategy and plans for the future

Relevance of the out lined strategy and research plans

The lined strategy and research plans for the future are adequate.

Adequacy of available means and human resources to achieve these plans

Available human and instrumentation resources of the Institute are, in general, adequate to its plans.

EVALUATION OF THE INSTITUTE OF PHOTONICS AND ELECTRONICS

Team No. 3: Dept. of Bioelectrodynamics

This report refers to the evaluation of the Dept. (or team) of Bioelectrodynamics (DB), Institute of Photonics and Electronics (IPE), 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.

The Institute of Photonics and electronics (IPE) has facilities in two locations in Prague. The DB is located in the main campus in Prague-Kobylisy, together with the other three departments of IPE (*Optical Biosensors*, *Fiber Lasers* and *Non-Linear Optics*, *Synthesis and Characterization of Nanomaterials*) and one specialized laboratory *(Laboratory of the National Time and Frequency Standard).* The main campus of IPE in Prague-Kobylisy also contains all the supporting units (*e.g.,* accounting, services and supplies, IT, and a mechanical workshop). The second IPE's facility located in Prague-Lysolaje accommodates *Laboratory of Optical Fibers* - a sub-unit of *Fiber Lasers and Non-linear Optics* research team.

1.2 Brief history of the institute and of the Department.

The Institute of Photonics and Electronics (formerly the Institute of Radio Engineering and Electronics) was established in 1950s to pursue mainly applied research in the field of electronics. During the following five decades, research activities of the Institute have been expanded to include fundamental and applied research in the fields of optoelectronics and photonics. Over the last twenty years the center of gravity of research activities of the Institute has shifted to photonics which has become a key research area of IPE. This shift resulted in a change of the name of the Institute in 2007 when the institute changed its name to the Institute of Photonics and Electronics.
In 2012 management of the Institute implemented restructuring of research units to reflect conclusions of the previous research evaluation exercise, enable sustainable development of the main research programs and create more efficient management structure. This restructuring has given rise to a flat organizational structure with a specialized laboratory *(Laboratory of the National Time and Frequency Standard)* and the current four research teams: 1) *Optical Biosensors,2) Fiber Lasers* and *Non-Linear Optics,3) Synthesis and Characterization of Nanomaterials* (created from the fusion of the two previous *Technology of Materials for Electronics & Optoelectronics* and *Diagnostics of Materials for Electronics & Optoelectronics* groups), and 4) *Bioelectrodynamics* (evolution of the previous *Speech synthesis and signal processing* group). Therefore, the *Bioelectrodynamics* Dept. activities actually started in 2013 as a result of generational transition within the previous team structure.

1.3 Mission and research topics

The activity of the *Bioelectrodynamics* Dept. has been focused on the electromagnetic properties of biomaterials: from the level of single molecules to that of cells. These research activities covered both experimental and theoretical aspects that involve the characterization of the electromagnetic properties of biomaterials. Specifically, this research has been focused on the electrodynamic properties of biological protein nanostructures with a focus on cellular fibers (microtubules), and endogenous radiofrequency and optical electromagnetic biosignals generated on the cellular level.

1.4 Staff size and full time equivalents age distribution

During the evaluation period, five of the seven team members retired. At the same time, two doctoral students of the team successfully defended their thesis and became postdoctoral fellows, and three other doctoral students and one technician joined the team. Dr. Pokorný was awarded the emeritus status and the leadership was handed over to Dr. Cifra. The team then returned back to the size of seven members (4.5 FTE), each below the age of 35 (see Dept. age structure in the figure 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	1	4	2								

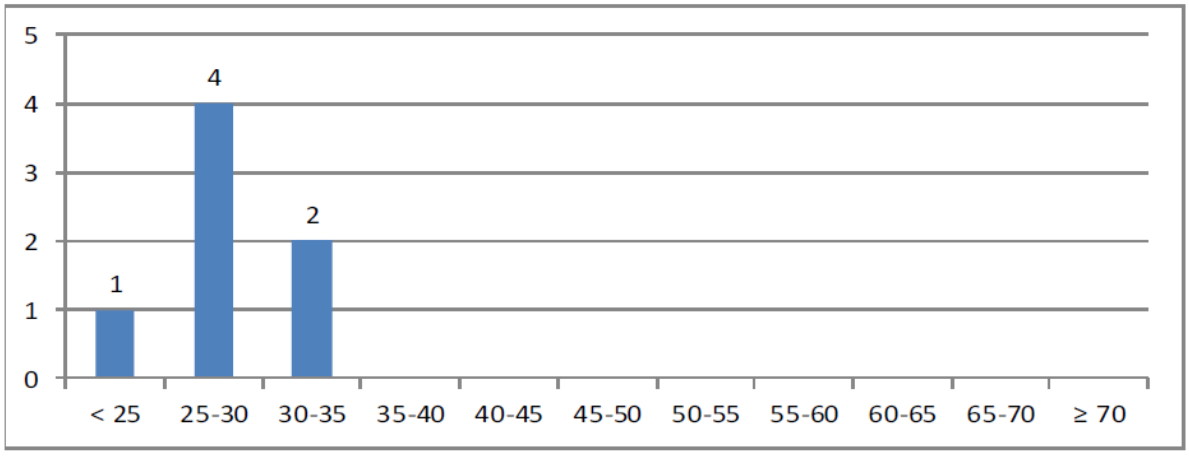


Figure 4: Age structure of the Dept. of Bioelectrodynamics

2. STRENGTHS AND OPPORTUNITIES

2.1 Timeliness of research topics

The research topics are interesting and relevant.

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

In the evaluation period, the Department received significant external funding for a total amount of 426 K€, all coming from national grants. The percentage from contractual resources is very low (only 21 K€ in five years). The funding contributed to set up completely new laboratories. The human and instrumentation resources currently available to the new team (after the restructuring of 2013) represent an adequate starting point to achieve its plans. Anyway, the group is very young and the capability of acquiring new funding to be further invested in human resources and instrumentation is a crucial point to be confirmed in the next future.

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

The intensity of national and international collaboration is very good.

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

The team is in a good position at national level. Because of its youth (just 2 years of activity), time is needed to perform an appropriate comparison with leading international teams.

2.5 The overall capacity of staff

The overall capacity of staff is good.

2.6 Reasonability of the structure of the institute and the departments

The structure of the team is very good.

2.7 Comments on the age structure

The team, made of 7 persons, includes 3 PhD students and 2 postdoctoral fellows (ex doctoral students of the team that in the evaluation period successfully defended their thesis and joined the group). All the members are below 35 years of age. The age structure is very good.

2.8 Frequency and quality of publications

Frequency and quality of publications is good.

2.9 Patents and role in contractual work

No patents have been deposited in the evaluation period, and the percentage of resources coming from contractual work is low (21 K€ only).

3. WEAKNESSES AND THREATS

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

The resources from contractual activities are very low (only 1 contract of 21 K€ in five years). The capability of acquiring new funding (also from international grants and contractual activity) is a crucial point to be addressed in the next future.

3.2 Patents and role in contractual work

The team declared the intention of initiating applications to protect intellectual property, which can enable commercialization of the techniques developed. This is a crucial point to be addressed.

4. RECOMMENDATIONS

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

Internal programs and actions are desirable:

- to improve the external (competitive) research funding from international projects and non public (industrial) contractual research;
- to support the development of the intellectual property and technology transfer;
- to increase the overall capability of attracting young foreign scientists, such as doctoral students and postdocs;
- to foster the internationalization of the research staff.

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)

BD activities cover experimental and theoretical work, together with the development of experimental equipment.

Relevance in the national and international context

The multidisciplinary research carried out by the Bioelectrodynamics research team shows a high degree of uniqueness on a national level and holds promise for future.

Overall quality of publications

The team submitted to the evaluation 4 scientific publications (articles in peer-reviewed scientific journals, all in Q1 or Q1* according to SJR), one for each of the categories that better characterize its research (applied physics, multidisciplinary sciences, cell biology and biophysics). According to the quality profile evaluation, reported in the figure. below, these publications are classified as "*internationally excellent*" or "*recognized internationally*".

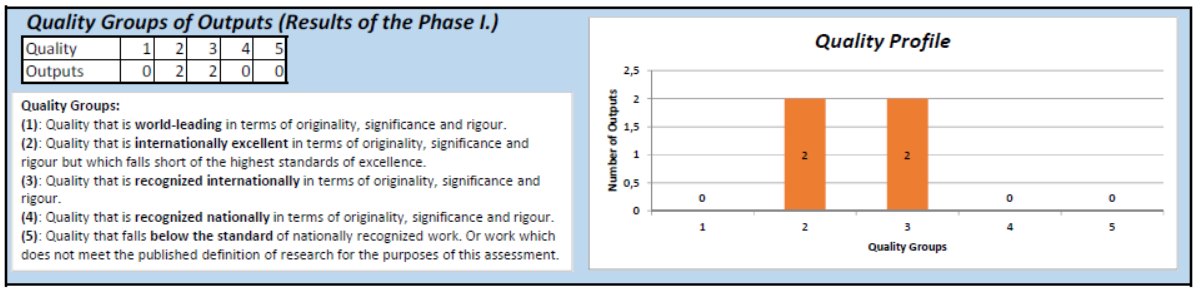
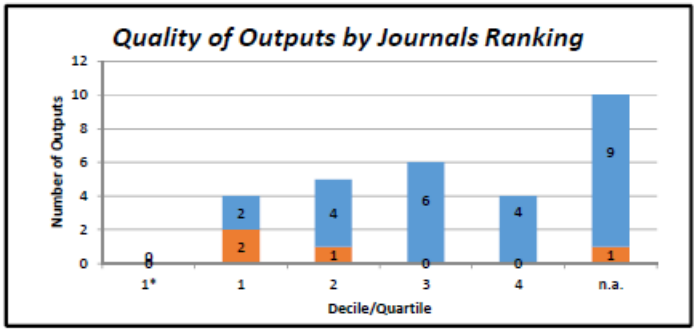


Figure 5: Quality profile of the team selected publications.

The quality of all the team outputs by journal ranking is reported in the fig. below.



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 6: Quality of outputs by journal ranking

Specification of the main achievements

The two main achievements during the evaluation period are about:

1) the development of an original electrodynamic/vibrational models of bionanostructures (microtubules) and of high frequency sensors for their verification;
2) the study of biological ultra-weak photon emission by biological samples and its role in cell signalling. In particular, the main activity is the development of novel experimental instrumentation to quantitatively study the underlying mechanisms.

5.2 Declaration on the involvement of students in research

Involvement of students (doctoral, undergraduate) into research

The team, made of 7 persons, includes 3 PhD students and 2 postdoctoral fellows (ex doctoral students of the team that in the evaluation period successfully defended their thesis and joined the group). The current involvement of students in research is therefore very high.

Particular contributions of students to research

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

The success rate of defended theses in relation to the number of the students involved in research activities is very high, as can be evinced from the table below, reporting the data about the supervised and defended theses in the evaluation period.

Table 2: Supervised and defended theses in the evaluation period.

Type of study	No. of supervisors (theses, dissertations)	No. of consultants and co-supervisors	Theses defended in 2010-2014
Bachelor	1	3	4
Master	3	7	10
Doctoral	1	4	2

Employment of former Phd students (career options)

The two PhD students that successfully defended the theses in the evaluation period have joined the research team with a postdoc fellowship. The career options offered by the team are therefore very good.

5.3 Declaration on societal relevance

Impacts of the results and other activities on education

The team members participate in higher education at domestic universities through supervision of the students. During the evaluation period, team members supervised and co-supervised several successfully defended doctoral, bachelor and master thesis. Furthermore, the research team regularly accepts educational visits organized for students from the Czech Technical University in Prague and students continuously seek thesis topics from a selection offered by the research team. Team members served as reviewers of several master and bachelor theses and as reviewers of 5 doctoral theses mainly from the Czech Technical University in Prague and Palacký University in Olomouc. The team leader is a member of Radioelectronics doctoral study branch - board at the Faculty of Electrical Engineering, Czech Technical University in Prague (duties in doctoral examination committees) and is often an invited member of Biophysics doctoral examination committee at the Department of Biophysics at the Palacký University in Olomouc.

Impacts of the results and other activities on culture

Team members have organized or co-organized several international conferences and workshops, such as:

- 9th Ultra-weak photon emission workshop in Prague, Czech Republic, 2014
- Ultra-weak Photon Emission From Living Systems, Olomouc, Czech Republic, 2013
- Fields of the Cell, Basel, Switzerland, 2012
- Electrodynamic activity of living cells, Prague, Czech Republic, 2011

- 2nd Young Biophoton Scientists Seminary, Prague, Czech Republic, 2010.

Team members also regularly serve as reviewers of research manuscripts submitted (about 30 reviews done in the evaluation period) to journals such as Biosystems, Biophysical Journal, Journal of Biological Physics, Journal of Photochemistry and Photobiology B, Scientific Reports, Naturwissenschaften, Cellular Biochemistry and Biophysics, or Nature Materials.
Members of the team have participated in the activities of professional societies like IEEE, SPIE, OSA, Material Research Society, Biophysical Society and Protein society. Moreover, Michal Cifra acted as a member of the project review panel committee of European Commission - FP7 program Future and Emerging Technologies in 2013, reviewing project proposals submitted to several European national science funding agencies and he's also a member of the Czech National Committee of International Union for Radio Science. Ondřej Kučera has acted as an expert evaluator for the Technology Agency of the Czech Republic; the largest governmental agency for funding of applied research in the country. While a doctoral student, he was also elected to the Academic Senate of the Faculty of Electrical Engineering, Czech Technical University in Prague.

Popularisation and similar activities

Members of the team usually devote their time to activities of popularization aimed at the increase of public awareness and understanding of their research. Main examples are:

1. The publication of "Electromagnetic fields of living cells" (2014), a pop-science booklet written by Ondřej Kučera for a general public. The booklet is freely available online (http://www.academia.cz/elektromagneticka-pole-zivych-bunek.html) and is also being disseminated in print version during public and educational events which team members organize or participate in.
2. A talk given by Michal Cifra at TEDx Bratislava conference (2012) entitled Light of living organisms, and available online (www.youtube.com/watch?v=gezEio1mdjs); it was the subject of a subsequent interview by the Slovak Economy Journal (http://ihned.cz/HNstyle/letoshn/c1-56706420-to-ako-bunka-ziari-nam-moze-pomoctv-medicine).
3. A talk given by Ondřej Kučera at the Week of Science and Technology (2014), the largest pop-science festival in Czechia, entitled "Do cells have radiofrequency antennae?" (http://cas.msite.cesnet.cz/CESNET/Viewer/?peid=4f103f1141d0456d9efe 0805c0556fd01d).
4. The participation to the AMPER electronics trade show, the largest (more than 40 000 visitors) and the most significant trade fair of Electronics, Automation, Communication, Lighting and Security Technologies in the region.
5. The participation to the Day of the Open Doors, where for two days the laboratory is open to public.

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

The team, founded in 2013, is very young. The multidisciplinary research carried out shows a high degree of quality and uniqueness on a national level, and promises to compete with international teams in the future.

Role and position in international collaboration

The team has effective international collaborations with the Dept. of Chemistry of the University of Chicago (USA), the Dept. of Analytical Biosciences of the University of Leiden (Netherlands), and the University of Applied Sciences and Arts of Southern Switzerland (Manno, Switzerland).

Breadth/completeness of the research activities compared to world leading teams of comparable size

The team is very young (just 2 years of activity), and time is needed to perform an appropriate comparison with leading international teams.

5.5 Declaration on the vitality and sustainability

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

Each member of the team is below the age of 35. Three of the seven members are PhD students, 2 are post docs (that in the evaluation period successfully defended their PhD theses). The leader, even though very young, has an excellent international experience. The gender composition is good with 2 women in the staff.

Attraction of research programmes for young people

Three of the seven members are PhD students, 2 are post docs (that in the evaluation period successfully defended their PhD theses). The group strongly attracts young people, and is based on their activity.

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

In the evaluation period, the Department received external funding for a total amount of 426 K€. The funding contributed to set up completely new laboratories, including biological/biochemical lab, high-frequency and microwave electronics labs, a dark room for ultra-weak photon emission measurement from biological samples, table-top dark chambers with sensitive photomultiplier detectors, temperature stabilization systems and in- house built detection electronics. The team also exploits equipments shared within the institute, especially electron lithography, atomic force microscope and spectroscopic systems that complement the team's instrumental capabilities. The new team (with the current configuration due to the restructuring of 2013) has taken advantage from this good starting point, and has carried out a significant research activity.

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

The research carried out is effective with respect to the funding and to the human resources available.

Organisational structure, recruitment methods, career system, incentives for females, young researchers, international researchers

The team takes advantage from the presence of young researchers and female scientists, even though information about incentives for females, young and international researcher is not available.

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 follows the current call for non-invasive low-cost therapeutic and diagnostic methods in biotechnology and medicine. Broader commercial exploitation and application of these techniques is still in the very early development phase and therefore economic and societal impact is expected on the long time scale of about 5-10 years. The team declared strategy of initiating applications to protect intellectual property, which can enable commercialization of the techniques developed, is right. For this purpose, the team looks at the support from the Technology Center of The Czech Academy of Sciences for technology transfer. They think that potential investors for commercialization using a spin-off company as a tool would be SmartBrain, Ltd., a company they cooperate with. They also expect that the patents would be directly sold to larger pharmaceutical/cosmetic product companies such as Johnson & Johnson (ultra-weak photon emission detection based methods for evaluation of skin care products) or to companies producing spectroscopy equipment for chemical analysis such as Agilent (microvolume dielectric spectroscopy techniques of biomolecules).

Adequacy of available means and human resources to achieve these plans

The team is competitive, and its expectation are high. The human and instrumentation resources currently available represents an adequate starting point to achieve its plans. Anyway , the team is very young and the capability of acquiring new funding to be further invested in human resources and instrumentation is a crucial point to be confirmed in the next future.

EVALUATION OF THE INSTITUTE OF PHOTONICS AND ELECTRONICS

Team No. 4: Dept. of ***Synthesis and Characterization of Nanomaterials***

This report refers to the evaluation of the Dept. (or team) of Synthesis and Characterization of Nanomaterials (DSCN), Institute of Photonics and Electronics (IPE), 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.

The Institute of Photonics and electronics (IPE) has facilities in two locations in Prague. The DSCN is located in the main campus in Prague-Kobylisy, together with the other three departments of IPE (*Optical Biosensors, Fiber Lasers* and *Non-Linear Optics,Bioelectrodynamics*) and one specialized laboratory *(Laboratory of the National Time and Frequency Standard).* The main campus of IPE in Prague-Kobylisy also contains all the supporting units (*e.g.,* accounting, services and supplies, IT, and a mechanical workshop). The second IPE's facility located in Prague-Lysolaje accommodates *Laboratory of Optical Fibers* - a sub-unit of *Fiber Lasers and Non-linear Optics* research team.

1.2 Brief history of the department

IPE (formerly the Institute of Radio Engineering and Electronics) was established in 1950s to pursue mainly applied research in the field of electronics. During the following five decades, research activities of the Institute have been expanded to include fundamental and applied research in the fields of optoelectronics and photonics. Over the last twenty years the center of gravity of research activities of the Institute has shifted to photonics which has become a key research area of IPE. This shift resulted in a change of the name of the Institute in 2007 when the institute changed its name to the Institute of Photonics and Electronics.
In 2012 management of the Institute implemented restructuring of research units to reflect conclusions of the previous research evaluation exercise, enable sustainable development of the main research programs and create more efficient management structure. This restructuring has given rise to a flat organizational structure with a specialized laboratory *(Laboratory of the National Time and Frequency Standard)* and the current four research teams: 1) *Optical Biosensors,2) Fiber Lasers* and *Non-Linear Optics,3) Synthesis and Characterization of Nanomaterials* (created from the fusion of the two previous *Technology of Materials for Electronics & Optoelectronics* and *Diagnostics of Materials for Electronics & Optoelectronics* groups), and 4) *Bioelectrodynamics* (evolution of the previous *Speech synthesis and signal processing* group). Therefore, the DSCN activities actually started in 2013 as a result of generational transition within the previous team structure.

1.3 Mission and research topics

In the evaluated period the DSCN went through a major transformation both in terms of scientific topics and in terms of personal composition and instrumental equipment. This transformation was based on the recommendations of the final evaluation report from 2011, in which the previous period 2005-2009 was evaluated. The major identified issues included an uneven age structure, where only a limited number of scientific workers had a long-term perspective, and a highly fragmented research focus. In 2010-2011 the section of Materials comprised two teams focusing on the technology and diagnostics of materials for electronics and optoelectronics. These two teams were unified in 2012 and formed grounds for the establishment of the DSCN in 2013. The transformation of the research structure has led to a substantial reduction in the size of the team mostly by retirement and most importantly, streamlining the research by focusing on the investigation of novel semiconductor nanomaterials and nanostructures with the emphasis on their growth mechanisms, advanced characterization, and potential applications.

1.4 Staff size and full time equivalents age distribution

The generational change had in the evaluation period can be evinced from the figure below reporting the DSCN age structure of the permanent staff in 2010 (blue) and 2015 (orange).

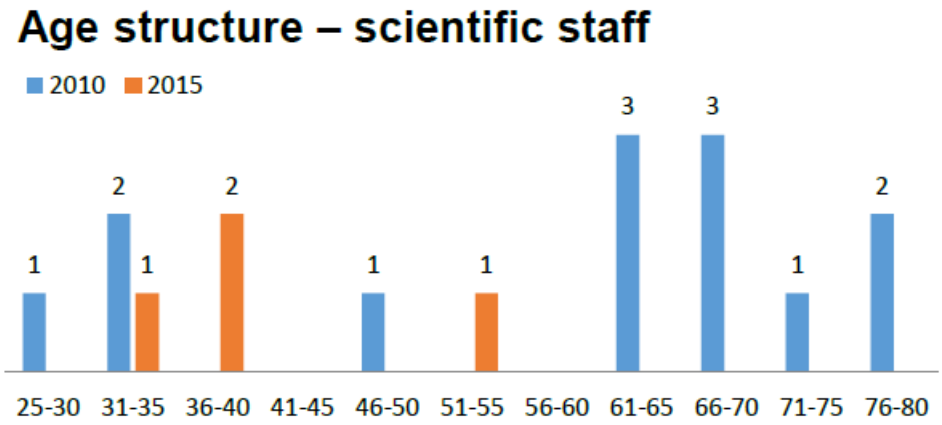


Figure 7: DSCN age structure of the permanent staff in 2010 (blue) and 2015 (orange).

Presently, the team bases its research activity on 3 young scientists (all below 40 years of age), Jan Grym (PhD in 2007, team leader from 3/2015), Roman Yatskiv (PhD in 2007, research scientist expert of electrical and optical characterization of materials), and Jan Vaniš (PhD in 2009, research assistant expert in scanning probe techniques). A senior research scientist (0.2 FTE), a PhD student, and other workers integrate the team staff for a total of about 8.8 FTE (in 2014).

2. STRENGTHS AND OPPORTUNITIES

2.1 Timeliness of research topics

The research topics are interesting and relevant.

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

In the evaluation period, the Department received external funding for a total amount of about 760 K€. A significant part of grants come from the participation to international projects, while the percentage from contractual resources is very low (only 1 K€ in five years). The funding contributed to maintain and upgrade the laboratories of the Dept., that can also take advantage of the new facilities of the Institute.
Therefore, the human and instrumentation resources currently available to the new Dept. (after the restructuring of 2013) represent an adequate starting point to achieve its plans. Anyway, the group is young and the capability of acquiring new funding to be further invested in human resources and instrumentation is a crucial point to be addressed in the next future to successfully carry out all the planned activities.

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

The intensity level of national and international collaboration is good.

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

The position in the Czech and international scientific community is good.

2.5 The overall capacity of staff

The overall capacity of staff is good.

2.6 Reasonability of the structure of the department

DSCN is the result of major transformation of the section of Material active in 2010-11, and organized in two separated teams working on the technology and, respectively, diagnostics of materials for electronics and optoelectronics. The previous evaluation exercise closed in 2011 (relative to the period 2005-2009) identified two major issues for this section of the Institute: an uneven age structure, where only a limited number of scientists had a long-term perspective, and a highly fragmented research focus. Therefore, the two teams were unified in 2012, resulting in the establishment of the current Department in 2013. The transformation has led to a substantial reduction in the size of the new team (mostly by retirement) characterized by a significant generational change. Moreover, 3 of the 6 main activities were gradually phased out, so focusing the activities on three major topics, where a greater critical mass could be gathered.
The Department structure is now reasonable.

2.7 Comments on the age structure

After the restructuring phase of 2013, the age structure of the DSCN is good, with quite all the permanent staff members below the age of 40 years.

2.8 Frequency and quality of publications

The frequency and quality of publications is good.

2.9 Patents and role in contractual work

No patents have been deposited in the evaluation period, and the percentage of resources coming from contractual work is very low (only 1 K€ in the evaluation period).

3. WEAKNESSES AND THREATS

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

The human and instrumentation resources currently available to the new Dept. (after the restructuring of 2013) represent an adequate starting point to achieve its plans. Anyway, the group is young and the capability of acquiring new funding to be further invested in human resources is a crucial point to be confirmed in the next future, to avoid also the risk of an inadequate critical mass to carry out all the planned activities in depth.

3.2 Comments on the age structure

The age structure is good, but the number of students (graduated and doctoral) involved in the research activity is very low. This is a critical point to address.

3.3 Patents and role in contractual work

The research activity has had poor results in term of patent production and contractual work. These are important points to be addressed in the next future.

4. RECOMMENDATIONS

Internal programs and actions are desirable:

- to increase the overall capability of attracting graduated and PhD students;
- to foster the internationalization of the research staff;
- to intensify the interactions with industries, and consequently increase research funding by contractual work;
- to better support the development of the intellectual property and technology transfer.

As a final comment, it is worth pointing out that the current plan of the Department answers to one of the major issue emerged from the previous evaluation exercise closed in 2011: that is, a weakness related to a highly fragmented research focus. The human capital of the Team is now mainly based on 3 young scientists. It is therefore young and with a limited critical

mass. So, the capability of acquiring new funding to be further invested in human resources is a crucial point to be confirmed in the next future, to avoid also the risk of an inadequate critical mass to carry out all the planned activities, as well as to propose and drive extensive research projects. In conclusion, a mid-term analysis of the adequacy of the staff dimension to the number of research topics is recommended.

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 of the DSCN are strongly experimental, with a long-term focus on the preparation and characterization of semiconductor materials, also at the nanoscale, for electronics and optoelectronics.

Relevance in the national and international context

The team relevance in the national and international context is good. In fact, in the evaluation period, it had intensive collaboration with other national and international research groups. In particular, at the national level,

a) it cooperated with the MOVPE group of the Institute of Physics ASCR. This collaboration, focused on the preparation and characterization of semiconductor structures, was about:
    - the characterization of HVPE grown GaN:Fe supplied by Kyma Technologies, USA within the project *Characterization of Low Defect Density Native Gallium Nitride Materials* funded by the Missile Defence Agency, USA.
    - the direct measurement of the quantum levels in self-assembled InAs quantum dots (QD) present in a GaAs/AlGaAs matrix grown by metal-organic vapour phase epitaxy. A significantly improved home-built BEEM/BEES system enabled the team to map the density of states of QDs (in correlation with their shape) for the two lowest observed energy levels.
    - the technology of lattice mismatch compensation in epitaxial growth by introducing porosity into the substrate and by the deposition of a low temperature buffer layer within the project *Lattice mismatch compensation in heteroepitaxy on micro and nanoporous A3B5 semiconductors and deposition of metals and semiconductors into micropores* of the Czech Science Foundation.
b) Another long-term collaboration in the field of preparation and characterization of special glasses was with Petr Kostka, head of the group of Special Glass Materials within the Laboratory of Inorganic Materials, University of Chemistry and Technology Prague and Institute of Rock Structure and Mechanics AS CR. This collaboration was supported by two joint projects in the evaluation period. Moreover, the team had a broad range of collaborations with scientists from international labs (see the list below) that brought to the publication of co-authored journal articles:

- James H. Dickerson, assistant director of the Centre of Functional Nanomaterials, Brookhaven National Laboratory, USA.
- Philomela Komninou, head of the Nanostructured Materials Microscopy Group, Dpt. Physics, University of Thessaloniki.
- Viktor Brus, University of California, Santa Barbara, USA.
- Leonid A. Kosyachenko, Dept. of Optics and Electronics, Chernivtsi National University, Ukraine.
- Andrey Lomov, Institute of Physics and Technology, Russian Academy of Sciences, Moscow.
- Peter Williams, Dpt. of Chemistry and Biochemistry of the Arizona State University. This collaboration was established under the bilateral Czech – US project Micro-Faraday array detector with high dynamic range for multicollector isotopic SIMS and focuses on SIMS fundamentals and instrumental development.

Other international collaborations with the following scientists were aimed at the optical characterization of special glasses:

- Marcel Poulain, Verres et Ceramiques of Université de Rennes;
- Zoya.G. Ivanova, Institute of Solid State Physics Bulgarian Academy of Sciences;
- Marian Kubliha, Slovak Technical University in Bratislava;
- Vladimir Labas, Catholic University of Ruzomberok;
- Mihail Iovu, head of laboratory of photoelectrical properties of semiconductors, Institute of Applied Physics, Academy of Sciences of Moldova.

Overall quality of publications

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, is reported in the table below.

Articles in journals with impact factor	69
Articles in other journals	5
Professional books	1
Chapters in professional books	2
Contributions to proceedings	32
Patents	0
Applied results	2

The total number of papers in peer-reviewed journals is 69, with many papers in highly-ranked journals such as Carbon (IF 6.19), Applied Physics Letters (IF 3.51), Journal of Alloys and Compounds (IF 3.00), Physical Review B (IF 3.74), Sensors and Actuators B (IF 4.09). The quality of publications by the journal ranking, reported in the figure below, shows that 44 (over the total of 64 in journals with AIS) are in the first two quartiles.

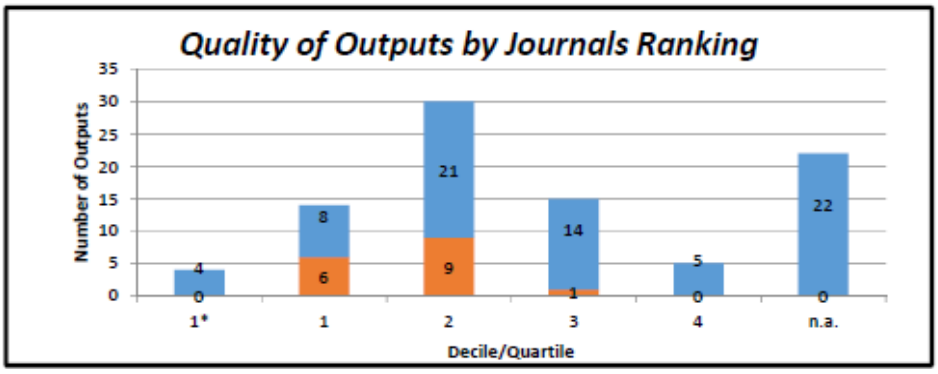


Figure 8: Number of outputs in top decile (1*) and quartiles (1-4) according to the AIS of journals. n.a. – outputs in journals without AIS. Orange: submitted by the team to the evaluation; blue: other outputs.

The 16 scientific publications submitted to the phase I of the evaluation, all in Q1 according to SJR, belonged to four research fields well representing the scientific activities of the DSCN (multidisciplinary materials science, electrochemistry, applied physics, and condensed matter physics). The quality profile of these publications, reported in the fig below, shows that the majority of them is qualified as "internationally excellent" or "recognized internationally".

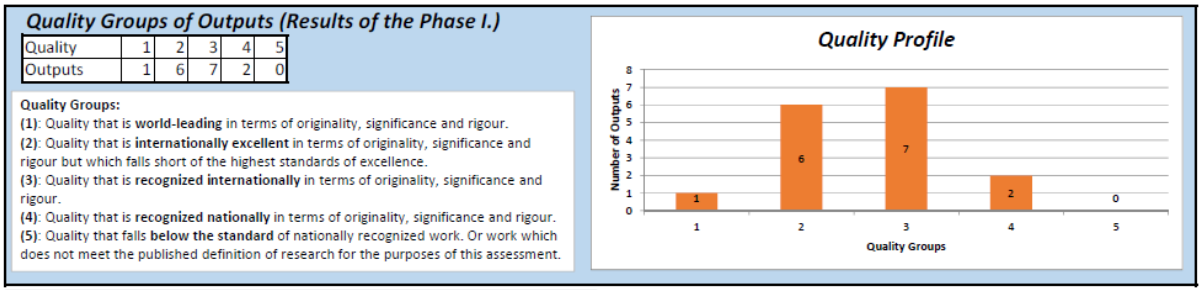


Figure 9: Quality profile of the selected publications.

Specification of the main achievements

In synthesis, the main results achieved by the team in the evaluation period concern:

1. High quality graphite Schottky contacts on bulk compound semiconductors and on ZnO nanorods and their application in highly sensitive hydrogen sensing elements.
2. Discovery of the method of non-destructive quantification of Fe doping levels in GaN, which pushes forward the technology of high electron mobility transistors.
3. Development of extremely stable ballistic electron emission microscope and its use for the mapping of the density of states of buried semiconductor quantum dots.
4. Development of the technology of pore etching of compound semiconductors for epitaxial growth.

5.2 Declaration on the involvement of students in research

Involvement of students (doctoral, undergraduate) into research

The involvements of students in the research activity is not high. In particular, three undergraduate students and one PhD student were involved in the research focusing on the preparation and deposition of metal nanoparticles on semiconductors for Schottky-based gas sensors. Two students of the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague defended their master theses in 2011 and one student of the Faculty of Biomedical Engineering defended her bachelor thesis in 2014. A summary table of the supervised and defended theses in the evaluation period is reported below.

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

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

No PhD theses was defended in the evaluation period.

Employment of former Phd students (career options)

No employment of former PhD students was done in the evaluation period.

5.3 Declaration on societal relevance

Impacts of the results and other activities on education

Some team members have been involved in teaching activities in university courses at the Faculty of Science of the Jan Evangelista Purkyně University and at the Faculty of Mathematics and Physics of the Charles University in Prague. They held also courses in some summer schools.

Impacts of the results and other activities on culture

The team leader Jan Grym was a committee member of the Czechoslovak Association for Crystal Growth in the *period 2010-2014 and a scientific committee member of the International Conference on Electrophoretic Deposition V: Fundamentals and Applications in 2014*. Jiří Zavadil was a member of the Condensed Matter Physics panel of the Czech Science Foundation in 2010-2011.

Popularisation and similar activities

The Department participated to the Open Science project of the Czech Academy of Sciences, aimed at capturing the interest of talented students for technical and natural sciences, so motivating them to pursue career in science. Five students participated to the project carrying out mainly experimental work in the preparation and characterization of nanostructured materials. Two students won the national competition and qualified at international level; one received the gold medal from the prestigious international competition for young engineers and scientists I-SWEEEP (Houston, USA, 2012) for the project *Quantum and superlattice structures - the future of thermoelectric*, and the other one won the silver medal for his project *Porous III-V semiconductors* at the International Olympiad INESPO (The Hague, The Netherlands, 2014).
The DSCN participated to the Week of science and technology organized by the Academy of Sciences CR in 2010, 2011, 2013, 2014. The team members took part in the educational tour for the public during the Open Doors Days of the Institute every year of the evaluation period.

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

The team has significantly contributed to the scientific and technological development of the Czech Republic by advancing fundamental knowledge in the field of electronic and photonic materials, and has carried out the following results of international relevance:

- development of laboratories of low-temperature photoluminescence spectroscopy, and of ultra-stable ballistic electron emission microscopy (and its use for the mapping of the density of states of buried semiconductor quantum dots);
- development of Schottky-based hydrogen sensors with short response times based on graphite/metal nanoparticle/semiconductor interface;
- original studies about the optical properties of infrared transmitting glasses for applications in photonics and biomedicine;
- development of an original technique for the contactless determination and mapping of the Fe-concentration in GaN crystals for microwave power high electron mobility field effect transistors;
- development of the technology of pore etching of compound semiconductors for epitaxial growth**.**

Role and position in international collaboration

The team had a relevant role in a broad range of international collaborations (see sec. 5.1).

Ability to attract foreign researchers at different levels

Even though the team is involved in several international collaborations, there is no evidence of ability to attract foreign researchers.

Position of the team in the national context

The position of the team in the national context is good.

5.5 Declaration on the vitality and sustainability

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

The transformation based on the recommendations of the previous evaluation report from 2011, answered to the suggestion of performing a generational change. Now the group bases its activity on three young scientists all below the age of 40 years. The international experience of all the members of the team is adequate.

Attraction of research programmes for young people

See sect. 5.2, sub-section "*Involvement of students (doctoral, undergraduate) into research"*

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

In the evaluation period, the Department received external funding from 19 research projects for a total amount of about 760 K€. Twelve of them had a principal investigator from the team, and seven had a co-principal investigator from the team. The funding structure was as follows: The Czech Science Foundation (8), bilateral international projects (5), multilateral international projects COST with additional funding from the Ministry of Education CR (3), and The Academy of Sciences CR (3). Therefore, a significant part of grants come from the participation to international projects. The percentage from contractual resources is very low (only 1 K€ in five years). The funding contributed to maintain and upgrade the laboratories of the Dept. (Laboratory of Electrochemical Technology, Laboratory of Scanning Probe Techniques, Labs of Electrical and Optical Characterization of Materials). The Team can also take advantage of the new facility of the Institute, a FIB-SEM (mod. TESCAN LYRA3 GM) allowing the a) visualization, manipulation, and machining of nanoobjects, b) focused electron and ion beam induced deposition and etching using the gas injection system, c) realization of 2D and 3D chemical maps at high resolution, d) in-situ electrical measurements with nanoprobes.
Therefore, the human and instrumentation resources currently available to the new Dept. (after the restructuring of 2013) represent an adequate starting point to achieve its plans. Anyway, the group is young and the capability of acquiring new funding to be further invested in human resources and instrumentation is a crucial point to be confirmed in the next future.

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

During the evaluation period, the research activities of the Team were spread on 6 topics:

- Schottky barriers on compound semiconductors and their application to hydrogen sensors.
- Optical properties of semiconductors and special glasses.
- Nanodiagnostics of semiconductor and photonic materials using scanning ion and electron beams (- interaction of ions with solid surfaces, focused ion beams and secondary ion mass spectroscopy, - ballistic electron emission spectroscopy and microscopy.
- Preparation of porous III-V semiconductors and their application in epitaxial growth (phased out in 2013).
- Thermoelectrics (phased out in 2012).
- Rare-earth elements in III-V semiconductors prepared by liquid phase epitaxy and their application in radiation detectors (phased out in 2011).

The last 3 activities were phased out in the period 2011-2013. This decision answered to one of the major issue emerged from the previous evaluation exercise closed in 2011, that is a weakness related to a highly fragmented research focus. The human capital of the Team is mainly based on 3 young scientists. Therefore, the risk of an inadequate critical mass to carry out all the planned activities, as well as to propose and drive extensive research projects, still exists.

Organisational structure, recruitment methods, career system, incentives for females, young researchers, international researchers

The contribute to the research activities from PhD students is low. The same holds for the presence in the staff of foreign scientists. Therefore, the attraction of graduated and doctoral students, as well as the internationalization of the staff are critical points to be addressed.

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 period 2015-19 are relevant. They have as main aim the investigation of novel semiconductor nanomaterials and nanostructures with the emphasis on their growth mechanisms, advanced characterization, and potential applications. The main objectives are:

- To develop growth and patterning techniques for the preparation of periodic arrays of one-dimensional semiconductors and to study their growth mechanisms.
- To engineer the technology of ohmic and highly rectifying Schottky contacts in one-dimensional semiconductor nanostructures.
- To describe the charge transport phenomena in nanoscale contacts.

- To correlate the properties of low dimensional semiconductor materials and structures with the mechanisms by which they grow.

Adequacy of available means and human resources to achieve these plans

The human and instrumentation resources currently available represents an adequate starting point to achieve the team plans. Anyway , the team is young and with a limited critical mass. Therefore, the capability of acquiring new human resources is a crucial point to be confirmed in the next future, to avoid also the risk of an inadequate critical mass to carry out all the planned activities in depth.

Date: January 20, 2016

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