Conference Paper

Personnel Training for High-tech Industries: The Experience of MEPhI Base Department 'Semiconductor Quantum Electronics'

Oleg N. Krokhin[1,2], Irina N. Zavestovskaya[1,2], Anastasiya A. Fronya[1,2], and Gevork T. Mikaelyan[1,3,4]

[1]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, Moscow, 115409, Russia
[2]P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia
[3]LLC VARTON Group, Moscow
[4]LLC LASSARD, Obninsk

Abstract

Industry is going through a ubiquitous technological renewal that determines the needed competencies of graduates and the content of educational programs offered by universities. Unfortunately, there is an imbalance between the education received and the entrance requirements for a graduate specialist in industry, in the research and development sector. One of the modern forms of interaction between enterprises and the university in the personnel training is the creation of the base department of the enterprise at the university. The article deals with the educational and scientific activity of the base department of the MEPhI 'Semiconductor quantum electronics'. The base department trains personnel for high-tech industries with the master's and post-graduate educational programs.

Keywords: personal training, base department, high-tech, semiconductor quantum electronics

Corresponding Author:
Anastasiya A. Fronya
AAFronya@mephi.ru

Received: 22 July 2018
Accepted: 9 September 2018
Published: 8 October 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the Breakthrough Directions of Scientific Research at MEPhI Conference Committee.

1. Introduction

Currently, the problem of the high-technology development is especially relevant for the Russian economy. There is a gap between the education received, the content of educational programs, and the requirements for personnel in modern industries [1, 2]. For the real high-tech development, it is necessary to work on advancing, it is required to accumulate the efforts of science, education, industries and the state, and their continuous, consistent interaction at all stages of preparation and implementation of educational programs.

Issues of higher education and high technology, interaction between state, universities, funds and business are discussed in [3], using the example of the United States.

In the course of training, each of the sides involved in the process seeks to derive the greatest benefit for themselves, incurring as few as possible obligations. Despite the different functions (and the disagreements), all stakeholders should strive to jointly solve this problem effectively.

The implementation of projects in the field of breakthrough technologies promotes international cooperation, both between organizations and at the state level (e.g., the International Space Station). An important role the international cooperation plays in the educational area, while in the world there is not only an activation and amplification of international cooperation, but also there is competition between educational and scientific organizations [4].

In Russia, the necessity to enhance the competitiveness of Russian education and research through the development and expansion of international cooperation is reflected at the legislative level [5, 6]. There are various forms of cooperation, for example, targeted training of specialists in Russian universities for foreign countries, the realization of joint educational programs by universities of different countries, educational internships at foreign universities, etc. [7].

International activities carried out by educational organizations of the Russian Federation have a significant influence on the organization status, and determine the quality requirements for the education, the availability and level of research and development. An important indicator is the university participation and its status in the development of breakthrough technologies.

At present, National Research Nuclear University MEPhI takes leading positions in the field of education and research in Russia and internationally. MEPhI is a participant in the The Russian Academic Excellence Project of Leading Russian Universities among Global Research and Education Centers (Project 5-100) [8, 9]. MEPhI demonstrates positive dynamics, confidently keeps in the TOP-100 QS subject rating in the direction of 'Physics & Astronomy' (the fourth consecutive year). In 2018, MEPhI entered into a number of other subject ratings of QS, in particular, Engineering & Technology, Mathematics and Computer Science & Information Systems (for the first time) [10].

In the USSR times and in the 1990s, MEPhI was a closed educational organization, and there were extremely limited opportunities for the development of international activity. Despite this fact, now the international cooperation MEPhI is being realized at all university levels.

MEPhI has a lot of experience in engineering personnel training, specialists training for Russian enterprises. MEPhI quite effectively uses its experience in the plane of international cooperation. Hence, specialists for developing branches of nuclear energy

of Belarus, Kazakhstan, Turkey, and other countries are being trained in MEPhI. In recent years, activities to bring up MEPhI to the international level is intensified: New and updated international agreements are being signed, cooperation programs with leading educational and research organizations are being developed, students, post-graduates, teachers are being exchanged, and distance education is being introduced.

One of the modern forms of interaction between enterprises and the university in the personnel training is the creation of the base department of the enterprise at the university. This form of educational process organization is not new, but with the intensive development of production technologies this form is becoming increasingly important. The main peculiarities of the basic department include: the possibility of using the resources of the basic organization in the learning process, involvement specialists of enterprises, leading scientists, designers, and researchers in the educational process. The base department allows to directly translate actual topical knowledge and professional experience of high-tech industries into the educational process, to use production and personal potential.

2. Science and Educational Activity of Base Department of MEPhI 'Semiconductor Quantum Electronics'

One of the examples of personnel training for high-tech industries in MEPhI is the master's and post-graduate educational programs of the base department #88 'Semiconductor quantum electronics'.

In connection with the development of semiconductor technologies in the world and in Russia [11–15], the creation of new types of semiconductor lasers, with the expansion of their possible applications due to their unique characteristics and high efficiency, there is an acute necessity to training the staff of technology enterprises and research laboratories. For this purpose, in 2013 an agreement on the establishment of the base department of Semiconductor Quantum Electronics was signed between MEPhI and P.N. Lebedev Physical Institute of RAS (LPI). The advancing training of specialists for the fields of laser technologies, semiconductor quantum electronics, the interaction of radiation with matter, photonics, the development and creation of elements and devices of semiconductor lasers, the use of these devices in various fields of science, technology, and medicine is the main goal of the department work. This research directions and the need for their continuation and expansion is an urgent task in terms of developing the scientific and technical level of Russian laser and optoelectronic equipment.

To create the production of completely domestic injection lasers, as well as rulers and matrices based on them, it is planned to create a scientific, technological and production center on the basis of MEPhI. Such a center should include:

1. High-tech area equipped with modern growth facilities for semiconductor heterostructures by the methods of MOCVD and MBE epitaxy;
2. an experimental technological line of planar cycle for semiconductor laser manufacturing (after growth processing, including the manufacture of laser crystals);
3. a system of forecasting and methods development, organization principles of promising production technologies;
4. a system for organizing and carrying out the necessary technological research and development works to improve the consumer qualities of products based on semiconductor lasers;
5. a system of interaction with organizations of Russia, in which prospective developments are carried out (LPI, Ioffe Institute, Prokhorov General Physics Institute, RPE 'Inject', etc.).

At the present time, advanced research works are carrying out on the base department. There are such as the development of a new generation of high-power laser diodes made on the basis of semiconductor nanoheterostructures; high-power laser diodes using heat dissipating sub-mounts of polycrystalline diamond films grown by the Plasma CVD method; optical modules based on high-power laser diodes; optical adder modules based on high-power laser diodes; solid-state diode-pumped (SSDP) lasers based on laser optical ceramics obtained by the method of sintering nanopowders; diode-pumped semiconductor disk lasers with intracavity transformation of the frequency generation; small-scale widely tunable medium-IR lasers (2–6 μm) based on crystals of A2B6 compounds doped with transition metal ions with diode pumping; the creation of SSDP lasers for microtechnologies in photonics and microelectronics including methods of ablation, welding, cutting, punching micro-holes, nanostructuring; high-power diode and SSDP lasers for medicine; continuous two-frequency SSDP laser for biharmonic pumping of terahertz-range generators; increasing the output power of single laser diodes (more than 10 W) and their service life (more than 5000hours).

For the organization of a modern production cycle, not only modern technological facilities for the production of active elements, installations of the construction cycle

('processing', installation, casing, resource testing and certification of finished products) is necessary, but also the availability of highly qualified specialists able to work on such equipment is needed.

Particular qualities of the educational process organization at the base department 'Semiconductor Quantum Electronics' are:

1. a network form of training involving the resources of specialized scientific organizations and enterprises with high-tech production [16];
2. development and expansion of international cooperation and realization of joint educational programs;
3. experience of practical work by students in leading specialized laboratories of enterprises, universities, etc.;
4. annual updating of specialization courses; and
5. involvement in the educational process of current industry experts, leading scientists and researchers for the teaching of professional courses.

The base organization of the department is a scientific organization that has a wide range of interaction with specialized research and enterprise organizations. Its circumstance expands opportunities for both the educational process and research activities at the base department. In this regard, students have the opportunity to perform research in leading laboratories of specialized scientific organizations and enterprises under the leadership of highly qualified specialists, scientists and researchers. Students and graduate students are involved in research work from the first days of training; they act as a performer on grants, government assignments, projects, etc.

With the participation of the base department, international conferences are organized, for example [17]. Delegates of the scientific community, industry of both Russia and foreign countries are involved in the educational process, students and postgraduates in the study period may go on internships, take part in scientific schools, conferences, competitions, research innovation projects.

In addition, international cooperation is developing in not only scientific area but also in education. So joint master's educational programs with the Rochester University (USA), master's and postgraduate programs with the Turin University (Italy) are being implemented.

In educational process, special attention is paid to the profile training of students. The curriculum provides in first semester the introduction to specialization, the study

of basic specialization courses, in the second semester the knowledge on basic specialization courses is deepened and more highly specialized disciplines are added, the 3rd and 4th semesters are filled with highly specialized disciplines. The highly specialized disciplines are distributed in the curriculum with the possibility of choice depending on the research work subject. Specialization courses are 'Photonics', 'Physical optics', 'Semiconductor lasers', 'Technology of heterostructures growth', 'Powerful single diode lasers', 'Solid-state lasers with diode pumping', 'Quantum cascade lasers', 'Semiconductor disk lasers', 'Physical basis of semiconductor lasers technology', 'Planar cycle technology', etc. Research work begins with the first academic semester. The overview excursion to the profile laboratories of MEPhI, the base organization of LPI, and profile organizations are organized for students. The project form of training is developing in the department. The student enters in university in the framework of the research project, and the professional part of the student's curriculum is built on the requirements of this project.

3. The Results of the Educational Activities

In 2016, the first graduation of masters took place in the educational program 'Physics and technology of semiconductor lasers'. The master's program is headed by Professor, Doctor of Physical and Mathematical Sciences, Academician of the Russian Academy of Sciences, head of the basic department Oleg Nikolaevich Krokhin. Master's dissertations were carried out in MEPhI, in the base organization of LPI, as well as in the profile organization of the Polyus research institute of M. F. Stelmakh. The high level of preparation and presentation of master's theses was marked on the defense of the dissertation. Four graduates were recommended for admission to graduate school. By the end of the training, five graduates had publications in the form of abstracts of conferences and articles in peer-reviewed journals.

In 2017, the second graduation of masters took place. To the defense, 10 graduating qualification theses were submitted, and 9 students were recommended to graduate school. Three masters graduated with honors. Among the graduates are four foreign citizens: representatives of the Republics of Belarus and Azerbaijan.

As examples, some graduate master's theses are:

1. Improvement of thermal characteristics of high-power laser lines by optimizing the construction of AlGaAs/GaAs heterostructures;

2. Investigation of the generation characteristics of new oxide laser ceramics;

3. Injection lasers based on a solid solution of Pb1-xSnxSe for the medium IR region of the spectrum;
4. Preparation of nanowires of aluminum nitride by pulsed laser deposition and their investigation; and
5. Methods for increasing the output power of semiconductor lasers emitting in the spectral range 1.5–1.6 μm.

Graduates of the base department are in demand on the labor market and work in the field of innovative economy. Part of the masters immediately after graduation was enlisted in the staff of the young intensively developing company LLC LASSARD (Obninsk Kaluga region), included in the group of companies LLC MC VARTON. Company LLC LASSARD is the first vertically integrated company in Russia to produce semiconductor lasers and devices based on them. The company's activity is focused on the production of machine tools for metalworking (laser cutting, welding, soldering), medicine (treatment of skin diseases, laser diagnostics), and science (various sources of coherent radiation). To date, in the company metal processing, assembly of optical fiber, assembly of laser dies and products have been started, work on launching a full planar cycle has been activated. Together with MEPhI, LPI, RPE 'Inject', the company conducts research and development work on the adaptation and improvement of production technologies for laser emitters; the creation of new types of metal-working lasers, the creation of solid-state lasers with diode pumping for the needs of science, etc. Graduates of the base department occupy positions at various levels, including leadership. The base department receives positive feedback about the graduates and the level of their training for professional work.

For MEPhI, there is an important goal – to become a center of advanced scientific research and training of world-class specialists recognized at the international level. Development and promotion of high technology in the university, personnel training for knowledge-based enterprises is one of the main and important areas of activity on the way to achieving the goal. And the base department is a good tool in solving this task.

4. Conclusion

The established base department 'Semiconductor quantum electronics' sets the main goal as the professional training and advanced training of scientific, engineering, technical and managerial personnel in the field of semiconductor lasers and technologies.

Significant results have been achieved for four years of base department work. Developed and realized educational master's program allows training the staff that satisfied the requirements of industrial enterprises and research organizations. This fact is evidenced by the professional trajectories of graduates. The base department is the organizer of scientific and educational events, a platform for interaction of education, science, business, industry and innovations.

Acknowledgments

This work has been supported by the National Research Nuclear University MEPhI in the framework of the Russian Academic Excellence Project (Contract No. 02.a03.21.0005, 27.08.2013).

References

[1] Vinogradov, B. (March–April 2011). Training of personnel for high-tech enterprises. *Industrial Vedomosti*, no. 3–4. Retrieved from http://www.promved.ru/articles/article.phtml?id=2064&nomer=69

[2] Sharina, A. V. (2008). Personnel training system for science-intensive production in the conditions of innovation economy formation. *Problems of Modern Economy*, vol. 3, no. 27. Retrieved from http://www.top-personal.ru/issue.html?2049

[3] Sheila Slaughter. (1990). *The Higher Learning & High Technology: Dynamics of Higher Education Policy Formation*. State University of New York.

[4] Lazutine, I. V. (2014). Priorities and tools for Russia's international cooperation in science and education. *Bulletin of International Organizations*, vol. 9, no. 1.

[5] Decree of the President No. 642 of 01.12.2016 'On the Strategy for Scientific and Technological Development of the Russian Federation'. Retrieved from http://publication.pravo.gov.ru/Document/View/0001201612010007

[6] The State Program of the Russian Federation 'Development of Education' for 2013–2020. Order of the Government of the Russian Federation of May 15, 2013, No. 792-r. 'Collection of Legislation of the Russian Federation', May 27, 2013, No. 21, art. 2671.

[7] On education in the Russian Federation: Federal Law No. 273-FZ of December 29, 2012//RG. December 31, 2012. Rossiyskaya Gazeta - Federal issue No. 5976 (303).

[8] Decree of the President of the Russian Federation of May 7, 2012 N 599 'On measures to implement state policy in the field of education and science'. *The Russian Newspaper – Metropolitan*, no. 5775 (102).

[9] Government Order No. 2006-r of October 29, 2012 on approving the action plan on the development of the leading universities to increase their competitiveness among the world's leading research and education centers https://5top100.ru/documents/regulations/672/

[10] QS World University Rankings. Retrieved from https://www.topuniversities.com/university-rankings

[11] Popov, Yu. M. (2011). The early history of the injection laser. *Physics-Uspekhi*, vol. 54, pp. 96–100. Retrieved from http://ufn.ru/ru/articles/2011/1/m/

[12] Alferov, J. I., Kremer, G., and Kilbi J. S. (2002). Nobelevskie lektsii po fizike — 2000. *Physics-Uspekhi*, vol. 172, p. 1067. Retrieved from http://ufn.ru/ru/articles/2002/9/d/

[13] Krokhin, O. N., Scherbakov, I. A., Mikaelyan, A. L., et al. (2004). Ob"edinennaya nauchnaya sessiya Otdeleniya fizicheskikh nauk Rossiiskoi akademii nauk i Ob"edinennogo fizicheskogo obshchestva Rossiiskoi Federatsii, posvyashchennaya 50-letiyu kvantovoi elektroniki. *Physics-Uspekhi*, vol. 174, p. 1117. Retrieved fromhttps://ufn.ru/ru/articles/2004/10/g/

[14] Kovsh, I. B. (2008). Photonics is the locomotive of innovation in the modern world. *Photonics*, no. 3. Retrieved from http://www.photonics.su/journal/article/2616

[15] Brockmann, R. (2009). Diode lasers are an economic miracle. *Photonics*, no. 4. Retrieved from http://www.photonics.su/journal/article/2564

[16] Vesna, E. B. and Gusev, A. I. (2013). Models of interaction between organizations in the network form of the implementation of educational programs. *Modern Problems of Science and Education*, no. 6.

[17] Krokhin, O. N., Zavestovskaya, I. N., Ananskaya, A. A., et al. Vth International Symposium on Coherent Optical Radiation of Semiconductor Compounds and Structures (Moscow - Zvenigorod, November 23–26, 2015). *Journal of Physics: Conference Series*, vol. 740, no. 1.