Fundamentals and curriculum of education on optical and laser metrology

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ABSTRACT

In this paper we are to observing the training system for specialists in the physics of optical and laser measurements at the Department of Optics, Saratov State University and at its Branch at Mechanical Engineering Institute of the Russian Academy of Sciences. The training course is presented in educational schedule. The specialists are prepared for researching and designing of laser measurements, testing, and diagnostical methods and systems at universities, academic and research institutes, enterprises with high technological level and at medical institutes and hospitals.

Keywords: optics, laser, measurements, education

Devoted to the memory of the Rector of Saratov State University Academician Anatoly M. Bogomolov (1932-1994)

1. INTRODUCTION

Laser application in measurements, diagnostics and testing constitutes the large share of laser application in scientific researches, engineering and production process. Laser measurements contactless by the nature are appreciated for high precision and high information capacity, high spatial and temporal resolution, possibility of static and dynamic problems solution, in a number of cases the light wavelength is used as a measure of length. Sharp focusing, great power and high coherence of laser light were the turning point for traditional optical measurements transforming and increasing its technological ability. It predetermined the wide use of optical measurements. Lasers gave rise to quite new measuring and testing techniques: holographic and speckle metrology, fiber optical metrology, confocal microscopy, heterodyne techniques, etc.

Up-to-date laser measurement techniques developed in laboratory conditions were adapted for scientific researches and production process in electronic industry, instrument engineering, precise machine building, etc. Laser measurements are mainly applied into the period of design and adjustment of complicate new specimens of production, requiring non-standard approach to product quality evaluation by means of laser equipment. Biomedicine - is the most perspective and developing trend for laser measurement and diagnostical application now. The variety of laser measurement techniques, original character of physical essentials and urgent demand for physicists specializing in laser optics for metrology in science and industry were the cause for introducing a new subspeciality *"Physics of Optical and Laser Measurements"* at the Department of Optics of Saratov State University.

2. SUBSPECIALITY AT THE BRANCH OF THE DEPARTMENT OF OPTICS

The Branch of the Department of Optics was founded on the base of Laboratory of Laser and Optoelectronic Measuring Systems at Saratov Branch of A.A.Blagonravov Mechanical Engineering Institute of the Russian Academy of Sciences. It was organized for educational purposes and for interaction of educational process with fundamental and applied researches. The Branch was opened by A.M.Bogomolov, the former rector of Saratov State University, the member of the Russian Academy of Natural Sciences, and A.F.Rezchikov, director of Saratov Branch of Mechanical Engineering Institute, the member of the Russian Engineering Academy of Sciences. They also signed an agreement concerning mutual obligations. According to the documents the University has to provide with teaching positions for laboratory scientific workers. The Institute, in its turn, has to provide with auditory, scientific laboratories and equipment for educational process.

The main objective of the Branch is intensive training of specialists in the sphere of laser measurement by involving students into research work in the Laboratory, preparing annual and diploma thesis and by computer and engineering practical studies, preparing post-graduate thesis under the supervision of leading specialists. Laboratory scientific area is closely connected with laser measurements (see, for example, Ref.1-4). It includes the following trends:

- interferential, diffractional and holographic measurements with speckle-modulated light fields;
- reflectometric and polarization measurements of scattering objects;
- laser scanning microscopy and scatterometry;
- computer-aided optical signal processing.

Eight Laboratory specialists are involved in the work. One Doctor of Sciences, six Candidates of Science and three scientific workers are among them. The Laboratory is headed by Professor V.V.Tuchin, the member of International Academy of Informatization, the Head of Department of Optics. The Head of the Branch of Department of Optics is Associate Professor V.P. Ryabukho, vice Head of the Laboratory. It predetermines closer cooperation between Laboratory researchers and Department teaching staff in scientific and teaching activity. Investigations are carried out by the Laboratory specialists together with teaching staff of the Department (4 persons).

The institute provides with auditory for lectures and practical studies, supplies by equipment for special practical study on computer-controlled laser measurements, offers devices, computer time and working places for students preparing an annual and diploma thesis. Students work at their thesis under the guidance of laboratory leading specialists, the subject matter of which coincides with the Laboratory scientific trends. The titles of the two last diploma thesis are the following *"Interference of speckle-fields in zone of diffraction of focused spatially modulated laser beam on a random phase object"* and *"Using of "lens-let" approach to description of far-zone partially developed speckle formation"*. In majority, Laboratory specialists have the degree of Candidates of Science, with scientific experience and are able to obtain Doctor's degree.

Specialists training for enterprises in Saratov and Saratov region is executed in close contact with laboratories of research institutes and industrial enterprises of the city, with account of definite aims predetermined by applied researches and industry requirements. Hand in hand with it the specialists for work promising directions of laser measurements are prepared. Holographic measurement, correlation and speckle techniques, diffractional and polarization measurements, optical fiber metrology have considerable promise. Laser measurement systems may be elaborated with computer systems for measurement and signal processing, feedback and controlled optical elements introduction. The curriculum on subspeciality *"Physics of Optical and Laser Measurements"* is formed according to main trends of laser measurement development.

3. TEACHING SCHEDULE

The training period of a specialist at University Physical Faculty is 5 years (10 semesters). During the last, tenth semester diploma thesis are written. The first three years and a part of the fourth year are devoted to fundamental mathematical and physical subjects studies. These disciplines and total time-volume including lectures, seminars, laboratory and practical training are presented in the Table 1.

The total time-volume for Physics speciality

Table 1.

Disciplines	Hours	Semester
1.Higher mathematics:		
Mathematical analysis	406	1,2,3
Analytical geometry and higher algebra	140	1,2
Principles of vector and tensor analysis	54	3
Differential and integral equations	72	3
Probability theory and mathematical statistics	68	6
2.General physics:		
Mechanics	126	1
Molecular physics	119	2
Electricity and magnetism	126	3
Optics	119	4
Physics of atom	90	5
Nuclear physics and physics of elementary particles	34	6
3. Laboratory training in physics	403	1,2,3
4. Physical principles of radioengineering	119	4
5. Theoretical physics:		
Methods of mathematical physics	106	4,5
Analytical mechanics	68	4
Theory of continues media	54	5
Quantum mechanics	140	6,7
Electrodynamics	140	4,5
Thermodynamics and statistical physics	140	6,7
Solid state physics	51	8
6. Computing:		
Computer and programming	105	1,2
Computational methods in physics	54	3
Data banks. Knowledge bases and data-base management systems	36	5
System analysis	54	7
Numerical simulation in physics	68	8
Computer-aided research and development	36	9
Computer-aided design systems	36	9
7. Foundations of research and engineering	34	9
8. Specialized training (see tabl.2)		

Specialized training starts usually at the third year (sixth semester) and includes the system of the basic special courses, laboratory practical studies and subspecial courses. They are listed in the Table 2. Special courses of subspeciality "*Physics of Optical and Laser Measurements*" are marked by the sign (*).

Subspeciality "*Physics of optical and laser measurements*"

Table 2.

	Disciplines	Hours	Semester	Exam.
1	1. Introduction to the theory of optical devises	34	6	Pass-exam.
	2. Emission theory	36	7	Exam.
	3. Introduction to laser physics	36	7	Pass-exam.
	4. Theoretical optics	36	7	Exam.
	5. Holography and information optical processing	36	7	Pass-exam.
	6. Optical spectroscopy techniques	36	7	Pass-exam.
	*7. Optical waveguides and resonators	36	7	Exam.
	8. Special practical physics - 1: "Spectral devices and optical spectroscopy techniques"	72	7	Pass-exam.
	9. Statistical optics	51	8	Exam.
	10. Atomic and molecular spectroscopy	51	8	Exam.
	11. Special practical physics - 2: *Part 1*: "Optical spectroscopy techniques for matter and laser investigations" , * *Part 2*: "Computer-aided laser measurements"	68	8	Pass-exam.
	*12. Physics of optical coherent measurements	34	8	Pass-exam.
	*13. Laser applications and engineering	34	8	Pass-exam.
	*14. Optical diffraction methods in biomedicine	34	8	Pass-exam.
	*15. Optoelectronics	34	8	Pass-exam.
	16. Nonlinear optics	36	9	Exam.
	*17. Special practical physics - 3: "Holography, interferometry and speckle photography"	36	9	Pass-exam.
	*18. Speckle interferometry	36	9	Exam.
	*19. High resolution spectroscopy	18	9	Pass-exam.
	*20. Lasers and fiber optics in biomedicine	36	9	Pass-exam.
	*21. Matrix polarization optics	36	9	Pass-exam.
	*22. C++ - Programming language for research	18	9	Pass-exam.

Student have their laboratory in computer-aided laser measurements at the Branch of Optics Department. This laboratory includes the following practical works:

1. "Computer-aided coherent scanning microscope".
2. "Homodyne interferometer with nonlinear digital signal processing".
3. "Heterodyne differential microinterferometer".
4. "Interference method of layer thickness measurement".
5. "Laser speckle-interferometer for temperature deformation measurements".
6. "Diagnostic of a random phase object with using of laser illuminating beam with interferential spatial modulation".
7. "Laser speckle-anemometer for biological fluids diagnostics".
8. "Methods of speckle-optics for biovibration detection."

The field of *"Physics of Optical and Laser Measurements"* subspeciality is in part common with another interdisciplinary subspeciality of Optics Department - *"Laser Biomedicine"* [5] . This includes methods of diagnostics and measuring techniques applied to bioobjects. Because of this, some practical works on laser measurements in biomedicine (works number 1,7, and 8) are incorporated in "Computer-Aided Laser Measurements" laboratory. Moreover, development and adaptation of laser methods and instrumentation of diagnostics and measuring for investigation of biological objects is dictated by the change of basic conception of applied research, conversion of industry and reorganization of science-based technologies towards new, substantially civil goals, among of which the problems of biomedicine being of vital importance.

In subspeciality particular attention is given to physical essentials of interference, diffraction and polarization measurements including holography and speckle-optics, experimental foundation of laser systems with computer control and data processing. It is determined by the themes of the main scientific researches carried out at the most prominent factors conditioned future specialization of students is the system of essays, annual and diploma thesis, tasks on computer and engineering practice connected with laser measurements, its physical essentials. The supervisors try to retain the succession of topics of annual thesises for students passing to senior courses by problems complicating. The students are allowed to have more time for independent work at senior courses. An important, educating factor is that students of different years work at the same subjects in the same research group. For instance, topics for annual thesis of one student (T.V.Keller) are the following:

1 year: "Laser measurements in technique and industry" (overview).
2 year: "Michelson laser interferometer for vibration measurement".
3 year: "Wave-fields matching in laser interferometers. Calculation of interferometer output signal parameters".
4 year: "Speckle-interferometer for displacement measurements".
5 year (diploma thesis): "The investigation of statistical characteristics of speckle-interferometer output signal".

Approximately 25-30 students of different years get specialization at the Branch of the Optics Department during one academic year.

Actually, the higher years (4 and 5) are involving in scientific researches at Laboratory. As a rule graduates have a possibility to prepare and publish 1 or 2 scientific papers in peer-reviewed journals or in Proceeding of SPIE International Conferences. It shoud be noted that on current year 2 undergraduate students (A. Chaussky and I.Peretochkin) specilizing at the Department Branch, were winners of the International Science Foundation (Soros Foundation) special grant for their excellent progress in studies and research activities. Stimulation of undergraduates scientific researches leads to their earlier adaptation to investigation process and to entering a postgraduate study. At present 4 students have postgraduate course on Physics of Optical and Laser Measurements, in 1995/96 we are waiting for another 4 students specializing in the area of Laser Measurements. As a rule students have possibility to continue study with research working in Laboratory of Laser and Optoelectronic Measuring Systems. High level of scientific investigations is supported, particularly, by activities in doctoral fellowship. At present 3 researchers (Candidates of Science) are preparing their Doctor of Science thesis in the area of coherent-domain optical measurements.

4. CONCLUSION

To our mind, progress in early and active specialization is predetermined by close connection and mutual interaction of educational process with scientific research and by personal contact of a student with actually working scientist. One of the expendient for realization of these connections is foundation of chair's Branches at academic and research institutes on the basis of scientific laboratories. Relative limitation and certain directionality of scientific research in institutes requires the introduction of certain subspecialities into the main speciality. This subspeciality should not be too profound, since it may lead to obtaining a specialist with too narrow speciality. For our opinion, the successfully this problem can be solved at the Universities.

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