Teaching of physical-technical fundamentals for laser applications

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ABSTRACT

The following problems are discussed: why, where, what and how to teach in the field of laser applications. The experiences of Laser Technologies department of Technical University "Institute of Fine Mechanics and Optics" (IFMO) form the basis of this paper. Information from the new Russian Federal Standard for university teaching in the field of laser engineering and laser applications is presented.

1. INTRODUCTION

Why? - We are witnesses of the rapid progress of laser appliactions (LA). General opinion is that lasers are producing a revolution in optics. But probably the same words could be expressed now for industry and medicine and, in the near future, for communication and information processing, etc. Some new results in LA such as 3-D laser prototyping and manufacturing, possibilities in genetic engineering, and in military industry, etc. convince us of the timeliness and perspective of LA teaching. As a confirmation of the significance of this direction the separate speciality "Laser engineering and laser applications" was established by the Federal Committee of Higher Education at IFMO's initiative this year and the Russian Federal Standard for university teaching approved this recommendation.

The obligatory minimum of the content for educational program from this standard which was prepared by IFMO is presented in Table 1. One can see the correlations between humanitarian and social-economy (HSE), natural sciences (NS), generally professional (GP) and special professional (SP) knowledge at this standard.

But there are many questions which should be answered before the optimal teaching system can be established. One of the first - is place of teaching - **Where** is it better to teach LA - at laser applications departments (in Russia - laser technologies) or at different special institutions? Probably both ways are possible. But our 15 years of experience (the experience of the Laser Technologies Department (LTD) of IFMO) is grounded in the first way.

The next question - the content of education - **What** should form the basis of this kind of higher education? And the last one - the methodology of teaching - **How** to teach it? One

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Table 1. Obligatory minimum of the content for educational program from the Russian Federal Standard for speciality "Laser engineering and laser applications".

Index	Name of disciplines	Quantity of hours
HSE.00	**The cycle of humanitarian and economic disciplines**	**2000**
HSE.01	Students choice disciplines and cources established by the faculty council	200
NS.00	**The cycle of mathematical and general natural science disciplines**	**2924**
NS.01	Mathematics	900
NS.02	Informatics	280
NS.03	Physics	650
NS.04	Theoretical mechanics	108
NS.05	Chemistry	114
NS.06	Ecology	72
NS.07	Physical fundamentals of quantum electronics	216
NS.08	Students choice disciplines and cources established by the faculty council	584
GP.00	**The cycle of general professional disciplines**	**1542**
GP.01	Electronics and computing machinering	360
GP.02	Fundamentals of metrology and optical physical measuring	240
GP.03	Safety of works	102
GP.04	Fundamentals of design and optical device technology	370
GP.05	Students choice disciplines and cources established by the faculty council	470
SP.00	**The cycle of speciality disciplines**	**1510**
SP.01	The special parts of optics	440
SP.02	Lasers, laser engineering and laser applications	270
SP.03	Students choice disciplines and cources established by the faculty council	800
DC.01	**Practics**	**756**
DC.02	**Diploma work**	**648**
DC.03	State examination on speciality	11
DC.04	Students choice disciplines and cources established by the faculty council	970
EC.00	**Additional kinds of education and optional courses**	**450**
EC.01	Military training (optional course)	450
Hours of theoretical education in all		10044

knows that there are no final decisions for these questions. But it is necessary for professionals to continually express some fresh points of view on these topics.

This paper attempts to present our point of view on the problems of the essence and the manner of teaching in LA.

2. CORE OF SPECIAL EDUCATION IN LASER APPLICATIONS.

This is the most important question: what should become the core of this kind of education? What should form its basis? This question is most important as further work specialization may tend to very different fields: from industry and production to environmental sciences and medicine.

We believe that focused education in laser applications has to be based on three whales (fig. 1) briefly: lasers, optics and interaction (laser radiation interaction with matter). It means that during their time of education students should get the necessary knowledge and abilities to answer substantiately and quickly to the next three questions.

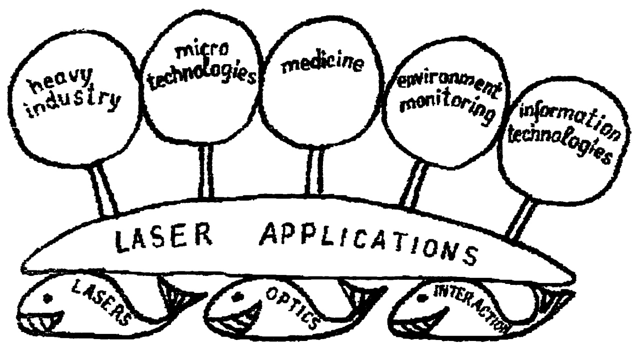


Fig.1. The roots and fruits of university education in laser applications.

1) **What type of laser source should be used for the concrete task "A" decision** (wavelength, mode of operation - continious or pulse repetition, power, pulse duration, coherence, cross-section energy distribution, monochromatism, polarization, etc in consideration with safety demands, reliability, stability and cost? And how to calculate and verify these parameters?

2) **What kind of beam-transporting and beam-shaping optical (opto-mechanical, opto-electronic, etc.) systems is necessary for decision of the task "A" ?** As the laser beam is a working tool it should be organized in space and time in optimal style. Special optics, opto-mechanical, opto-acoustical, electro-optical and other modulators can provide the necessary time of action. Other optical systems: electro-mechanical, acousto-optical, opto-mechanical scanners

and controlled diaphragm define the dimensions and shape (cross-section, energy distribution, caustic shape) of laser beam.

At the same time the tasks of transporting of laser energy and collimation, focusing or projection should be solved. Graduate students should know ways of calculation and design, measuring and testing of the main parameters of shaped laser beam.

3) Which kind of interaction (action) of laser radiation with (on) the object matter should be cho-sen to reach the aim of action (resonance - nonresonance, scattering - absorbing, photo - or thermoabsorbing, exitation, heating, hardening, melting, softening, evaporation, decomposition, coagulation, etc.). Solving this question is probably the most important part of task "A" and correspondingly - the most important part of the focused education core for laser applications. This knowledge should give the possibilities to make good-quality estimates and to decrease real expences (because "the good theory is a highly profitable thing!"). This approach was realized in our books (see for example [1]).

This knowledge and abilities are provided by general cources NS.07, SPP.02 (486 h), by additional disciplines NS.08, GP.05, SP.03 and DC.04 (2824 h), practics (756 h) and diploma work (648 h).

3. GENERAL STRUCTURE OF SPECIAL PROFESSIONAL EDUCATION IN LASER APPLICATIONS AT LASER TECHNOLOGIES DEPARTMENT OF IFMO.

Structure of courses SP.03, proposed by the physical-engineering faculty in LA and provided by the LTD is presented in Table 2. Five basic and three optional elective courses are given every year.

Certainly each subject, i.e. industrial technologies, medicine, environmental studies is supported by all basic courses. They have many common issues in interaction of radiation with matter, in optics, laser equipment and processes control.

Students have a laboratory training in every subject. Some of them are located in the premises of production facilities (technology) of the institute (environment) and clinics (medicine).

Theoretical seminars are held under items 1, 2, 3. There by students acquire practical skills in quantitative estimates of laser-matter interaction models and substantiation of processes, devices and instruments.

Basic sections of SP.03 courses was given earlier [2] and as classical for this speciality disciplines have no substantial alterations. Elective courses E.5, E.6, E.7 programms (tables 3, 4, 5) are presented below.

Table 2. Structure of special professional cources at LTD (SP.03).

Basic courses

B.1 Interaction of laser radiation with matter 108 hours

B.2 Optics of laser beams and laser equipment 52 hours

B.3 Physical-engineering fundamentals of laser technologies (in industry) 108 hours

B.4 Laser equipment, automation and technological processes control 52 hours

B.5 Laser safety 17 hours

Elective courses

E.5 Laser technologies for medicine 52 hours

E.6 Laser environmental studies 52 hours

E.7 Information laser technologies 34 hours

Table 3.Basic sections of the course E.5 "LASER TECHNOLOGIES FOR CLINICAL MEDICINE".

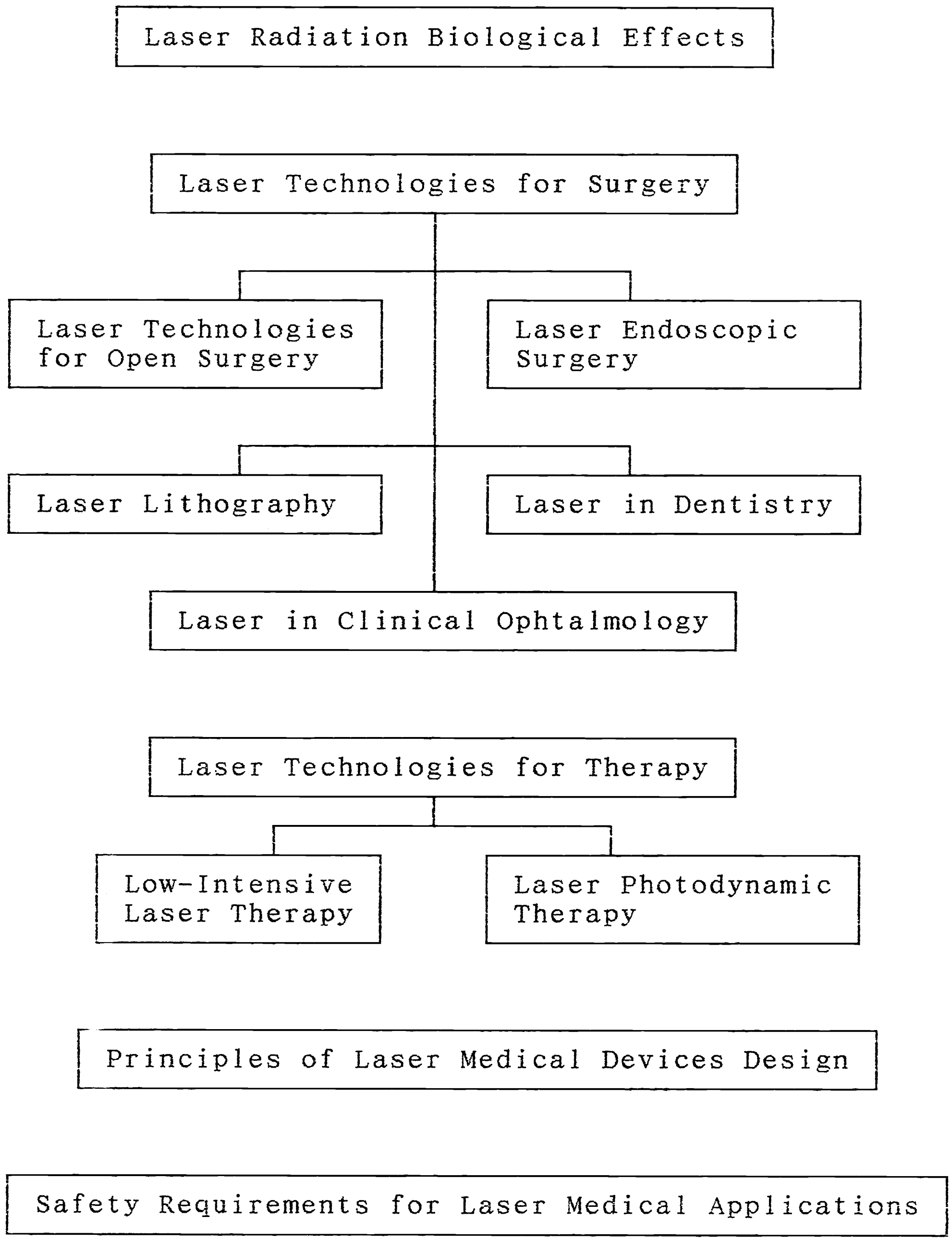


Table 4. Basic sections of the course E.6 "OPTICAL METHODS IN ENVIRONMENTAL MONITORING".

Part 1. Physical background of optical methods application to ecological problems

1. Optics of homogeneous media. Optical constants. Absorptive spectroscopy. Refractometry.
2. Optical media with continuous variations of parameters. Light propagation in refractive turbulence.
3. Molecular scattering. Raman scattering.
4. Light scattering by discrete unhomogenities. Air- and hydrosoles.
5. Radiative transfer theory. Optical characteristics of the atmosphere and the ocean.
6. Fluorescence. Fluorescence spectra of atmospheric and ocean constituents.

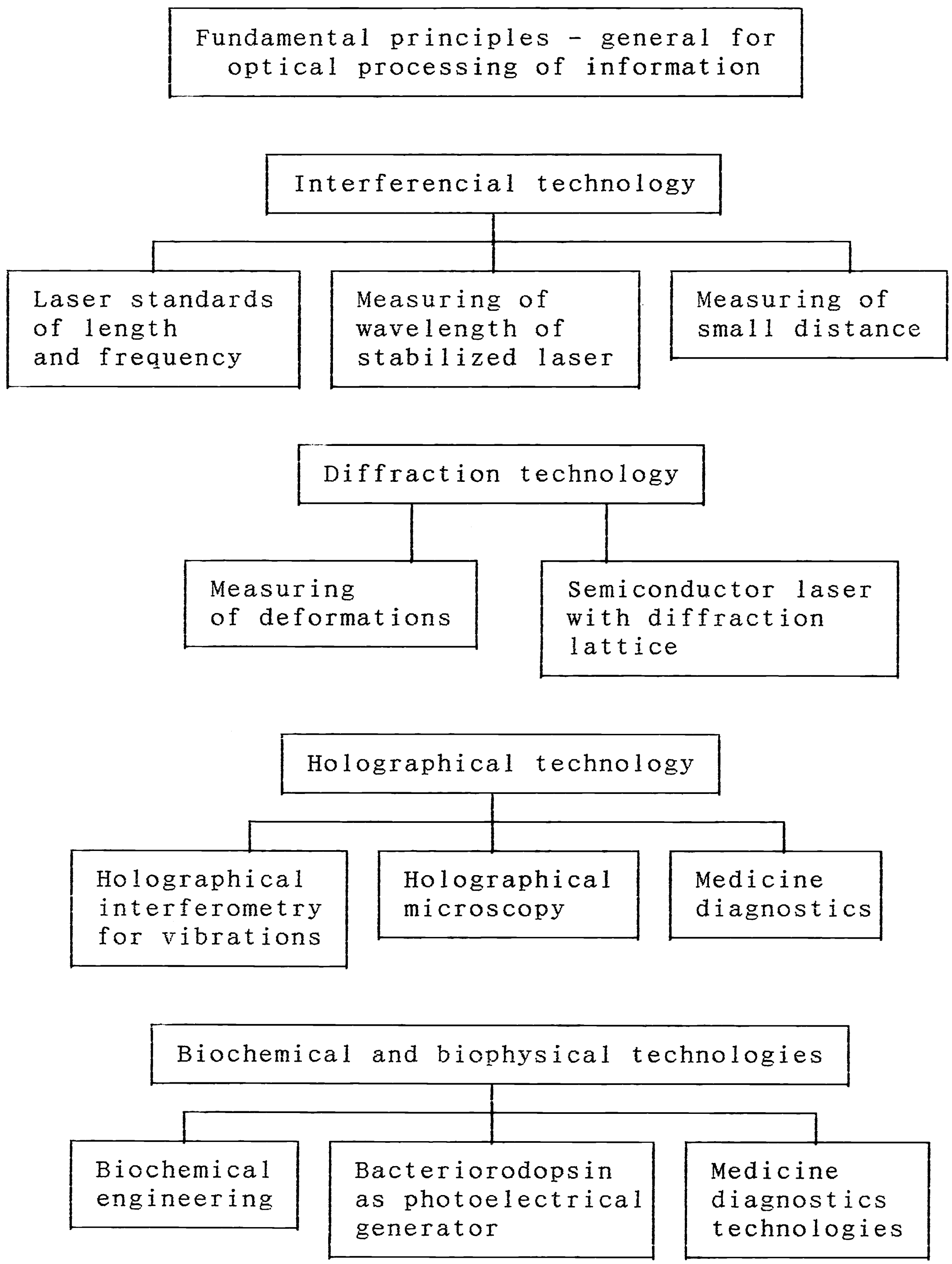
Part 2. Laser-based methods and instruments for environmental monitoring.

7. Various laser sources. Generated radiation wavelengths. Detectors of laser radiation.
8. Lidar equation for atmospheric and oceanic laser-pulsed sounding. Back-scattering characteristics.
9. Differential absorption and Raman scattering lidars for remote sensing and pollution monitoring of the atmosphere.
10. Laser bathymetry and lidar sounding of near-surface ocean waters. Data processing and inverse problems.
11. Remote detection of oil spots on water surface with airborne lidars.
12. Advanced laser methods. Coherent lidar technology; inter-cavity spectrometric techniques.

Part 3. Optical passive methods for remote sensing and imaging in the atmosphere and the ocean.

13. Downwelling and upwelling radiation flux in the atmosphere and the ocean. Sun light spectra at various horizons.
14. Multi-spectral photometry of upwelling visible radiation in the ocean. Color index and its interpretation.
15. Multi-spectral (visible) imaging of the earth's surface through the atmosphere. Satellite and aircraft-mounted instruments.
16. IR-radiometry. Radiation temperature of the earth's surface and remote temperature measurements.
17. Remote IR-imaging of ground and sea surface. IR sensing of biological films and oil spills on the water.
18. UV-photometry of natural light fields in the atmosphere. The problem of ozone concentration retrieval from multi-spectral UV photometric data.

Table 5. Basic sections of the course E.7 "INFORMATION LASER TECHNOLOGIES".



4.HOW TO TEACH LASER APPLICATIONS.

There are no special means to teach LA - it is a common question. let me discuss a little bit about this topic.

It is necessary for students to be very motivated for hard learning. In most cases we have deals with normal young people who have only one life for learning, for living, for sport, for love, for art etc. So we should have some special ways to attract them to our subject. First of all, it is necessary to have good science labs, where students can watch and take part in the real process of using of the knowledges. It stimulates them to acquire a new knowledge.

A second problem primarly for lectures - students attention concentration. Well known joke is that the normal student auditorium consists of the following audience (Fig. 2), but I will interprete it form optical point-of-view: complete reflection, complete transparance, complete absorbance, refraction and partial absorbance (optimal type of perception) and persons out of sound (at dead zone seatting). Probably this is a result of a passive education. Most of all we are interested in providing students with not passive (dead) but active (living) knowledge.

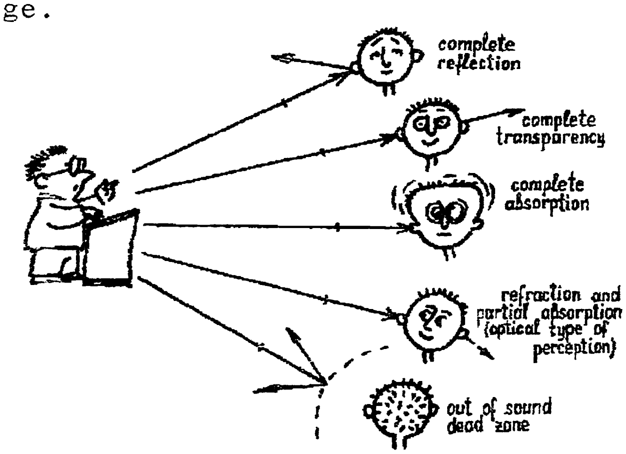


Fig.2. The students auditorium personnel from the lecturer in optic point-of-view.

So we are required to give a number of tasks for using of knowledge (better as versions of real projects, investigations etc). In this case the task deciding is the purpose, and the knowledge is higher purpose. From psychological point-of-view it permit us to overcome the antisuggestive barrier of persons.

That is why we widely use the exercises at this topic, and approximately 60-100 hometasks should be decided per last graduate year. Some examples of them are given at Appendix 1.

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APPENDIX 1.

Hometask example. Define the threshold intensities of CO_2-laser radiation for cutting of the number of constructional materials and biological tissues depending on laser beam scanning speed (slow or fast moving source).

6. REFERENCES.

1. S.M.Metev, V.P.Veiko. Laser-assisted microtechnology. Heidelberg, Sppringer, 1994.

2. V.P.Veiko, M.N.Libenson. Higher education in laser applications. Proceeding of SPIE, vol. 1603, Education in Optics, p.222-231, 1991.