PROBLEMS OF OPTICAL EDUCATION FOR INTERDISCIPLINARY APPLICATIONS: TEACHING BIOMEDICAL OPTICS TO PHYSICS AND MEDICAL STUDENTS

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1. INTRODUCTION

The contemporary medicine witnesses and endures extensive and intensive penetration of science and engineering into all fields of diagnostics, therapeutic and surgical treatment procedures, and research. Among different branches of science and engineering optical science and engineering seem to play a leading role in the development of qualitatively new horizons in medicine. Partially this is due to the advent of lasers - generators of optical radiation with unique properties in broad ranges of wavelengths, intensities and other parameters.

To a great extent the development of novel optical and laser equipment, diagnostic and treatment procedures in medicine appeared possible thanks to joint efforts of scientists, engineers and physicians. Nonetheless there is a lot of evidence for failures in collaboration of actually good specialists in optics science and engineering on one hand and physicians on the other hand.

These failures are to a certain extent due to poor understanding of each other by both parties, narrow sightedness of designers, and objective difficulties for working in such interdisciplinary fields as biomedical optics and/or optical medicine.

The amount of success and failures in joint work very much depend on the quality of education and university curricula. We have to admit that up to very recently courses on biomedical optics were very rare and did not cover the whole variety of phenomena, techniques and applications.

The aim of this presentation is to share the authors' experience and understanding of current status and problems of optical education of medical and physics students in major Russian medical and classical universities.

2. BASIC OPTICAL EDUCATION IN RUSSIAN MEDICAL UNIVERSITIES

In the majority of Russian medical schools the future physicians study Optics as a small fraction (35 hours) of a year-long obligatory course on Medical and Biological Physics (216 hours, including 72

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hours of lectures). This fraction includes basic principles of geometrical and diffraction phenomena, interaction of light and matter, photothermal effects, elements of light spectroscopy.

Peculiarities of teaching this course are:

- low level of mathematical background of the students which prevents from the essential use of mathematical description of optical phenomena and effects;
- the necessity to adapt the course to biomedical applications in order to ensure better understanding of the material by the students;
- comparatively wide use of optical equipment and techniques in practical training classes.

The above course is usually taught to the first or second year students. Unfortunately in the majority of medical courses taught to senior students the acquired knowledge and skills in optics do not find implementation and are therefore practically lost for future applications.

Hopefully at least to certain extent the situation will improve as a result of a reform currently underway, restructuring the curricula for physicians so that starting with 1996 physics, mathematics and informatics will be taught within equally long courses of 200 hours each.

Different approach to the training in optics of medical students is practiced of the medico-biological department of the Russian State Medical University which focuses on the preparation of specialists in medical biophysics, biochemistry and cybernetics for further work in research medical laboratories. On the expense of some clinical disciplines the training in physics and mathematics disciplines is significantly increased.

The half year course (108 hours) of Optics is taught there as part of general physics and a continuation of the course of electricity and magnetism. Basing on the Maxwell equations the electromagnetic waves are treated in general with illustrative examples from Optics. The major topics are:

- classical theory of radiation;
- interference;
- diffraction;
- polarization;
- propagation of radiation through the boundary between two media.

Some topics including:

- quantum theory of radiation;
- photo- and Kompton effects;
- luminescence;
- lasers

are thought within a course on Atomic Physics.

Both lecture courses are supported by practical training which includes problems covering all major topics of the courses.

Such curriculum enables the students to comprehend the fundamental issues of such special topics as:

- absorption spectroscopy (in UV, visible and IR ranges),
- scattering spectroscopy, including optical mixing spectroscopy,
- fluorescence spectroscopy, including bioluminescence,
- photochemistry and photobiology

as well as the applied problems of handling optical equipment.

Practical training in biophysics, biochemistry, and pharmacology, making use a variety of optics based techniques, which is performed coherently with the lecture course ensures continuous optical training of the students all through the education process, including the preparation of their graduate research work.

The above peculiarities characterize the basic differences of medico-biological education from the more traditional medical education. But one of the consequences of this difference is that the graduees of the medico-biological department are not allowed to perform patient treatments themselves but work at the clinics only as researchers and consultants.

Nonetheless the fast development of many optics based fields of medicine can no longer be ensured by the current practice in Optical education. This specifically concerns the clinical applications of functional diagnostics and phototherapy, and laser surgery.

We believe that in the frames of the current system of basic optical education of physicians the problem of significant raise of level and application of novel medical high technologies can hardly be solved.

3. POST GRADUATE RETRAINING OF PHYSICIANS

Within the existing system of continuous education and retraining of physicians there are several institutions in Russia where additional knowledge and skills in optics and laser applications can be acquired. These are:

- Academies of post-graduate medical education and retraining;
- Specialized federal research centers (e.g. the State Research Center for Laser Medicine);
- different university-based educational centers.

Some companies involved into the development and production of laser medical equipment also organize a variety of specialized training and retraining courses for physicians.

The educational programs for retraining are based on specialized courses including those on quantum electronics and interaction of low- and high-energy radiation with biological objects and tissues. The major problems faced by the attendees and the instructors are due to low level basic knowledge of optics by physicians which make it difficult to comprehend, teach, and discuss rather complicated contemporary issues of optics and laser applications in medicine, and of the mechanisms of light-tissue interactions.

4. BIOMEDICAL OPTICS FOR PHYSICS STUDENTS

Optical education at the physics departments of most Russian universities is traditionally performed on a high level of contemporary knowledge and educational technologies. One of the best and well known basic courses in Optics has been created and taught during many years at the Physics Department of Moscow State University by Professor Sergei A. Akhmanov. The course includes extensive lecture part, tutorials and hands on training.

Biomedical optics courses are taught to senior students specializing in biomedical research. One of the drawbacks of biomedical training of physicists is the lack of basic knowledge in biology and medicine, which are not taught at the physics departments as separate disciplines. To overcome this gap in knowledge and skills special measures are taken at Moscow State University. These include the harmonization of courses taught to physics, biology and medical students. Similar courses are taught to different students with different accents to optical, biological or medical components.

A course on Laser Biomedical Diagnostics taught by one of the authors of this paper to the 4-th year students of the Physics Department of Moscow State University may be considered as an example of such approach. Topics include:

- Overview of optical techniques in contemporary biomedical diagnostics: the increasing role of lasers.
- Physical phenomena underlying the diagnostic procedures: absorption, scattering, fluorescence.
- Diagnostic techniques based on absorption of laser light by cells and tissues:
  - absorption-transmission analysis with use of tunable lasers;
  - absorption spectroscopy of ultrafast phenomena;
  - calorimetry;
  - photo-acoustic diagnostics.
- Diagnostic techniques based on light scattering:
  - static light scattering (laser nephelometry, flow cytometry, particle_aggregometry, tomography, etc.);
  - dynamic light scattering (*in vitro* and *in vivo* measurements of diffusion coefficient and flow velocities, intracellular and molecular dynamics, blood perfusion flowmetry, etc.);
  - Raman scattering (spontaneous and resonance Raman, CARS, SERS, time-resolved spectroscopy and microscopy, biomedical applications)

- Diagnostic techniques based on fluorescent analysis (spectroscopy, microscopy and microspectrofluorimetry of cells and tissues, remote fluorescent diagnostics of plant, etc.)

The experience of students who have previously attended this course and are currently collaborating with physicians shows that they better understand the collaborating party than other students. On the contrary the physicians collaborating with physicists exhibit much lower understanding. Basing at this experience we judge that certain measures should be taken to restructure optical education of physicians.

5. WAYS OF RESTRUCTURING OF TRAINING AND RETRAINING OF PHYSICIANS IN OPTICS

We suggest the following ways of improvement of optical expertise of medical students who plan to work in interdisciplinary areas:

- organization of special departments of ophthalmology, functional diagnostics, laser surgery, phototherapy, and morphology at Medical Universities;
- organization of basic and advanced (specialized) courses with hands-on training at universities, research centers and clinics;
- harmonization and standardization of curricula and course programs in frames of international cooperation and concerted actions.

6. SUMMARY

Regular education in optics for medical students is subject to reconstruction based on the improvement of mathematical and informatics background, and on specialized training. Retraining of physicians should be performed on regular basis in frames of basic and advanced courses including hands-on training in clinics. Retraining should be performed with wide use of novel educational technologies including video-courses, teleconferences, means of telemedicine, computers, CD-ROMs, etc. Harmonization of educational and retraining experience gained in different countries should be performed as part of concerted action.