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Teaching Optics

In the *Editorial*, which appeared in Optica Applicata **25** (1995), 3, I invited the authors to send us articles concerning more important problems met while teaching optics. Let me cite my inviting declaration of those days again.

"Now, we intend to widen the subject matter of our journal by including also some problems of didactic nature under a common title: *Teaching Optics*. This could contain both general information about the concepts and programs of optics study in different specialized fields and solutions of some specific teaching problems aiming at improvement of the clarity of presentation of more difficult problems or introduction of new demonstrations, student labs or particular experimental set-ups. All optics teachers interested in developing new teaching concepts and methodologies are invited to share their experience with others in the form of communications, papers or others elaborations adequate to the problems discussed. We hope that such an exchange of information will meet the needs of many teachers, especially (though not exclusively) less experienced lecturers and organizers of student labs. We would consider it both an honour and a pleasure to have the opportunity of widening our activity by contributing to the development of didactics of optics."

Unfortunately, there has been no response to that appeal so far, in spite of the obvious fact that the progress in general development in all fields of optics depends on the level, deepness, completeness and modernity of the respective programs of study (to mention a few of many). Especially, the reasonable up-to-dateness of the whole curricula and single courses with the progress in the due research can constitute serious didactic problems. Hereby, we repeat the invitation. It seems to be worthwhile to publish, at least, two categories of articles: those dealing with the general concepts of optics study offered at different universities and colleges and the other proposing novel solutions of selected optical problems faced in both lecturing and the student labs.

The following two papers provide an illustration of each of the two said categories. We hope that this will encourage other authors to send us new articles on their teaching experiences as well as critical remarks on the two papers presented.

Vice-Editor

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Selected problems in teaching optics in the presence of economic restrictions

I. WILK

Institute of Physics, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50–370 Wrocław, Poland.

Optics being taught at our Institute in three fields of specialization: Physics-Optics, Biooptics and Optical Engineering provides a number of didactic problems concerning both the programs of study and the level of lecturing of particular courses, especially if taken account of the interference of the economic factor. In this paper, a solution is presented in the form of a common kernel of study (obligatory for all the fields of specialization) and three specialized branches. This solution being acceptable from the economic point of view creates some didactic difficulties of general character, for instance, how to help the students to catch up with those having a better background. Additionally, some forms of teaching optics other than those mentioned above are intended and announced.

1. Introduction

In spite of having tradition of over thirty years of teaching optics on both undergraduate and graduate levels, we still have different problems in designing the fully satisfying programs of study in the way assuring high level of the offered knowledge, effective teaching methodology and rational economy of teaching. This is especially true for the last years, when we widened our didactic offer to include three fields of specialization: Physics-Optics, Biooptics and Optical Engineering. Being convinced that a perfect solution is not achievable, below we present some reasonable compromising solutions.

2. Present state

As mentioned in the *Introduction*, our Institute of Physics, Faculty of Fundamental Problems of Technology, offering the study in optics in the specialized versions: Physics-Optics, Biooptics and Optical Engineering encountered some economic restrictions forcing us to rationalize the programs of study also in this direction. In order to specify the problems to be solved, a short characteristic of each of the specialization fields would be helpful.

Physics-Optics. This ten-semester study offers a profound education in optics based on strong physical background. The study is completed by developing some technological skills concerning mainly the designing of optical elements and systems as well as mastering specialized measuring methods. After first five semesters of studying physics in order to master: **the necessary mathematical tools** (including linear algebra I and II, mathematical analysis I and II, complex functions,

probability and mathematical statistics), **solid physical background** (including general physics I, II and III, electrodynamics, analytical mechanics, quantum mechanics I, crystallography, solid state physics I, statistical thermodynamics), some **fundamentals in chemistry** (including general chemistry, physical chemistry, and crystallography) the students intending to study optics are offered a program composed of three major fields:

– *"Pure" classical optics* (represented by introduction to wave optics, physical optics I and II, optics of anisotropic media, interferometry, holography and optical data processing, interference-polarization phenomena in measuring, fiber optics I and II, and others).

– *Physicochemical surrounding of classical optics* (represented by quantum electronics, non-linear optics, physics of thin films, physics of semiconductors, photography, sources and detectors, eye and vision).

– *Technological skills* (including technical drawing, fundamentals of precision design, geometric theory of imaging, instrumental optics, and electronic systems).

Biooptics. The aim in this ten semester study is to educate interdisciplinary specialists capable to solve biological and medical problems using optical methods. The program of study has been developed to achieve three goals:

– Providing a reasonable amount of Biomedical Science based on Physicochemical Foundations (this is achieved by offering courses in chemistry, biochemistry, biophysics, microbiology, biology, anatomy and physiology).

– Providing a necessary knowledge in Optics and Optical Measurements (realized by offering courses in physical optics I and II, nonlinear optics, optics of anisotropic media, interference-polarization phenomena in measurements, interferometry, holography and optical data processing, eye and vision, fiber optics, optical instruments).

– Offering Complementary Courses and Techniques (such as photography, lasers in medicine, biosensors, biospectroscopy, EPR and NMR, sources and detectors, interaction of light with biological tissue, optical diagnostics in medicine).

– Providing training in Technical and Computer Skills (including skills in engineering drawing – CAD, precision design in optical instrumentation, geometric theory of optical imaging, computer science I, II and III, processing programs, microprocessors).

Optical Engineering. This is a six semester study. Here the emphasis is put on developing technological skills mainly. This is realized by offering three types of courses:

– Fundamentals in Mathematics and Physics (including linear algebra, mathematical analysis I and II, selected topics in physics I and II).

– Optics (being represented by introduction to optics, physical optics I and II, optics of anisotropic media, instrumental optics, optical measurements, interferometry, holography and optical data processing, eye and vision, sources and detectors, fiber optics).

– Optical Skills (optical technologies, mechanical and optical processing, workshop drawing, fundamentals of precision design, mechanical design in optical

PREPARATORY STUDY

OPTICAL ENGINEERING

LINEAR ALGEBRA I
MATHEMATICAL ANALYSIS I, II

INFORMATICS I, II
ALGORITHMS AND DATA STRUCTURES

PHYSICS I, II

FIRST 3 SEMESTERS

PHYSICS–OPTICS

LINEAR ALGEBRA I and II
MATHEMATICAL ANALYSIS I, II and III
COMPLEX FUNCTIONS
PROBABILITY AND STATISTICS

INFORMATICS I, II
INTRODUCTION TO COMPUTER PHYSICS I and II

GENERAL PHYSICS I, II and III
THEORETICAL MECHANICS
ELECTRODYNAMICS
STATISTICAL THERMODYNAMICS
QUANTUM MECHANICS I
SOLID STATE PHYSICS
PHYSICS OF SEMICONDUCTORS

CHEMISTRY
PHYSICAL CHEMISTRY
CRYSTALLOGRAPHY I

FIRST 6 SEMESTERS

BIOOPTICS

LINEAR ALGEBRA I
MATHEMATICAL ANALYSIS I, II and III
PROBABILITY AND STATISTICS

INFORMATICS I, II
MICROPROCESSORS
OPERATION SYSTEMS
COMPUTER NETWORKS
ALGORITHMS AND DATA STRUCTURES

GENERAL PHYSICS I and II
BIOPHYSICS

CHEMISTRY (BIOCHEMISTRY)
PHYSICAL-CHEMICAL RESEARCH METHODS

BIOLOGY (MICROBIOLOGY) I
ANATOMY I and II
PHYSIOLOGY I and II

FUNDAMENTALS OF ELECTRONICS
ELECTRONIC SYSTEMS

FIRST 6 SEMESTERS

COMMON KERNEL STUDY

INTRODUCTION TO WAVE OPTICS
PHYSICAL OPTICS I and II
INTERFERENCE-POLARIZATION PHENOMENA IN MESUREMENTS
INTERFEROMETRY
HOLOGRAPHY AND OPTICAL DATA PROCESSING
OPTICS OF ANISOTROPIC MEDIA
OPTICAL MEASUREMENTS I and II
GEOMETRIC THEORY OF OPTICAL IMAGING
SOURCES AND DETECTORS
THIN-FILM PHYSICS
INSTRUMENTAL OPTICS
FIBER OPTICS I and II
EYE AND VISION
PHOTOGRAPHY

SPECIALIZING STUDY

OPTICAL ENGINEERING

OPTICAL MEASUREMENTS III
MECHANICAL MATERIALS SCIENCE
OPTICAL MATERIALS SCIENCE
OPTICAL TECHNOLOGY (PROCESSING)
PRODUCTION TECHNIQUES
WORKSHOP DRAWING
PRECISION DESIGN
MECHANICAL CONSTR. OF OPTICAL INSTR.
FUNDAMENTALS OF ELECTRONICS
ELECTRONIC SYSTEMS
DIPLOMA SEMINAR
DIPLOMA PROJECT
DIPLOMA EXAM

7-SEMESTER STUDY FOR ENGINEER DIPLOMA

PHYSICS–OPTICS

QUANTUM ELECTRONICS
NONLINEAR OPTICS
DIPLOMA SEMINAR
DIPLOMA PROJECT
DIPLOMA EXAM

10-SEMESTER STUDY FOR MASTER DEGREE IN PHYSICS–OPTICS

BIOOPTICS

BIOSENSORS LIGHT-TISSUE INTERACTION
EPR AND NMR SPECTROSCOPY
BIOSPECTROSCOPY
NONLINEAR OPTICS
OPTICAL DIAGNOSTICS IN MEDICINE
DIPLOMA SEMINAR
DIPLOMA PROJECT
DIPLOMA EXAM

10-SEMESTER STUDY FOR MASTER DEGREE IN BIOOPTICS

CONTEMPORARY OPTICS

A FUTURE PROGRAMME OF STUDY IN ENGLISH NOW AVAILABLE COURSES:

INTRODUCTION TO WAVE OPTICS
PHYSICAL OPTICS I AND II
FIBER OPTICS I AND II
INTERFEROMETRY
POLARIZATION INTERFEROMETRY
SOURCES AND DETECTORS
HOLOGRAPHY AND OPTICAL DATA PROCESSING
NONLINEAR OPTICS
BIOSENSORS
LIGHT-TISSUE INTERACTION
OPTICAL DIAGNOSIS IN MEDICINE

instrumentation, optical material science, photography, fundamentals of electronic measurements, electronic systems, computer science I and II, algorithms and data structures.

In addition to the above mentioned courses constituting the so-called standard program of study, a wide range of optional courses is offered, provided that the number of participating students is not less than 12.

3. Concept of common kernel

Under these circumstances (*i.e.*, when offering optical specialization field of essentially different philosophy, while having rather limited financial resources) the economic rationalism forced us to work out a modified concept of study with a common kernel for all three specializations as shown in the insert before page 215.

For the purpose of this presentation three stages of study can be distinguished in each specialization * (see insert before page 215): preparatory study, common kernel study and specialized study. The preparatory study includes the courses offered to the students of each specialization before entering the common kernel study. In contrast to this the common kernel study is, in principle, the same for all the optics students **. Finally, the specializing studies differ essentially from each other, while the degree of individualization of courses taken by particular students is much higher due to the fact that the number of optional courses offered at this stage is significant.

4. Critical review of the concept

It is obvious that from purely economic point of view the organization scheme presented in the insert is more rational than the concept of teaching all the three specializations independent of each other. On the other hand, too high integration, in the face of different backgrounds (achieved mainly in the fields of mathematics and general physics in the first years of study), would produce a number of different negative factors (see text below). Therefore, a reasonable compromise is necessary. Going in this direction let us consider some advantages and disadvantages of the organizational scheme considered in this paper.

Advantages. The obvious consequence is the reduction of the number of teachers and lecture rooms necessary to implement the whole program. This increases (unpleasent but true) the competition among the teachers, allowing to choose the better ones. On the other hand, the higher integration of the respective students community creates better conditions for exchange of both information and knowledge among the students. This, in turn, can lead to broadening and deepening their

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* Note that the specializations differ from each other also by the period of studying and the type of diploma, *i.e.*, Optical Engineering offers 7-semester study ended with Diploma of Engineer (which roughly corresponds to Bachelor Degree), while Physics-Optics and Biooptics offers 10-semester study ended with Diploma of Magister (which roughly corresponds to Master Degree).

** Though some individual differences among the students are admissible if agreed with the students advisors since some of the courses are optional. This creates sometimes some organizational problems not to be discussed in this text.

professional horizons. In some cases, this results in either widening the individual programs of study or even changing the specialization to that better corresponding to the individual interests.

Disadvantages. Unequal level of preparation of the students (to enroll for particular common courses offered at higher years of study) causes the lecturing to be more difficult (and consequently, possibly less effective) since it is not easy to keep the attention of such a variety of students at a reasonable level during the lecture. The level of the mathematical formalism to be used in particular lectures creates a special problem, since the differences in mathematical backgrounds can cause some essential difficulties in understanding the physical meaning of the topics discussed. Finally, the exchange of the mentioned above knowledge among the students is by no means a mass phenomenon.

5. One of the possible solutions

Obviously, no optimum slution exists, since the intellectual dispersion both among particular students and the students communities constitutes also some essential factors to be taken into account. Therefore, we can speak rather about partial solutions, trying to approach the optimum in the way adjusted to the average abilities of particular groups of students. Nevertheless, some general proposals can be formulated. In my opinion, it is better to lecture on relatively higher level, even when knowing that this may create some understanding difficulties for the minority of students, than to try to bring the point home to everybody. However, the resulting discrepancy should be mildened by offering the tutorials at different levels which could help the groups of weaker students to catch up with those more advanced. The cost of tutorials is usually lower than that of the lectures, while the teaching methods can be applied in a more flexible way.

6. Widening the offer of training in optics under the watch-word contemporary optics

In the near future, we intend to widen our teaching offer to include a flexible program of study under the provisional name *Contemporary Optics*. The courses will be given in English (some lectures could be given also in German). The program will be available both to our and foreign students and can be realized on different levels. The students can enroll for one year, one semester or even one course. Below, you will find the list of some courses available in English:

- Introduction to Wave Optics,
- Physical Optics I and II,
- Fiber Optics,
- Interferometry,
- Interference-Polarization Phenomena in Measurements,
- Sources and Detectors,
- Holography and Optical Data Processing,
- Non-linear Optics,

- Biosensors,
- Sources and Detectors,
- Light-tissue Interaction,
- Optical Diagnosis in Medicine.