Tendencies in Education on Optical Design in Europe

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Abstract

Tendencies of international cooperation in engineering education became very visible during recent years. We demonstrate this statement on two currently running EU projects SMETHODS and ADOPSYS in the field of optical design, which is an important part of engineering education in photonics. These examples show the importance of the input from different countries and organizations - both from industry and academia. Seven universities and eight optical companies are involved in the project ADOPSYS.

Keywords
Education, optical design, photonics, hands-on training, globalization, innovation, e-learning.

1. Introduction
Education in engineering sciences faces a lot of problems because of the fast development of this field, see Fig.1. We are going to discuss the key enable technology – PHOTONICS, which is widely used in modern society.

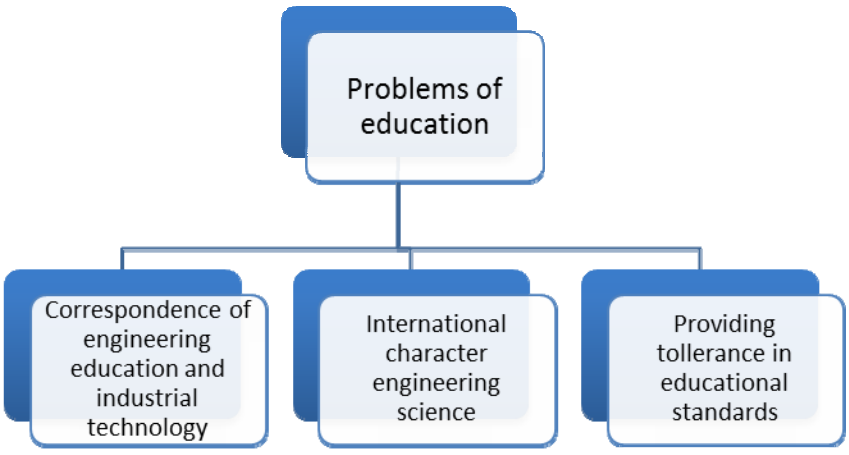

Figure 1: Problems of education

Let us list some problems that have to be dealt with in the education of engineering, in particular Photonics:

- A technology of engineering education has to grow and develop as fast as industrial technologies – otherwise graduate students are not ready for immediate employment at high-tech industrial companies. To solve this problem postgraduate and additional education (e.g. continuous learning) are used.
- Engineering science became very international. For communicating between people from different countries the English language is now used almost exclusively..
- Another issue is that for a fruitful collaboration between people from different nations, in multi-national projects, tolerance and respect are required between people of different political, cultural, educational backgrounds.

2. International cooperation in optical design education

2.1. Academia educational projects for Small and Medium Enterprises (SME's)

At present two international training programs on Optical Design are currently being implemented in the European Union (EU) namely: SMETHODS and ADOPSYS. Optical Design and Simulation has a great potential to further develop photonics and innovation. The important role of the photonics industry has been acknowledged by the European Commission by its decision to grant photonics the status of Key Enabling Technology (KET) [1].

Optics as a part of Photonics is a «starting point» for developing any modern optical engineering device. As a cornerstone technology for making optical devices, optical design is a tool to determine optimum values for the constructional parameters of the device, such that the requirements for the envisaged applications are met. In spite of the advanced technological development of present information society, optical design is still strongly dependent on personal experience of the designing engineer [2]. Therefore, Optical Design education and hands-on trainings are extremely important.

There are many companies in Europe where optical design engineering is used. These companies produce modern high-tech products and therefore optical design process requires creativity, basic knowledge in optics and practical skills to achieve engineering (design based) targets.

General Photonics education in Europe is usually focused on providing extensive theoretical knowledge, and some of the existing courses lack hands-on training and practical exercises. Furthermore, European academic courses in optical design given by universities are often not close enough to practical applications [2]. This was an important reason for deciding to invite the National Research University of Information Technologies, Mechanics and Optics (NRU ITMO), Saint Petersburg, Russia, which already had extensive experience in hands-on teaching of optical design, to become full partner in the two European projects SMEHODS and ADOPSYS.

SMETHODS (SME's Training and Hands-on Practice in Optical Design and Simulation) is training in applied optical design for European companies, especially, small and medium sized companies (SME's).

Trainings are organized by a consortium consisting of the following universities:

- TUD – Delft University of Technology, The Netherlands (coordinator).
- FSU – Friedrich – Schiller - Universitaet, Jena, Germany
- IOGS – Institut d'Optique Graduate School, Orsay, France
- ITMO – Saint-Petersburg State University of Information Technologies, Mechanics and Optics, Russian Federation
- VUB – Vrije Universiteit, Brussels, Belgium
- UEF – Ita – Suomen Yliopisto/ University of Eastern Finland, Joensuu, Finland
- UPM – Universidad Politechnica de Madrid, Spain

The educational program started in September 2011 and will be funded by the EU for 2.5 years. There are plans to extend the program as a self-sustaining educational activity after the EU funding has ended. Training is usually held at one of the consortium member sites and lasts 4 or 5 days.

The objectives of SMETHODS are “to improve the competitiveness of European photonics related industry and in particular SME's and to strengthen Europe's technological base in the field of photonics by providing training and hands-on practice in optical design and simulation to workers in industry, in particular SME's in the following four domains”:

Training domain 1: ***Optical Design for Imaging: geometric optics, diffraction, aberration reduction.***

Hands-on training in design and optimization of optical imaging systems supported by a theoretical introduction. At the end of the session, trainees will be able to specify an optical imaging system, propose the general layout, and understand the methods used to characterize its performance. On simple systems, they will be

able to select a starting point, run the optimization and estimate tolerances. On more complex cases, including for their own needs, they can interact efficiently with highly skilled experts.

Training domain 2: ***Design and optimization of non-imaging optical systems***.

Hands-on training in design and optimization of optical non-imaging systems supported by a theoretical introduction. At the end of the session, trainees will be able to specify light sources and optical components for illumination systems, energy concentration systems, light coupling and other non-imaging optics. They will have a good understanding of the applicable physical limitations and a personal experience in the use of at least one of the relevant software tools.

Training Domain 3: ***Wave Optics: Modeling for Micro Optics and Laser Systems.***

Hands-on training of modeling and design of laser systems and micro-optics with special emphasis on the inclusion of wave optical phenomena. At the end of the sessions, the trainees will be able to perform the modeling of coherent and partially coherent light propagation through lens and micro-optical systems and to analyze and design such systems for example for focusing, light coupling, laser beam shaping and homogenization, interferometry, and polarization optics.

Training Domain 4: ***Optical Design for Diffractive Optics.***

Hands-on training in design and optimization of diffractive optics elements of different scales for imaging and non-imaging systems. At the end of the session, trainees will understand the applicability and limitations of different computational diffraction models. Furthermore, trainees will learn to formulate optimization problems in diffractive optics, will learn methods to obtain an initial design and methods for optimizing these.

2.1.1 Example of SMETHODS project implementation

Example of time-schedule in Domain 1 (imaging optics) is presented in Table 1.

Table 1. Example of time-schedule in Domain 1

Monday, October 08, 2012

Start	Finish	Type	Topic
9.30	10.00	Welcome	Presentation of course, coaches and trainees
10.00	11.30	Course 1	Applications of optics, nature of light
11.45	13.15	Course 2	Ray optics / stigmatism
14.15	15.45	Course 3	Paraxial optics / aberrations
16.00	17.30	Exercise 1	Exercises on previous material

Tuesday, October 09, 2012

Start	Finish	Type	Topic
10.00	11.30	Course 4	Main specifications of image forming systems
11.45	13.15	Course 5	Radiometry of image forming systems
14.15	15.45	Course 6	Spectral properties of components
16.00	17.30	Exercise 2	Exercises on previous material

Wednesday, October 10 , 2012

Start	Finish	Type	Topic
10.00	11.30	Course 7	Local optimization
11.45	13.15	Course 8	Local/global optimization
14.15	15.00	Course 9	Global optimization
15.30	Evening	Recreation	Visit of porcelain factory/dinner/bowling

Thursday, October 11 , 2012

Start	Finish	Type	Topic
10.00	11.30	Lab 1	Optimization expertise with code V, exercise
11.45	13.15	Lab 2	Real world design with CODEV
14.15	15.45	Lab 3	Hands on training with 1 element, including HOE, DOE, aspheric
16.00	17.30	Lab 4	Mirrors systems, exercises

Friday, October 12, 2012

Start	Finish	Type	Topic
10.00	11.30	Lab 5	Optical system classification; combining optical elements; exercise
11.45	13.15	Lab 6	Practical exercise in designing OS with 2 or more opt. elements
14.15	15.45	Lab 7	Image quality evaluation exercises
16.00	17.30	Lab 8	Examples of multi-element designs; exercise
17.30	18.00	Conclusion	

2.2. Education for the scientific elite in Europe

After success with SMETHODS project, the consortium of seven universities has decided to continue working together and create a new project – ADOPSYS [Advanced optical system design].

The main objectives of this project are:

- To develop new strategies for inverse problem of optical design which reduce the amount of human trial-and-error efforts significantly, and to apply these in close collaboration with the industrial partners to design problems that occur in modern applications [1].
- Building a unique European training infrastructure for PhDs in the field of optical design methods for a future career in European academy and the photonics industry [1].

ADOPSYS consists of the same seven academic partners that collaborate in SMETHODS (TUD, VUB, ITMO, CNRS-IOGS, UPM, FSU) and in addition of three industrial full partners, namely Carl Zeiss AG, OSRAM, and LPI. Furthermore there are four industrial partners of level 2: Datalogic, Carl Zeiss SMT, Simax and KLA Tencor. Two of the industrial partners are SME's, namely LPI and Simax. There will be twelve ESRs who all will work towards a PhD to be granted by one of the academic partners. All level 1 partners recruit at least one Early-Stage researcher (ESR) for 36 months. In agreement with the ITN rules, an ESR will spend at least 26 months at the partner that recruits the ESR and will receive at most 10 months of secondment by another partner [1].

An ESR that is recruited by an academic partner will thus spend at least 26 months at the academic host, who will grant the PhD degree. The ESR will receive secondment from at least one industrial partner (level 1 or level 2) for at least 3 months. This industrial partner has core competences in the field of application in which the ESR does research, hence the industrial partner is well qualified to provide high quality secondment to the ESR.

There are three multi-disciplinary applications areas:

- Energy efficient lighting systems.
- High resolution systems.
- Machine vision, inspection and safety.

The training of ADOPSYS consists of:

- Training by doing research. Every ESR is trained by the supervision and secondment(s) received throughout the project while doing research. Collaboration with other ESR and with the industrial partner is very essential for the project, hence social skills like working in a team will be practiced while doing research.
- Training by courses of the Personal Career Development Plan (PCDP). The ESR will receive training by attending courses described in the PCDP.
- On-the-job training in transferable skills by industrial secondments. The secondments provided by the industrial partners (which all eight industrial partners provide) strengthen the multi- disciplinary character of ADOPSYS and imply training on-the-job in transferable skills that are needed in an industrial environment.
- Training by ADOPSYS network events. Six network training events will be organized. All ESR fellows have to attend all network trainings.

There are three types of network training sessions:

- General Scientific Training (GST): two events which provide broad high level (PhD level) education in the following three major fields of optical modeling and design:
    - *Optical Design in imaging and non-imaging systems.*
    - *Optical Design in wave and diffraction optics.*

  The GST is given early in the project to bring all ESR at the same high level of knowledge at an early stage which is essential for a fruitful collaboration.
- Research Workshop (RW): three events during which the ESR fellows present their work, discuss problems and solutions and brainstorm on common research topics. Also lectures will be given on advanced new

topics by either external lecturers or by a lecture from one of the partners. During the first three years, one RW is organized every year. The RW also serve as Consortium Meeting. Since all (full) partners are represented at a RW, a meeting of the Supervisory Board will always be combined with a RW.

- Training in Transferable Skills (TTS). These skills are "How to pursue a successful PhD", "How to collaborate in a large research project", "how to write a successful (research) proposal, "IPR, searching IP databases, applying for a IP" and "entrepreneurship" and "how to start your own company". The first two topics are given as part of RW1 in Month 7 (.i.e. at the start of ADOPSYS) whereas the other topics are treated in a special network event dedicated to transferable skills at the end of ADOPSYS [1].

Conclusion

Currently running projects: SMETHODS [1] and ADOPSYS [2] confirm the success of idea of international cooperation in both research and education in the field of photonics (optical design). An important requirement for a successful international collaboration is to install a suitable consortium that consists of the right partners who not only bring in high level research and educational skills but also know how to collaborate successfully in an international environment.

Acknowledgments

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Biography

Irina Livshits graduated in Optical Devices and Spectroscopy from National Research University of Information Technologies, Mechanics and Optics (former named as Leningrad Institute of Fine Mechanics and Optics) with master degree, and got her Doctor of Science degree in 1980. Since 1974 she has been a research scientist at the same University at the department of Theory of Optical Devices. She is presently the Research Director of the Engineering Center OPTICA and the head of Laboratory of CAD of Opto-information and Energy saving Systems at the same university. At the same time she is the Director of Russian-Korean Optical Design Center ITMO-KPU since 2010. Her research interests include imaging and non-imaging optical systems, expert systems and genetic algorithms for optical design, optical design software and opto-electronic computing. Her publications include some total number of 170 articles, about 70 patents, 3 books.

Vladimir Vasilev is the President of the University since 1996, the Head of Department Computer Technologies, graduated from Leningrad Polytechnic University. Got his doctor degree at ITMO. He is the honored worker of a science and high professional education of the Russian Federation. Chairman of All-Russian Interdisciplinary Council of the Optical Industry Development and the Head of Technology platform PHOTONICA, Chairman of All-city Council of rectors of Saint Petersburg, corresponding member of Russian Academy of education and Russian Academy of Sciences. He has over 150 scientific publications and patents. Founder of scientific-educational school "Computer, net and telecommunication technologies"

Paul Urbach is a Professor and Optica Group at Delft University of Technology and project coordinator for SMETHODS and ADOPSYS. He got his PhD from the University of Groningen. Until 2008 he was a principal scientist at Philips Research Laboratories in Eindhoven. In 2000 he became part-time professor Diffraction Optics in the Optics Research Group of TUD and in 2008 he became leader of this group. His main expertise is the electromagnetic modelling of problems of applied optics and diffraction optics in particular. He is the President of the European Optical Society, Member of the Dutch URSI committee, Member of the Advisory Committee of the Dutch Government on metrology and member of the national photonics initiative "IOP Photonic Devices".

Ilya Mimorov is a PhD student at National Research University of Information Technologies, Mechanics and

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Marina Letunovskaya is a PhD student in Optics at National Research University of Information Technologies, Mechanics and Optics, and Project Manager of ADOPSYS at laboratory CAD Opto-Information and Energy Saving Systems, Russian Federation. Her research interests include optical design, new educational technologies.