Photonics education within the framework of electrical engineering program of studies

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ABSTRACT

Except of specialists, dealing with different photonics areas, the education of all technical professionals about basic photonics principles, components, applications and system solutions is necessary. Paper deals with the place of photonics in the basic range of education and also in other facultative subjects developing the basic photonics knowledge to the area of systems solution. Photonics education is carried in the three steps: in electrical engineering subjects, in the facultative subjects and in the professional subjects. Basic professional spheres of electrical engineering student education could be as follows: theory of field, theory of signals, theory of information, electronic signals and systems, and electronic measurements. In Electrical Engineering and Electronics Department we offer two facultative subjects for different professions: Opto-electronics, and Fiber Optics. Both subjects are based on the lectures and also on the laboratory practice.

Keywords: Photonics education, electrical engineering students, opto-electronics, fiber optics, integrated optics.

1. INTRODUCTION

During the last decades of the past century there was beside the rapid development of electronics also to the development of area, connecting branches of electronics and optics. The milestone in this development was invention of laser, development of high-quality optical wave-guides, mainly fibers and mastered production of electronic components for generation and detection of optical radiation.

This new area could be very roughly and simplify characterized so that electron coupling is substituted by photon coupling in components.

More frequently used name Photonics analog to the name Electronics results from this idea. Some estimations of development even indicate 20^{th} century like century of electrons and 21^{th} century like century of photons. In spite of hard estimation of further development during next tens of years, we can receive the characteristics before with fact that electronics and photonics will be affected each other. So for example series of today applied quantum structures in photonics could be applicable in electronics too. In addition today we confuse photonic and pure electronic parts in the systems. However the main contribution of photonics could be qualitative novel accesses to the solution of questions of scanning, transmission and processing of information. For these reasons substitution of electronic coupling by the photonic one is only rough characteristic of photonics.

2. POSITION OF ELECTRICAL ENGINEERING AND ELECTRONICS DEPARTMENT

Department of Electrical Engineering and Electronics belongs to the Faculty of Air Force and Air Defense and covers all basic education of Military electronics program. In present time there is the topical requirement concerning of the new arrangement of educational plans in the sense of extending the general electrical engineering and electronics fundamentals.

The plans of study for Military electronics 5-year engineer, 3-year bachelor and 2-year master program, respectively are given in Tab. 1.

For the case of 5-year study it is possible to see how different subjects are taught in the individual terms, but in the present time with respect to the Bologna declaration we would have to prepare the educational program for fulfillment of the new criteria. This process will be more complicated because of indistinct social order. In the Tab.2 we can find program of 5-year study, where our department guarantees five obligatory subjects and also two facultative subjects covering discussed topics 1.

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The majority of students of Air force and Air Defense Faculty take part in 5-year study program. The electrical engineering and electronics fundamental subjects start in the 3rd term. They are Electronics components and Electrical engineering fundamentals, in the 4th term after that we have Electronics circuits, Electronics measurement and Power electrical engineering. The first two subjects are continuing during the 5th term, too. The general problem is concentration of fundamental electrical engineering subjects during the 2nd academic year. Practically all students of faculty must be passed through our department and lot of educational matter must penetrate into them.

Branch of study⇒ Subject ⇓	5-year program	3-year bachelor program	2-year master program
Sum of hours	4050	2430	2190
Subjects of theoretical fundament	690	360	270
Electrical Engineering fundament	720	540	210
Materials in EE	60	60	-
Technical documents	90	60	-
Electrical Engineering fundamental	120	90	-
Electronics components	90	60	30
Electronics measurements	90	60	30
Electronics circuits	150	90	90
Power electrical engineering	60	60	60
Automated control	60	60	60
Branch profiled subjects	1740	930	1380
Management and social subjects	240	180	150
Military fundament subjects	450	240	120

Tab.1 Educational programs of Military electronics

Subject ⇓	1st year		2nd year		3rd year		4th year		5th year	
Term	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Subjects of theoretical fundament	180	330	120	60						
Engineering fundamentals										
Materials in EE	60									
Technical documents	90									
Electrical Engineering fundamentals			120							
Electronics components			90							
Electronics measurements				30	60					
Theory of circuits				90	60					
Power electrical engineering			30	30						
Automated control				60						
Branch profiled subjects (sum)				60	240	330	300	420	390	
Opto-electronics					30					
Fiber and Integrated Optics						30				
Management and social subjects	30	30	30	30	30	30	30			
Military fundament subjects	90	90	60	90	60	60	60	30	60	

Tab.2 Subjects for 5-year educational program

Military electronics – two-stage program (3-year bachelor and 2-year master) was opened at the Air Force and Air Defense Faculty 4 years ago, but for some professions only. Most of bachelor graduates are continuing the second stage - the master 2-year course. This process is not typical, because the initial idea has been in the sense, that students could continue the 2nd stage after one-year practice. The main problem in this type of educational program we see in variance

between the requirement of some military professional knowledge on one side and the general requirement of wider electrical engineering fundamentals on the other side. There was a compromise received and additional general knowledge is given during the 1st year of the second stage. This way is not optimal and the requirement of compatibility is not fulfilled in the all range.

3. DELIMITATION OF PHOTONICS CONCEPTION

Besides more frequently used notion of photonics we can meet the other names of branches connecting the electrical and optical principles. Electro-optics operates with electric phenomena in optical devices as lasers, electro-optic modulators etc. The term Opto-electronics usually includes area deals with optical phenomena of electron principle. This notion is used also from the end of 60th years for area, which is equivalent with one today delimitated latterly by the notion photonics. We can meet also other terms as quantum electronics dealing with interaction of optical radiation with substance, quantum optics dealing with the study of quantum and coherent properties of optical radiation or technology of optical waves (opto-technology), dealing with questions of optical communication and signal processing.

The branch named photonics or opto-electronics comes from the fundamentals of electronics and optics and covers:

- components and function blocs as basic building stones of all electronic systems;
- systems solving questions of scanning, recording, transmission and processing of information by the methods similar as in the electronics, or in the other side by the complete specific methods.

From the submission of photonics to the electrical engineering study point of view we can see typical commonness of some principles, enabling to place this problems to the basic subjects in one side, or particularity exigent the knowledge overcoming the basic subjects, in the other side.

First of all the area of systems supposes wider integral knowledge, enable finalization of studied problems to the outline of systems solution. Insertion of this part is difficult compatible with concrete subjects of specializations without deeper theoretical fundament. We suppose that this theoretical fundament should be inserted to the basic study and should be deeper and wider then it corresponds to the particular specializations profile. In not last series, the significant role has also laboratory base, which is very sophisticated for photonics by the equipments and also by the experimental experiences. Orientation of research work creates the fundament for development of branch and personal resource.

Based on the common and specific properties of photonics branch and also from its use in systems of today´s technique, mainly in the technology of final school branches point of view, we suppose insertion of photonics in three steps:

- to the fundamental subjects, there is possible to insert the particular problems of photonics, which belong functionally and they not need deeper knowledge, mainly optics;
- in the scope of integral subject to deep knowledge of photonics from the fundamental subjects mainly these, resting about deeper knowledge, for example from area of optics and quantum electronics, and to make integrated view on photonic systems of scanning, transmission and processing of information.
- in the scope of professional subjects, after that to deep obtained pieces of knowledge from the area of photonics in the directions desirable for given specialization.

4. EDUCATION OF PHOTONICS IN THE DEPARTMENT OF ELECTRICAL ENGINEERING AND ELECTRONICS

4.1 Historical view

For assessment of place of photonics in the framework of technical branches and professional preparation of students it is suitable to make a small historical excursion. Electronics and optics have been developed as relative individual branches. Certain break point there was discovery of laser, which enabled qualitative new optical radiation. This evoked an invention to apply this radiation – photon flux for similar operations as were realized electronically – by the electron flux. This led to the development of optical modulators, detectors and systems for different operations with information (record, processing, transmission etc.). In some cases there were technological barriers, corresponding to era. To the important developments, which shift opto-electronics from theoretical considerations to the realization of systems was

development of semiconductor sources and detectors, covering significant area of wavelengths of optical radiation and development of wave-guide structures, mainly fibers. This provided effective connection of opto-electronics with fast evolving area of microelectronics. Opto-electronics, which has grown on the boundaries of optics and electronics, has started to affect as previous classical electronics, as optics. It is possible actually to say today, that some integral branch is growing and will be farther developed, including electronic and optic principles. We can hardly imagine the transmission, scanning, recording, and frequently also processing of information without application of optical principles, on the other side early classical optical principles of imagery, record of picture, its processing and transmission, etc., we can not imagine without the participation of electronic principles. Presented development has reflected also in the education of students of electrical engineering professions. Problems of opto-electronics were inserted step by step to the subjects of classical electronics [2].

4.2 The levels of photonics insertion

At first it was in the area of electronics components, where problems of semiconductor photoelectric components, mainly photodiodes, and light emitting diodes were included. With respect to the scope of subject, there was impossible to insert in sufficient latitude problems of lasers, optical modulators, optical wave-guides and integrated optical circuits. Similar in the other subjects, novel problem for example optical signals, two-dimensional Fourier transform etc. were inserted. But generally there were limits of subject scopes and also insufficient grounding of students in the area of optics, mainly wave, electromagnetic, and photon optics. The new problem was also 2-D space interpretation of signal, its possibilities from the transmission point of view and mathematical methods of decomposition by means of 2-D Fourier transform. For students of electronics in the some sense also the guiding of optical wave in dielectric materials and its connection with imaginations of optics could be problem. There was shown usefulness of complex view on the new branch, going from the specifics of optical signal, from the necessary deepening the knowledge from classical, wave-electromagnetic and photon optics, during the realization of opto-electronic components including wave-guide structures, and opto-electronic systems integrating common pieces of knowledge with specific possibilities of these systems. For this reason the new subject dealing with common problems of opto-electronics including opto-electronic systems named Opto-electronics were inserted to the electrical engineering education program.

Regarding to the specificity of fiber optics and its application in communication and sensor systems the other subject named Fiber Optics was developed. Both these subjects are facultative, educated in two sequential terms. Even if both subjects are partially overlapping each other, our effort is alignment of them, so for the case when an student selects both subjects, he has not the same or similar matter two times, but he obtains theoretical fundament and common view to the level of systems in subject Opto-electronics, and with deeper interest also wider view including practical experience and art of the work with fibers in subject Fiber Optics.

With respect to the insertion of subjects to 3rd year and corresponding knowledge of students we cannot suppose to give the students complex compact knowledge. This goal can't be realized finally neither in the present fast evolving technical world in no branch, nor after graduation of school. We can suppose that students could obtain next knowledge from opto-electronics and fiber optics in professional subjects during 4th and 5th years by the way how these problems will penetrate to the systems and after that by the self study. In this process both subjects can have significant effect of motivation.

Insertion of both subjects to the system of facultative study does not solve the need of sufficient submission of opto-electronics problems to the whole system of study. As we said use of optical principles for scanning, recording, processing and transmission of information is spreading. This process needs also next spreading of optics fundamentals to the early pure electronic subjects. Specializations dealing with optics similar will solve the requirement for wider insertion of electronics with coupling to the opto-electronic solution of tasks from the area of work with signal and information. If we limit our considerations on the electrical engineering only, the requirements on insertion of optic principles fundamentals could be as follows:

Theory of field – fundament is equivalent with theory of RF waves, specified in the possibility of beam generation with small divergence and their propagation through dielectric materials.

Theory of signals – expansion of 2-D signals and their analysis in time and space division, application of quantum principles of detection and generation, signal processing.

Theory of information – basic theory expanded for small power signals with physical limits of communication.

Electronic signals and systems – possibility of some electronics systems principles application to the solution of photonic systems and its coupling to some special photonics subjects.

Measurements – photonic measurement is near rather to the physical measurement than electronic measurement, detection of physical quantities (sensors) based on the interaction of measured quantity with the matter a subsequent influence of optical wave propagation.

Integration of these requirements must correspond to the recent condition of use of opto-electronics in electronic systems, for which students are prepared and also certain estimated perspective for their preparation on the new conception of electronic or rather opto-electronic systems. At the same time untroubled preparation in the main branch of education – electronics, is necessary. This is besides permanent problem, resulting from the growing of knowledge volume, which students need for required preparation on their profession.

Significant problem in the insertion of individual parts opto-electronics to the subjects of electrical engineering we consider need of coordination of this activity. Beside the own individual access of teachers to the development of subject in this spirit, mutual alignment of subjects is important. This could be reached by the coordination of thematic polarization by means of teachers dealing with opto-electronics, and also by the mutual judgment of individual accesses in the department meetings, interchange of opinions, for example by the lectures with disputation etc.

We present further how these accesses are realized in our department, what is our imagination about their realization with next development of photonics.

The first level of photonics fundamental problems is realized by their insertion to the basic subjects. In the subject Electronics components for example, students are familiarized with problems of sources, detectors and optical wave-guides, mainly fibers with the accent to principles of function, their description by characteristics and parameters and application possibilities. Similar in the subject Circuits theory is for photonics applicable part dealing with theory and analysis of signals, which is in the finish extent about problems of 2-D Fourier transform. For area of photonics is doubtless important part of circuit theory dealing with problems of solution of circuits. For example one of the significant questions during the solution of detection systems is tuning of requirement of noise and dynamic properties of detection systems, application of specific integrated circuits as transimpedance amplifiers etc. Very suitable can be also insertion of specific optical measurements to the subject Electronics measurements. It is for example measurement of optical lines, some spectral measurements etc. Unfortunately these practical measurements are very finance demanding and this practical part could be in classical measurements a little bit forcible. In this case the solution can be in special subject, which is next step in the insertion of photonics to electrical engineering study.

The second level of photonics study in the programs of selected electrical engineering professions is solved by means of two facultative subjects: Opto-electronics and Fiber optics. Programs of both subjects are given in the paper too.

The third level of photonics insertion to the study performs solution of actual problems in subjects of branches according professional focus of students. Previous theoretical training gives the possibility to deal with problems of actual existing or perspective systems without possibility of novel basic conceptions and physical apparatus and imaginations about system properties of photonics.

4.3 The facultative subjects of the second level

The subject **Opto-electronics** has wider survey corresponding of whole branch of photonics and it is divided into three parts. In the first part basic view on optical signal inclusive its propagation and interaction with optical medium is summarized from the access of beam, wave, electromagnetic and quantum optics point of view. First of all it is definition of quasi-monochromatic and polychromatic wave and possibilities of their decomposition to monochromatic waves from the time view and plane wave from the space view with the application of Fourier transform in the time and space domain.

Wave character of optical signal is discussed from the possibility of modulation optical wave parameters point of view. Further the conditions pertinent simplification from the standpoints of ray and beam optics, are defined for propagation

of optical wave. Interaction of optical wave with matter is studied from standpoints of electromagnetic optics, especially on the properties as homogeneity, isotropy and dispersion. Fundamental conception of quantum character of optical signal is described, and fluctuation character of such signal with coupling on the quantum or photon noise is explained too. Problems of photon flux interaction with matter are solved in part of opto-electronics components - sources and detectors. Definition of individual views on the optical signal serves for understanding of fundamental phenomena which students can meet in the next part of subject during the description of signal propagation in optical medium, generation and detection.

The second part of subject is given by the description of components and function blocks of opto-electronics, serving for generation, modulation, detection, and guiding of optical signal. The accent is put first of all to the analysis of properties of these components from the quality of realized functions point of view. For the optical sources it is quality of generated radiation, which gives possibility of application of individual types of modulation, for example intensity, frequency, phase, polarization. At the study of optical sources we are going from fundamentals of optical amplifiers. Conditions of inverse population of power levels and basic principle of amplifying in the consequence to parameters and characteristics of amplifiers as its gain and spectral characteristics are explained. Explanation of optical sources goes from the theory of lasers by the introduction of optical feedback in optical amplifier. Main properties of lasers especially influence of longitudinal and transverse modes on spectral characteristics and spatial distribution of laser beam are described. Special attention is paid to the semiconductor sources of radiation with regard on their use in contemporary opto-electronics systems. Their power and spectral characteristics, possibilities of achievement of single-mode and single-frequency regime and structural design for launching of power into optical fiber and optical integrated structure are described. In parts dealing with optical modulators, the fundamentals of electro-optic, magneto-optic and acousto-optic modulators are explained. Main emphasize is focused on the possibility of time modulation, partially also on the possibility of spatial modulation. The spatial modulation in detail is solved in part of optical signal processing.

For the detectors there are questions of sensitivity characteristics with noise, and dynamic characteristics. For optical wave-guides there are their properties affecting mainly the velocity of transmitting information, or specific properties which enable their less usual application for example in sensors. The attention is concerned to the point-detectors e.g. for communication systems and spatial detectors e.g. CCD structures for scanning. For point-detectors, which are typically semiconductor photodiodes, relationship between noise of detector and its dynamic properties and spectral sensitivity is especially solved.

A part dealing with the wave-guide structures is going from common theory of propagation of optical waves in dielectric wave-guides applied a simplification from beam and wave theory point of view. The solution is based on a model, which shall point out distribution of electromagnetic waves in core and cladding (evanescent wave), from standpoints mode distribution and polarization characteristics. Some measuring principles of fundamental optical fiber parameters and examples of optical cable construction are mentioned. Also the possibilities of realization of fiber and integrated optical components as couplers, phase modulators etc. are shown.

The third part of subject deals with the optical systems for information reading, processing and communication. Common principles of these systems are delimited in this part, requirements for individual parts are determined and in the case of communication systems there is chart of frame access to the design of system with required properties.

In part dealing with the communication systems, direct detection system and coherent system are solved. The second one will find application in coherent systems of communication and also in other interferometric systems (e.g. sensor). Regarding to insufficient previous preparations of student's brief summary, some fundamental pieces of knowledge from the transmission theory are introduced and some parameters as SNR, BER, etc. are defined. On the base of that, a common proposal solving system with direct detection either in the relation of power calculation and disperse limitation are explained. In part of coherent systems main attention is concentrated on advantage of this systems in comparison with direct detection, but also on the problems, having to be solved for satisfactory operation, too. A view of systems for homodyne and heterodyne synchronous and asynchronous detection is done in the next part. Lastly summary of contemporary state under development of communication systems and state of art in the area of measurement and standardization is brought out.

The part dealing with optical signal processing methods goes from theoretic fundament of two-dimensional Fourier transform. Some operations with two-dimensional optical signal, its spectral distribution and operation of convolution

and correlation in spectral region are explained. Attention is focused to the methods of spatial modulation and some examples of spatial modulators are introduced. Holographic theory as a recording technique of module and phase of optical wave is described. Besides analog methods of signal processing, based on Fourier transform, some examples of logic components e.g. mainly switches and their space matrix realization e.g. on the holographic principal. The possibilities of nonlinear optical phenomenon utilization at realization of logic optical and opto-electronic components and systems are presented too.

The last part of subject deals with opto-electronic sensors. Main attention is given to the part describing fiber optic sensors, based on the detection of electromagnetic wave intensity and also interferometric and polarization sensors. Some important principles and possibilities of utilization for sensing of physical quantities are described. Encompassment of this problem in relatively short time given by timetable of study, is possible just thanks to the previous parts dealing with optical signal, components and function blocks already from their application in opto-electronics systems point of view.

Theoretical pieces of knowledge students evaluate in the laboratory practice. Laboratory practice take place in special laboratory, which enables realization of measurements on the sources, detectors and optical fibers, in present time also including of spectral measurements and realization of simple communication and sensor systems. The scope of practical training determining by the range of subject, is limited by the severity of experiments. Main themes of practical exercises are as follows: measurement of electro-optical and magneto-optical characteristics, basic manipulation with optical fibers and measurement of attenuation, demonstration of communication system with fiber, evaluation of space filtration principle, and measurement of intensity sensor characteristics. Students are also familiarized with construction of some types of lasers and other optical components necessary for experiments in opto-electronics, informatively also with some results of research work in department. Measurements of semiconductor photodiodes and light emitting diodes is led in the frame of subject Electronics components.

The second subject **Fiber optics** is drawn similar like subject Opto-electronics with difference, that all problems are limited only on the fiber systems. In the first part our focus is given to the theory of optical wave propagation in the fibers, i.e. in dielectric wave-guides, description of fibers, their technology, practical manipulation with fibers and their measurements. All basic parameters of fibers are derived and typical values of all types of fibers are compared. Technological processes are focused on the preparation of different fibers (MM, GI, SM and polarization preserving types), definition of fiber parameters (attenuation, dispersion) and different types of optical cables and connectors. Measurement of individual important parameters, as attenuation, numerical aperture, cut-off frequency, and also four pole matrix parameters (Stokes parameters and Jones matrix) is also described.

The second part deals with optical components for generation, detection with accent on their application in fiber optics and also with integrated structures, used as function blocks of fiber systems. They are mainly fiber attenuators, couplers, polarizers, and filters, fiber Bragg gratings, fiber isolators, circulators, phase modulators and also GRIN lenses.

The third part deals with fiber communication and sensor systems and perspectives of fiber systems in the area of communication and signal processing. Chapter dealing with communication systems solve analog and digital systems and difference in the composition of components of transmitter and detector sides. The basic parameters of communication link are defined with fundamentals of coding and multiplexing in this chapter together with architecture and hierarchy of optical networks.

The last part deals with fiber amplifiers, fiber coherent links, different types of modulation and detection, and also DWDM systems. Chapter dealing with the sensors is subdivided into two parts: analog and phase (interferometric) sensors. In the analog part, sensors with variation of attenuation, transmission, reflection, boundary conditions of propagation, mutual coupling of fibers are explained. In the phase part, sensors based on the Mach-Zehnder, Michelson and Sagnac interferometer and principals of signal processing are presented. There are also sensors based on the Faraday effect and typical structure of chemical sensor.

Laboratory base enables modeling and evaluation of these systems. In the first exercise students prepare ends of fiber and measure numerical aperture and attenuation by the two lengths method. In second exercise students familiarize with launching of power to fiber from LED and LD with application of GRIN lenses, and also from He-Ne laser with suitable coupler applied microscope objective. The forth exercise solve evaluation and measurement of different analog

sensors for measurement of pressure, level of water, and position. The last exercise deals with communication fiber links and students evaluate quality of link, frequency characteristic of one type and composition of digital link.

Time structure of both subjects is as follows:

OPTO-ELECTRONICS

Facultative subject: 30h (Lectures – 24h, Practice – 6h)

1.	Optical signal	L 2
2.	Propagation of optical signal in the optical media	L 2
3.	Optical sources	L 2
4.	Optical modulators	L 2
5.	Optical detectors	L 2
6.	Measurement of optical components	P 2
7.	Optical fibers	L 2
8.	Integrated optical structures	L 2
9.	Optical fibers measurement	P 2
10.	Optical communication systems	L 2
11.	Fiber communication systems	L 2
12.	Optical systems for information processing	L 2
13.	Optical memories and computers	L 2
14.	Optical sensors	L 2
15.	Optical systems	P 2

FIBER OPTICS

Facultative subject: 30h (Lectures – 22h, Practice – 8h)

1.	Theory of wave propagation and mode structure of fiber	L 2
2.	Types of fibers and their parameters	L 2
3.	Technology of fiber manufacturing and manipulation with the optical fibers and cables	L 2
4.	Measurement of optical fiber parameters	L 2
5.	Manipulation with fibers and measurement of their parameters	P 2
6.	Optical sources and their coupling with the fiber	L 2
7.	Photo-detectors for fiber systems	L 2
8.	Fiber components and planar structures	L 2
9.	Launching of optical power to the fiber	P 2
10.	Fiber amplitude sensors	L 2
11.	Fiber phase sensors	L 2
12.	Fiber sensors measurement	P 2
13.	Fiber communication systems	L 2
14.	Perspectives of fiber systems in the area of communication and signal processing	L 2
15.	Measurement of fiber communication systems	P 2

Both subjects are based also on the results of research work and investigation made in the last period on the area of fibers, mainly the measurements and modeling of their parameters in the Jones matrices form, polarization properties, evaluation of rare earth doped fibers, fiber sensors applied Faraday effect and other different types for detection of mechanical quantities and chemical agents. Other investigation dealt with decomposition of Jones matrix parameters on the quaternions field [3], evaluation of torsion affect on fibers parameters [4] and its combination with measured quantity.

5. CONCLUSIONS

We can summarize the basic arguments for given approach. Photonics is first of all multidisciplinary branch, expectant beside the supposed knowledge of electronics also knowledge of optics, quantum physics, modern technologies and deeper knowledge of some parts of mathematics. For these facts introduction of such integrated subject enabling deeper knowledge of fundamentals and making complex view on photonics seems to be efficient. With respect to the

importance of optical fiber systems it is suitable for students with interest of special knowledge from fiber technology to offer alternative subject focused to the fiber optics. Suitability of these two subjects could be seen in fact, that involve as possible the whole area, so also problems of photonics, which students must not meet in final subjects of individual branches, but which can be important for their view and next possible practice. Knowledge obtained in these subjects can be raised in special subjects dealing with the principles of different parts of military electronic equipments, according of individual branches of study.

Presented model is evaluated by the three years experience, where was at first evaluated abilities of students to accept lectures, suitability of extent and also sequences on the other subjects were create. The subjects are finished by classified credits, realized by the individual works of students and laboratory results. Students have available textbooks for both subjects [5, 6] and also laboratory practice manual [7], written by the department teachers.

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