

Ten years of optical communications laboratories in the Institute of Electronics and Telecommunications, Poznan University of Technology, Poland

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ABSTRACT

For thirty years, the Institute of Electronics and Telecommunication has been teaching students in the field of telecommunications. In the academic year 1990/91, a course in optical communications was introduced. Currently, within electronics and telecommunication programmes, we offer an undergraduate course entitled: Optotelecommunications, two courses for master level specialities: Optical Networks and Advanced Fiber Optic Systems, and finally, a course for extramural students. We also provide lab projects for Computer Science and Electrotechnics students and contribute to continuous education training. Over the last ten years, a number of students participating in our laboratories has increased seven times. At present, we have two laboratories, offering 40 projects, which fall into 5 categories: basics projects, fundamental projects, applied projects, advanced projects, optical systems. Such a variety of topics allows to offer a flexible choice to suit individual student interests.

Keywords: optical fibers, optical communication systems.

1. INTRODUCTION

Last century witnessed an extensive development of science and technology. Practical achievements of the second half of the twentieth century basing on the solid state physics and, in particular, on microelectronics and optoelectronics boosted growth of telecommunications and information technology. In 1970, the era of optical communications began, and soon, optical fibers became the principal transmission media in use. New technologies required varied strategies in the field of education.

In the mid 80-ties, in the Institute of Electronics and Telecommunications (IET), Electrical Engineering Faculty, Poznan University of Technology (PUT) a decision to introduce a course in optical fiber communications was made. The courses were addressed to both regular students, people interested in professional training courses and continuous education students. Since the early 90-ties, beside lectures, IET started offering laboratory projects in order that students acquire practical skills and deepen their knowledge.

The first optical fibre laboratory offered very basic projects for students. Gradually, new equipment was gathered and more advanced projects were being introduced. Quick growth in the laboratory potential was basically due to IET's participation in EU Tempus projects, which strategic aim was to adjust the quality of teaching process to this in European Union universities. Tempus projects enabled close cooperation with foreign partners, mutual exchange of experience, and purchase of laboratory equipment. Following a further growth of optical fibre technology, in the years of 1996–98 a new advanced optical fibre laboratory was built. In the meantime, other institutes and faculties were getting interested in our laboratory projects. We also introduced fiber optic communication courses for extramural students, and for students in new branches of PUT, Ph. D studies were started.

The following table shows courses for students of different specialisations and faculties supported by optical fibre laboratory.

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STUDY FIELD	YEAR	SPECIALITY	COURSE
Electronics and Telecommunications	II, BSc	All IET specialities	Optocommunications
Electronics and Telecommunications	V, MSc	Information Transport Networks	Optical Networks
Electronics and Telecommunications	V, MSc	Telecommunication	Fiber Optic Communication Systems
Electronics and Telecommunications	IV, BSc	Telecommunication	Optocommunications
Computer Science	V, MSc	Computer Networks and Distributed Systems	Telecommunications Networks
Electrical Engineering	V, MSc	Electronics Instrumentation and Measuring Systems	Optoelectronics
Telecommunications	Contin. Education	Multimedia	Introduction to Fiber Communications

Fig. 1: Courses in the area of optical communication offered by the Institute of Electronics and Telecommunications, PUT.

At the same time , over the period of ten years the number of students in our laboratories increased by 7 times.

Clearly, projects carried out within various courses are diversified. The most expanded and advanced program in optical communications is offered for the students of Electronics and Telecommunications. Second year students of this study field take part in a two-semester Optocommunications course. Optical fibre communications courses are run for two specialities at the M.Sc. stage. Information Transport Networks students are offered a course Optical Fibre Networks, whereas Telecommunication Systems students can choose to participate in “Advanced Optical Fibre Systems”. All the above courses, beside lectures and classes, include laboratory projects.

Now, we would like to focus on the presentation of optical fibre projects, putting aside programs carried out within particular courses.

2. LABORATORY PROJECTS DESCRIPTION

Projects carried out in optical telecommunications laboratories serve as a testing field where students have to apply their theoretical knowledge acquired at lectures and classes and gain an understanding of the operation of the recent fiber technology tools. At the same time, students should attain the skill to handle optical elements, get acquainted with principles of operation and managing typical professional equipment. They are also expected to familiarise themselves with measurement methods. And finally, they should get abilities and confidence in identifying and solving practical problems.

At present, the laboratory offers about 40 projects. The subjects formally go to 5 categories and are as follows:

Basic laboratory projects

handling fibers, fiber and connector geometry, measuring attenuation: cutback method, measuring attenuation by insertion, numerical aperture, loss by connection, coupler parameters, WDM couplers, measuring the power $P=f(I)$ curve for a LED, measuring the power $P=f(I)$ curve for a laser diode, measuring the multiplication index $M=f(V_r)$ curve for an avalanche photodiode, investigation of Fabry-Perot tunable filter.

Fundamental projects

Fabry-Perot resonator, backscattering technique, mode properties of optical fibers, integrated modulator, Mach-Zehnder modulator, phase modulator, acousto-optic modulator, investigation of LED and LD spectrum, EDFA, EDFL.

Applied projects

fiber attenuation, splicing fibers, OTDR, investigating fiber link by an OTDR, optical spectrum analyser, LD controller.

Optical systems

investigating fiber transmitter, investigating fiber receiver, digital fiber transmission system, WDM analog fiber system, EDFA – WDM systems, coherent detection, coherent communications.

Advanced projects

semiconductor diode laser characterisation, effects of reflections on diode lasers, coherence properties of semiconductor laser sources, characterisation of fiber 3dB couplers, polarimetric sensors, single-mode interferometric sensors.

Computer experiments

EDFA: properties, optimisation and configurations, EDFA/WDM systems, fiber lasers.

Computer experiments form a separate group and complete existing hands-on experiments. An evident advantage of this type of exercise is a high flexibility enabling multi-option investigation, which is difficult, if not impossible with traditional methods.

To carry out the projects, we use both commercial educational sets SVFO Pirelli¹ and Newport² and projects designed by IET staff. In our laboratories we also have the following equipment: optical power meters, optical sources, fusion splicers, OTDR, F-P spectrum analyser, laser diode controller, digital network analyser, A-O cell and opto-mechanical sets. Additionally, we have an access to unutilised university campus network fibers. Thanks to our cooperation with Poznan Metropolitan Computer Network, the students can carry out projects basing on currently applied technologies and equipment. In the nearest future, we are going to use municipal optical fibre CATV networks for educational purposes.

Our up-to-now experience proves that the majority of students have had no practical contact with fibres or fibre cables. Accordingly, first classes are devoted to preparation of cables and optical fibres, microscope observation of quality of cuts and geometry of various fibres. Another important step is to understand and learn techniques of effective coupling of fibres with different sources of light. And here, using HeNe laser students have a possibility for direct observation of a phenomenon of waveguiding, scattering on heterogeneity, light leakage on fiber band or geometry of an output beam. Subsequent exercises deal with mode properties of fibres which can be also carried out in visible light. The possible results of field distribution is shown in Fig.2.

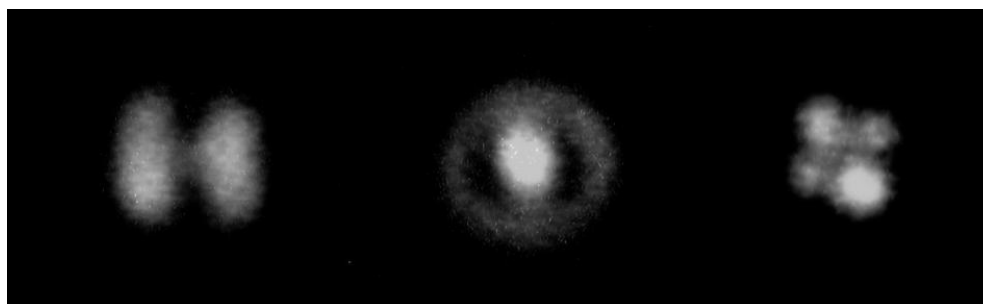


Fig. 2: An illustration of field configurations for LP_{11} , LP_{02} and LP_{21} modes.

Another group of exercises aim at pointing out losses occurring in fibres, connection losses, and losses brought by couplers. Fibre attenuation measurements are carried out by the end-to-end testing, the cutback method, and with OTDR. In the latter case, students build their own reflectometer with separate functional modules in order to learn the method and encounter measurement problems (Fig. 3). They are also expected to comment on the results. Later, they investigate properties of the optical fibre cable installed in real urban conditions using professional equipment.

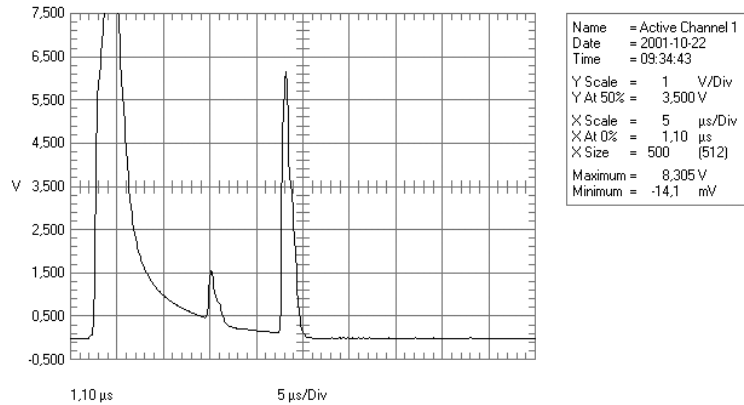


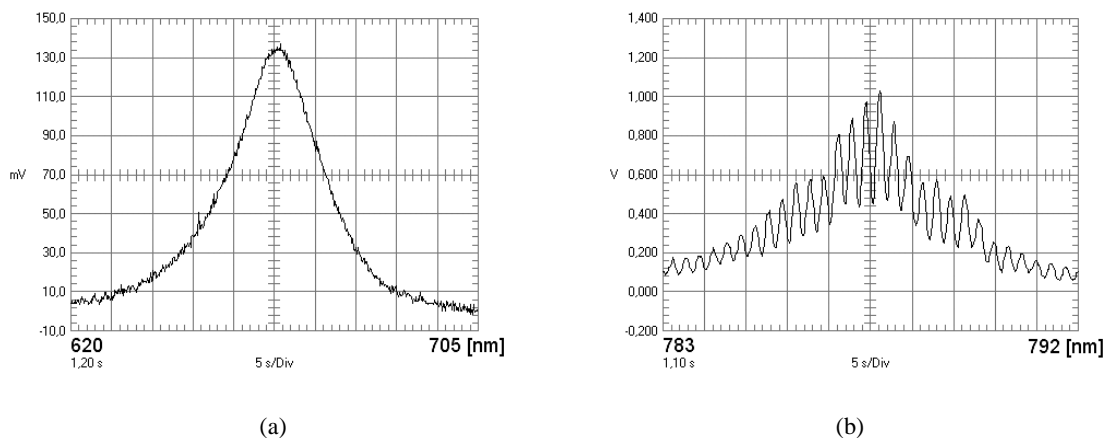
Fig. 3: An illustration of backscatter plot, reflection from joint and Fresnel end reflection.

A similar methodical approach was applied in case of projects connected with optical fibre splicing. Initially, students get acquainted with technology of splicing and methods of measuring splicing attenuation on an entirely manual, old-fashioned fusion splicer. At this stage, you can meet all the problems connected with a precise fibre alignment, both in multi and single modes, and how the preparation of fibres and splicing parameters influences the final result. A further step could be learning to operate a modern, entirely automatic splicer.

Numerous exercises are devoted to researching different types of light sources. At the first stage, when students lack experience, they use sources in the range of visible light. Next, as soon as they have acquired methods and worked out habits, they are ready to use infra-red sources. In the course of the projects, they start with measuring properties of LEDs, HeNe lasers, F-P and DBF semiconductor lasers, DFB MQW pump laser and advanced modules meant for contemporary DWDM systems, and finish with assembling the ring EDFL laser. Research of basic electro-optic properties and more advanced examination of coherence and spectral characteristics are carried out. Measuring spectral characteristics belongs to the most significant procedures in optical fibre technology. As in case of OTDR or splicing projects, the first step is to present students with various measuring methods and then, they learn the properties of professional equipment and how to operate it.

Subsequently, one of the projects is devoted to investigating properties of the F-P resonator and the problems of its application to spectral analysis. Moreover, F-P analysers and filters of different parameters are also used as measuring tools in some other projects.

Figure 4 shows a possible LED spectrum and spectrum of a F-P laser operating at threshold point at the optimum current, and deformed by direct modulation measured by a grating monochromator.



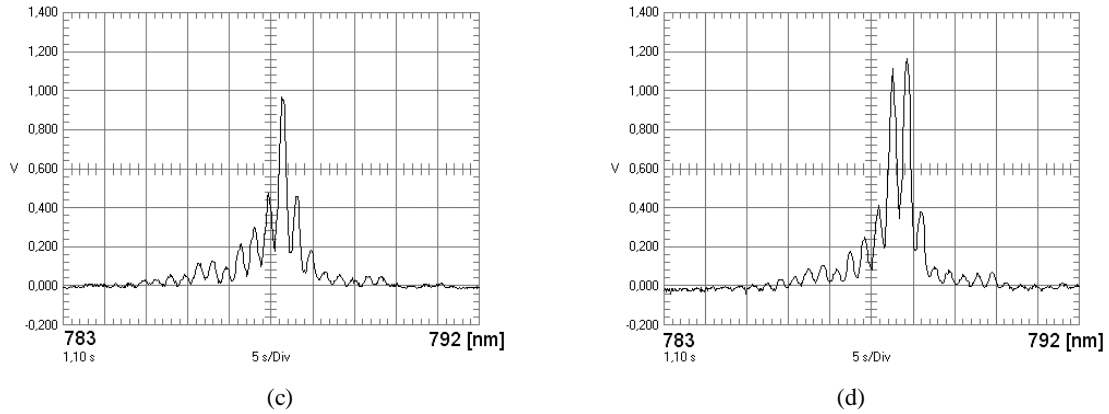
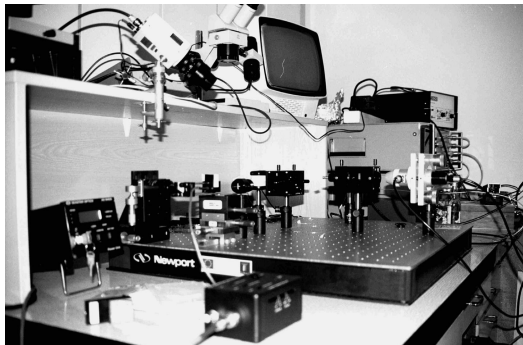
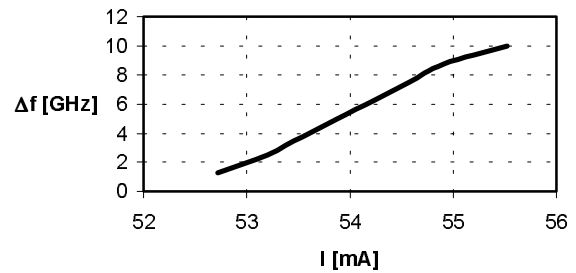


Fig. 4: Output spectra: a) LED, b) F-P LD operating at threshold current, c) F-P LD at optimum operating point, d) modulated F-P LD.

In other exercise, students build Michelson interferometer and investigate the influence of the laser current on the output frequency (Fig. 5).



(a)



(b)

Fig. 5: A Michelson interferometer: a) laboratory set-up, b) influence of LD current on output frequency.

Other possibilities of carrying out spectral analysis are highlighted when carrying out investigation of an A-O cell, especially in case of integrated optical technology and SAW applications. In the exercise devoted to the A-O modulator, students examine Bragg's diffraction effect and ways of its application in intensity and frequency modulators, in deflectors and frequency shifters (Fig. 6). Bragg's A-O cell is also used in the coherent system and in the original HDWDM system.

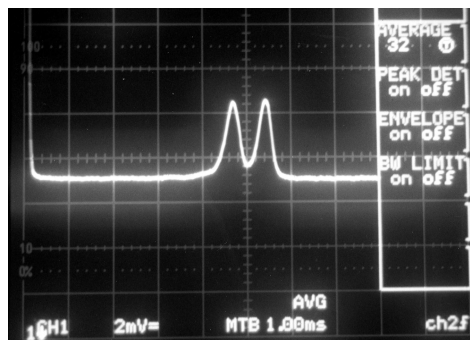


Fig. 6: Output spectrum of A-O shifter with 50% efficiency.

In other exercises, students can investigate the integrated modulator, phase modulator and M-Z modulator (Fig.7).

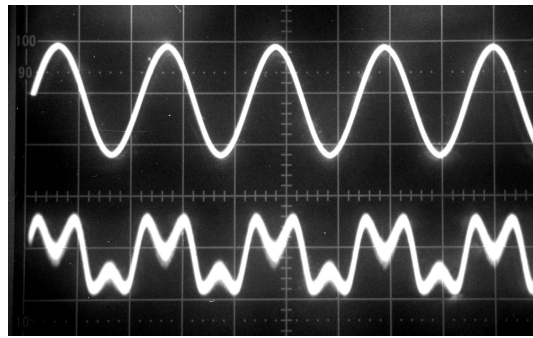


Fig. 7: An illustration of nonlinear distortion observed in fiber M-Z modulator.

Getting to know fibre properties of active and passive elements makes it possible to carry out exercises depicting operation of optical fibre systems. Here, students start from determining basic properties of optical fiber transmitters and receivers, a digital transmission optical fibre system, and a simple WDM system. Following that, they study the technology of optical amplifiers and carry out research of their basic properties such as: gain, ASE and transient response (Fig. 8). Additionally, a structure of a ring laser with EDF is examined.

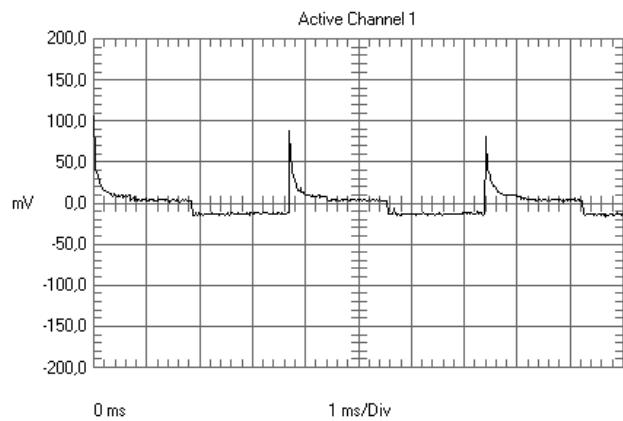


Fig. 8: Transient response of EDFA.

Successive experiments focus on measuring properties of the DWDM/EDFA system, with special regard to methods of power control in case of a variable number of channels (Fig. 9-11).

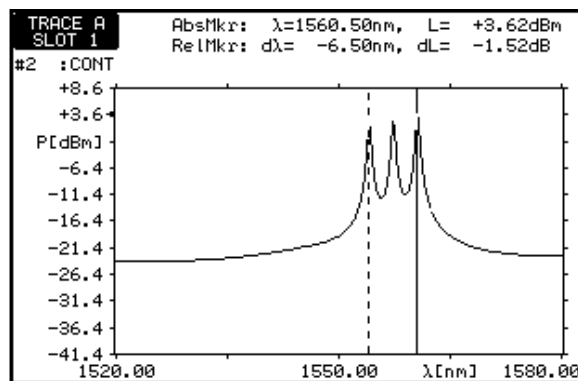
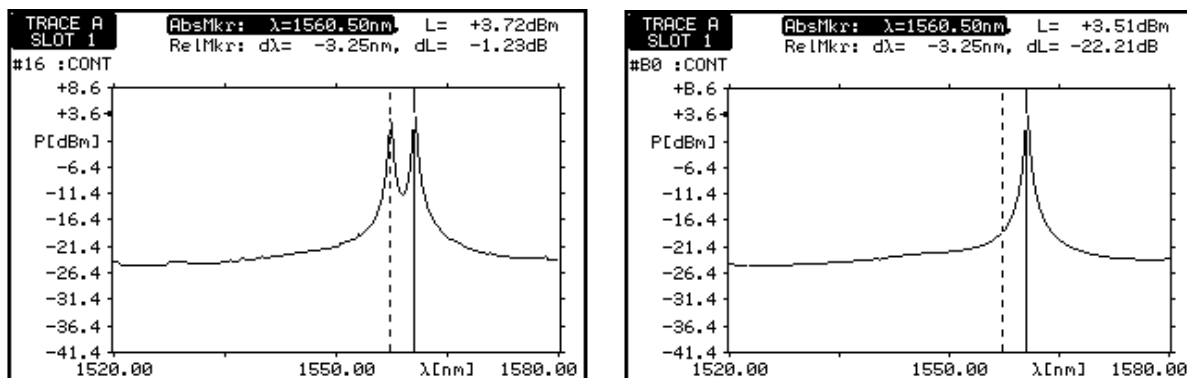


Fig. 9: Spectrum of amplified WDM signal.



(a)

(b)

Fig. 10: An illustration of channel power stabilisation.

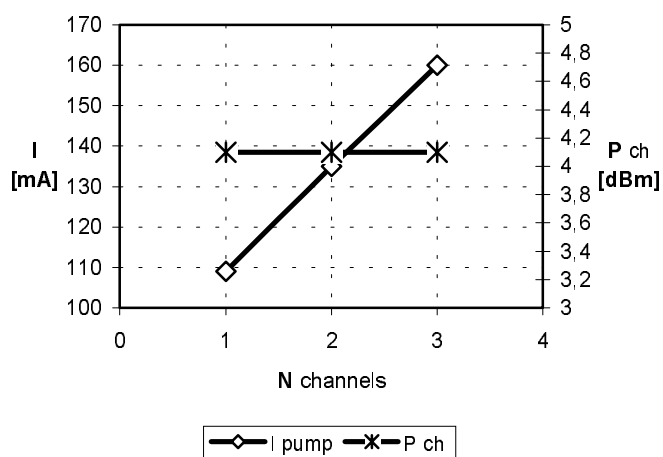
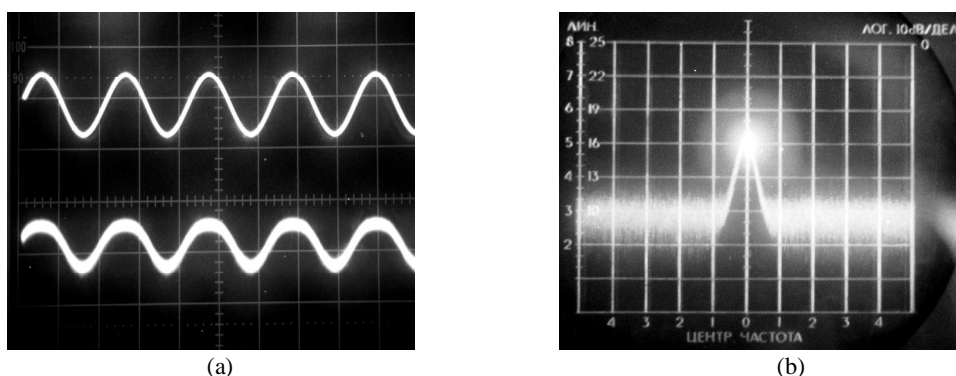


Fig. 11: Stabilisation of output channel power by varying pump laser current.

A coherent system model is probably the most complex structure, requiring a lot of experience and skills. As the time of classes is limited, students focus on some selected parts of the project (Fig. 12).



(a)

(b)

Fig. 12: Coherent detection a) homodyne: input and output signals, b) heterodyne: IF RF spectrum.

Laboratory projects on amplifiers and systems are accompanied by simulation exercises carried out using professional simulation software. On one hand, the exercises allow to compare experimental and numeric results, and on the other, enable examining a wide range of systems and carrying out their optimisation (Fig. 13).

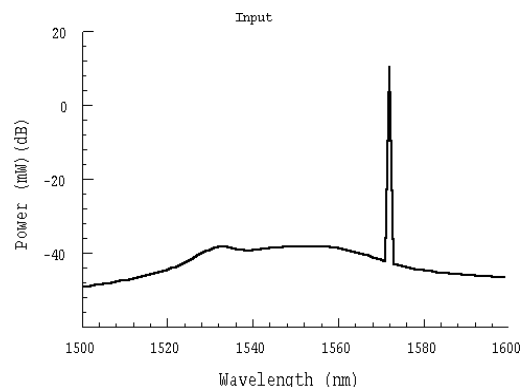
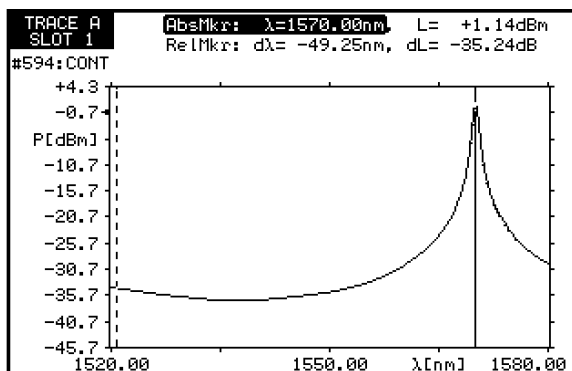
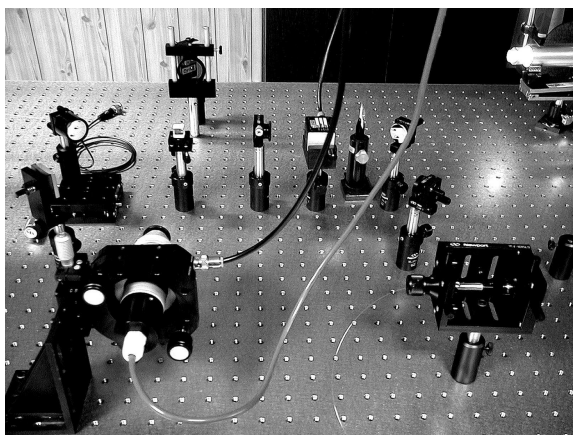
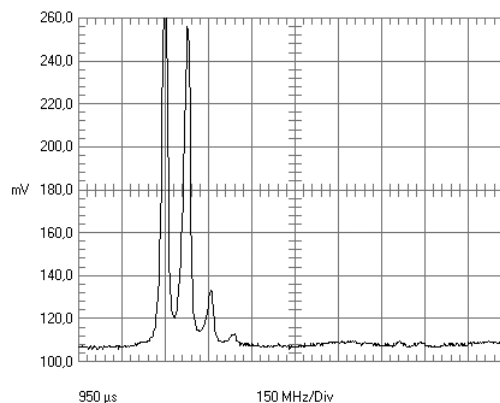


Fig. 13: Comparison of the measured (a) and calculated (b) EDFL spectra.

Diploma and Ph. D. students most frequently focus on the subjects connected with the research carried out by the staff. As an example, we show an original set of a multi-wave source for DWDM system (Fig. 14).



(a)



(b)

Fig. 14: Multichannel DWDM source a) laboratory set-up, b) output spectra.

3. CONCLUSIONS

In this work, we presented information about courses in optotelecommunication run at Institute of Electronics and Telecommunications, Poznan University of Technology for students of various faculties and specialities. Exercises offered to students were listed and selected groups of laboratory classes were discussed. Currently, we are focusing on developing interactive tutorials and experiments.

REFERENCES

1. J. Froment, *Eduoptic*, SVFO, Poissy, 1987
2. Newport's technical staff, *Projects in Single Mode Fiber Optics*, Application Workbook, 1993