

Undergraduate and graduate study in optics
at Czech Technical University

Vaclav Sochor

Czech Technical University, Faculty of Nuclear Science
and Physical Eng., 115 19 Prague 1, CSFR

ABSTRACT

Present curriculum of optics education at undergraduate and graduate level at Czech Technical University in Prague namely at the Faculty of Nuclear Science and Physical Engineering is reviewed. Syllabuses of basic and special lectures as well as laboratory tasks and demonstrations are discussed. Following questions are examined - what optics related topics should be implemented into current courses? what new courses should be developed? how the effectiveness of educational process should be increased? Answers to these questions are suggested in the paper.

2. CORE LECTURES IN OPTICS

Optics traditionally has been concerned with systems and devices using light rays /incoherent/. These picture of optics changed dramatically with the invention of a laser - source of coherent light. Spectral area of interest in optics has been extended from far infrared to vacuum ultraviolet recently even to X ray region. If previously an optical engineer has been sufficiently equipped by knowledge of geometrical optics and to some extent by simplified wave theory and knowledge of light propagation in mainly isotropic media, presently he should display knowledge of complete wave theory, basic quantum theory of light and light propagation in isotropic as well as anisotropic and dispersive media. Since 1960 new fields of optics emerged and should be covered in the lectures:

laser physics-which studies laser as a new instrument and investigates its characteristics and different regime of performance

coherent optics-which investigates propagation of coherent beams, their spatial and temporal characteristics as coherence, interference and propagation in different media

holography-establishes itself as a new branch of optics with many applications in different fields,

nonlinear optics-which investigates nonlinear response of optical medium to high intensity light beams,

fibre and integrated optics-studies propagation of optical beams or waves in guiding structures.

What core courses should an optical engineer absolve to be able to work creatively in one of these fields?

Electrodynamics- with emphasis on following topics: Maxwell eq. of classical electromagnetic field, theory of wave propagation, diffraction and interference, laws of refraction and reflection of waves, critical angle, Brewster angle, propagation in nonlinear media, guidance of optical waves in planar and circular dielectric waveguides.¹

Electronics- basic electronics elements and circuits with special attention to semiconductor elements, photodetectors, light emitting diodes, laser drivers, measurement of short impulses.

Laser physics and technique-lectures provide an overview of different types of lasers, their operational regimes, spatial and temporal characteristics of generated radiation, different theoretical models of laser /classical, semiclassical, quantum mechanical.²

What are possible electives which extend student's knowledge?

Optoelectronics-the core of this course is devoted to propagation of light waves in anisotropic media e.g. uniaxial and biaxial crystals and to the problem of birefringence. Electrooptic effect /linear, quadratic/ is discussed in detail as well as electrooptic devices, deflection and bistability. Stimulated effects e.g. scattering, induced birefringence are briefly mentioned.^{4,5}

Laser physics and technique-lecture provides an overview of different types of lasers, their operational regimes, spatial and temporal characteristics of generated radiation, treats different theoretical models of a laser, classical rate eq., semiclassical and quantum mechanical model.^{6,7}

2.1 Electives extending students knowledge

Interaction of radiation with matter- which deals with the problem of radiation - matter interaction in details: absorption and emission of light, theory of linewidth, light scattering and resonance fluorescence which may serve as an introduction to the laser spectroscopy.³

Fibre and integrated optics-treats polarization of the medium and its permittivity, second harmonics generation, mode synchronization, propagation of ordinary and extraordinary waves, parametric three wave interaction, beam self-focustion and phase conjugation, stimulated light scattering, steady state and transient scattering, stimulated Raman and Brillouin scattering.⁸

2.2 Undergraduate study improvement

In recent year new student laboratory of laser physics and technique was set up based on the use of Multipurpose Educational Laser Kit /MUL-1/ purchased from Leningrad Institute of Fine Mechanics and Optics /LITMO/ and extended by few laboratory tasks covering gas lasers and fibre optics. Students working in this lab have possibility to experiment with different types of lasers /gas, solid-state, dye/, to measure spatial

and temporal laser beam characteristics, to investigate main characteristics of nonlinear crystals and adjust them for second harmonics generation. They are introduced to the basic principles of laser spectroscopy and holography /see Table 1 and Fig.1/. Further extension of the laboratory will be aimed on tasks in integrated optics /planar waveguides, microoptics elements, electrooptics switches/. Support in this field of Institute of Radio- and Electronics of Czechoslovak Academy of Sciences is expected. Holography tasks will be extended by HOE characteristics measurement /see Table 1 and Fig.1/.

3. GRADUATE STUDIES

Graduate study leading to the scientific degree of Candidate of Science /which is considered to be equivalent to the PhD degree/ has been organised in the field of Quantum Electronics and Optics and in the field of Optoelectronics. Study has been planned for three years with possible extension for one year. Graduate student working for PhD is attached usually to senior educational or scientific worker who serves as his supervisor. Study is usually divided into three periods:

First year- is devoted to the introduction to general scientific problem, study and examination in foreign languages and introduction to laboratory work. Knowledge of mathematics and physics may be improved by taking special courses organized by the Department of Mathematics / see Table 3/.

Second year- student is occupied by studying special topics selected by supervisor in connection with proposed PhD. theses. Recommended special lectures organized by Dept. of Physics may be taken /see Table ../. This period is finished by examination in Mathematics and Physics and by submitting introductory part of PhD. theses to examination committee. Successful passing of this examination is considered to be equivalent to MSc. degree /usually not awarded/.

Third year- /and four respectively/ is fully devoted to the scientific and research work and is completed by submitting and defence of PhD. theses for what a committee of respectful scientists is established. The theses are accepted for public defence if at least two of three referees respond positively. After the defence procedure student is awarded a title of Candidate of Sciences /either in Mathematics and Physics or in Technical Sciences/ by the University Scientific Council. Described procedure is at present time converted to the standard of PhD studies at west-European universities. The successful student will be in the future awarded the title of doctor /Dr. Ing./

3.1 Improvement of graduate studies

The lack of scientific and educational contact with European universities should be overcome. Students should have possibility to visit different laboratories, fulfil part of their work there, to present and confront their results and ideas with unknown auditorium and to pursue their knowledge of foreign languages.

Having this idea in mind last year a Joint European Project entitled "Enhancement of Modern Optics Engineering in University Education" has been proposed in the frame of TEMPUS Programme /Trans-European Mobility

Scheme for University Studies/,supported by EC countries.Intensive cooperation in the field of optic education, exchange of students and lecturers,organization of topical seminars between Czechoslovak Universities /Technical University Prague, Palacky Univ. Olomouc, Komensky Univ.Bratislava/ and west-European Universities /Katholieke Univ.Leuven, Univ,degli Studi Lecce and Aquilla, Queens Univ.Belfast,Imperial College London, Tech. Hochschule Darmstadt/ is envisioned. The proposal is at present time under consideration at the TEMPUS main office in Brussel.

4.BACHELOR STUDIES IN OPTICS

New programs of Bachelor studies in Optics has been launched recently in the Department of Physical Electronics.Duration of the study is three years with emphasis on university physics and mathematics,two foreign languages,computers science , programming and management topics.

The course entitled "*Laser technique and technology*" is devoted to experimental work with different types of lasers and optical components as well as to introduction of new laser technologies e.g. material cutting,welding,treating,laser printing and scribing,laser lithography and application of lasers in different areas as medecine,measurement technique,nondestructive and distance diagnostics,applications in civil engineering.

The course "*Optoelectronics*"deals with modern optics and electronics elements , circuits and nets,to the laboratory work with coherent and incoherent light sources,elements of optical communication and fibre sensors.Students of both courses will be trained for high-level servicing,managering and possibly for bussines.

5.REFERENCES

- 1.G.Loncar,"Elektrodynamika",CVUT Publ.House,Prague,1990
- 2.V.Sochor,"Lectures in Quantum Electronics",CVUT Publ.House, Prague,1982
- 3.L.Pina,"Lectures in Quant.Electronics,CVUT Publ.House,Prague 1991
- 4.J.Wilson,J.F.B.Haukes,"Optoelectronics:An Introduction",Prentice Hall Internat.,London,1983
- 5.A.Yariv,P.Yeh,"Opt.waves in crystals",Wiley Intersci.Publ., New York,1984.
- 6.W.L.Lamb,"Laser Physics", Academic Press,N.Y.,1969.
- 7.R.Loudon,"The Quant.heory of Light",Clarendon Press,Oxford,1973
- 8.M.Adams,"An Introduction to opt.waveguides",J.Wiley,N.Y.,1981

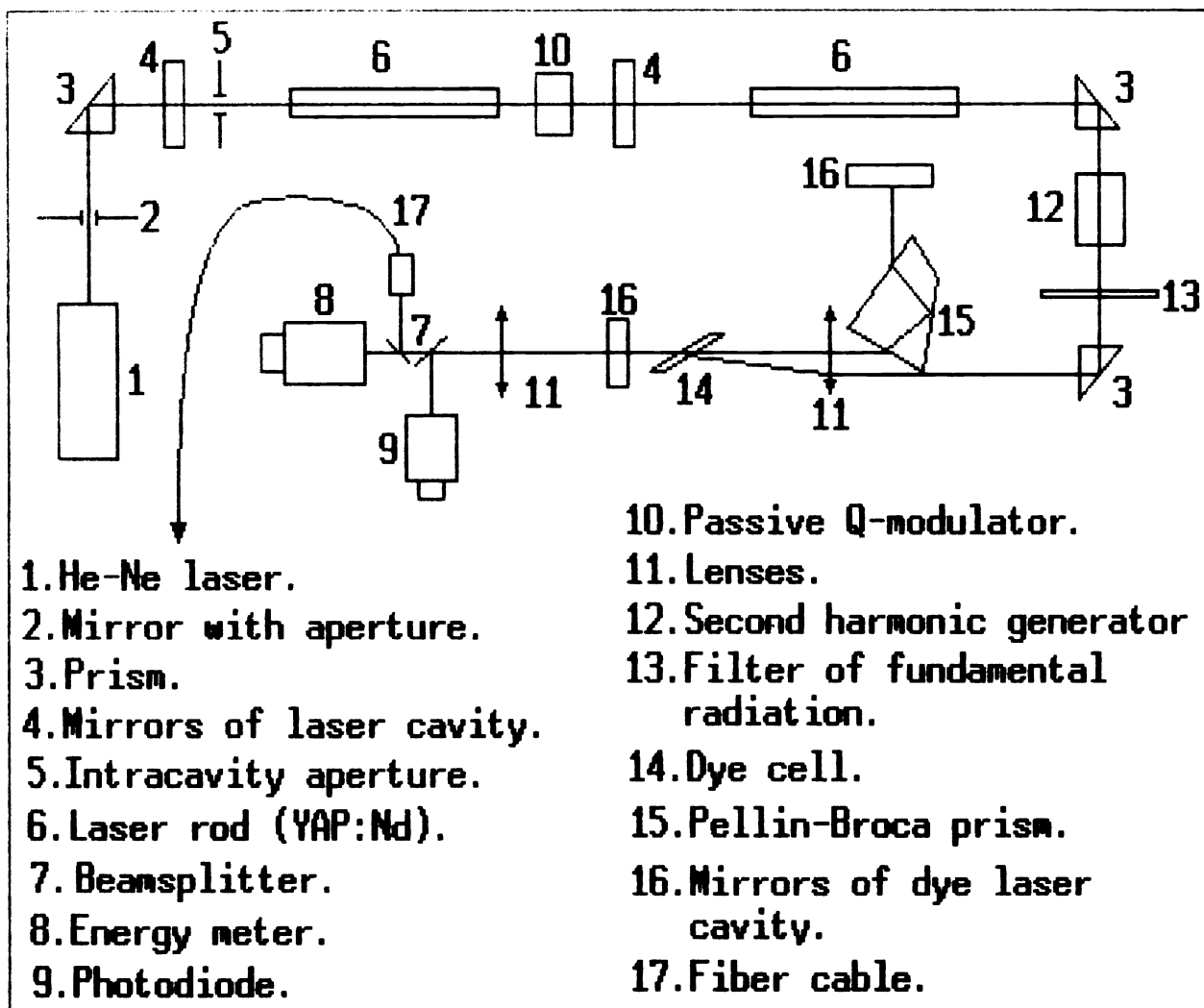


Fig.1. Principal arrangement of Multipurpose Educational Laser Kit (MUL-1).

Quantum Electronics and Optics Laboratory

- Task No.1: Measurement of laser beam coherence properties, spatial coherence, visibility of interference pattern
- Task No.2: Laser beam optics, intensity profile and focusation
- Task No.3: Laser resonator, adjustment of mirrors and inside elements, influence of misalignment on laser beam characteristics
- Task No.4: Laser regime of free oscillations, radiation output time dependence, measurement of generated power and its dependence on losses and pumping power
- Task No.5: Q modulated solid-state laser, obtaining of gigant pulse generation using passive switch, power and time characteristics of generated pulse
- Task No.6: Laser solid-state amplifier, amplification of free running pulses, amplification of gigant pulses
- Task No.7: Laser mode synchronization, mode synchronization by means of saturable absorber, time measurement of pulse duration
- Task No.8: Nonlinear optics, second harmonics generation, adjustment of synchronization angle, SHG in different regime of laser operation /free running, Q-switching, mode synchronization
- Task No.9: Dye laser, elements adjustment, measurements of power, time and spectral characteristics, choice and dye density optimalization
- Task No.10: Polarization of light, measurement of polarization state use of phase retardation elements, measurement of elliptically polarized light
- Task No.11: Discharge characteristics of gas laser, measurement of discharge start-up voltage, time development of discharge voltage and current, current dependence of generated power
- Task No.12: TEA CO₂ laser marking, adjustment of optical system, measurement of marking threshold energy for different materials

- Task No.13: Fibre optics, beam coupling into the fibre of different characteristics, measurement of fibre attenuation and of numerical aperture
- Task No.14: Diffraction of coherent radiation, measurement of laser beam wavelength by means of its diffraction at optical grating with large grid parameter
- Task No.15: Lifetime measurement of excited doppants in optical fibre, measurement of doppants induced fluorescence and its time development stimulated by YAG SHG beam
- Task No.16: Holographic recording and restoration, creation of transmission and phase holograms and simple holographic elements /HOE/

Table 1. Survey of Quantum Electronics and Optics laboratory tasks.

Quantum Electronics and Optics Tutorial and Demo Programs
--

Laser free running regime

Laser Q-switching

Mode locking

Photon statistics of coherent and noncoherent light

Laser system design

Optical system design

Laser amplifier

Single-pulse solid-state laser

Coherently pumped laser

Table 2. Survey of tutorial and demonstration programs in Quantum Electronics and Optics.

Lectures in Physics and Mathematics for PhD.students
--

Overview of University Mathematics - algebra, matrixes, differential eq.
analyses of complex variables,
numerical computational methods

Group theory and application - introduction to the group theory, group
representation, applications in theoretical
mathematics and solid state physics

Numerical comp.methods - differential methods, variational methods,
solution of integral equations

Soliton solution of nonlinear equations - Korteweg-deVries eq., sine-
Gordon eq., nonlinear Schroedinger eq.

Mathematical statistics - method Monte Carlo, solution of eq.systems,
solution of integrals and integral eq.,
solution of differential eqs.,

Quantum physics - pure and mixed quantum states, dynamics of quantum
variables, quantum mechanics of two and more particle
systems

Quantum theory of radiation - Dirac theory of atom-radiation interaction,
absorption, spontaneous and stimulated emis-
sion, theory of linewidth, Lamb shift, light
scattering, quantum theory of dumping, Marko-
vian process, Langeven and Fokker-Planck eq.
semiclassical theory of radiation, self indu-
ced transparency, photon echo.

Table 3. Survey of lectures in Mathematics and Physics for PhD.students