Lascala
Erasmus Mundus Master

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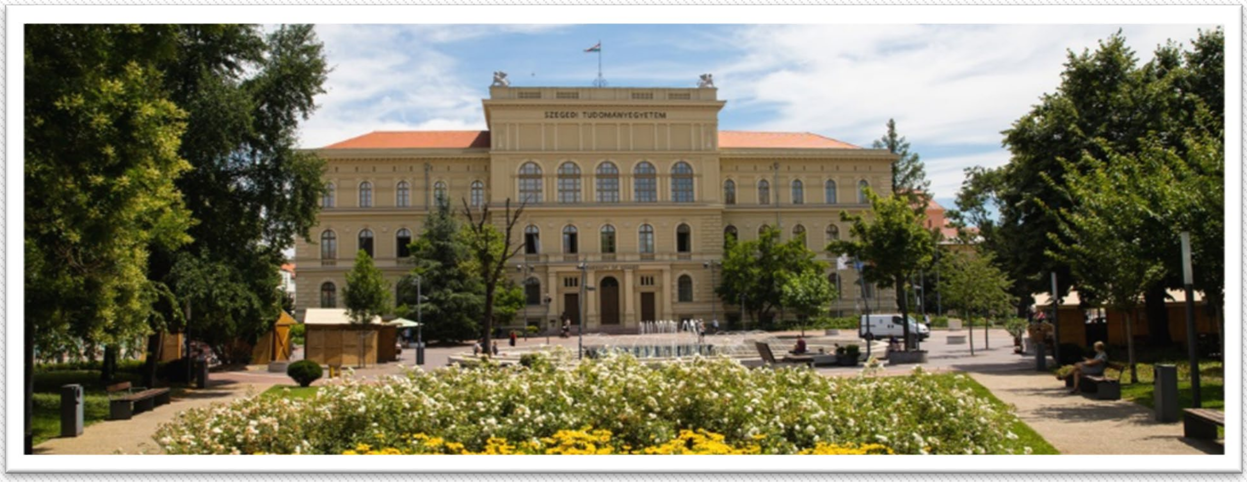
Syllabus
Semester 3
University of Szeged

ERASMUS MUNDUS JOINT MASTER DEGREE LASCALA

université PARIS-SACLAY
SZTE UNIVERSITY OF SZEGED
SAPIENZA UNIVERSITÀ DI ROMA
LUND UNIVERSITY

CONTENT

Year 2 – Semester 3
University of Szeged, Hungary



Course Title: Weekly practice work at the ELI facility
Course Semester: Autumn term of 2023 (3rd semester)
Country: Hungary
Number of ECTS: 6

Aims: To provide hands-on experience for students at the ELI ALPS large scale facility

Content (including lab trainings, projects, industry visits, etc.):

1. **Optical coating technologies** (Veronika Hanyecz):
   The students briefly study different coating technologies (thermal evaporation, electron-beam evaporation, sputtering) and become familiar with different thin film and substrate characterization methods. They perform ellipsometric, photometric and profilometric measurements on one-layer thin film samples in order to determine the layer thickness.
2. **Vacuum technologies** (Árpád Mohácsi):
   The goal of this practice is to get the students acquainted with the basics of the „clean" vacuum technologies. The laboratory practice will involve practical experience with handling and assembling of clean vacuum systems.
3. **Nanofabriaction tools** (Judit Budai):
   The major objective of the „Nanofabrication tools" laboratory exercise is to introduce the students to scanning electron microscopy (SEM), electron beam lithography (EBL) and focused ion beam (FIB) milling. The students will participate in the recording of several SEM micrographs to demonstrate the factors influencing the image quality via the comparison of micrographs recorded with different detectors at different conditions (accelerating voltage, working distance, etc.) on different samples. They will analyse Energy Dispersive X-Ray Spectra of different samples. FIB milling technique will be demonstrated to them via analysing cross sections of thin and thick gold layers, and by milling contours of nanostructured objects. Finally, the main steps of EBL will be shown by preparing test nano/microstructures in polymethyl methacrylate (PMMA).
4. **Command control schemes for large scale facilities** (Lajos Schrettner):
   The purpose of the exercise is to introduce the students to control system related concepts and technologies. We give an overview of the history of control systems for large scale facilities and summarize recent trends in the area. We enumerate core control system functionalities and related software tools and software engineering practices employed. A few hands-on programming exercises will be provided to implement and/or extend existing

simple control system components, such as monitoring a temperature sensor, controlling a motor, automating a scan process, creating a graphical user interface for a device, and acquiring and saving data from a diagnostic equipment or measurement. (Familiarity with the Python programming language is assumed.)

5. **Radiation safety protocols at a high intensity laser institute** (Tamara Kecskés): The purpose of the course is providing the students with a detailed picture on the relations of an extremely high intensity laser source with operational radiation protection for protecting operators and other personnel of the facility against consequences of ionizing radiations generated in various processes of this laser facility. Methods of radiation protection (RP) planning on the basis of modelling calculation and measurements will be presented. The objects of the course involve: Introduction of radiation protection protocols applied in the operation and maintenance of a high intensity laser facility. Various measurement techniques for determining the dose, dose rate, energy spectrum, and potential activation effects of ionizing radiations generated during the application of the primary laser beamlines will be presented and practiced. Calibration and utilization of measuring devices involved in different procedures of personal and area monitoring will be explained as a relevant part of the compound personal safety system (PSS) of the ELI ALPS laser facility.
6. **Radiobiological studies** (Emília Rita Szabó):
   The main goal of the practice is to provide introduction to radiation biology, the significance of radiobiology and radiotherapy for cancer treatment, and the experimental and theoretical studies in radiation biology which contribute to the development of radiotherapy. The laboratory practice includes: 1. Dosimetry principles (ionization chamber, film and FBX dosimetry), dose measurements (Monte Carlo calculation) and radiation protection. 2. Irradiation-induced damage and the DNA damage response in different type of cell lines. Cell death after irradiation with different doses, colony formation and MTT assays. How, when and why cells die? (Quantitative detection of radiation caused DNA double-strand breaks (DSB) by immunostained γ-H2AX foci on irradiated and photographed cells.) 3. Zebrafish as an in vivo novel vertebrate system for studying the radiation caused organ deteriorations on macro- and microscopic level. (Evaluation of survival and morphological abnormalities after irradiation with ionizing radiation.)
7. **Experiments with a high average power laser** (Abdollah Malakzadeh):
   The aim of the laser laboratory practice is to gain hands-on experience with femtosecond laser systems. After a mandatory laser safety training, the students will study the structure of modern chirped pulse amplification

architectures, including oscillators, pulse stretchers and different high power solid state amplifiers based on ytterbium (Yb) and titanium-sapphire (Ti:S) crystals and compressors. Ultrashort pulse metrology including average power, pulse energy, spectrum, pulse duration, contrast ratio, beam profile and repetition rate will be performed. The measured data will be analyzed.

8. **Applications of attosecond pulses** (Balázs Major):
   The goal of the practice is to give an overview on the basic technologies involved in generation and applications of attosecond pulses. The students will get knowledge and practical training on research equipment that are used to characterize spectral, temporal and spatial properties of extreme-ultraviolet (XUV) radiation that is produced using high harmonic generation (HHG) in gases. The students will learn and implement themselves basic evaluation methods of raw data obtained with the above equipment.
9. **THz spectroscopy** (József Fülöp):
   This practice includes a preparation on the theory of time-domain THz spectroscopy and generation of intense THz pulses based on material provided to the students before the lab practice. The measurements to be carried out during the laboratory work: characterization of THz pulses, reference measurements without sample, measurement of absorption and refractive index of samples at different THz intensities. The goal and last task of the practice is the calculation of the frequency dependent absorption and refractive index of samples based on the measurement data.
10. **Condensed matter physics experiment** (László Óvári):
    The exercise will provide a direct insight into various electron based surface sensitive characterization methods and related in-situ sample preparation tools. In order to obtain atomically clean solid surfaces, an ultra-high vacuum (UHV) environment is required. After appropriate cleaning treatments, the surface structure will be characterized by low energy electron diffraction (LEED). The chemical composition will be determined by X-ray photoelectron spectroscopy (XPS). The nanoscale morphology of the sample will be revealed by the NanoESCA, applying its energy resolved photoemission electron microscopy (PEEM) mode. An in-depth analysis of the electronic structure will be performed with the help of the momentum microscopy mode of NanoESCA. The exercise will be completed by the evaluation of obtained data.

Prerequisites: Will be given in each laboratory practice Syllabus

Recommended Books: Will be given in each laboratory practice Syllabus

Teaching Staff: Balázs Major, Veronika Hanyecz, Árpád Mohácsi, Judit Budai, Lajos Schrettner, Tamara Kecskés, Emília Rita Szabó, Abdollah Malakzadeh, József Fülöp, László Óvári

Course responsible: Balázs Major

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.) 100% lab training

Hours: (Lecture / Tutorial / Practical courses 10 laboratory practice (8 hours each) with homework

Course Title: Selected topics in femto- and attosecond pulse phenomena
Course Semester: Autumn term of 2023 (3rd semester)
Country: Hungary
Number of ECTS: 6

Aims: To deepen the understanding of the students via advanced numerical modelling in the field of ultrashort light pulses

Content (including lab trainings, projects, industry visits, etc.):
The course consists of theoretical lectures on the above topics and related consultation.Topics :

- Introduction to short light pulses. Spectral and temporal description. Chirp and GDD of ultrashort pulses.
- Gaussian beam propagation (monochromatic beams, ultrashort pulses); truncated Gaussian beams.
- Modelling the high-order harmonic generation process: a) classical model, b) Lewenstein model, c) saddlepoint approximation
- Harmonic- and attochirp in HHG.
- A short introduction to nonlinear optics. Phasematching in 2nd harmonic generation.
- Macroscopic aspects of HHG (phasematching, absorption).
- Compression of ultrashort pulses
- Non-perturbative methods for time-dependent quantum systems
- Theory and numerical modelling of strong-field ionization
- High-harmonic generation in solids
- Basics and principles of Density-functional theory (DFT) and Time-dependent density-functional theory (TDDFT) with applications in attophysics

Prerequisites: -

Recommended Books:
Diels-Rudolph: Ultrashort laser pulse phenomena
Chang: Fundamentals of attosecond optics
Teaching Staff: Katalin Varjú, Balázs Major, Attila Czirják, Péter Földi
Course responsible: Péter Földi
Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.) 100 % advanced homework

Hours: (Lecture / Tutorial / Practical courses) 2 hr/week lectures + 1 hr/week practicals

Course Title: Femtosecond optics with Python
Course Semester: 3rd
Country: Hungary
Number of ECTS: 4

Aims:

To provide students with an understanding how the Python programming language with its modules can be used for modelling

- temporal distortions of ultrashort laser pulses caused by propagation through dispersive optical elements,
- temporal pulse stretching and compression.

Content (including lab trainings, projects, industry visits, etc.):

- Fundamentals of Python programming
- Scientific computing with NumPy
- Plotting with Matplotlib
- Fourier transform, Discrete Fourier transform, Fast Fourier transform
- Optical transfer function – spectral amplitude, spectral phase
- Taylor expansion of the spectral phase
- Temporal shape of transform limited laser pulses
- Effects of the phase derivatives on the temporal shape of the pulses
- Propagation of ultrashort laser pulses through dispersive optical elements (glass slabs, prism pairs, grating pairs)
- Simulation of pulse stretching and compression

Prerequisites:

Recommended Books:

[1] P. Wentworth, J. Elkner, A. B. Downey and Ch. Meyers: How to Think Like a Computer Scientist, Learning with Python 3 (2012) http://openbookproject.net/thinkcs/python/english3e/

[2] H. Fangohr: Introduction to Python for Computational Science and Engineering (University of Southampton, 2016)
https://fangohr.github.io/teaching/python/book.html

[3] J-C. Diels, W. Rudolph: Ultrashort Laser Pulse Phenomena (Academic Press, 2006)

Teaching Staff:
Attila P. Kovács

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.)
60 % homework, 20% mid-term exam, 20% final exam

Hours: (Lecture / Tutorial / Practical courses)
3 hr/week lecture

Course Title: Fundamentals of femtosecond and nonlinear optics
Course Semester: 3rd
Country: Hungary
Number of ECTS: 4

Aims:

This module will provide a general overview about how the temporal-spatial shape, intensity and spectrum of ultrashort laser pulses change when they go through linear and nonlinear media.

Content (including lab trainings, projects, industry visits, etc.):

- Propagation of ultrashort laser pulses in dispersive media
- Dispersion properties of optical elements
- Material and angular dispersion measurements
- Laser beam propagation (Gaussian and flat top)
- Focusing of ultrashort laser pulses
- Propagation of high intensity femtosecond pulses
- Frequency conversion and phase matching
- Optical parametric amplification
- Generation and amplification of ultrashort laser pulses
- Amplitude and phase reconstruction of ultrashort laser pulses

Prerequisites:

Recommended Books:

[1] J-C. Diels, W. Rudolph: Ultrashort Laser Pulse Phenomena (Academic Press, 2006)

Teaching Staff:

Attila P. Kovács, Károly Osvay, Roland S. Nagymihály

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.)

50% mid-term exam, 50% final exam

Hours: (Lecture / Tutorial / Practical courses)

2 hr/week lecture

Course Title: Theory and detection of gravitational waves by laser interferometric instruments
Course Semester: 3rd
Country: Hungary
Number of ECTS: 6

Aims:

The course will provide a general overview about the formation of gravitational waves and present status of their detection.

Content (including lab trainings, projects, industry visits, etc.):

- Introduction (the four interactions, elements of special relativity, free motions in arbitrary coordinates, elements of general relativity, harmonic coordinates)
- Gravitational waves in weak field (wave equation on flat background, retarded solution, plane wave solution, electromagnetic analogy, helicity and polarizations)
- Gravitational waves in strong gravity regimes (the geometrical optics approximation, exact gravitational waves)
- Sources of gravitational waves (compact binary dynamics, the first 90 detections from compact binary coalescence by LIGO and Virgo, pulsar timing, B-mode polarization of the Cosmic Microwave Background)
- Laser interferometric gravitational wave detection. Earth-based laser-interferometric gravitational wave detectors: LIGO, Virgo, Kagra, noise sources, detection techniques. Einstein Telescope, Cosmic Explorer. Space-born instruments: LISA Pathfinder, LISA.
- Other detection methods (Weber bar, Hulse-Taylor pulsar, prospective detection from pulsar timing and from B-mode polarization of the Cosmic Microwave Background)
- Gravitational waves in modified gravity theories (new polarizations, modified dispersion). Confrontation with observations (Solar System tests, screening mechanisms, astrophysical and cosmological tests). Stability analysis of perturbations.

Prerequisites:

Recommended Books:

[1] L. Á. Gergely, Theory and detection of gravitational waves, course notes, 2023

[2] M. Maggiore, Gravitational Waves: Volume 1: Theory and Experiments, Oxford University Press, 2007

[3] H. Grote, Gravitational Waves, A History of Discovery, Taylor & Francis, 2019

[4] C. M. Will, N. Yunes, Is Einstein still right?, Oxford University Press, 2020

Teaching Staff:

L. Á. Gergely

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.)

25% homework, 25% presentation, 50% final exam

Hours: (Lecture / Tutorial / Practical courses)

2 hr/week lecture + 1 hr

Course Title: Scalar diffraction theory and its applications
Course Semester: Autumn term of 2023 (3rd semester)
Country: Hungary
Number of ECTS: 4

Aims:
This module will provide a general overview about the foundation of scalar diffraction theory and some important applications.

Content (including lab trainings, projects, industry visits, etc.): Review of Lebesgue integral, complex analysis and vector calculus. Fourier transform, Laplace transform. The Huygens-Fresnel principle, Scalar diffraction integrals, Fresnel and Fraunhofer diffraction. Example of Fraunhofer diffraction patterns, Examples of Fresnel diffraction. Fresnel diffraction at a circular aperture. Fresnel diffraction at a circular aperture, structure of the diffraction patterns. Imaging properties of thin lenses, Fourier transform properties of thin lenses. Focusing of femtosecond pulses.

Prerequisites:
Electrodynamics, Linear algebra, Mathematical analysis

Recommended Books:
[1] M. Born and E. Wolf, Principles of Optics, Pergamon Press, 1989

[2] M. V. Klein and T. E. Furtak, Optics, John Wiley & Sons, 1986

[3] E. Hecht, Optics, Addison Wesley Publishing Company, 1997

[4] J. W. Goodman, Introduction to Fourier Optics, McGraw-Hill Book Company, 1968

[5] W. Rudin, Real and Complex Analysis, McGraw-Hill Book Company, 3rd ed., 1986

[6] D. W. Kammler, A First Course in Fourier Analysis, Cambridge University Press, 2008

Teaching Staff: Balázs Major, Péter Földi, Attila Czirják

Course responsible: Balázs Major

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.)
100% final exam

Hours: (Lecture / Tutorial / Practical courses)
2 hr/week lecture

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