SYLLABUS

1. Information regarding the program

1.1 Higher education institution	Babeş-Bolyai University
1.2 Faculty	Faculty of Physics
1.3 Department	Doctoral School of Physics
1.4 Field of study	Physics
1.5 Study cycle	Doctorate
1.6 Study program / Qualification	Doctoral training/PhD in Physics

2. Course data

2.1 Name of discipline			Applications of bio(nano)medical spectroscopy and imaging				
2.2 Teacher responsible for lectures			Prof.dr. Zoltan Balint, Prof.dr. Vasile Chiş, Conf.dr. Monica Focșan, Prof.dr. Nicolae Leopold				
2.3 Teacher responsible for seminars			Prof.dr. Zoltan Balint, Prof.dr. Vasile Chiş, Conf.dr. Monica Focșan, Prof.dr. Nicolae Leopold				
2.4 Year of study	I	**2.5 Semester**	I	**2.6 Type of evaluation**	E	**2.7 Course framework**	DS

3. Estimated total time of teaching activities (hours per semester)

3.1 Hours per week	3	Out of which: 3.2 Lectures	2	3.3 Seminars / Laboratory classes	1
3.4 Total hours in the curriculum	36	Out of which: 3.5 Lectures	24	3.6 Seminars / Laboratory classes	12
Allocation of study time:					**89**
Study supported by textbooks, other course materials, recommended bibliography and personal student notes					34
Additional learning activities in the library, on specialized online platforms and in the field					24
Preparation of seminars/laboratory classes, topics, papers, portfolios and essays					15
Tutoring					12
Examinations					4
Other activities: -					–

3.9 Total individual study hours	89
3.10 Total hours per semester	125
3.11 Number of ECTS credits	10

4. Prerequisites (if necessary)

4.1 Curriculum	Quantum mechanics, Statistical physics, Physics of atoms and molecules, Numerical methods, Calculus, Algebra, Probability theory
4.2 Competences	- computational skills for molecular modeling - skills in using programming environments and graphical applications - skills in using the research equipments

5. Conditions (where applicable)

5.1 Conducting lectures	Course hall, appropriate board, projector, dedicated software, computer
5.2 Conducting seminars/laboratory classes	Course hall, appropriate board, projector, dedicated software, computer network

6. Specific competences acquired

Professional competences	- Acquiring advanced concepts and models of molecular modeling. - Abilities to build molecular models and prepare input data for advanced numerical codes. - Ability to select appropriate models and options for complex simulations. - Correct use of quantum chemistry methods and appropriate models for calculating molecular properties - Correlation of theoretical and computational data with experimental ones - Communicating complex scientific ideas, the conclusions of experiments or the results of a scientific project. - Ability to obtain and support scientifically argued results; ability to develop scientific papers. - Use of scientific methods and models in narrow or interdisciplinary fields. - Advanced ability to plan and organize. - Operation with the principles of digital image data processing. Ability to analyze and synthesize data; the ability to model the effect of external factors on images. - Use and adaptation of software packages for data analysis and processing. Use of automated computer systems for processing and extracting data from 2D and 3D digital images, respectively. - Carrying out data processing experiments and evaluating their results based on existing theoretical models. Multi- and interdisciplinary way of thinking through biomedical applications.
Transversal competencies	- Modeling and analysis skills in an interdisciplinary context. - Competences in using high performance computing technology. - Carrying out professional tasks efficiently and responsibly, in compliance with the legislation and field-specific deontology. - The application, in the context of compliance with the legislation, of intellectual property rights (including technology transfer), of the product certification methodology, of the principles, norms and values of the code of professional ethics within its own rigorous, efficient and responsible work strategy. - Application of efficient work techniques in multidisciplinary team on various levels hierarchical. Identify roles and responsibilities in a team, apply techniques effective relationships, and work within the team. - Efficient use of information sources and communication and training resources professional, both in Romanian and English. - Demonstrate involvement in scientific activities, such as the development of specialized articles and studies. - To participate in scientific projects, compatible with the requirements of integration in European education and research.

7. Course objectives (based on the acquired competencies grid)

7.1 The general objective of the discipline	- Learning physical models and advanced computational methods used to calculate spectroscopic properties of molecular systems. - Foster interdisciplinary collaboration between fields such as spectroscopy, and clinical biophysics, enhancing research that spans across physics, chemistry, and biomedical engineering. - Learning basic concepts and principles of fluorescence spectroscopy and imaging with particular emphasis on applications in nanotechnology, sensing and clinical diagnostic. - Learning interdisciplinary applications of biomedical image analysis for the development of integrated clinical decision support systems.
7.2 Specific objectives	- Acquiring the ability to use advanced computational methods and algorithms in complex simulation projects in the fields of computational spectroscopy, physical chemistry, materials science, imaging and biophysics. - Familiarization of doctoral students with the most used models molecular models and methods in interdisciplinary applications. - Encourage interdisciplinary research. - Learning the principles, methods and computational techniques for calculating different molecular properties. - Efficient use of computational resources for molecular modeling. - knowledge of designing and utilizing nanostructured materials (such as metal nanoparticles) to amplify Raman scattering. -skills in interpreting Raman spectra from biological samples (such- acquiring knowledge in biomedical image analysis. -geting familiar with modern fluorescent techniques and equipment in biomedical research. - knowledge in single molecule fluorescence techniques and super resolution fluorescence imaging. - acquiring knowledge in biomedical image analysis. - insight into novel techniques for decision support tool development. - knowledge upon integrating various modalities in a decision pipeline. - getting familiar with novel, AI-algorithm based approaches for image segmentation, feature extraction, texture analysis

8. Content

8.1 Lectures	Teaching methods	Comments
1. Digital image data processing. Theoretical methods for improving and analyzing digital image data. Filters for automatic and semi-automatic 2D data processing. Biomedical applications: data processing of 2D images obtained by a microscope, respectively 2D images obtained by MRI and CT.	Interactive lecture, Directed discussion, debate, Case-based learning, Just-in-time teaching	2 hours

2. Techniques for simulating the effect of noise on the results of digital image data analysis. Automatic and semi-automatic operations and processes for 3D image data processing. Biomedical applications: data processing such as 3D images obtained with the microscope, respectively 3D images obtained by CT and MRI.		2 hours
3. Decision support tools in medicine: Development of supervised and unsupervised algorithms for biomedical image segmentation using microscopy, CT and MRI as input.		2 hours
4. Modeling weak intermolecular interactions: the role of dispersion in weakly bound molecular systems; Modeling of host-guest systems; Modeling the adsorption of molecules on surfaces.		2 hours
5. Calculation of photophysical parameters of molecular systems: modeling of electronic absorption and fluorescence emission spectra; calculation of radiative fluorescence lifetime.		2 hours
6. Introduction to fluorescence spectroscopy and imaging; Concept; Overview of fluorescence measurements and applications; Fluorescence Sensing		2 hours
7. Fluorescence Lifetime Spectroscopy and Imaging Principles; Applications in biomedical diagnostics. Principles of Fluorescence Lifetime Instrumentation. Tissue Fluorescence Lifetime Spectroscopy. Tissue Fluorescence Lifetime Imaging - Endogenous. Fluorescence Lifetime Imaging - Exogenous Probes.		2 hours
8. Plasmon-enhanced Fluorescence Spectroscopy and Imaging; Enhanced Fluorescence Sensing		2 hours
9. Fluorescence super-resolution microscopy; Principles; Single Molecule Fluorescence Detection		2 hours
10. Electrical and optical properties of materials		2 hours
11. Surface-enhanced Raman scattering: Theory and applications		2 hours
12. Clinical Raman Spectroscopy		2 hours
8.2 Seminars / laboratory classes	**Teaching methods**	**Comments**
1. Advanced methods of 2D image data processing.	Problem based learning, Project based learning, Inquiry guided learning, Experiential learning	1 hour
2. Automated 2D image segmentation techniques: characterizing cells and objects of interest from 2D microscopy images with application in histology.		1 hour
3. Medical decision support tools: methods for extraction and characterization of various organs and features from MRI acquisitions – from image segmentation to texture analysis. 3D model preparation.		1 hour
4. Modeling the adsorption of molecules on a graphene model surface. Modeling the host-guest complexes. Interaction energy calculation and BSSE correction.		1 hour

5. Calculation of the electronic transitions (absorption and fluorescence emission) spectrum for solvated molecules using the "state specific" approach. Calculation of the radiative lifetimes of solvated molecule		1 hour
6. Instrumentation for fluorescence spectroscopy; Spectrofluorometers used.		1 hour
7. Analysis of Fluorescence Lifetime Data.		1 hour
8. Nanoplatforms for Metal Enhanced Fluorescence detection.		1 hour
9. Single molecule fluorescence detection.		1 hour
10. Electrical and optical properties of materials. Selected examples		1 hour
11. Experimental setups in surface-enhanced Raman scattering		1 hour
12. Assignment of biofluids SERS spectra		1 hour

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9. Aligning the contents of the discipline with the expectations of the epistemic community, representatives, professional associations and standard employers operating in the program field

The content of the discipline is in line with what is studied in other university centers in the country and abroad. In order to adapt to the requirements imposed by the labor market, the content of the discipline was harmonized with the requirements imposed by the specifics of postgraduate education, research institutes and the business environment.

10. Examination

Activity type	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Weight in the final grade
10.4 Lectures	Assessment of knowledge	Written exam	25%
	Assessment of knowledge	Ongoing tests	25%
10.5 Seminars / laboratory classes	Activity during seminars	Discussions, answers to questions	25%
	Assessment of knowledge	Written exam	25%
10.6 Minimum performance standard			
Correct assessment of methods and models to be used to solve a particular problem. Proper use of computational techniques and available hardware and software resources.			

Signature of course coordinator	Signature of seminar coordinator
Prof.dr. Zoltan Balint	Prof.dr. Zoltan Balint
Prof.dr. Vasile Chiș	Prof.dr. Vasile Chiș
Conf.dr. Monica Focșan	Conf.dr. Monica Focșan
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Date

21.09.2025

Signature
Head of department
Prof. dr. Vasile Chiș