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			Spectroscopic methods for environmental monitoring, pharmaceutical characterization and bioprocessing / Metode spectroscopice pentru monitorizarea mediului, studiul medicamentelor și bioprocesare				
2.2 Teacher responsible for lectures			Prof. dr. Monica Baia, CS I dr. Alina Magdaş, Prof. dr. Simona Pinzaru				
2.3 Teacher responsible for seminars			Prof. dr. Monica Baia, CS I dr. Alina Magdaş, Prof. dr. Simona Pinzaru				
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	Atomic and molecular physics, Quantum mechanics, Optics, Spectroscopy and Lasers,
4.2 Competences	- experimental skills for molecular characterization of environmental, pharmaceutical, biological samples - skills in using spectroscopy techniques and technology for developing target applications in pharmaceutical field, environmental control and monitoring, molecular exploring, food control, authentication, biomaterials engineering, plastisphere; data analysis, metabolomics, bioeconomy

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	- Competencies to formulate hypotheses and interpretations based on scientific arguments, measurements and experimental data specific to spectroscopic methods applied environmental monitoring, pharmaceutical characterization and bioprocessing - -Practical skills in using high performance equipment. - The ability to obtain and interpret experimental data correlated with current knowledge in the field; - The capacity for scientific synthesis and academic writing of research results - Ability to plan and organize. Interdisciplinary way of thinking - ability of molecular characterization of real-world samples. - Abilities to develop quantitative analyses in complex samples, build molecular models and use AI based data processing - Correlation of experimental data with theoretical models -discrimination and authentications of pharmaceutical, food and beverage products - 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. - ability to develop specific applications in demand to new regulations or business- specific. -translating science to market

Transversal competencies	- Competences in using high performance spectroscopy technology for developing market-demanded applications - Application of nanotechnology and spectroscopy methods in multidisciplinary projects - Effective work in multidisciplinary team on different hierarchical levels, fulfilling specific roles within a team, showing initiative and entrepreneurial leadership based on dialogue, cooperation positive attitudes, mutual respect, diversity and multiculturalism and continuous improvement of the own activities. -Effective use of information sources, scientific communication and professional training resources, both in Romanian and English.

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

7.1 The general objective of the discipline	- Acquiring advanced experimental and theoretical knowledge of spectroscopic methods suitable for environmental monitoring, pharmaceutical characterization and bioprocessing - Learning spectroscopic technology to develop specific applications in answer to market demand and current regulations
7.2 Specific objectives	- Knowledge of different spectroscopic methods theory and their practical use for different interdisciplinary applications related to environmental monitoring, pharmaceutical characterization and bioprocessing - Acquiring the ability to use advanced experimental methods in interdisciplinary applications - Familiarization of doctoral students with the most used spectroscopic methods, their advantages and limitations - Encourage interdisciplinary research . - Learning the principles, methods and experimental techniques operating in environmental conditions, handling real- world samples including those from extreme conditions. - Developing and validating specific analytic applications

8. Content

8.1 Lectures	**Teaching methods**	**Comments**
1. Raman and surface-enhanced Raman spectroscopy- tools for various applications - theoretical considerations	Interactive lecture, Directed discussion, debate, Case-based learning, Just-in-time teaching	2 hours
2. Raman and SERS investigations of pharmaceuticals		2 hours
3. Round-robin experiments– a step from Raman spectroscopy lab towards analytical applications		2 hours
4. Spectroscopic methods used for environmental applications (e.g. investigations of different dual/multi-functional materials)		2 hours

5. Development and validation of analytical methods. Determination of performance parameters and measurement uncertainty.		2 hours
6. General principles of mass spectrometry.		2 hours
7. Applications of mass spectrometry in environmental studies and food safety.		2 hours
8. Metabolomic and AI-based omics approaches in food safety. Perspectives and constraints.		2 hours
9. Surface-enhanced Raman spectroscopy - a versatile tool for environmental applications: case study -salt water bodies		2 hours
10. Development of multidisciplinary detection, monitoring and/or biosensing applications based on optical spectroscopy techniques and technologies (Raman, IR, UV-VIS, SERS, resonant Raman, resonant SERS)		2 hours
11. Process control based on Raman spectroscopy and complementary methods		2 hours
12. Spectroscopy solutions for plastisphere		2 hours
8.2 Seminars / laboratory classes	**Teaching methods**	**Comments**
1. Vibrational analysis (Raman, IR, SERS) of some pharmaceutical and biomedical compounds	Problem based learning, Project based learning, Inquiry guided learning, Experiential learning	2 hours
2. Interlaboratory study on SERS-case study		1 hour
3. Spectroscopic methods tackling specific features of some photocatalysts (e.g. self-cleaning SERs substrates)		1 hour
4. Case study: wines authentication		1 hour
5. Improvements of wine recognition models based on fused spectroscopic data		1 hour
6. Case study: Food products authentication (I)		1 hour
7. Case study: Food products authentication (II)		1 hour
8. Environmental water analyses using SERS: understanding dependencies		1 hour
9 Optical spectroscopy techniques addressing aquatic microbial community, aquatic biotoxin and their control		1 hour
10. Reusing biogenic materials of aquatic origin; Blue bioeconomy		1 hour
11. Macro, micro and nanoplastic management: Spectroscopy Solutions		1 hour
Bibliography 1. M. Baia, S. Astilean, T. Iliescu, Raman and SERS investigations of pharmaceuticals, Springer-Verlag GmbH, Berlin/Heidelberg, Germany, pp 214, 2008.		

2. S. Fornasaro, F. Alsamad, M. Baia, L. A. E. Batista de Carvalho, C. Beleites, H. J. Byrne, A. Chiadò, M. Chis, M. Chisanga, A. Daniel, J. Dybas, G. Eppe, G. Falgayrac, K. Faulds, H. Gebavi, F. Giorgis, R. Goodacre, D. Graham, P. La Manna, S. Laing, L. Litti, F. M. Lyng, K. Malek, C. Malherbe, M. P. M. Marques, M. Meneghetti, E. Mitri, V. Mohaček-Grošev, C. Morasso, H. Muhamadali, P. Musto, C. Novara, M. Pannico, G. Penel, O. Piot, T. Rindzevicius, E A. .Rusu, M. S. Schmidt, V. Sergo, G. D. Sockalingum, V. Untereiner, R. Vanna, E. Wiercigroch, A. Bonifacio, Surface Enhanced Raman Spectroscopy for Quantitative Analysis: Results of a Large-Scale European Multi-Instrument Interlaboratory Study, *Analytical Chemistry* 2020 *92* (5), 4053-4064, DOI: 10.1021/acs.analchem.9b05658
3. Rusu, E.-A.; Baia, M. Moving from Raman Spectroscopy Lab towards Analytical Applications: A Review of Interlaboratory Studies. *Instruments* **2023**, *7*, 30. https://doi.org/10.3390/instruments7040030
4. M. Baia, V. Danciu, Z. Pap, L. Baia, Towards Improving the Functionalities of Porous TiO_2-Au/Ag Based Materials, chapter 7 in Advanced Sensor and Detection Materials, Book Editor(s):Ashutosh Tiwari, Mustafa M. Demir, Copyright © 2014 Scrivener Publishing LLC. All rights reserved, 13 June 2014, https://doi.org/10.1002/9781118774038.ch7
5. Székely, I.; Kovács, Z.; Rusu, M.; Gyulavári, T.; Todea, M.; Focșan, M.; Baia, M.; Pap, Z. Tungsten Oxide Morphology-Dependent Au/TiO_2/WO_3 Heterostructures with Applications in Heterogenous Photocatalysis and Surface-Enhanced Raman Spectroscopy. *Catalysts* **2023**, *13*, 1015. https://doi.org/10.3390/catal13061015
6. Simona Cîntă Pînzaru, A. Fălămaș, C.A. Dehelean, Chapter 6 - Raman Spectroscopy: A Key Analytical Tool for New Drugs Research and Development, Editor(s): Atta-ur-Rahman, Studies in Natural Products Chemistry,Elsevier, Volume 61, 2019, P.211-250, https://doi.org/10.1016/B978-0-444-64183-0.00006-3.
7. Confocal Raman Microscopy, Editors: Toporski, Jan, Dieing, Thomas, Hollricher, Olaf (Eds.), Springer Series in Surface Sciences, 2018
8. Atomic and Molecular Spectroscopy; Basic Concepts and Applications, Rita Kakkar, Cambridge University Press, 2015.
9. Surface Enhanced Raman Spectroscopy: Analytical, Biophysical and Life Science Applications Cap. 6. Simona Cinta Pinzaru, I.Pavel, SERS and pharmaceuticals; Wiley-VCH, 2011
10. S. Guo, O. Ryabchykov, N. Ali, R. Houhou, and T. Bocklitz, in Reference Module in Chemistry, Molecular Sciences, and Chemical Engineering (Elsevier, Amsterdam, The Netherlands, 2020). https://doi.org/10.1016/B978-0-12-409547-2.14600-1.
11. I. Marica, S. C. Pînzaru, **A** Raman spectral database of naturally aged plastics: A proof-of-concept study for waste plastic sorting *J Raman Spectrosc* 2023, 54(3), 305. https://doi.org/10.1002/jrs.6484
12. Food Authentication: Management, Analysis, and Regulation", Constantinos A. Georgiou &Georgios P. Danezis, (2017) Chichester, UK; Hoboken, NJ: John Wiley & Sons Ltd., ISBN 9781118810262).
13. Magdas, D.A. and Berghian-Grosan, C. (2021). Raman Spectroscopy. In Electromagnetic Technologies Food Science (eds V.M. Gómez-López and R. Bhat). https://doi.org/10.1002/9781119759522.ch13
14. Magdas, D.A., Cozar, B.I., Feher, I. et al. Testing the limits of FT-Raman spectroscopy for wine authentication: Cultivar, geographical origin, vintage and terroir effect influence. Sci Rep 9, 19954 (2019). https://doi.org/10.1038/s41598-019-56467-y

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	-
	Assessment of knowledge	Ongoing tests	50%
10.5 Seminars / laboratory classes	Activity during seminars	Discussions, answers to questions	50%
	Assessment of knowledge	Written exam	-
10.6 Minimum performance standard			
Identification and proper use of the suitable investigation methods for environmental monitoring, pharmaceutical characterization and bioprocessing. Drawing out specific information obtained by these methods.			

Signature of course coordinator	Signature of seminar coordinator
Prof. dr. Monica Baia	Prof. dr. Monica Baia
CS I dr. Alina Magdaş	CS I dr. Alina Magdaş
Prof. dr. Simona Pinzaru	Prof. dr. Simona Pinzaru

Date	Signature
21.09.2024	Head of department Prof. dr. Vasile Chiș