A COURSE SYLLABUS – DOCTORAL SCHOOL

REGARDING THE QUALIFICATION CYCLE FROM 2025/2026 TO 2028/2029

GENERAL INFORMATION ABOUT COURSE	
Course title	**DOCTORAL SEMINAR**
Name of the unit running the course	Rzeszów University Doctoral School
Type of course *(obligatory, optional)*	compulsory subject
Year and semester of studies	years I-IV, semesters: I-VII
Discipline	**Physical Sciences**
Language of Course	Polish/English
Name of Course coordinator	**Dr Józef Cebulski, Professor at the University of Rzeszów**
Name of Course instructor	**Dr Józef Cebulski, Professor at the University of Rzeszów**
Prerequisites	Completed higher education, demonstrated research interests in solid state physics, semiconductor physics and the fundamentals of epitaxial technology; knowledge of English at B2 CEFR level, focused on specialist vocabulary.

BRIEF DESCRIPTION OF COURSE
(100-200 words)

The doctoral seminar aims to systematically monitor the progress of scientific research conducted as part of a doctoral dissertation on epitaxial growth and the physical properties of HgCdTe and HgTe structures, in particular quantum wells obtained by molecular beam epitaxy (MBE). The topics covered in the doctoral seminar include the analysis of the influence of growth parameters on the crystallographic quality of epitaxial layers, structural, morphological and compositional studies (XRD, SEM, ToF-SIMS) and the evaluation of the potential of the studied nanostructures for applications in the terahertz (THz) spectral range.

The doctoral seminar supports the development of skills in conducting independent experimental research, critical analysis of literature, interpretation of measurement results, and preparation of reports, scientific publications, and doctoral dissertations.

The aim of the doctoral seminar is to:

- prepare doctoral students for independent research,
- critically analyse the current state of knowledge in the field of HgCdTe/HgTe,
- developing skills in planning and conducting research on epitaxial layers,
- acquiring competence in interpreting structural research results,
- systematically preparing a doctoral dissertation.

COURSE LEARNING OUTCOMES AND METHODS OF EVALUATING LEARNING OUTCOMES

Learning outcome	The description of the learning outcome defined for the course	Reference to learning outcomes for qualifications at Level 8 of the Polish Qualification Framework (PRK) (symbol)	Learning Format (Lectures, classes,...)	Method of assessment of learning outcomes (e.g. test, oral exam, written exam, project,...)
Knowledge: (no.)	***knows and understands***			

P8S_WG1	Has extensive and structured knowledge of solid state physics and II–VI semiconductor physics, in particular concerning HgCdTe and HgTe structures and their electronic and structural properties.	**P8S_WG**	seminar	oral presentation, discussion,
P8S_WG2	He is familiar with the current scientific achievements and global research trends in MBE epitaxial growth, quantum wells and the applications of HgCdTe/HgTe structures in terahertz radiation detection.	**P8S_WG**	seminar	oral presentation, discussion,
P8S_WG3	He understands the relationships between epitaxial growth parameters, the crystallographic quality of layers and their physical and application properties.	**P8S_WG**	seminar	oral presentation, discussion,
Skills: (no.)	***is able to***			
P8S_UW1	They are able to use interdisciplinary knowledge from various fields of science to independently plan and carry out scientific experimental research on HgCdTe/HgTe epitaxial structures HgTe epitaxial structures, and is able to define the aim and subject of the research, formulate a research hypothesis, select appropriate growth and characterisation methods, and draw appropriate conclusions based on the results obtained.	**P8S_UW**	seminar	oral presentation, discussion, written assignments,
P8S_UW2	He/she analyses, interprets and critically evaluates the results of structural, morphological and compositional studies (including HRXRD, SEM, ToF-SIMS) and compares them with reference data.	**P8S_UW**	seminar	oral presentation, discussion, written assignments,
P8S_UW3	Is able to prepare reports, scientific publications and presentations of research results in English, in accordance with the principles of reliability and ethics in scientific research.	**P8S_UW**	seminar	written assignments,
P8S_UK6	Actively participates in the international research and professional community, communicating in a foreign language at level B2 of the Common European Framework of Reference for Languages.	**P8S_UK**	seminar	written assignments,
Social competence: (no.)	***is ready to***			
P8S_KK1	He is ready to critically evaluate his own research results and scientific achievements in the field of semiconductor physics, while	**P8S_KK**	seminar	oral presentation, discussion,

	respecting the principles of scientific integrity and reliability.			written assignments,
P8S_KK3	Using his knowledge, he is ready to solve various theoretical and practical problems, present research results in the academic community, and collaborate with members of research teams.	**P8S_KK**	seminar	oral presentation, discussion, written assignments,

LEARNING FORMAT – NUMBER OF HOURS

Semester (no.)	Lectures	Seminars	Lab classes	Placements	other	ECTS
I - VII	-	**-**	-	-	**7 x 15 hrs. - 105 hrs.**	**7 x 2 ECTS – 14 ECTS**

METHODS OF INSTRUCTION

- ACADEMIC DISCUSSION**,**
- STUDY OF ACADEMIC LITERATURE**,**
- MULTIMEDIA PRESENTATION**,**
- PREPARATION AND PRESENTATION OF RESEARCH OBJECTIVES**,** ***RESEARCH METHODS*****,** ***RESEARCH RESULTS*****,**
- FINAL PROJECTS**,**
- PROGRESS IN THE PREPARATION OF A DOCTORAL DISSERTATION

COURSE CONTENT

Semester I

- review of global research on HgCdTe, HgTe and quantum wells,
- physical principles of terahertz radiation detection,
- characteristics of MBE technology and the research equipment used,
- analysis of epitaxial structures and available measurement results,
- preparation of a semester report covering the characteristics and analysis of epitaxial layer research and assessment of their potential for applications in the terahertz spectral range,
- work on the development of an Individual Research Plan.

Semester II

- detailed analysis of HgCdTe/HgTe epitaxial growth parameters,
- influence of chemical composition and growth conditions on crystallographic quality,
- interpretation of HRXRD, SEM and ToF-SIMS test results,
- presentation and discussion of test results,
- preparation of an Individual Research Plan.

Semester III

- optimisation of epitaxial structures,
- analysis of structural defects and their impact on material properties,
- comparison of experimental results with literature data,
- problem-based seminar.

Semester IV

- extension of research to include further epitaxial structures,
- correlation between structure and physical properties,
- preparation of results for publication,
- preparation of the first manuscript of a scientific article.

Semester V

- research on the transport and optoelectronic properties of structures,
- analysis of possible applications in THz detection,

- development of the interpretation of results,
- editing of chapters of the doctoral dissertation.

Semester VI

- synthesis of experimental research results,
- comparison of results with theoretical models,
- preparation of further scientific publications,
- structuring of the doctoral dissertation.

Semester VII

- comprehensive analysis of the results of the doctoral dissertation,
- editing of the complete version of the doctoral dissertation,
- seminar summarising scientific achievements,
- preparation for the submission of the dissertation.

COURSE ASSESSMENT CRITERIA

The assessment covers the doctoral student's continuous work in each semester and academic year in the following areas: conducting research, expanding knowledge, studying literature, commitment and progress in preparing the doctoral dissertation.

The course ends after each semester of implementation:
pass – pass,
fail – fail.

TOTAL DOCTORAL STUDENT WORKLOAD REQUIRED TO ACHIEVE THE EXPECTED LEARNING OUTCOMES – NUMBER OF HOURS AND ECTS CREDITS

Activity	Number of hours
Scheduled course contact hours	**7 x 15 hrs. – 105 hrs.**
Other contact hours involving the instructor (duty hours, examinations)	**5**
Non-contact hours – student`s own work (preparation for classes or examinations, project, etc.)	**310**
Total number of hours	**420**
Total number of ECTS credits	**7 x 2 ECTS – 14 ECTS**

INSTRUCTIONAL MATERIALS

Compulsory literature:	1. **Sze, S. M., & Ng, K. K.** (2007). *Physics of Semiconductor Devices* (3rd ed.). Hoboken, NJ: Wiley-Interscience. ISBN: 978-0-471-14323-9. 2. **Yu, P. Y., & Cardona, M.** (2010). *Fundamentals of Semiconductors: Physics and Materials Properties* (4th ed.). Berlin–Heidelberg: Springer. ISBN: 978-3-642-00709-5. 3. **Chuang, S. L.** (2009). *Physics of Photonic Devices* (2nd ed.). Hoboken, NJ: John Wiley & Sons. ISBN: 978-0-470-29319-5. 4. **Herman, M. A., & Sitter, H.** (1996). *Molecular Beam Epitaxy: Fundamentals and Current Status*. Berlin–Heidelberg: Springer. ISBN: 978-3-642-80062-7.

	5. **Henini, M.** (Ed.). (2018). *Molecular Beam Epitaxy: From Research to Mass Production* (2nd ed.). Oxford: Elsevier. ISBN: 978-0-12-812136-8. 6. **Rogalski, A.** (2010). *Infrared Detectors* (2nd ed.). Boca Raton, FL: CRC Press. ISBN: 978-1-4200-7671-4 7. **He, L., Becker, C. R., Bicknell-Tassius, R. N., Scholl, S., & Landwehr, G.** (1993). Molecular beam epitaxial growth and evaluation of intrinsic and extrinsically doped Hg_{0.8}Cd_{0.2}Te on (100) Cd_{0.96}Zn_{0.04}Te. *Journal of Applied Physics, 73*(7), 3305–3312. https://doi.org/10.1063/1.352979 8. **Oehling, S., Ehinger, M., Spahn, W., Waag, A., Becker, C. R., & Landwehr, G.** (1996). Mechanisms of molecular beam epitaxial growth of (001) HgTe. *Journal of Applied Physics, 79*(2), 748–751. https://doi.org/10.1063/1.362682 9. **Bajaj, J., Arias, J. M., Zandian, M., Pasko, J. G., Kozlowski, L. J., DeWames, R. E., & Tennant, W. E.** (1995). Molecular Beam Epitaxial HgCdTe Material Characteristics and Device Performance: Reproducibility Status. *Journal of Electronic Materials, 24*(9), pp. 1067-. https://doi.org/10.1007/BF02653055 10. **Harrison, P., & Valavanis, A.** (2016). *Quantum Wells, Wires and Dots: Theoretical and Computational Physics of Semiconductor Nanostructures* (4th ed.). Chichester: Wiley. ISBN: 978-1-118-92336-8
Complementary literature:	1. **Amarasinghe, P. M., Qadri, S. B., & Wijewarnasuriya, P. S.** (2015). High Resolution X-ray Diffraction Studies Molecular beam epitaxial grow…Layers on Bulk-Grown CdZnTe Substrate. *Journal of Electronic Materials, 44*(8), 2762 https://doi.org/10.1007/s11664-015-3695-7 2. **Becker, C. R**. (2014). *Growth and properties of HgTe quantum wells – A topic review*. **Physica Status Solidi (b), 251**(6), 1125–1132. https://doi.org/10.1002/pssb.201350121 3. **Qin, G., Kong, J. C., Yang, J., Ren, Y., Li, Y. H., Li, H. F., Yang, C. Z., Wang, J. Y., Yu, J. Y., Qin, Q., Zhao, J., & Zhao, P**. (2023). *HgCdTe Films Grown by MBE on CZT(211)B Substrates*. **Journal of Electronic Materials, 52**, 2441–2448. https://doi.org/10.1007/s11664-022-10193-w 4. **Mitin, V., Kochelap, V., & Stroscio, M. A**. (1999). *Quantum Heterostructures: Microelectronics and Optoelectronics*. Cambridge: Cambridge University Press. ISBN: 978-0-521-59099-1. 5. **Herman, M. A.** (1989). *Heterozłącza półprzewodnikowe*. Warszawa: Wydawnictwa Naukowo-Techniczne (WNT). ISBN: 83-204-1213-5

***(1 ECTS POINT CORRESPONDS TO 25–30 HOURS OF TOTAL WORK BY THE DOCTORAL STUDENT REQUIRED TO ACHIEVE THE INTENDED RESULTS)**

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Date and signature of the Course instructor

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Approved by the Head of the Department or an authorised person