# A COURSE SYLLABUS – DOCTORAL SCHOOL

## REGARDING THE QUALIFICATION CYCLE FROM 2021 TO 2025

| GENERAL INFORMATION ABOUT COURSE | |
|---|---|
| Course title | **Fourier transform in high-resolution spectroscopy** |
| Name of the unit running the course | Doctoral School at University of Rzeszów |
| Type of course *(obligatory, optional)* | Obligatory |
| Year and semester of studies | 3rd/summer semester 2023/2024 (semester VI) |
| Discipline | Physics |
| Language of Course | English |
| Name of Course coordinator | dr hab. Wojciech Szajna, prof. UR |
| Name of Course lecturer | dr hab. Wojciech Szajna, prof. UR |
| Prerequisites | Completed course on the basics of the Atomic and Molecular Physics, in particular knowledge about modern experimental techniques of the atomic and molecular spectroscopy and optics. |

**BRIEF DESCRIPTION OF COURSE**
**(100-200 words)**

The aim of the lecture is to present the basics of the Fourier transform and its practical application in the analysis of physical signals, with particular emphasis on the analysis of molecular spectra. Lecture content will include: a) practical application of the Fourier transform in modern Fourier spectrometers in the infrared (IR) range and high resolution spectrometers operating in the visible (VIS) and ultraviolet (UV) regions; b) presentation of practical aspects of selected methods, i.e. Discrete Fourier Transform (DTF) and the Fast Fourier Transform (FFT) algorithm; c) implementation of the Fast Fourier Transform (FFT) algorithm for the analysis of selected physical signals using MatLab/Python software; d) the influence of the selection of selected parameters, e.g. time window, on the resulting Fourier transform of selected physical signals.

**COURSE LEARNING OUTCOMES AND METHODS OF EVALUATING LEARNING OUTCOMES**

| Learning outcome | The description of the learning outcome defined for the course | Relation to the degree programme outcomes (symbol) | Learning Format (Lectures, classes,...) | Method of assessment of learning outcomes (e.g. test, oral exam, written exam, project,...) |
|---|---|---|---|---|
| **(No.)** | **Knowledge**<br>The PhD student knowns and understands | | | |
| 1. | The world achievements covering the theoretical basis of the using Fourier transform in high-resolution (molecular) spectroscopy. | P8S_WG/1 | L. | discussion, oral exam |
| 2. | The main development trends of the modern experimental techniques in high-resolution Fourier spectroscopy. | P8S_WG/2 | L., c. | discussion, oral exam, project |
| 3. | Methodology of scientific research in the field of the Fourier transform high-resolution (molecular) spectroscopy. | P8S_WG/3 | L., c. | discussion, oral exam, project |
| 4. | The construction issues and working of the Fourier transform spectrometers. | P8S_WG/3 | L., c. | discussion, oral exam, project |

| (No.) | **Skills**<br>The PhD student is able to | | | |
|---|---|---|---|---|
| 1. | Use knowledge from various fields of science (e.g. physics, mathematics, optics) to perform research tasks leading to obtaining and analysing high-resolution Fourier transform (molecular) spectra. | P8S_UW/1 | L., c. | discussion, oral exam, project |
| 2. | Make a critical analysis and evaluation the obtained results of the analysis of high-resolution Fourier (molecular) spectra. | P8S_UW/2 | L., c. | discussion, oral exam, project |
| 3. | Communicate freely about the using of the Fourier transform in experimental high-resolution spectroscopy. | P8S_UK/1 | L., c. | discussion, oral exam, project |
| 4. | Disseminate the results of the own research gathered by using of the high-resolution Fourier transform spectrometers. | P8S_UK/2 | L., c. | discussion, oral exam, project |
| 5. | Initiate a debate on the use and optimization of the Fourier transform spectrometers work. | P8S_UK/3 | L., c. | discussion, oral exam, project |
| 6. | Participate in the scientific discourse on the use of Fourier transform in experimental high-resolution spectroscopy. | P8S_UK/4 | L., c. | discussion, oral exam, project |
| 7. | Speak a foreign language at level B2 of the European System of Language Education to a degree that enables participation in an international scientific and professional environment. | P8S_UK/5 | L., c. | discussion, project (in cooperation with English language teacher) |
| **(No.)** | **Social competence**<br>The PhD student is ready to | | | |
| 1. | Critical assessment of the own scientific achievements in the field of high-resolution Fourier transform (molecular) spectroscopy. | P8S_KK/1 | L. | discussion, |
| 2. | Recognizing the importance of acquired knowledge in solving cognitive and practical problems in the field of experimental high-resolution Fourier transform spectroscopy. | P8S_KK/3 | L. | discussion, |
| 3. | Act in the public interest. | P8S_KO/2 | L. | discussion, |

**LEARNING FORMAT – NUMBER OF HOURS**

| Semester (no.) | Lectures | Seminars | Lab classes | Internships | Others | ECTS |
|---|---|---|---|---|---|---|
| VI | 5 | 10 | ----- | ----- | ----- | |

**METHODS OF INSTRUCTION**

Lecture - a lecture supported by a multimedia presentation, discussion
Laboratory classes - designing and conducting experiments,
Classes – discussion, project work (implementation project on using MatLab/Python programs for calculation of the Fourier transform)

## COURSE CONTENT

**Lectures/ Seminars:**

1. Mathematical foundations and conditions for using the Fourier transform to analyse physical signals.
2. Discrete Fourier Transform (DTF) and implementation of the Fast Fourier Transform (FFT) algorithm.
3. Examples of analytical determination of the Fourier transform for simple periodic waveforms.
4. The construction issues and working of the Fourier transform spectrometers.

**Seminars / Lab classes/ others:**

1. Registration and analysis of spectra using a high-resolution Fourier transform spectrometer in the VIS and UV range and an FTIR spectrometer.
2. Fourier analysis of physical signals using MatLab/Python software.

## COURSE ASSESSMENT CRITERIA

The condition for passing the lecture is to present a report/presentation containing a discussion of the most important conclusions from the issues discussed during the lecture.
The condition for passing the classes is to complete a project using MatLab/Python software using the Fast Fourier Transform (FFT) algorithm for selected physical signals and to prepare a report (in English) on the implementation and results of the above-mentioned project.
The final grade will be issued depending on the number of points obtained for the project (the correctness and completeness of individual elements of the project are assessed):
poor; 3.0 (51 - 60)% pkt.,
satisfactory; 3.5 (61 - 70)% pkt.,
good; 4.0 (71 - 80)% pkt.,
very good; 4.5 (81 - 90)% pkt.,
excellent; 5.0 (91 - 100)% pkt.

## TOTAL PhD STUDENT WORKLOAD REQUIRED TO ACHIEVE THE INTENDED LEARNING OUTCOMES – NUMBER OF HOURS AND ECTS CREDITS

| Activity | Number of hours |
|---|---|
| Scheduled course contact hours | 15 |
| Other contact hours involving the teacher (consultation hours, examinations) | 1 |
| Non-contact hours – student`s own work (preparation for classes or examinations, project, etc.) | 20 |
| **Total number of hours** | 36 |
| **Total number of ECTS credits** | |

## INSTRUCTIONAL MATERIALS

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|---|---|
| Compulsory literature: | 1. P. F. Bernath, Fourier Transform Techniques, in the *Encyclopedia of Analytical Science*, 2nd edition, P. J. Worsfold, A. Townshend and C. F. Poole, eds., Elsevier, Oxford, vol. 3, 498-504, 2005.<br>2. L. Glasser, Fourier transforms for chemists. Part 1. Introduction to the Fourier transform, *J. Chem. Educ.* 1987, 64, 10, A228.<br>3. L. Glasser, Fourier transforms for chemists. Part 2. Fourier transforms in chemistry and spectroscopy, *J. Chem. Educ.* 1987, 64, 11, A260.<br>4. L. Glasser, Fourier transforms for chemists. Part 3. Fourier transforms in data treatment, *J. Chem. Educ.* 1987, 64, 12, A306. |
| Complementary literature: | 1. B. Osgood, The Fourier Transform and its Applications, Stanford University. |