Fundamentals of modern optics
FoMO22

by Prof. Thomas PERTSCH
at Abbe School of Photonics, Friedrich-Schiller-Universität Jena
in winter term 2022/2023

The course will be given as a hybrid offline/online version to allow students who are present at the Friedrich Schiller University Jena as well as students who could not come to Jena in time at the beginning of the semester to successfully participate in the course. The details of this arrangement will be adjusted continuously during the semester reflecting the potentially occurring specific social-distancing regulations at that time and to optimize for the (online/in-person) learning success. All times given in this document are given for the local German time, which is equivalent to UTC/GMT+2 until 29.10.2022 and UTC/GMT+1 from 30.10.2022.

We expect that all students, who are in Jena and who are not quarantined because of a Covid-19 infection, to attend the lectures and seminars in person. All students have to obey the Covid-19 infection prevention rules set by the university, when attending the lectures and seminars. The online lectures and seminars are provided only for the students, who cannot come to Jena because they did not get their visa or flight, or for the students, who are quarantined at that time.

LECTURES:
>   Monday, 08:30-10:00, auditorium ACP, Albert-Einstein-Straße 6 & online
>   Thursday, 08:15-10:00, auditorium ACP, Albert-Einstein-Straße 6 & online

IN PERSON SEMINARS:
>   S-A) Monday, 10:15-11:45, auditorium ACP, Mostafa ABASIFARD
>   S-B) Monday, 10:15-11:45, seminar room 1 ACP, Anastasia ROMASHKINA
>   S-C) Monday, 10:15-11:45, seminar room 2 ACP, Xiao CHEN
>   S-D) Monday, 14:15-15:45, auditorium ACP, Tina (Shiu Hei) LAM

ONLINE SEMINAR:
>   S-E) Monday, 14:15-15:45, Shreyas RAMAKRISHNA

TUTORIUM:
>   T) Wednesday, 14:00-16:00, auditorium ACP, by Bayra NARANTSATSRALT

LIVE STREAM FOR ONLINE PARTICIPATION IN LECTURES:
>   https://online.mmz.uni-jena.de/acp.html

LINK TO ZOOM VIDEO CONFERENCE FOR ONLINE DISCUSSION DURING LECTURE
>   Zoom link: https://uni-jena-de.zoom.us/j/62095484228
>   Meeting ID: 613 5636 0566
>   Passcode: FoMO22

Lecturer

Thomas PERTSCH   Email: thomas.pertsch@uni-jena.de (lectures)
Visiting Address: Institute of Applied Physics, Abbe Center of Photonics,
                        Campus Beutenberg, room 305, Albert-Einstein-Str. 6, 07745 Jena

Seminar teachers and tutors

Franz LÖCHNER   Email: franz.loechner@uni-jena.de (coordinator)
Bayra NARANTSATSRALT   Email: n.bayarjargal@uni-jena.de (tutorium)
Anastasia ROMASHKINA   Email: anastasia.romashkina@uni-jena.de
Mostafa ABASIFARD   Email: mostafa.abasifard@uni-jena.de
Pawan KUMAR   Email: pawan.kumar@uni-jena.de
Tina (Shiu Hei) LAM   Email: shiu.hei.lam@uni-jena.de
Shreyas RAMAKRISHNA   Email: shreyas.ramakrishna@uni-jena.de
Xiao CHEN   Email: xiao.chen@uni-jena.de

Lectures

The lecture will be held in a "normal" synchronous teaching style. This means we will have lectures every Monday and Thursday morning at the indicated times in the lecture theater of the Abbe Center of Photonics. If you are in Jena you should come to the lecture theater and follow the lectures there. Only if you are not in Jena or your mobility is restricted since you are ill or quarantined you can follow the lectures in a live stream (see above for the access information). In parallel to the live stream there will be a video conference to allow for interaction with the online students during the lecture (see above for the access information). The lectures will be recorded and the recordings will be made available in the moodle page of the course.

Seminars & task sheets

- The seminars will be held in the indicated rooms of the Abbe Center of Photonics. Every student will be registered for a specific seminar group during the first lecture and should attend the seminars of this group throughout the semester. If you have a valid reason to change the seminar group, this has to be discussed with and approved by the seminar teacher and Prof. Pertsch.
- The alternative online seminar is again reserved only for the students who cannot attend the local seminars for the above stated reasons.
- You are expected to solve weekly exercise tasks to practice applying the knowledge, which you obtained in the lecture. Afterwards the solutions of these tasks are discussed in the seminars.
- Task sheets are distributed every Thursday after the lecture. You will also find them in the moodle page of the course for download.
- Students are expected to solve the tasks by themselves. Nevertheless, teamwork is strongly encouraged, in the form of a discussion of the task and possible solution strategies. However, plain copying of solutions is strongly discouraged.
- Please use a new sheet of paper for your solution of every task to make the correction easier.
- If not stated otherwise in the task sheet, solutions must be returned in the lecture hall the following Thursday before the beginning of the lecture (08:15). This is a strict deadline. Solutions submitted late won't be accepted.
- Only online students can submit their solutions as pdf files by email to teaching.nqo@uni-jena.de. Email submission of solutions must originate from your official university email account. The subject line of the email must be: 6-DIGIT STUDENT ID + solution.

- Only online students must use their university email of the Friedrich Schiller University Jena (e.g. first_name.last_name@uni-jena.de) for all communication with us (homework submission etc.).
- Rules for preparing your solution files for only online students:
  o preferably as one pdf file with the name:
    FoMO22_SeriesNN_SeminarTeacherLastName_StudentLastName_StudentIDNo.pdf
    NN: number of series (01, 02, 03, …)
    SeminarTeacherName: Mostafa, Anastasia, Tina, Shreyas, or Xiao
    StudentLastName: your last name
    StudentIDNo: your student ID number of the university Jena
  o Only if you are unable to convert your homework to one pdf file you can also submit it as separate pdf files or in the worst case also jpg by numbering the individual files in addition to the convention above:
    FoMO22_SeriesNN_SeminarTeacherName_LastNameStudent_StudentIDNo_FileNumber.pdf/jpg
    FileNumber: 01, 02, 03, …

Weekly quizzes
- There will be a 10-minute quiz before the beginning of every Thursday's lecture.
- The quiz will test your understanding of the topic covered by the seminar tasks of that week.
- The quizzes will be conducted in the lecture hall before the start of the lecture.
- We will start the quizzes at 8:15 am sharp and solution sheets have to be returned at 8:25 am.
- Only online students can solve the quizzes outside the lecture hall. For them the quiz questions will be made available on the moodle page on Thursday at 8:15 am. Then they have 10 minutes to solve the quiz, take a photo, and send it by email to teaching.nqo@uni-jena.de. The email with your solutions must be sent before 8:30 (before the beginning of the lecture). This is a strict deadline. Solutions submitted late won't be accepted.
- Rules for preparing your solution file:
  o preferably as pdf file (not in one file with your homework) with the name:
    FoMO22_QuizNN_SeminarTeacherName_StudentLastName_StudentIDNo.pdf
  o Only if you are unable to convert to pdf quickly at the mornings of the quiz, you might also submit as jpg. Try to comply with the given naming convention above. If this is impossible for you to do quickly in the morning on your cell phone, then it would also be acceptable to send it just as your picture file named by your camera. However, in this case make sure that it is indicated in the email, what this file contains.

Tutorium
- The tutorium is meant to help students who have specific problems following the course. The tutorium is by invitation only, to allow intensive interaction with a limited number of students. You will be invited if the seminar teachers feel that you will need it. The tutorium will start only after some weeks of the winter term have passed and after we have identified the students, who really need the additional tutorium.

Midterm exam (test exam)
Subject: content of lectures and seminars
Date/time: 12.12.2022, 8:15 am
Location: auditorium ACP, Albert-Einstein-Straße 6 & online for the online students

Duration: 90 minutes

Procedure:

- The midterm is mainly for you to receive some feedback from us on the status of your abilities in comparison to our expectations. It will not count towards your final grade. Hence, we will not strictly surveil you during the exam and assume that you will follow the given examination rules in order to receive objective feedback from us on your performance.
- The midterm should be performed without any help (no documents, calculator, internet, friend, or grandmother), just you, a pen, and empty sheets of paper!
- The midterm covers all subjects of the lectures up to the last lecture before the midterm.
- The midterm will be conducted in the auditorium. For the online-students the question sheet of the midterm will be made available at 8:15 on moodle of FoMO22 in the section "General". You have 90 minutes to solve the questions. Thus, you should stop solving the questions at 9:45.
- The question sheet will contain slightly more questions than you are expected to be able solving in the given time. Thus, be selective and solve those questions first which appear easiest to you.
- Write with your best readable handwriting. Try making your answers unambiguous. We will not pick the correct answers from among a lot of contradicting wrong ones.
- Do not change the questions intentionally, e.g. if the question is asking for the equation for the H field, do not give the equation for the E field. However, even if you feel that you would not be able to find a comprehensive solution for a task, try to collect points by writing down what you know.
- Please take a new sheet of paper when you start solving a new question (1, 3, 4). Otherwise, it will be hard for us to collect all answers to one question from multiple pages appearing here and there in your entire solution document.
- Online students must finish solving the questions at 9:45 am as well. Then they have 15 minutes (until 10:00) to submit their solutions.
- The online students should submit their solutions as a single pdf file by email to teaching.nqo@uni-jena.de. The email submission must originate from your official university email account (e.g. fist_name.last_name@uni-jena.de).
- The subject line of the email must be: 6-DIGIT STUDENT ID + midterm.
- Rules for preparing your solution file:
    o Order all your answer sheet in the right sequence (questions 1 a b c, question 2 abc, …).
    o Prepare all your answer sheet as a single pdf file with the name:
      FoMO22_Midterm_StudentLastName_StudentIDNo.pdf
      StudentLastName: your last name
      StudentIDNo: your student ID number of the university Jena
    o Only if you are unable to convert your several answer sheets into one pdf file you can also submit it as separate pdf files or in the worst case also jpg by numbering the individual files in addition to the convention above:
      FoMO22_Midterm_StudentLastName_StudentIDNo_FileNumber.pdf/jpg
      FileNumber: 01, 02, 03, …
- If online students have a question during the midterm, e.g. you don't understand a task because you think it is ambiguously stated, we will be available in a zoom session to discuss it with you. It will be our weekly lecture's zoom link.
- When a question by one student comes up and as result we think that we should give an extra explanation to all students, we will communicate it in the chat function of the zoom session. Thus, please log into the zoom session during the exam, open the chat, and check it from time to time for updates. However, we try to minimize the communication to not distract you from your work.

Final exam

Type: written examination
Subject: content of lectures and seminars
Date/time: 17.03.2023, 10:00 am
Duration: 120 minutes
Location: auditorium ACP, Abbe Center of Photonics, Albert-Einstein-Straße 6

Retake of exam

Date/time: 21.04.2023, 16:00 am
Duration: 120 minutes
Location: auditorium ACP, Abbe Center of Photonics, Albert-Einstein-Straße 6

Grading

The final grade will be determined as the better grade of the following two options:

Option A) 15%   from the results of the weekly seminar tasks
           up to 15%   from the results of the weekly quizzes
           the rest (>=70%)   from the result of the final exam
Option B) 100%   from the result of the final exam.

The final exam must be passed to pass the entire course. An extra 15% positive influence on the final grade can be derived from the midterm exam.

Literature

- lecture script, which will be continuously updated. There current version can be downloaded from the lecture's moodle page.
- B. E. A. Saleh and M. C. Teich, "Fundamentals of Photonics," Wiley, 3rd edition, 2019 – fits well to the course. The e-book of an older version (1st edition, 11991) is available at: https://onlinelibrary.wiley.com/doi/book/10.1002/0471213748
- M. Born and E. Wolf, "Principles of Optics," Cambridge University Press (1999) – advanced topics covered in more detail. When registered at the university's library the e-book is available at: https://doi.org/10.1017/9781108769914
- E. Hecht, "Optics," Addison-Wesley (2001) – gives more intuitive explanation of several phenomena.

Miscellaneous

All lecture scripts, videos, and additional material will be posted in the moodle system of the Friedrich Schiller University Jena at: https://moodle.uni-jena.de/

Lecture and seminar schedule

#	Date	Topics	Script (up to page)
L01	17.10.	Introduction and Maxwell's equations I (seminar registration)	27
S01		Fourier transform; delta distribution	
L02	20.10.	Maxwell's equations II	30
L03	24.10.	Optical properties of matter; classification of types of media	34
S02		Vector analysis; Stokes' theorem; Maxwell's equations; Polarization	
L04	27.10.	Material models	44
	31.10.	NO LECTURE due to the public holiday "Reformation Day"	
S03		Poynting vector and continuity equation	
L05	03.11.	Poynting vector and energy balance	52
L06	07.11.	Normal modes in homogeneous isotropic media	56
S04		Lorentz model, normal modes, and vector waves	
L07	10.11.	Plane wave solutions in different frequency regimes	60
L08	14.11.	Beams and pulses – analogy of diffraction and dispersion	65
S05		Diffraction in Fresnel approximation (slit, Talbot effect, Airy waves)	
L09	17.11.	Arbitrary narrow beams (cont.) & Fresnel- (paraxial) approximation	69
L10	21.11.	Paraxial wave equation	74
S06		Fresnel approximation, paraxial wave equation, Gaussian beams	
L11	24.11.	Propagation of Gaussian beams	80
L12	28.11.	Gaussian optics with q-parameter formalism	85
S07	W48	Gaussian optics (telescope, laser beam, resolution limit)	
L13	01.12.	Dynamics of pulsed beams described by differential equation	95
L14	05.12.	Pulse dynamics without spatial effects	103
S08	W49	Preparation for midterm exam	
L15	08.12.	Diffraction theory – derivation of Fraunhofer approximation	109
	12.12.	MIDTERM EXAM	
S09	W50	Propagation of Gaussian pulses (dispersion compensation, SVEA, …)	
L16	15.12.	Diffraction theory – examples of Fraunhofer diffraction pattern	116
L17	02.01.	Fourier optics – optical filtering	
S10	W01	Fraunhofer diffraction (gratings, near field diffraction)	
L18	05.01.	Polarization of electromagnetic waves	123
L19	09.01.	Crystal optics – susceptibility, crystal classes, index ellipsoid	128
S11	W02	Fourier optical filtering, anisotropic materials	
L20	12.01.	Normal modes for arbitrary propagation direction in index ellipsoid	129

L21	16.01.	Normal surfaces of normal modes	133
S12	W03	Optical wave plates, double refraction, principal component analysis	
L22	19.01.	Uniaxial crystals & optical fields in piecewise homogeneous media	138
L23	23.01.	Matrix method, Reflection – transmission problem	145
S13	W04	Jones formalism, interfaces, total internal reflection	
L24	26.01.	Single interface	162
L25	30.01.	Total internal reflection, Brewster angle, Bragg mirrors	169
S14	W05	Brewster angle, Bragg mirrors	
L26	02.02.	Periodic multilayer systems	176
L27	06.02.	Fabry-Perot resonators	180
S15	W06	Bragg-mirrors	
L28	09.02.	Guided waves in layer systems & consultation for exam	188
E01	17.03.	Exam (10:00-12:00, Auditorium, Abbe Center of Photonics)	
E02	21.04.	Retake (16:00-18:00, Auditorium, Abbe Center of Photonics)	

General rules for the seminars, quizzes, midterm, and final exam

- The exam and the quizzes are performed without any documents and without calculator, cell phone, etc. You just need empty sheets of paper.
- Write with your best readable handwriting.
- Do not use pencil in the midterm and final exam.
- Make your answers unambiguous for the correctors. We will not pick the correct answers from among a lot of contradicting wrong ones.
- Do not change the questions intentionally, e.g. if the question is asking for the equation for the H field, do not give the equation for the E field. However, even if you feel that you would not be able to find a comprehensive solution for a task, try to collect points by writing down what you know.
- Put your answers for different questions on individual pages.
- The quizzes and midterm cover subjects of the lectures up to that date. The final exam covers all subjects from the entire semester.
- Please exercise throughout the entire semester and not just before the midterm and exam!