PHYS/ECE 554 002: Advanced Optics II
CRN: 54520 & 54521

Description of the class
This class is a continuation from Advanced Optics I of the Fall Semester 2019. It covers three major sections: crystal optics; coherence; and Fourier optics. The first section – crystal optics – is focused on optical response of dielectric and semiconductor crystals and covers the following topics: classical Lorentz oscillator model for ideal dielectric crystals; complex optical response; Kramer-Kronig relations; dispersion if optical response; quantum-mechanical model of optical response; overview of absorption mechanisms; tensor of optical response of anisotropic crystals; strong-field and non-perturbative effects; magneto-optic effects; electro-optic effects; acousto-optic effect; and applications of those effects in devices. The second section – coherence – covers temporal and spatial coherence; coherence function; interference of partially coherent light; transmission of partially coherent light through optical systems; image formation; and Van-Cittert-Zernike theorem. The third section – Fourier optics – includes analysis of 2D signals and systems; foundations of scalar diffraction theory; wave-optics and frequency analysis of optical imaging systems; applications of Fourier optics in spatial filtering, holography, and analog processing of optical information. The fourth section includes a selected special topic. Offered are basics of plasmonics, introduction to fiber optics, optical tweezers, and fundamentals of quantum optics. Also, topics suggested by students will be under consideration for this section. This class is calculus based. Complex algebra, Fourier transform, and series expansions are routinely utilized in the three major sections. This class also includes an oral presentation.

Pre-requisites
PHYS 463: Advanced Optics I; Electromagnetics or Electricity and Magnetism; Calculus; Differential Equations; Linear Algebra; Complex Algebra; Matrixes; Grad Quantum Mechanics I.

Lectures:
Tuesdays and Thursdays; 5:30 pm – 6:45 pm

Instructor:
Dr. Vitaly Gruzdev, Department of Physics and Astronomy
PAIS Building, room 2244
E-mail: vgruzdev@unm.edu

Teaching Assistant:
TBA

Office Hours:
Instructor: Tuesday and Thursday; 7:00 pm – 8:00 pm. You may also arrange a meeting for another time depending of instructor availability.
TA: TBA

Textbooks:

There are many useful textbooks on the topics of this class. For each of the 3 major topics of this semester, there are recommended 1 or 2 textbooks.

Topic 1: Crystal optics:
(P3) Frank L. Pedrotti, Leno M. Pedrotti, Leno S. Pedrotti, "Introduction to Optics", 3d edition.
(FOX) Mark Fox, "Optical Properties of Solids", 2nd Ed., Oxford University Press, 2010.

Topic 2: Coherence:
(MF) Miles V. Klein, Thomas E. Furtak, "Optics", 2nd or 3d Edition.
(GS) Joseph W. Goodman, "Statistical Optics", 2^{nd} Ed.

Topic 3: Fourier Optics:
(GF) Joseph W. Goodman, "Fourier Optics", 2^{nd} Ed.

Additional resources:
Hartmut Haug, Stephan W. Koch, "Quantum Theory of the Optical and Electronic Properties of Semiconductors", 4th or later edition.
Jacques I. Pankove, "Optical Processes in Semiconductors".
Max Born, Emil Wolf, "Principles of Optics", 6th or later edition.
Lev D. Landau, E. M. Lifshitz and L. P. Pitaevskii, "Electrodynamics of Continuous Media", 2^{nd} Edition or later (Pergamon Press, 1984).

Homework assignments

There are planned 14 homework assignments this semester, approximately one assignment per week. Each assignment includes a few problems from the recommended textbooks and other sources. The assignments will be given throughout the semester a week before they are due. Homeworks must be turned in to instructor's mailbox on the due date by 8:00 pm. If unable to turn in a hard copy, a PDF file with your homework can be e-mailed to instructor by 8:00 pm on the due date.

Grading

The final grade will be based on the homework assignments, mid-term exam, oral presentation and report, and final exam. The contributions to the final grade are as follows:

1. Homework: 26% (2% each homework);
2. Report and presentation: 14%
3. Mid-term exam: 25%
4. Final exam: 35%

Exam dates (subject to change):

Mid-term: 03/12 (no makeup date).
Final exam: 05/12; makeup date: 05/14.

Formal Report:

A formal report is focused on one of suggested topics related to fundamental concepts and/or applications. It can be your lab report or a part of your lab report if the report topic is acceptable for this class. The objective of this task is to master students' writing skills and improve their style of technical/scientific writing. The report is prepared using LaTeX, which is a standard tool used in the scientific community in various areas including physics and engineering. The style should follow the format of a scientific paper from Physical Review, Optics Letters, or Applied Physics Letters. Length range is from 2 journal pages (minimum) to 4 journal pages (maximum). The report should be submitted to the instructor as a PDF file via e-mail (subject "Formal Report") by noon of Thursday, 05/07. The file name should include your last name in the style "Name_Report". Formal reports and presentations are individual. Samples of journal styles and LaTeX/TeX templates will be provided by instructor via e-mail.

Presentation:
The objective of this task is to improve the skills of public presentation on scientific and technical topics. You will deliver a presentation at the end of the semester on 05/07/20 on the topic of your Formal Report. Duration: 15 minutes of presentation + 5 minutes for questions/answers. It should cover fundamentals, relevant theoretical background, development/state-of-the-art in the field, and applications in science and/or technology. Slides for the presentation can be run from either instructor's laptop or your own laptop. Preferable formats, tips for slide preparation, and suggestions on presentation style will be shared later.

Syllabus Topics

Below is a tentative list of topics and sub-topics that will be covered by this class.

A. Crystal optics

1) Classical model of optical response of ideal dielectrics; dispersion; Kramer-Kronig relations.
2) Classical model of absorption by free carriers in solids; optical response of semiconductors.
3) Tensor of optical response; birefringence; polarization rotation (chirality); anisotropic reflectivity.
4) Basics of quantum theory of crystals; overview of absorption mechanisms in crystals.
5) Quantum theory of linear absorption in non-metal crystals; semiconductor Bloch equations.
6) Strong-field electron dynamics in crystals; laser-driven electron oscillations; non-perturbative approaches; the Keldysh photoionization formula.
7) Crystals in magnetic fields: Faraday effect; Cotton-Mouton effect; Zeeman effect; Landau levels; magneto-absorption.
8) Crystals in electric fields: Pockels effect; Kerr effect; Stark effect; Bloch oscillations; Franz-Keldysh effect.
9) Acousto-optic effect; crystal-optic devices.

B. Coherence

1) Temporal coherence; coherence function; contrast of interference pattern.
2) Statistical optics; autocorrelation function; coherence time and spectral bandwidth;
3) Spatial coherence; Van Cittert-Zernike theorem; transverse coherence; longitudinal coherence.
4) Fluctuations; light as a stochastic process; correlation momenta; quantum analysis.
5) Transmission of partially coherent light through optical systems; optical transfer function.

C. Fourier optics

1) Analysis of 2D signals and systems: 2D Fourier analysis; local spatial frequency.
2) Basics of scalar diffraction theory; Fresnel-Kirchhoff & Rayleigh-Sommerfeld diffraction; angular spectrum of plane waves.

3) Fresnel and Fraunhofer diffraction.
4) Wave-optics analysis of coherent optical systems; Fourier transforming properties of lenses.
5) Frequency analysis of optical imaging systems; resolution beyond the classical limit.
6) Applications in spatial filtering: wave-front modulation, spatial light modulators.
7) Applications in analog optical information processing; discrete analog optical processors.
8) Applications in holography; image locations and magnification.

D. Selected special topics (depending on available time).
1) Basics of plasmonics.
2) Optical tweezers.
3) Introduction to guided wave optics (fiber optics).
4) Radiation pressure and ponderomotive force.
5) Other topics if proposed by students.

Tentative schedule

Topic	Date	Subject	Reading	Homework	HW Due	Solutions
Crystal optics	01/21	Lorentz model of optical response	P3; Ch. 25			
	01/23	Absorption by free carriers	P3; Ch. 25	HW1	01/30	
	01/28	Tensor of optical response				
	01/30	Absorption mechanisms	Pn; Ch. 1	HW2	02/06	
	02/04	Quantum theory of absorption	Pn; h. 3			
	02/06	Strong-field electron dynamics	Lecture	HW3	02/13	
	02/11	Crystals in magnetic fields	HK			
	02/13	Crystals in electric fields	HK	HW4	02/20	
	02/18	Acousto-optic effect				
Coherence	02/20	Temporal coherence	KF; Ch. 8.1	HW5	02/27	
	02/25	Statistical optics	KF; Ch. 8.2			
	02/27	Spatial coherence;	KF; Ch. 8.3	HW6	03/05	
	03/03	Light as a stochastic process	GSO; Ch.			
	03/05	Fluctuations of light	KF; Ch. 8.4	HW7	03/12	
	03/10	Optical transfer function	KF; Ch. 8.5			
	03/12	Midterm test	Equation list			
	03/17	SPING BREAK				
	03/19	SPING BREAK				
Fourier optics	03/24	2D signals and systems	GFO; Ch. 2	HW 8	03/31	
	03/26	Basics of scalar diffraction theory	GFO; Ch. 3			
	03/31	Fresnel & Fraunhofer diffraction	GFO; Ch. 4	HW 9	04/07	
	04/02	Wave-optics analysis	GFO; Ch. 5			
	04/07	Frequency analysis	GFO; Ch. 6	HW 10	04/14	
	04/09	Applications: spatial filtering	GFO; Ch. 7			
	04/14	Applications: analog processing	GFO; Ch. 8	HW 11	04/21	
	04/16	Applications: holography	GFO; Ch. 9			
Selected topic	04/21	Selected topic lecture 1		HW 12	04/28	
	04/23	Selected topic lecture 2				
	04/28	Selected topic lecture 3		HW 13	05/05	
	04/30	Selected topic lecture 4				
	05/05	Selected topic lecture 5				
	05/07	Student presentations				
	05/12	Final exam	Equation list			
	05/14	Makeup final exam	Equation list			