PHYS 554.001 and ECE 554.001: Advanced Optics II
CRN: 55189 (Physics) & 54521 (ECE)

Description of the class
This class is a continuation from Advanced Optics I of the Fall Semester 2019. It covers four major sections: optical properties of materials (including crystal optics); coherence; statistical optics; and Fourier optics. The first section is focused on optical response of dielectric and semiconductor crystals and covers the following topics: classical Lorentz oscillator model for ideal dielectric crystals; Drude model of optical response of metals; basics of plasmons; complex optical response; Kramer-Kronig relations; dispersion of optical response; overview of absorption mechanisms in optical materials; tensor of optical response of anisotropic crystals; magneto-optic effects; electro-optic effects; acousto-optic effect; and applications of those effects in devices. The second section 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 includes analysis of statistical properties of light, auto-correlation and mutual correlation functions, and thermal noise of light. The fourth section includes Fourier analysis of 2D signals and systems; wave-optics and frequency-domain analysis of optical imaging systems; applications of Fourier optics in spatial filtering, and applications of Fourier optics in image analysis. If the schedule allows, some special topics will be included based on the specific interests and suggestions of students. This class is calculus based. Complex algebra, calculus, Fourier transform, and series are routinely utilized in the four 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:
Mondays and Wednesdays; from 10:30 am to 12:00 pm
Room: 1160 PAIS Building, first floor.

Instructor:
Dr. Vitaly Gruzdev, Department of Physics and Astronomy
PAIS Building, room 2012
E-mail: vgruzdev@unm.edu

Teaching Assistant:
TBA

Office Hours:
Instructor: Mondays; 12:30 pm – 2:00 pm. You may also arrange a meeting for another time depending on instructor availability.
TA: TBA

Textbooks:

Because of the supply-chain issues this year, lecture notes are considered as a major source of information for students of this class. However, there are many useful textbooks on the topics of this class. For each of the 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.

Topic 3: Statistical Optics
(SO) Joseph W. Goodman, “Statistical Optics”, 2^{nd} Ed.

Topic 3: Fourier Optics:
(FO) Joseph W. Goodman, “Fourier Optics”, 3^{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 7 homework assignments this semester, approximately one assignment each other week. Each assignment typically includes 3 problems from the recommended textbooks. The assignments will be given throughout the semester a week before they are due. Solutions to homework problems should be turned in to instructor’s mailbox on the due date by 2:30 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: 21% (3% each homework);
2. Report and oral presentation: 15%
3. Mid-term exam: 26%
4. Final exam: 38%

Grade brackets:
“B”: 66.7% - 80%
“A-”: 80% - 90%
“A”: 90.1% – 95%
“A+”: 95.1% - 100%

Exam dates (subject to change):
Mid-term: **03/09** (no makeup date).
Final exam: **05/11**; makeup date: **05/13**.

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 Monday, **05/09**. The file name should include your Student ID Number in the style "Number_Report". Formal reports and presentations are individual. Samples of journal styles and LaTeX/TeX templates will be provided by instructor via e-mail.

Oral 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 05/04/22 and on 05/09/22 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. <u>Crystal optics</u>

1) Classical Lorentz model of optical response of ideal dielectrics; dispersion;
2) Classical Drude model of optical response of free electrons in solids; plasmons;
3) Complex optical response; Kramer-Kronig relations; light absorption;
4) Tensor of optical response; birefringence; polarization rotation (chirality);
5) Anisotropic reflectivity; Fresnel crystal equation;
6) Crystals in magnetic fields: magneto-optical effects; Faraday effect; Cotton-Mouton effect; Zeeman effect; Landau levels; magneto-absorption.
7) Crystals in electric fields: electro-optical Pockels effect; Kerr effect; Bloch oscillations; Franz-Keldysh effect.
8) Applications of electro-optical and magneto-optical effects; control of polarization;
9) Acousto-optic effect; crystal-optic devices.

B. <u>Coherence</u>

1) Temporal coherence; coherence function; examples of coherence functions;
2) Interferometers; Michelson interferometer; contrast of interference pattern;
3) Spatial coherence; Young's two-slit interference experiment;
4) Transverse coherence; longitudinal coherence.

C. Statistical optics

1) Light as a stochastic process; statistical description of random processes; correlation functions;
2) Statistical optics; autocorrelation function; coherence time and spectral bandwidth;
3) Coherence from the viewpoint of correlation functions; Van Cittert-Zernike theorem;
4) Fluctuations and noise in optics – classical treatment; introduction into quantum analysis;
5) Transmission of partially coherent light through optical systems; optical transfer function.

D. Fourier optics

1) Analysis of 2D signals and systems: 2D Fourier analysis; local spatial frequency.
2) Overview of scalar diffraction theory; Fresnel-Kirchhoff & Rayleigh-Sommerfeld diffraction; angular spectrum of plane waves; Fresnel and Fraunhofer diffraction.
3) Wave-optics analysis of coherent optical systems; Fourier transforming properties of lenses.
4) Frequency analysis of optical imaging systems; resolution beyond the classical limit.
5) Applications in spatial filtering: wave-front modulation, spatial light modulators.
6) Applications in optical-image formation and analysis.

Tentative schedule

Topic	Date	Subject	Reading	Homework	HW Due	Solutions
Crystal optics	01/19	Introduction; math clinic	Lecture note			
	01/24	Lorentz model of optical response	P3; Ch. 25			
	01/26	Drude model for free carriers	P3; Ch. 25	HW1	02/02	
	01/31	Complex dielectric function	FOX; Ch. 2			
	02/02	Kramer-Kronig relations	FOX; Ch. 2			
	02/07	Tensor of optical response.	Lecture	HW2	02/14	
	02/09	Fresnel crystal equation	Lecture note			
	02/14	Crystals in magnetic fields	Lecture note			
	02/16	Crystals in electric fields	Lecture note			
	02/21	Acousto-optic effect	Lecture note	HW3	02/28	
	02/23	Polarization-control devices	Lecture note			
	02/28	Topic overview and summary	Lecture note			
Coherence	03/02	Temporal coherence	KF; Ch. 8			
	03/07	Spatial coherence	KF; Ch. 8			
	03/09	Midterm test	Equation list			
	03/14	SPING BREAK				
	03/16	SPING BREAK				
	03/21	Longitud. & transverse coherence	KF; Ch. 8			
Stat. optics	03/23	Stochastic processes	SO; Ch. 3, 4	HW4	03/30	
	03/28	Correlation function & coherence	SO; Ch. 4, 5			
	03/30	Coherency matrix	SO; Ch. 4			
	04/04	Van Cittert-Zernike theorem	SO; Ch. 5	HW5	04/11	
	04/06	Fluctuations and noise	KF; Ch. 8			
	04/11	Images by incoherent light	KF; Ch. 8			
	04/13	Optical transfer function	SO; Ch. 8	HW6	04/20	
Fourier optics	04/18	2D Fourier analysis	FO; Ch. 2			
	04/20	Overview of scalar diffraction	FO; Ch. 3			
	04/25	Wave analysis of optical systems	FO; Ch. 5			

	04/27	Spatial-frequency analysis	FO; Ch. 6	HW7	05/04	
	05/02	Spatial filtering and modulation	FO; Ch. 7, 8			
	05/04	Student presentations				
	05/09	Student presentations				
	05/11	Final exam	Equation list			
	05/13	Makeup final exam	Equation list			

UNM Requirement on Masking in Indoor Spaces

All students, staff, and instructors are required to wear face masks in indoor classes, labs, studios and meetings on UNM campuses, see the masking requirement. Students who do not wear a mask indoors on UNM campuses can expect to be asked to leave the classroom and to be dropped from a class if failure to wear a mask occurs more than once in that class. Students and employees who do not wear a mask in classrooms and other indoor public spaces on UNM campuses are subject to disciplinary actions. **Medical/health grade masks are the best protection against the omicron variant and these masks should be used, rather than cloth**.

COVID-19 Symptoms and Positive Test Results:

Please do not come to a UNM campus if you are experiencing symptoms of illness, or have received a positive COVID-19 test (even if you have no symptoms). Contact your instructor and let him know that you should not come to class due to symptoms or diagnosis. Students who need support addressing a health or personal event or crisis can find it at the Lobo Respect Advocacy Center.