Physics 4302, Optics, Fall 2014

Lectures: Monday and Friday 12.00-12.50am in Room BA 108, Barton Hall

Laboratory: Wednesday 11.00 -12.50 am in Room BA 202, Barton Hall
(additional time slots to be determined during first week of class)

Instructor: Prof. A. Marjatta Lyyra
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Office hours: Monday 1-2.30 pm or by appointment by email

Teaching Assistant: Xinhua Pan (tel. 215-204-7656, Room BB 16, Barton Hall, B wing basement, use B wing elevator to get there)

Required Textbook: F. L Pedrotti, L. S Pedrotti and L. M. Pedrotti: Introduction to Optics, 3rd edition, ISBN 0-13-149933-5, available from the SAC bookstore.

Homework: Homework assignments are given on Mondays every two weeks and are due in class after two weeks from the day of assignment on Mondays.

Exam Format: There will be two exams, a midterm and a final. The midterm exam is a one-hour exam, whereas the final exam is scheduled for two hours.

If you have a time conflict with the exam dates, please notify me well in advance by email.

Exam Schedule and exam, lab and homework credit:

Midterm: October 27, normal class time in BA 108	20% of total grade
Weekly homework:	25% of total grade
Laboratory reports:	25% of total grade
Final exam: December 17, 10.30-12.30am, in BA 108	30% of total grade

Course description:

Introduction: Optics and Lasers and their applications

Knowledge of introductory optics is very useful in many fields of research and technology. Please read the 2012 report by the National Research Council on Optics and Photonics: Essential Technologies for Our Nation (on Blackboard). These include optical communications using fiber optics to provide the large bandwidth and fast speed required for quick transfer of large amounts of data in telecommunications networks. Optical fiber bundles are also used in medicine in various diagnostic devices such as endoscopes in which light is introduced inside the body noninvasively to illuminate tissues and at the same time light is brought back through optical fibers to collect image data from the body. Laser beams delivered through optical fibers are also used to cauterize, ablate and cut tissue, thus allowing doctors to replace the scalpel in some procedures.

A focused laser beam is also a versatile microscopic tool in materials science and is used for tagging and moving cells. This application is called laser tweezers.

A fast developing new area of optics applications is that of optogenetics, which is a neuromodulation technique used in neuroscience that uses a combination of techniques from optics and genetics to *control* the activity of individual neurons in living tissue-even within freely-moving animals—and to precisely measure the effects of those manipulations in real-time.

Short pulses of laser light are used to study the 'mechanics of chemistry', i.e. chemical bond breaking and formation at the very short time scale in real time with the high time resolution available from such lasers ($\sim 10^{-15}$s). The highest time resolution available with lasers is approaching 100 x 10^{-18}s (attosecond) range making it possible to probe electron motion is atoms and molecules.

Such a wide range of applications of lasers in science and engineering has led some scientist to name this new century the "Light Age". The previous century was dominated with advances in electronics.

However, in order to use optical devices in research and applications you will have to understand the physical principles of optical devices and laser beam characteristics within the frequency domain. This course intends to give you a solid foundation in that sense.

For career options in Optics please visit: http://www.optics.rochester.edu/

Course Content:

Selected chapters in the required textbook **Introduction to Optics**

Chapter 1. Nature of Light, short review

Chapter 2. Geometrical Optics, short review

Chapter 18. Matrix Methods in Optics

Chapter 4. Wave Equations

Chapter 5. Superposition of waves

Chapter 6. Properties of Lasers

Chapter 7. Interference of Light

Chapter 8. Optical Interferometry

Chapter 9. Coherence

Chapter 10. Fiber Optics

Chapter 11. Fraunhofer Diffraction

Chapter 15. Production of Polarized Light

Chapter 27. Characteristics of Laser Beams

Laboratory exercises:

The course starts with laser safety class. Some of your labs will be done in BA 202 in the beginning of the semester and in our laser laboratory in Room BB10 during the second half of the fall semester using research equipment. We are also in the process of moving to the new SERC building and will inform you if there are any changes.

I recommend that you read Chapter 10 on fiber-optics as soon as possible for the fiber-optics labs that come early in the semester.

You will be applying the matrix methods from Chapter 18 in the two-lens laboratory. In general the idea with the matrix methods is to develop a system matrix that makes it easy to handle mathematically any number of optical components in any optics set up automatically.

The labs also include experiments on interference of light such as Newton's rings and Michelson interferometer.

You will be able to use an open cavity Helium Neon (HeNe) laser to learn to align the mirrors of the laser cavity and make the laser lase as well as to characterize the transverse beam profile of the fixed frequency (HeNe) laser beam. Fixed frequency simply means that the laser output wavelength is not tunable and thus the frequency $\nu = c/\lambda$ may not match any molecular or atomic transition frequency and would not be absorbed. You will also determine the laser E field amplitude from the measured laser output power and the measured laser beam waist.

Towards the end of the semester your labs will also involve the use of tunable lasers with an internal wavemeter that allows you to scan the laser under computer control as a function of the laser frequency. This frequency tunability will be used to match the laser frequency with the absorption frequency of an atomic or a molecular transition to study

Doppler broadening or the quantized energy level structure of atoms or molecules and their response to absorption of light. These frequency stabilized high resolution lasers in the laser laboratory BB10 include the use of etalons (see interference in a parallel plate) to stabilize the laser to lase on a single longitudinal cavity mode and thus narrow the laser bandwidth to a width of about 1MHz from about 5GHz, the latter being too broad to use as a tool to scan over a Doppler broadened atomic or molecular fluorescence emission line. Chapter 8 on Optical Interferometry is one of the most important ones in the course since it describes the physical principles of how etalons work to narrow the laser output to a single longitudinal laser cavity mode and thus eliminate all other competing modes at slightly different frequencies within the laser gain bandwidth.

These labs allow you to learn about the advantages of a tunable laser compared to one that only produces fixed frequency output such as the HeNe laser. By using laser induced fluorescence (LIF) you will tune the laser frequency across a Doppler broadened molecular transition and record the spectral line width of this transition to determine the temperature of the molecular gas. You will also use a scanning monochromator with a diffraction grating to resolve the spectral components of laser induced fluorescence to identify the ro-vibrational energy levels of the molecular species in question and the transition that the laser beam was tuned to excite. This excitation results in laser induced fluorescence as a result of the sample molecules absorbing the laser light in the first place. Understanding the basic mechanisms leading to electric dipole transitions in atoms and molecules and subsequent fluorescence and its lineshape is important in a broad sense for your learning about atomic, molecular and optical physics.

Pre-requisites: The course has a prerequisite of one year of introductory Physics. Ideally you should have had Modern Physics or Physical Chemistry. You should be familiar with matrix multiplication, trigonometry and have some rudimentary knowledge on Analytical Geometry (Cartesian surfaces).

Time conflicts: If you miss class for some reason, please let me know by email. If you have a conflict with the exam dates please discuss with me alternative arrangements well before the exam date. If you are sick, please email or call 215-204-3776.

Integrity: We learn in a group environment, but we must demonstrate our mastery of materials on an individual basis. Misrepresenting other people's work as one's own ("copying" or "plagiarism") is a serious breach of academic integrity. All tests, homework solutions and lab reports must reflect a student's own individual work, and must be done in the specified time period. Cheating or helping others cheat violates the spirit of trust that we all value. Cheating will be considered an admission that a student does not understand the material, and grading will reflect this admission.

These guidelines are in conformity with the rules concerning <http://www.temple.edu/bulletin/Responsibilities_rights/responsibilities/responsibilities.shtm>Student

Disability Statement: This course is open to all students who meet the academic requirements for participation. Any student who has a need for accommodation based on the impact of a disability should contact the instructor privately to discuss the specific situation as soon as possible. Contact Disability Resources and Services at 215-204-1280 in 100 Ritter Annex to coordinate reasonable accommodations for students with documented disabilities.