6.637 Optical Signals, Devices and Systems

Course Syllabus and Outline - Fall 2015

6.637 covers the fundamentals of optical signals and modern optical devices and systems from a practical point of view. Its goal is to help the student develop a thorough understanding of the underlying physical principles such that device and system design and performance can be predicted, analyzed, and understood.

Most optical systems involve the use of one or more of the following: sources (e.g., lasers and light-emitting diodes), light modulation components (e.g., electro-optic-crystal and MEMS light modulators), transmission media (e.g., free space or fibers), photodetectors (e.g., photodiodes, photomultiplier tubes), information storage devices (e.g., optical disk), information processing systems (e.g., imaging and spatial filtering systems) and displays (e.g., liquid-crystal-on-silicon microdisplays). These are among the topics covered by this course.

**Prerequisites:** The prerequisite is 6.003. Exceptions can be made by the Lecturer.

**Lecture:** Room 34-304, TR 2:00-3:30pm

**6.161 Laboratory (optional):** Optics Lab: 38-633, Time TBA. Optics Lab Phone: x3-4619 (Note: we share the lab phone with 6.115, 6.003, and 6.002).

**Course Staff**

**Lecturer:** Prof. Cardinal Warde  
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**Laboratory Assistant:** Christos Samolis  
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**Course Website:** [http://web.mit.edu/6.161](http://web/mit.edu/6.161)
1. Course Content

Homework
One homework problem set will be assigned each week. The homework problems are designed to encourage outside reading, and to strengthen your grasp of the fundamentals. How you got to your answer is very important. Show your work! The grader will deduct points for answers which lack justification. Problem sets will not be accepted after the solutions are handed out. Points will be deducted for late problem sets. Late homework should be handed directly to the TA.

Quizzes
There will be two in-class quizzes during the term. These quizzes will cover broad ideas, as presented in lecture and homework. The quizzes will consist of questions intended to test your knowledge of basic optical principles. These quizzes will be open book (Prof. Warde’s class notes). You should not stress over these quizzes. If you have done the reading, attended lectures, completed the homework, you should be well prepared for the quizzes. The quizzes will count for approximately 40% of your grade (20% each). These quizzes will enable the teaching staff to diagnose both our teaching and your comprehension.

Research Project
One of the homework assignments will be a two-week research project for which the student will prepare a research paper (30 page limit) and make a conference-style 10-minute in-class presentation.

In preparation for the final project, you will submit a one-page design Project Proposal that presents an accurate and compelling account of your working idea. At this stage, the objective is not to “sell” an incomplete design, but rather to elicit the most useful feedback possible from your audience of experts (Instructor, TA, or other expert). To do so, you should present evidence of the significance of the problem, of the merit of your proposed solution to that problem, and of the novelty of that solution.

Areas that may be considered for research projects include:
Lasers for next-generation fiber-optic systems
WDM and DWDM challenges
Microdisplay technologies
Flat panel display technologies
Real-time holography
Electronic imaging systems
Thermal imaging systems
2-D and 3-D optical storage technologies
Photon-counting with avalanche photodiodes
Optoelectronic networks and processors
Optical neural networks
Adaptive optical systems
Optically-controlled phased array radar
Optical inference engines
Fluid velocimeters
Coherence tomography
Recent Advances in Microscopy

Students may work alone or in a team of two on the research project. The presentation must include a discussion of the relevance or the potential impact of the technology on society. The presentations will be graded on: (a) the clarity of the presentation [2 pts], (b) the substance of the material presented [2 pts], and (c) the creativity/innovation in showing or speculating on the impact or application (present or future) of the technology [1 pts]. The accompanying written report is worth 15 pts.

Writing the Report
The final project report should be written in accordance with the outline followed by most professional journals in the field (e.g., Applied Optics or Journal of the Optical Society of America). Alternatively, you may use the outline provided below. Your laboratory exercises and project reports must therefore contain, at the very least, the following information:

1. A cover page which states the title of experiment, your name, subject number, the date, and the name of the person who supervised your work.
2. A one-paragraph Abstract that states the problem being addressed or the goals of the research, the procedures used to solve or analyze the problem, and the salient findings, conclusions or implications of the work.
3. An Introduction that contains a brief description of the problem being investigated as well as brief background information to familiarize the reader with the significance or importance of the work to the field. Be sure to define all uncommon terms.
4. A section describing the Approach used. This section should briefly describe the general techniques or methods used to explore the phenomena being investigated. It may, therefore, include a brief theoretical formulation or modeling of the problem. For brevity, you should cover the principles at a level such that one with a similar educational background (MIT junior or senior) can follow your reasoning. Do not re-derive complicated equations. Instead you should state the equation, cite the reference (see 8 below) where one can find the derivation, but interpret each term in the equation so the reader can understand the physical concepts involved.
5. A brief description of the apparatus used, followed by your Experimental Procedure. Use as many diagrams as you need to describe the apparatus and its operating principles, and how the data were taken.
6. A section describing your Experimental Results and Analysis. Present raw data, whenever possible, in tabular form, and derived results or analysis, whenever possible, in graphical form.
7. A section summarizing your Conclusions with comments on the errors in your measurements, and recommendations for improving the measurements or the
experiment. Your conclusions should also tie in to the stated objectives of the experiment so that the reader gets your opinion of the overall success of the work. This is also a good place to speculate on the potential applications of your work.

8. A list of References that support claims made in your report.

Should you still be in doubt, use the bold-face words above as section headings in your reports.

Grading Policy
Homework will account for 40% of the final grade, the research project 20% and the quizzes 40% (20% each).

2. General Policies

Neatness and Clarity
To ensure that you get the maximum number of points on each homework assignment, make sure to be neat! The TA or grader will not grade messy work. Additionally, messy work will delay turnaround on both problem sets and homework. Questions must be answered clearly and succinctly. The TA will be looking for demonstrated understanding. It is preferred that you explain in words when possible; this will ensure that you get the maximum number of points for your effort. However, do not neglect mathematical rigor. When math is needed, it must have the proper units and be clearly written. However, do not compromise important details.

Labeling and Formatting
Whenever a problem asks for a graph, you must create computer-generated graphs. All graphs must be labeled and titled - a copy of the graph must be transferred to your homework problem solution. Use callouts to point out important regions of your graphs. Any written answers exceeding one page must be typed. It is suggested that you format all your answers using LaTeX or a comparable typesetting package.

Label your answers clearly; the grader will not search extensively for an answer. Circle your answers, and underline key portions of your work which directly aid in the creation of the answer. Points may not be given back if an answer is skipped in the grading process because the answer was difficult to find.

Matlab, Mathematica, LabView and Maple
When computer-based problems are presented, please use Matlab, Mathematica, LabView or Maple to do your work. If you feel much more comfortable with other math packages, that is okay, but please put the code in your public directory along with instructions on its execution. You can download homework-specific Matlab scripts and Matlab notebooks from the website for this class. Please include any code and graphs you use in your solutions. Often, unless stated, graphical solutions may be used,
especially if they show that you really understand the material. To use Matlab, Mathematica or Maple on Athena, type: `add matlab`, `add math`, and `add maple` at the Athena% prompt. These software packages can also be found on the MOL machines (6.161 Laboratory)

**Late-Work Policy**
The TA knows that some of you may have obligations which inhibit your ability (on rare occasions) to turn in work on time. If such an emergency arises, notify the TA before the homework is due (if possible). In order to be fair to your classmates, we must still penalize late work (unless the tardiness was due to medical or similarly urgent reasons). Additionally, an incomplete problem set will not be accepted. We expect you to make an effort on ALL parts of ALL problems. This gives us the chance to see where you are having problems, if any. If you need additional time, ask for it. You will always receive more points for a completed late problem set than an on-time incomplete one (assuming you turn it in before solutions are handed out). If tardiness becomes a chronic problem, it will significantly degrade our final evaluation of your performance.

**Collaboration**
Collaboration is encouraged. Talking with peers about problems helps everyone ("To teach is to learn twice." – Joseph Joubert). However, blatant copying and other forms of cheating will not be tolerated. Always acknowledge your collaborators. This will not hurt your grade. In fact, it may help. We care that you learn the material. If you learn best from a friend, that is fine with us.

**Plagiarism**
While collaboration is encouraged, plagiarism will not be tolerated. Please become familiar with the various forms of plagiarism so that you avoid making embarrassing and perhaps costly mistakes. Here are two MIT websites where you can learn more about plagiarism:

http://web.mit.edu/writing/Citation/plagiarism.html

**Office Hours**
Group office hours will be conducted weekly in Prof. Warde’s office (13-3102). Office hours will address questions from the laboratory exercises, quizzes, and problem sets. Office hours may also include hands-on demonstrations of applied concepts. While office hours are not mandatory (except to deliver oral presentations of your laboratory exercises) they may cover concepts and material that may show up on quizzes, homework and labs. Students are expected to ask questions and come to office hours prepared.

**3. Textbooks and Reading Materials**
Some of the topics that we will cover are still areas of active research and are not yet treated in textbooks. Consequently, a combination of class notes and lecture slides will be provided on each topic. However, several of the basic concepts are covered in the following textbooks:

We recommend you purchase the book by Hecht. Hecht’s *Optics* can be purchased at the Coop or Quantum books (Quantum is much cheaper than the Coop). Purchase of the other textbooks is not essential. These books are on reserve in the Barker Library - but occasionally disappear during the term (especially when problem sets are due). They are intended for use as reference material. Please note that Hecht is a required book for 8.03, and Saleh is recommended for 6.631.

Portions of the material we will cover can also be found scattered throughout a number of journals and conference proceedings that include:

*Journal of the Optical Society of America*
*Applied Optics*
*Optics Letters*
*Applied Physics Letters*
*Optics Communications*
*Optical Engineering*
*Proceedings of the SPIE (Society of Photo-Optical Instrumentation Engineers)*.

Occasionally, students will be expected to read and apply material covered in articles selected from these journals.