2003 Modern Optics Project Laboratory
Course Information and Syllabus

The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them. - Sir William Bragg

To: Our students
From: The Modern Optics Laboratory staff
Date: Sept. 2003

1 Prerequisites

6.161, Modern Optics Project Lab, is designed to teach the fundamentals of optical science and engineering. The prerequisite for this course is 6.003. Exceptions can be made by the Lecturer.

2 Questions

If you have any questions regarding this course, please feel free to contact either Prof. Cardinal Warde (warde@mtl.mit.edu) or Laboratory Instructor David Dunmeyer (ddunmey@). Questions regarding problem sets and labs should be addressed to the class collaboration webpage.

3 Safety

Why put safety at the top? Because it is EXTREMELY important. We strongly urge you to always follow prescribed safety instructions- if you are unsure about anything, especially when dealing with high-intensity light sources (such as lasers), or with high-voltage power supplies (such as those found powering lasers or other laboratory equipment), ask someone who knows (namely the lab staff). You will receive training in how to deal with lasers and optics. However, some basic pointers to remember are:

1. Never look directly into a laser source, even low-power lasers can blind!
2. Keep track of all stray light (and then block it).
3. Keep all high-intensity light beams at table-level.
4. Always keep your eyes a couple feet above table level. (if you violate this exclusion zone, you will be asked to either leave the laboratory for the day, or you will be excluded from working on your project or laboratory exercise).
5. Wear safety glasses when appropriate. You MUST wear them when working with IR and UV laser light, as well as with mercury discharge lamps and strong light sources.
6. Keep your colleagues notified - tell them what you are doing so that they may protect themselves (and you). Always notify them if you turn on a laser or change the direction of the beam. Precautions also include closing the laboratory door, closing the window drapes (if appropriate), as well as turning on the laser warning light (light switch behind the chemical cabinet).
7. Always listen to the suggestions of the laboratory staff and your colleagues.
8. Keep your optics clean.
9. Practice good common sense.
10. Institute policy requires that all persons working with high-voltage, work in pairs. (See high voltage safety requirements below.
11. No drinking or eating is allowed in the lab. Hands must be washed before handling optics or electronics.
12. You may not work in the lab without supervision of an LA or a TA until final-project time. During final-project time you must work in pairs (only the TA, LA or lecturer may ever be in the lab alone).
13. Cell phones (except for the lab staff) are not allowed to be turned on inside the Modern Optics Lab.
14. Always inspect optical fiber carefully -- bare fiber can easily puncture your skin or your eye!

**HIGH VOLTAGE Safety Requirements**

SHIELDING: Live parts of all electrical equipment must be completely enclosed or otherwise guarded against accidental contact.

INTERLOCKING: Where continual maintenance or adjustments must be performed, enclosing shields must be provided with interlocks which will disconnect all power to conductors and short out capacitors when the shield is removed or opened.

DISCONNECTS: Provide an accessible, labeled main power disconnect switch.

GROUNDING: Ground all exposed non-current carrying parts. (Metallic optical table tops should be grounded to the nearest water pipe.)

BONDING: All grounded parts must be bonded to each other to keep them at the same grounded electrical potential.

INSULATORS: Adjustment mechanisms must be insulated from live electrical parts or be made of nonconductive material.

SPACE: A minimum of 30 inches width should be maintained on all working sides of equipment operating at 600 volts or less; 36 inches if over 600 volts.

WORKING ALONE: Working alone at any time is contrary to Institute policy.

CPR: It is recommended that all persons working with lasers have training in cardiopulmonary resuscitation, available through the Safety Office.

**Note:** Violation of safety rules, if severe enough, may lead to automatic dismissal from the class. Such dismissible offenses include roughhousing, as well as moderate or serious injury due to careless action. Severe safety violations will lead to an automatic failing grade as well as possible action by the Institute as well as possible criminal liability. Some general rules follow:

For minor safety violations, you will receive a warning. After two warnings, you will be asked to leave the lab and come back for another lab session. If you are asked to leave due to an
accumulation of minor safety violations (more than twice), you will receive an incomplete for
the current lab, and therefore will not be able to receive a passing grade for the class.
Likewise, if you commit a safety violation which is deemed serious enough by the lab staff, you
will be asked to leave for that day, but you will be able to come back on the next lab day (if it
exists).

Safety violations can be caused by a lack of sleep, drug use (antihistamines, pain killers,
alcohol, etc.), or emotional strife (daydreaming, family illness, etc.). Therefore, temporary
dismissal from the lab is not meant to be punishment, but rather an opportunity for you to
remedy what ails you. You may discuss your temporary dismissal with the lab staff AFTER the
lab day. However, no excuses or arguments will be accepted at the time of dismissal - arguing
will only result in disciplinary measures.

So far, we have never had to dismiss a student for safety violations... please don't be the first.

4 Course Content

4.1 Objective

The objective of this course is to provide the student with broad laboratory experience in the
fundamentals of modern optical techniques, devices and systems. There are two lectures and
one laboratory period each week. During the first several weeks, the lectures will review and
develop fundamental principles and concepts in classical optics, and optical and quantum
electronics. The remaining lectures address contemporary topics in modern optics. The
assignments consist of: (1) laboratory exercises, (2) homework problems, and (3) an
experimental project in modern optics.

Since this is a laboratory course, the intent is not to dwell on detailed theoretical treatments of
the topics, but to provide a sufficient background for the student to grasp the principles and
confirm the associated phenomena in the laboratory. For more theoretical treatments the
student is encouraged to enroll in other optics subjects that are specifically designed for this
purpose (e.g., 6.630, 6.631, 6.634, 6.637).

4.2 Laboratory Exercises

There are eight short laboratory exercises concerned with the measurement and observation
of basic optical and quantum phenomena. Each laboratory exercise consists of pre-lab
exercises (to be completed before entering the lab) and several experiments dealing with the
same theme, designed to complement the lecture material. Each laboratory exercise will be set
up by the course staff for one week only, and you must complete each laboratory exercise
sometime during the week that it is set up. Some of the laboratory exercises require a
considerable amount of setup time, and once they have been taken apart, they will not be set
up again. Laboratory exercise reports must be turned in to the Teaching Assistant (TA) or
Laboratory Instructor (LI) one week after the exercise was scheduled. In the event the report is
due on a day when the Institute is closed, the report should be turned in to the TA or LI by 5:00
pm on the first day that classes resume whether or not the Laboratory is open on that day. This
may be a day when 6.161 does not meet. Late homework should be placed in the bin outside
13-3102 or handed directly to the TA or LI. All laboratory write-ups (along with pre-lab
exercises) MUST be done in a carbonless-copy lab notebook. Currently, we will only accept
lab writeups using the Hayden McNeil Physical Sciences Student Lab Notebook with Spiral
Binding (There is also a spiral-bound Chemical Sciences version of this notebook, which is acceptable)-- this notebook may be purchased from the Coop (it costs about $19) and is 70 numbered pages long. Students must turn in the yellow copies and keep the blue copies for themselves and for reference. Blue copies are NEVER to be removed from the lab notebook. Plots, tables and graphs must be pasted onto both the blue and yellow copy. More information as to laboratory writeup specifics will become available during the first week of the term.

### 4.3 Homework Problems

The homework problems are designed to encourage outside reading, and to strengthen your grasp of the fundamentals. One homework problem set will be handed out each week and will be due one week later. Problem sets will not be accepted after the solutions are handed out. Points will be deducted for late problem sets.

### 4.4 Quizzes

There will be two 45-minute quizzes during the term. The quizzes will be given during the regular 1.5 hour class. These quizzes will cover broad ideas, as presented in lecture, lab, and homework. They will test your understanding of the fundamentals and their applications. These quizzes will be open class notes (Prof. Warde's course notes). You should not stress over these quizzes. If you have done the reading, attended lecture, completed the homework, and worked the labs, you should have no problem with the quizzes. The quizzes will consist of 12 short questions intended to test your knowledge of basic optical principles and laboratory optics. The quizzes will count for approximately 20% of your grade (10% each). These quizzes will enable the teaching staff to diagnose both our teaching and your comprehension. Quizzes, like homework may be a determining factor if your grade is borderline.

### 4.5 Final Project

To make all the Final Projects roughly equal in difficulty and time requirement, we will provide you with several possible Final Projects (which will still allow for, and require, innovation). Additionally, we will allow students to start on the Final Project as soon as they want... hopefully reducing end-of-the-term stress. We will provide the necessary lab equipment and all the technical help we can to ensure that your experience is both educational and rewarding. Of course, if you still want to find your own project, or have a hankering to do something different, just tell us, and we will try to accommodate you (we encourage you to look around MIT for groups that may have projects that interest you). Many final projects found outside of class turn into RAships and M.Eng. work. Alas, one more thing... the Final Project report will require a full write-up, which may be submitted for Phase-Two of the Institute Writing Requirement. It should be on the order of 15 to 30 pages in length (please, no longer... you should be able to condense any relevant prose into that space). Additional information will be distributed later in the term.

### 5 General policies

To make laboratory exercises flow smoothly, please arrive on time for your assigned lab sessions. Additionally, please come prepared: this means that you will have read the lab material before arriving, completed the pre-lab and have brought your questions with you. As part of the pre-lab, you must find and review the equations necessary to complete the lab before you begin. In order to ensure that you will have all the data you need for your write-ups,
you will be required to take notes in a laboratory notebook (Hayden McNeil Physical Sciences Spiral Bound Student Lab Notebook). These notebooks may be checked at any time by the TA, LI or Professor Warde to make sure they contain all necessary information. A well-kept notebook will help ensure that you not fail to gather all the necessary data for your writeup (as you may not be able to come back and retrieve the data before the apparatus for a given laboratory exercise is dismantled). Additionally, short oral quizzes may be given in lab to test your comprehension of the current laboratory material -- these quizzes or notebook checks will count toward your laboratory grade (between 5% and 10% depending on difficulty).

5.1 Grading

The laboratory exercises are an integral part of 6.161, constitute the majority of your learning, and thus the final grade. Each homework problem set makes up a small, but non-negligible portion of the final grade. The two quizzes are obviously very important since they represent 20% of the grade. Your performance on the Final Project is also a very important portion of our evaluation of your overall performance. The approximate percentage values are as follows:

40% Labs (active participation in lab, performance on pre-lab, and good laboratory notes will form a significant portion of this grade), 20% Homework, 20% In-Class Quizzes and in-class participation, 20% Final Project.

We will take into account participation in-class and in-lab as well as attendance when deciding borderline final grades.

Please note: To earn a passing grade (A,B,C) in this subject, the student must complete all six of the Laboratory Exercises in the prescribed time period. Also, since most students do well on both the labs and the Final Project, performance on both the problems sets and quizzes become an extremely important factor in determining the final grades.

Grading Breakdown

All homework problem sets account for the same number of points (re-normalized at the end of the term). How you got to your answer is very important. Show your work! The grader will deduct points for answers which lack justification.

The worth of each Laboratory Exercise is based on the length and difficulty of the lab (e.g. Lab 3 counts for more than Lab 1). For all labs, write your answers in your lab notebooks. Be sure to include derivations, solutions, graphs, diagrams, data, and physical explanation when answering the lab questions -- be sure to include copies of any computer print-outs on both the normal sheet and the second carbonless-copy sheet. (Note from the TA: Please do not become discouraged if your score on the first lab seems low. Lab 1, while it does count as part of the final grade, should be viewed as a steppingstone into the course. Just do the best you can on this lab. Assume nothing, and be very thorough! Do not assume that the grader knows how you arrived at your answer -- assume the grader has never taken this class, and thus needs a full and detailed explanation. While you may have the correct answer, how you got there is more important! You will not receive credit for answers without explanation.)
The TA will only grade your lab report if you showed up to lab and actively participated in the lab experiments. **Note: at the end of the term no incompletes will be given due to incomplete final projects!**

**Neatness and Clarity**

To ensure that you get the maximum number of points on each lab and 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 on both problems sets and labs 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. Use diagrams to show what specific symbology means. The TA and a grader grade all labs and homework; the more clear and succinct your answers, the better. However, do not compromise important details. The grader will not accept numerical answers without their derivation. Likewise, the grader will not accept written answers, without appropriate reasoning.

**Labeling and Formatting**

Whenever a problem asks for a graph, the student **must** create computer-generated graphs. All graphs must be labeled and titled - a copy of the graph must exist both on the blue and yellow carbonless-copy sheets of your lab notebook. 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. If you wish to use one of your labs for Phase II of the writing requirement, notify the TA beforehand.

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.

**5.2 Late-work policy**
Having been an undergraduate once, your TA knows that many of you have obligations which inhibit your ability (on rare occasions) to turn in work. 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.

### 5.3 Phase II of the Writing Requirement

Students may use material from this course to satisfy Phase II of the Writing Requirement. The student may choose to submit either their final project (suggested) or an expanded formal report of a laboratory exercise that the MOL lecturer approves. A suggested format for writing the Final Project report is given in a following section. This same format can be used to write the laboratory exercise that you intend to submit to the Writing Program. Alternatively, you can follow the guidelines provided by the Writing Program. If you choose to use a laboratory exercise report for the Phase II writing sample, it should be limited to a maximum of 15 single-spaced pages with fonts no smaller than 10 point. This 15-page limit does not apply to the final project report.

### 5.4 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. In no way can this hurt your grade (in fact, it may help). We care that you learn the material - if you learn it best from a friend, that's fine. Collaboration (online) must be done through the moderated collaboration web page (that way everyone has access to the same resources, and if you have a problem or question, someone may be able to help you -- including the TA). There you can get help from the Lab staff, as well as your peers. You can find the collaboration page on the class website: [http://web.mit.edu/6.161/www/index.html](http://web.mit.edu/6.161/www/index.html)


This site was designed to aid you in obtaining relevant data and information for your studies in 6.161. This site will provide a resource where you may: access homework, communicate with classmates, sample quiz material and view lecture/tutorial notes. Additionally, you will be able to find applicable scripts and other homework aides here. This site will be where updates to the lab schedule, homework assignments, and labs are posted. Since this page is updated often, make sure to refresh every time you view it.

### 5.6 Office Hours

Office Hours will be conducted weekly, by appointment. 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, they may cover concepts and material that may present itself on quizzes, homework and labs. Students
are expected to ask questions and come to office hours prepared. Questions and concerns addressed on the class electronic mailing list, as well as the class collaboration page may be addressed in office hours.

6 Reading Material

A set of class notes will be handed out as the term progresses. Textbooks that contain some of the material we will cover include:


Purchase of these textbooks is not essential. The first five are on reserve in the Barker Library - but occasionally disappear during the term (esp. when problem sets are due). They are intended for use as reference material. Hecht's Optics can be purchased at the Coop or Quantum books (Quantum is MUCH cheaper than the Coop) as well as Saleh's Fundamentals of Photonics (Hecht is a required book for 8.03, Saleh is recommended for 6.631). However, Hecht and Yariv are the most highly recommended for this course. We strongly recommend the purchase of Hecht.