The Master Level Optics Laboratory at The Institute of Optics

Per Adamson
The Institute of Optics, Hajim School of Engineering
University of Rochester, Rochester, New York 14627

ABSTRACT

The master level optics laboratory is a biannual, intensive laboratory course in the fields of geometrical, physical and modern optics. This course is intended for the master level student though Ph.D. advisors which often recommend it to their advisees. The students are required to complete five standard laboratory experiments and an independent project during a semester. The goals of the laboratory experiments are for the students to get hands-on experience setting up optical laboratory equipment, collecting and analyzing data, as well as to communicate key results. The experimental methods, analysis, and results of the standard experiments are submitted in a journal style report, while an oral presentation is given for the independent project.

Key words: Optics Laboratory, The Institute of Optics, Master level laboratory

1. INTRODUCTION

Students taking master level coursework at The Institute of Optics will have at least three courses in optical theory, depending on which master's level track they are taking, and the laboratory class. The masters level optics laboratory has been added to the curriculum since it was impractical to have extensive laboratory experiences in each of the theoretical classes due to the level of necessary resources. Therefore, master level optics laboratory is included in the curriculum to enhance the student's understanding of optical phenomena presented in the theory courses. It also gives them a broad skill set they can use in their studies and careers. This laboratory class does not only emphasize the hard skills in working with optical equipment, but also offers the chance for students to learn and experience soft skills and problem solving. Soft skills are the abilities of a person to interact with others. Communication and leadership skills are the main themes within soft skills. The problem-solving portion within the laboratory experience first involves framing the problem and then asking the "correct" questions to solve a seemingly complicated problem. The students are expected to think about process of finding an answer instead of just finding the answer. This process will allow students to tackle new and more challenging problems as they continue on with their lives.

2. RELEVANCE TO THE GRADUATE PROGRAM

There are two different paths for students to take for the full-time master program in optics: a thesis route and a non-thesis route, as shown in Table 1. Within both of these paths, students that come to The Institute of Optics to acquire a master's degree must complete the master level optics laboratory course, OPT 456. The only exception to this is when a student is taking master classes as a part-time student. Under this situation, the student is not required to take the laboratory course. It is assumed that part-time students have sufficient experience in the optics field and have shown some adepthness in soft skills. However, the optics laboratory course can be taken by a part-time student and used as one of their elective classes. It has been observed that even some Ph.D. students who have a desire to learn more about optic laboratory practices also take the four-credit hour course. Some Ph.D. students enroll in the optics laboratory class because they do not have extensive backgrounds in optics so their advisors encourage the students to take the class to enhance their knowledge and skill set. This laboratory course is offered both in the fall and spring semesters.

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Table 1: Standard paths for attaining a MS degree[1]

Thesis Route	Non-Thesis Route
OPT 463 -Wave Optics and Imaging	OPT 463 -Wave Optics and Imaging
OPT 443 - Foundations of Modern Optics	OPT 443 - Foundations of Modern Optics
OPT 423 - Detection of Optical Radiation	OPT 423 - Detection of Optical Radiation
OPT 456 - Optics Laboratory	OPT 456 - Optics Laboratory
Elective	Elective in Physical Optics
Research	Elective in Geometrical Optics
Research	Elective in Quantum Optics
Writing of Thesis	Elective

3. COURSE DESIGN

All students that enroll in the class will have an introductory three-hour class to ensure everyone has a minimum skill set before entering the actual laboratories. During this introductory class, students have the opportunity to learn how to use power meters, operate an oscilloscope, perform basic optical alignment, and spatial filtering. and how to operate an oscilloscope. The oscilloscope training includes knowing the importance of impedance matching, triggering, when to use the AC or DC coupling, and the limitations of oscilloscopes. Students will also be exposed to basic radiometry and radiometric measurements. Basic laser safety is also covered in this class. The laser safety that is offered for the class is satisfactory training for operating lasers in the teaching laboratories, but more extensive training is needed to work in the research laboratories. Research laboratory laser safety training is offered on the University of Rochester intranet.

Safety is of great concern while novice students are working in laboratories with potentially dangerous equipment. Inside each of the laboratory rooms a sheet with standard operating procedures can be found posted on the wall. Students are also encouraged to ask for assistance when unsure of proper operation of laboratory equipment. This understanding between the student and the instructor protects the student and the equipment from harm. The laboratory rooms that contain lasers with high laser classifications have appropriate laser eye protection and students are instructed on the usage of such personal protective equipment. Laser signage can be found posted on the outside of each laboratory room that contains a working laser.

During the first class, students will form in a group of three to four depending on the size of the class enrollment. Each group will complete a total of six experiments consisting of four of the seven laboratory experiments listed in Table 2, the PIN diode characterization laboratory, and an independent laboratory experiment. Each laboratory experiment will be performed in four three-hour class periods. Students are not allowed to enter into a laboratory room unless they all have a general understanding of the experiment they are performing. It should be noted that groups will experience different laboratory activities. However, all groups will characterize two different PIN photodiodes due to the importance of radiometric detection. Students are given two types of PIN photodiodes and will then measure the dark current, responsivity, linearity and the speed of each detector. One type of PIN photodiode is designed for photovoltaic operation and the other type photodiode is constructed for photoconductive operation. The measurements of the diodes will then be compared to the manufacturer's data. Working and testing of these detectors, as with other detectors, requires complete control of ambient lighting. Therefore, every experiment in the master level laboratory course exists in a separate laboratory room which allows for independent control of the lighting as well proper containment of laser radiation.

The independent lab project is the third type of laboratory experiment that is performed in the master level laboratory course. This independent lab exists to give the students a design experience, thus reinforcing the students' desire to get an optics degree by working on a project in which they are passionate about. The main requirement for this lab is that the experiment must have a quantitative component so the students are measuring a certain feature. Qualitative measurements do not give satisfactory outcomes for the independent laboratory. Each laboratory experiment is broken into three sub-components: presentation of three independent laboratory proposals, the laboratory experiment, and a final oral presentation. The independent laboratory consultation determines if any or all of the three proposed laboratory experiments are feasible and if the students are asking the "correct" questions. These questions can be rudimentary such as "What am I measuring?", "How accurate and precise does my measurement need to be?", and "Do I understand how to make the measurement?" These questions can lead to the answers of additional questions such as: "How many times does the measurement need to be made?" "Are these measurements good enough to answer the proposed question?" After the students choose an "acceptable" laboratory experiment, they are given three class periods to complete it. These experiments can be performed in the teaching laboratories or other research laboratories within the university.

Table 2: Laboratory titles and experiences

Lab Title	Activity	Equipment/Software Exposure
Fiber Laser	Assemble both CW and mode-locked fiber lasers and measure their output. Characterize each individual fiber laser component and compare to known data.	Optical spectrum analyzer, fiber fusion splicer, fiber optic components
Video Transmission with an Optical Carrier	Encode a video signal on a Helium neon laser beam and reconstruct the video signal on an analog television.	Wideband amplifier, Pockels cell, Babinet-Soliel compensator
Acousto-Optics	Measure the deflected angle and power as a function of drive frequency. Observe the laser mode and acoustic beat frequency. Calculate the number of resolvable spots.[2]	RF spectrum analyzer, sweep oscillator, Acouto-optics deflector
Pulsed Dye Laser	Assemble a dye laser with a nitrogen pump laser and measure tuned output using a spectrometer and utilizing the opto-galvanic effect to determine wavelength.[3]	Fiber coupled USB spectrometer, oscilloscope
Optical Fourier Transforms	Align a 4F optical system and insert filters in the Fourier plane and collect the resultant images. Use image processing software to taking FFT's of images and make digital filters to modify images.	ImageJ [4], CCD camera, and associated software
Nd:YAG Laser	Assemble a Nd:YAG laser, characterize the output, and use a frequency doubling crystal to generate the second harmonic.	Infrared viewer, power meters and associated detectors
Helium Neon Laser	Assemble a helium neon laser with external cavity mirrors. Measure/characterize the longitudinal modes and spatial modes of the laser while adjusting the spacing and tilt of the cavity mirrors.	Scanning Fabry-Perot interferometer, RF specrum analyzer, oscilloscope

4. ASSESSMENT OF STUDENTS

The student assessments are based on three parts: the bi-weekly laboratory activities (including the PIN photodiode characterization), the independent laboratory project, and general participation. Seventy-five percent of the final grade is based on a cookbook style laboratory experiment. These cookbook style labs have step-by-step procedures necessary to complete the laboratory activities (excluding the PIN photodiode lab). The requirements the labs is that they need to be written in a journal style report and be longer than ten pages in length. The students are given a rubric to ensure expectations are communicated to the students. The current rubric is shown in Figure 1. The independent lab project is assessed on the oral presentation. Group and individual students are evaluated on the content of the material, the presentation ability of the group members, the accuracy of the material, and questions answered by the group. The independent lab is worth fifteen percent of the final grade. General participation of the students is worth ten percent of the final grade. This is added to encourage the students to actively participate in the class and communicate with their peers.

1. Is the abstract clearly written? Does it **summarize** the topic to be addressed and include **key results** and conclusions?
   [~10 points]

2. Conceptual understanding: Does the presentation of the underlying model choose a **clear starting point,** present **useful formulas** into which to plug experimental data**,** and provide a succinct but sufficient **connection** to demonstrate that the authors know how to get from the starting point to the useful formulae? Does the report contain **adequate references** for the theoretical framework? Elsewhere in the write-up, are concepts used correctly to describe what was observed?
   [~20 points]

3. Is the experimental procedure **adequately outlined and sketched** so that another person could repeat the experiment based on this document? Are **instrumentation figures** (sketches, photographs) used effectively and judiciously?
   [~10 points]

4. Are **values** given for all of the important experimental parameters? Is **error information** included, including (when appropriate) both **precision** (e.g. the precision of a translation stage's micrometer drive readout) and **accuracy** (which includes sources of offset/bias)?
   [~15 points}

5. Are the data of **sufficient quality** to match established theory, each step of the way? If not, have repeated attempts been made to improve the results, and is there an explanation for **discrepancies with theory** and any other general shortcomings?
   [~20 points]

6. Are the **data in tables and figures** well used and effectively presented?
   [~10 points]

7. Rate the overall style, **ease of reading**, and quality of English.
   [~15 points]

Figure 1. Grading rubric for written laboratory reports.

5. CHALLENGES FOR DUPLICATION

There exists challenges in this individual laboratory room model and may not be transferrable to other universities. At The Institute of Optics the rooms for the master level laboratories were specifically designed for small group sizes. The rooms vary in size from 12 m^2 to 16 m^2 (See figure 2). Larger laboratory rooms may not be appropriate for dividing into small work areas, due to the lack of control of room lighting and laser beams. The size of the room and experiential expectations limit the number of students per class. Eight laboratory rooms and a optical lecture classroom are designated for use in master level laboratory class. The various laboratory setups are in a semi-static state, and generally do not move due to the size of the equipment and utility needs. The students get four three-hour periods to complete the laboratory experiments, which allows for repeated measurements and time for ideas to be contemplated. During these two weeks, the laboratory equipment and setup does not get disturbed. In addition, equipment for each individual laboratory experiment can be expensive, since the equipment is so specialized. In conclusion, duplication of a diverse laboratory course will require a concerted effort by many professors and staff members alike.

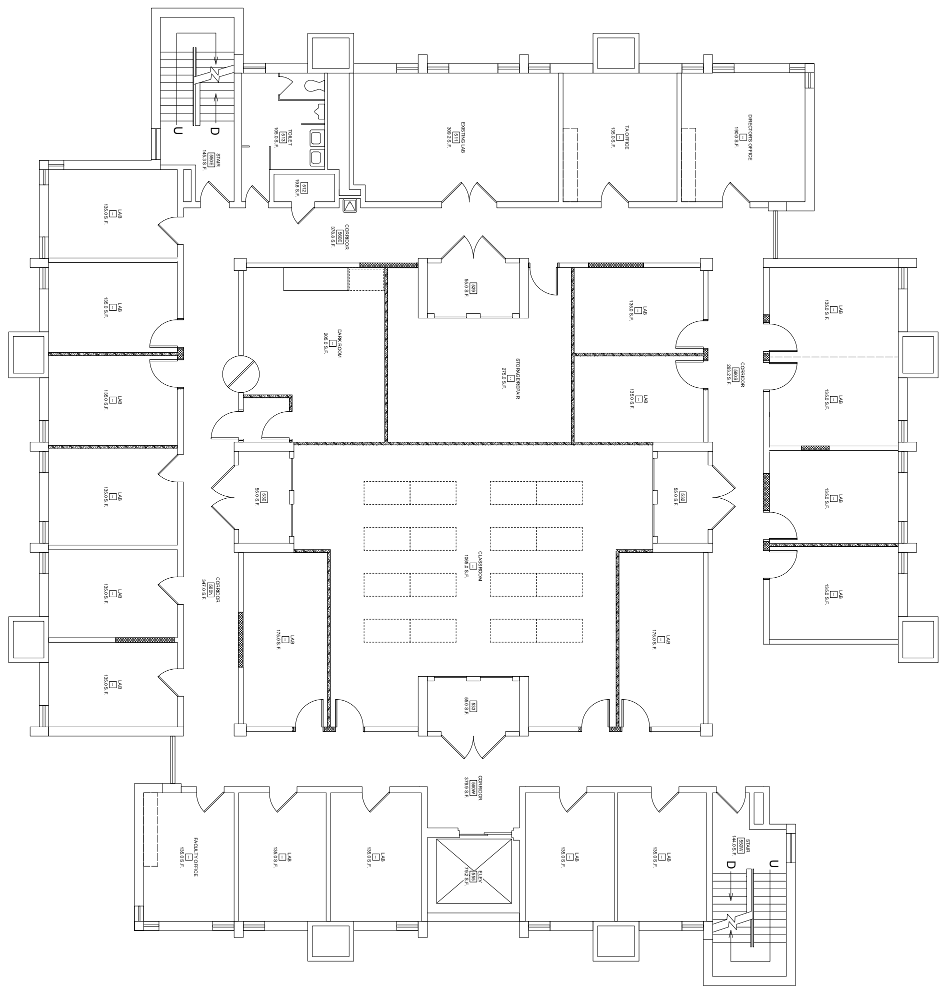

Figure 2. Layout of the optics teaching laboratories on fifth floor of the Wilmot building.[5]

6. CONCLUSION

The group based, multi-project, master level laboratory class allows students to explore optics phenomena in a safe and nurturing environment. Students experience the technical, hard skills, as well as soft, interpersonal skills. The students work with a culturally and educationally diverse group of individuals. The students learn that appropriate preparation for the laboratory experiments are required to meet the expectations of the instructor. Interpersonal skills are currently more anecdotal in nature and are only reflected in the student participation. Student written communication, in the form of journal style laboratory reports, is important as the laboratory experiment itself. Continual development of new laboratory experiments is vital to stay current with technology and the skills needed by the students.

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