

Laboratory Emphasis in Interdisciplinary Photonics Related Courses

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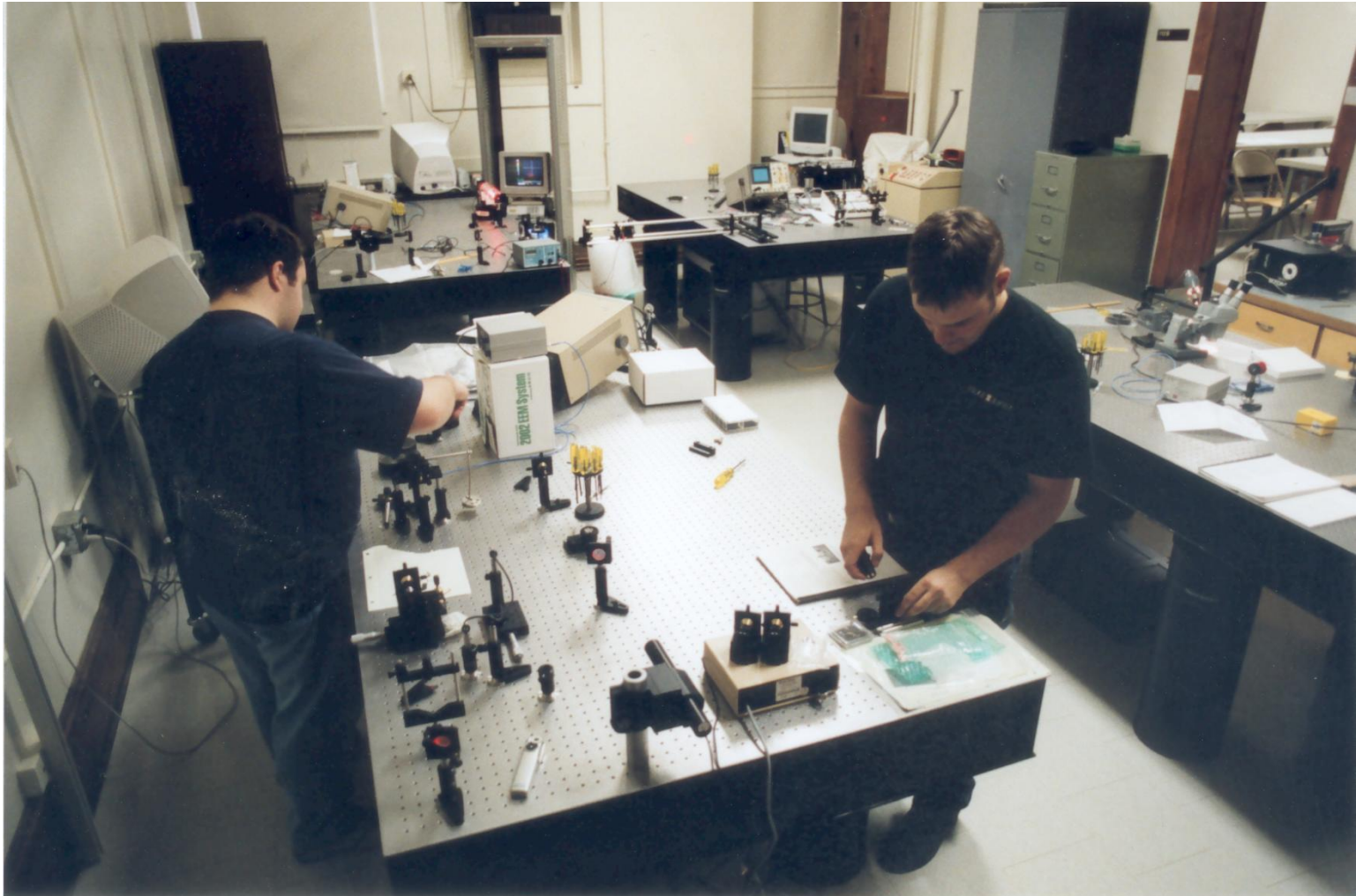
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INTERDISCIPLINARY APPLIED OPTICS COURSE AND LABORATORY

- Joint Project of the Colleges of Engineering & Architecture and Science & Mathematics.
- Partial support for this work was provided by the National Science Foundation's Course, Curriculum and Laboratory Improvement Program under grant DUE - 0088516.
- Modeled after course originated at New Jersey Institute of Technology in the Optical Science and Engineering Program.

NDSU Optics Teaching Laboratory



Background

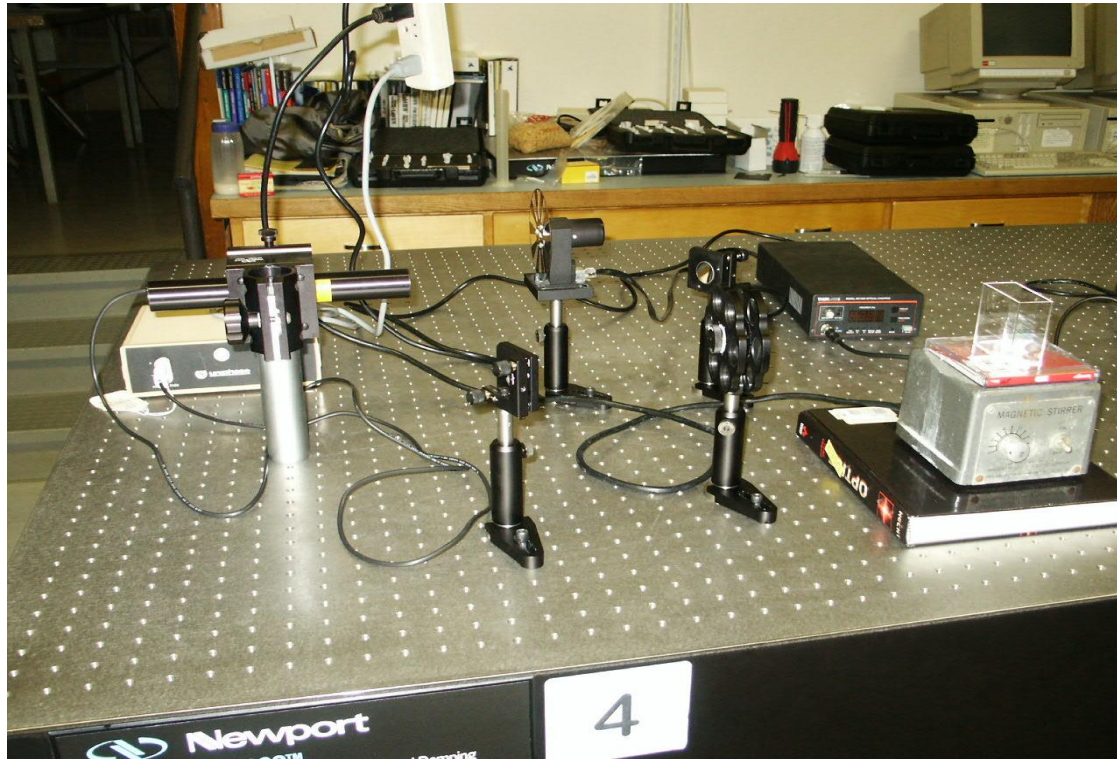
- Laboratory developed to serve the needs of a general optics course.
- Introduced in Fall 2001 and offered annually.
- Provides students with fundamentals to enable them to successfully apply optics in their respective majors.
- Emphasizes use of research grade equipment to experience and understand the most important concepts and phenomena of optics.
- Open to undergraduate and graduate students in engineering and science who have completed calculus-based university physics.
- Optics course has become the base course for interdisciplinary photonics options for undergraduate majors in the ECE and Physics Departments

NDSU optics sequence with embedded laboratories

- Physics/ECE 411 Optics for Scientists and Engineers
- Physics 413 Lasers for Scientists and Engineers
- Physics 415 Elements of Photonics
- ECE 417 Optical Signal Transmission

Physics/ECE 411 Optics for Scientists and Engineers

- 3 semester-credit-hour lecture course and a co-requisite 1 semester-credit-hour course.
- Lectures based on Eugene Hecht's *Optics, 4th Edition*.
- Laboratories are scheduled in three-hour blocks.
- Students are paired to maximize their hands-on experience.
- A graduate student teaching assistant is present in the laboratory for all the groups.
- Adapted NSF funded laboratory experiments developed at the New Jersey Institute of Technology.
- Adapted Newport Corporation fiber optics kits.
- Labs are continuously revised to support important concepts covered in the lecture course.

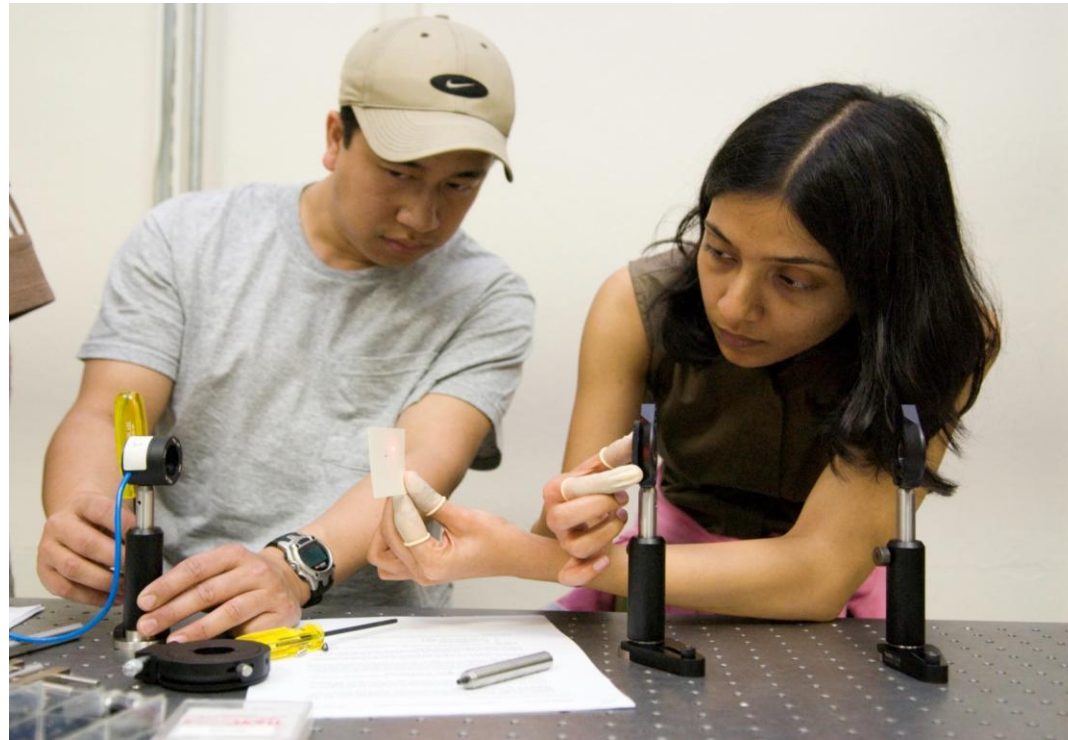


Lab 1. Detection of light

Lab 2. Absorption

Lab 3. Index of refraction, total internal reflection,
and critical angle

Lab 4. Lenses and simple lens systems



Lab 5. Preparing optical fibers and numerical aperture

Lab 6. Fiber optic light attenuation

Lab 7. Single-mode fibers

Lab 8. Optical polarization

Lab 9. Interference and diffraction

Lab 10. Spectrometry

Major optics experiment

- Selected by groups of three to four students for the last four-week project.
- Devote both lecture and laboratory course time to their project.
- Each group presents their results in class during the last week.
- Each group writes a research paper on their experiment.

Student formative assessment

- *“...also the lab has been more help than any other lab I have had.”*
- *“The hardest part of lab is the setup. If it were ready when we came it would be beneficial in our understanding of the lab, rather than wanting to just be done with it when the learning portion starts.”*
- *“The labs, so far, have been very informative. I have learned a lot and think they have solidified what I have learned in the course.”*

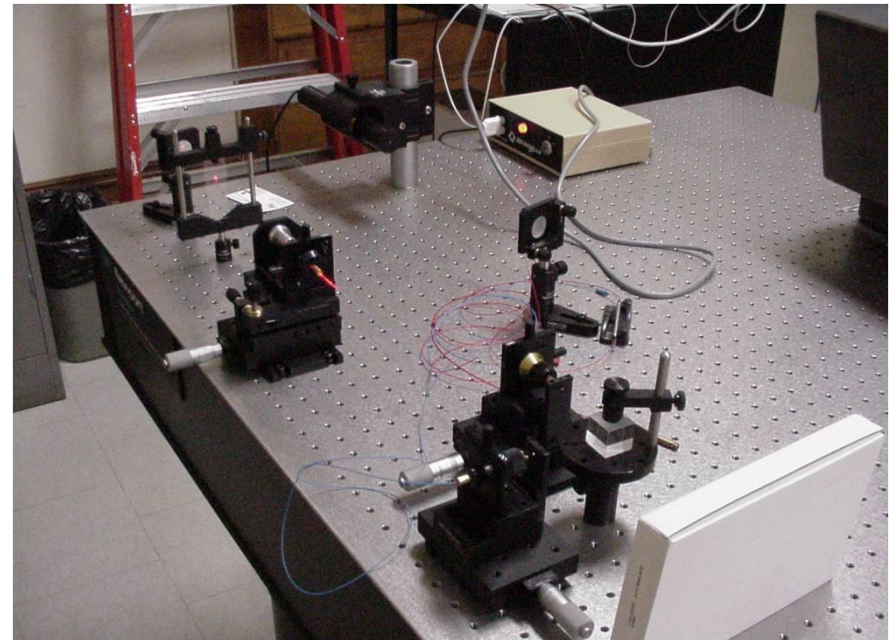
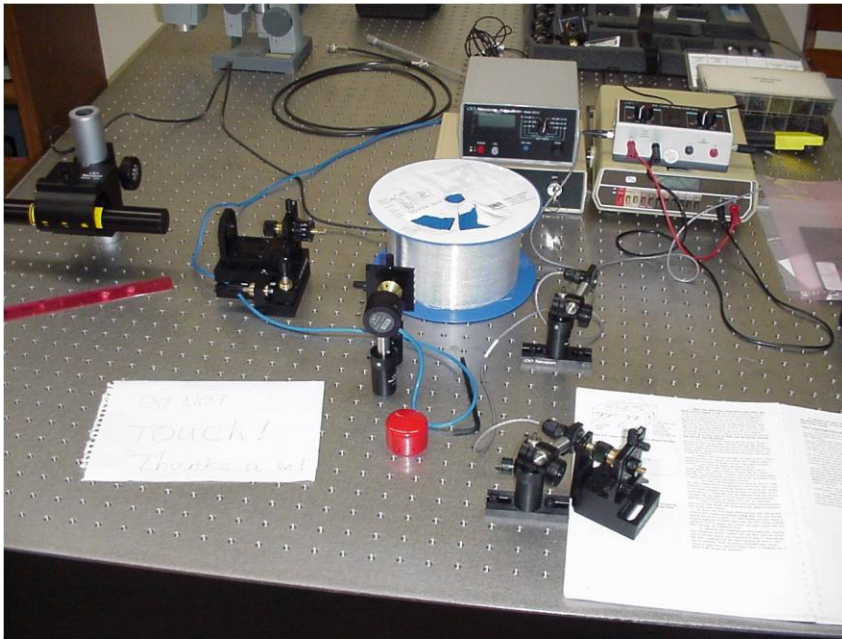
ECE 417 Optical signal transmission

- Optics teaching lab first incorporated in 2003.
- Lectures based on Gerd Keiser's *Optical Fiber Communications*.
- Includes basic electromagnetics, propagation of light in cylindrical dielectric structures, solid-state sources, and photodetectors.
- Culminates with a study of digital signal transmission over optical fibers.
- Serves undergraduates and beginning graduate students in electrical engineering, computer engineering, and physics.

ECE 417 Lab experiments

- Adapted from a Newport fiber optics kit.
- Measurement of numerical aperture.
- Use of the cutback method to measure optical fiber attenuation.
- Observation of linearly polarized (LP) modes in a four-mode fiber.
- Sufficient components allow four student groups to do their experiments independently.
- Physics/ECE 411/611 is not a prerequisite for 417/617 as the study of optics itself is confined to what is necessary for comprehending optical communication.

Fiber optics lab



Lectures more meaningful when related to "hands-on" work

- Numerical aperture experiment helps to understand the light-gathering capability of a fiber.
- Attenuation measurements clearly show the impact of a loss of several dB of optical power.
- Single-mode fiber experiment allows student to become familiar with a common telecommunications technology.
- Optional lab involving audio transmission over fiber.
- Optional experiment involving polarization-preserving fibers makes use of techniques that are useful in building optical communication lab skills.

Student formative assessment

- *“In my opinion the lab portion of this class provided the best learning experience. This was most helpful to me I think because I am going into the optics field after graduation (hopefully) and it was very nice to get a lot of hands on experience both with fiber and optical hardware.”*
- *“I think that the added lab times really help the concepts sink in. Also the small class size makes for a more personal learning experience, that helps me learn easier.”*

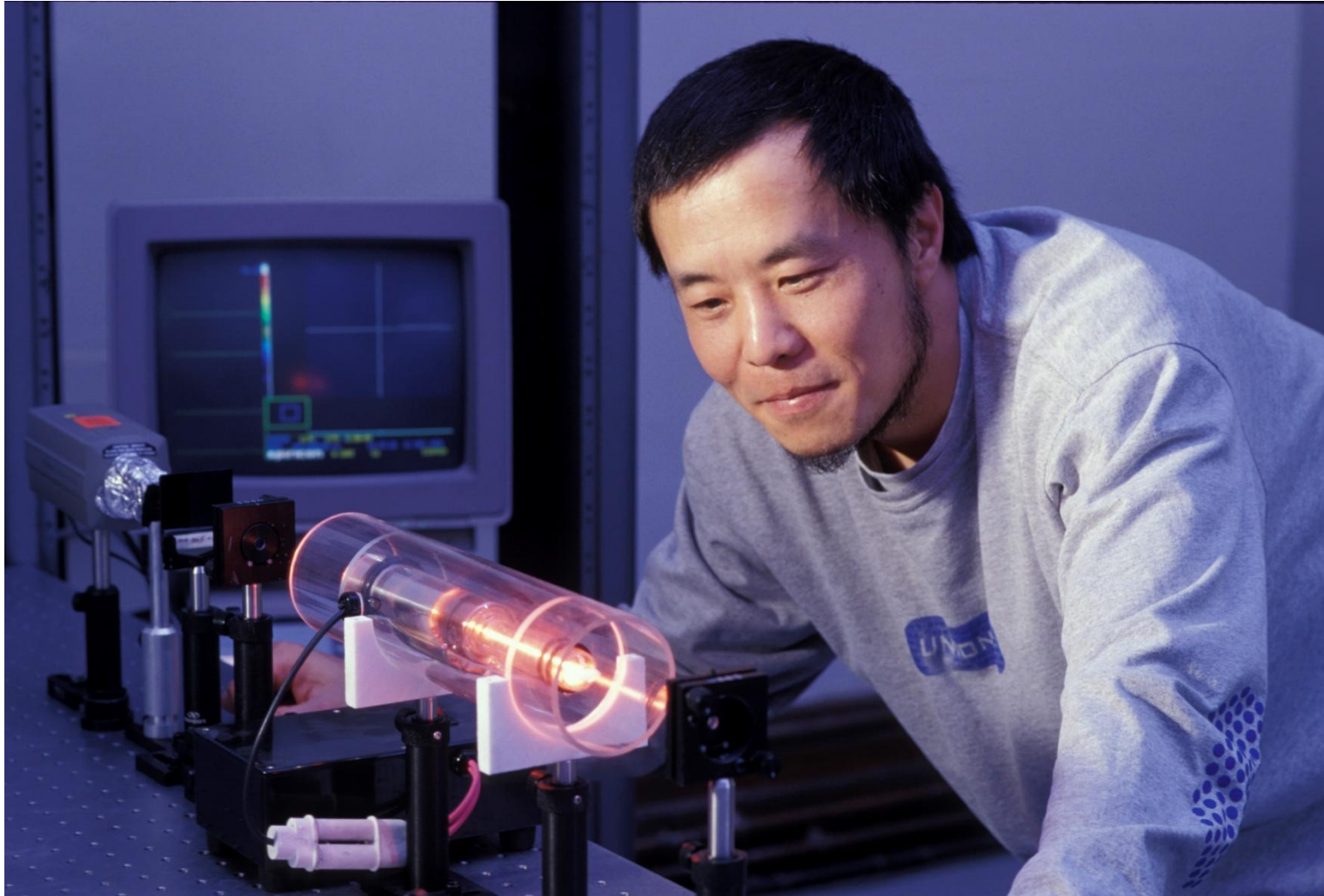
Physics 413 Lasers for Scientists and Engineers

- Originally offered as a two semester-credit- hour summer course.
- Centered around laboratory experiments.
- Student feedback resulted in a 3 semester-credit-hour course with embedded laboratory experiments.
- Lectures based on the text *Fundamentals of Photonics, 2nd ed.*, by Saleh and Teich.
- Laboratories are scheduled in 3-hour blocks—each laboratory replaces 1 lecture period.
- Students are paired to maximize their hands-on experience.

Physics 413 Lab experiments

- Lab 1 Setting up an open cavity HeNe laser
- Lab 2 Characterization of open cavity HeNe laser
- Lab 3 Gaussian optics with beam profiler
- Lab 4 Expanding laser beams, diffraction of circular apertures
- Lab 5 Spectral characterization of light sources
- Lab 6 Scanning Fabry-Perot interferometer
- Lab 7 Laser diode/LED characteristics

Open cavity HeNe laser



Student formative assessment

- *“The labs are a very important part of learning in this class. It's much easier to understand the material after physically experimenting with different properties of lasers...”*
- *“The labs are instructive as well. The strength would probably be the synergy between the course material and the lab work itself.”*
- *“All of the labs have been appropriate for the course material, in my opinion. However, clearer instructions for much of the needed equipment use would most likely be helpful to future classes.”*

Physics 415 Elements of Photonics

- Evolved from optical electronics course.
- Developing and embedding laboratory experiments.
- Goals are to introduce selected principles of photonics.
 - Polarization states of optical waves.
 - Physical origin of optical nonlinearities.
 - Applications to optical second harmonic and parametric generation.
 - Electro-optic modulation of laser beams.
- Future lectures will be based on *Fundamentals of Photonics, 2nd ed.*, by Saleh and Teich.

Lessons Learned

- A well equipped optics teaching lab can benefit multiple courses
- Experiences in this lab are significantly different than those obtained in many common computer-oriented or circuits-oriented labs.
- Students develop skills that are radically different from those obtained in other labs.
- The lab allows students to visually experience abstract concepts in optics.
- The major experiments encourage the students to be creative and resourceful.
- The courses and student projects are occasions for fruitful collaborations across disciplines.