Stimulating student interest in optics via a versatile optics demonstration laboratory

Stephen H. Cobb and Louis M. Beyer

Department of Physics and Astronomy
Murray State University, Murray, KY 42071

John T. Tarvin

Department of Physics
Samford University, Birmingham, AL 35229

ABSTRACT

Funding from a NSF-ILI grant has been used to establish an Optics and Laser Demonstration Laboratory at Murray State University. This facility is proving to be very versatile, with experiments and demonstrations supporting undergraduate courses in geometrical and physical optics, modern physics, and an advanced laboratory instrumentation course. The lab includes a CCD camera system which is used by upper level students to investigate diffraction effects, signal/noise ratios of detection systems, and efficiency of binary optical elements. Also, the lab supports two new courses which have been developed to accompany the grant. One course, Laser Physics, is for upper level physics majors, while the second course, Light and Lasers in Action, will use optical phenomena to introduce physical concepts to non-majors of various disciplines. The lab is receiving recognition as the centerpiece for departmental outreach into the public schools. Local elementary, middle, and high school classes visit the lab on field trips and are given demonstrations in optics and lasers. Faculty also transport lab equipment to area schools for demonstrations, and have loaned equipment to schools for use in the classroom and at science fairs. The content, activities, and reception of the lab are described.

Keywords: undergraduate optics education, curriculum development, laboratory demonstrations, pre-college optics education

1. INTRODUCTION

The Department of Physics and Astronomy at Murray State University consists of eight faculty members and approximately 80 declared majors. Undergraduate programs in the department lead to a Bachelor of Science or Bachelor of Arts degree in physics or engineering physics. The curricula for these programs are designed to prepare the student for graduate or professional work in physics, engineering, and teaching, as well as related fields which require a broad basic education in physics, mathematics, and computer science. The department also has pre-professional programs in engineering and optometry, and serves approximately 800 students per year by providing general education laboratory science courses in physics and astronomy. The innovative engineering physics program has proved very popular, combining a required core of basic physics, mathematics, and computer science courses with elective applied courses in a variety of fields including advanced physics, electronics, computer science, mathematics, and engineering. The choice of these elective courses is determined by what the student selects as his or her "area of

0-8194-1884-6/95/$6.00

specialization". The success of this program is evidenced by the fact that our graduates are eagerly recruited by graduate schools and major industries across the nation, and a recent invitation to share details of this program at the 1995 APS/AAPT annual meeting.[1]

Traditionally, our program has excelled in imparting to the student a thorough background in the theory and underlying principles which govern physical systems. More recently, we have sought to reinforce these principles by establishing undergraduate laboratories where applications are emphasized by hands-on experimentation and computer simulation. Until recently, one important and relatively new area of experimental physics lacked laboratory support in the department. In order to address the need for undergraduate exposure to the fundamentals of modern optics and laser physics, a proposal was submitted to the National Science Foundation (NSF) for an Instrumentation and Laboratory Improvement (ILI) grant. This proposal to create a "Laser Demonstration and Optics Laboratory" was funded beginning in the Fall of 1992 and expired at the end of 1994. The total amount of the grant was $95,108, with half of the amount coming from the university as a matching contribution.

This paper summarizes the equipment acquired as a result of the ILI grant, and outlines the courses developed and the activities supported by the laboratory.

2. DESCRIPTION OF LABORATORY

The equipment needs for a laboratory of this type are quite significant. However, the items budgeted for the laboratory were carefully chosen so that they would be versatile in providing service to several areas of the curriculum. The laboratory strengthens programs already in place in the department by introducing modern instruments which complement the instructional capabilities of the faculty. It also allows for advanced laboratory experiments to be tailored to fit the special interests and background of the student. The design of the lab was modeled after a similar one created by John Brandenberger at Lawrence University.[2] It includes optical equipment, lasers, electronic instrumentation, and computing equipment as outlined below:

Quantity	Description	Approx. Cost
	Optical Equipment	
1	Spectrum Analyzer/Controller Coherent Model 240, -1B,-1C, 251 7.5 Ghz; 550-650nm; 750-875 nm	$7K
1	Burleigh Wavemeter Jr.	$5.5K
2	Laser Power Meters Coherent 210, 212	$2.3K
1	Scanning Monochromator Spex 270M	$8K

Quantity	Description	Approx. Cost
6	Optical Tabletop Breadboard TMC 2' x 4' x 2"	$4.2K
1	Optical Table TMC 74-455-02 4'x 8'x 8"; 28" legs	$3.8K
2	Photomultiplier Tube and Housing Hammamatsu 1P28A Products for Research PR1402 RF	$1K
1	Holography Kit; Newport HL-1, -1A	$3K
1	Fiber Optic Attachment for Nitrogen Dye Laser; Laser Science 337700, 337712	$1K
6	Laboratory Workstation Optical Systems with Support Optics and Hardware:	$14K
6	25 mm lens	
6	50 mm lens	
6	100 mm lens	
6	-25 mm lens	
6	-50 mm lens	
6	-100 mm lens	
2	Cylindrical lenses, 100 mm and 300 mm	
3	Neutral Density Filter set	
2	Colored Glass Filter set	
12	Flat Mirror, 2"Dia.	
10	Dichroic Polarizer	
3	Half Wave Plate	
3	Quarter Wave Plate	
6	Laser Holder	
1	Laser Beam Expander	
12	Magnetic bases	
2	Laser mounting posts	
2	Laser post carriers	
24	Optics mounting posts	
24	Post Holders	
8	Lens Holders	
8	Filter Holders	
36	Mirrors/mounts	
1	Rotation Stage	
6	Translation Stage	
8	Si PIN photodiodes/housings	

Quantity	Description	Approx. Cost
	Lasers	
2	He-Ne linearly pol. 4 mW	$1.1K
4	He-Ne random pol. 4 mW	$2K
1	He-Ne discharge tube with high reflector and Brewster window; Melles-Griot 05-LHB-570; 05-LPM-340	$1.4K
1	Diode Laser System; Melles-Griot 06-DLL-303; 06-DLD-003; 06-DTC-003	$6K
	Electronics	
1	Analog oscilloscope; Tektronix 2467B	$13K
1	Digital oscilloscope; Tektronix 2432A	$10K
1	Plotter; Tektronix HC100	$1K
1	XY Recorder; HP 7035B	$1.5K
	Computer	
1	IBM compatible/printer	$5K

Many of the electronic equipment items are general purpose in nature, and thus contribute extensively to the departmental curriculum. Others are more specialized and are dedicated to a specific task. In total this equipment, when combined with additional items acquired via other funding sources, constitutes a well-supplied teaching laboratory and provides for substantial investigation into many research topics of interest to students and faculty. Additional laboratory equipment includes a nitrogen laser with tunable dye modules, a Beckman IR 10 spectrophotometer, a Cary 14 spectrophotometer which has been converted to a NIR reflectance spectrometer, a synchronous detection system using a lock-in amplifier and a boxcar signal averager, and a Photometrics Star I CCD camera system which is used to investigate diffraction effects of small obscured apertures, signal/noise ratios of detection systems, and efficiency of binary optical elements. The latter instrument was purchased with funds from a research grant funded by NASA/Kentucky Space Grant Consortium.

3. CURRICULUM AFFECTED BY LABORATORY

The optics laboratory directly supports two courses which were developed to accompany the grant. The first course, Laser Physics, is intended for upper level physics majors who are interested in fundamentals of lasers and electrooptics. Taught at the level of O'Shea's An Introduction to Lasers and Their Applications and Milonni and Eberly's Lasers, this course teaches basic laser operating principles and applications. In the laboratory students study longitudinal mode structure of lasers using the spectrum analyzer and practice cavity alignment and transverse mode recognition with the open-cavity He-Ne laser. They can design and construct beam expanders and collimators, and monitor the temperature stability of a diode laser. In other experiments, the students become familiar with lineshape functions, usually Gaussian, which characterize the radial intensity profile of laser beams, and are able to express these intensity distributions mathematically. They are also introduced to various detection methods using photomultiplier tubes and solid-state detectors. The course has been taught three times and is very popular with the students. Advisory groups in industry and graduate schools have also indicated to us the importance of this type of course, and the increasing demand for students with training in this area.

The second new course with accompanying laboratory support is designed for non-physics majors with an interest in scientific or engineering-related fields, and also future public school teachers. This course, "Light and Lasers in Action", will be an overview course, emphasizing properties of different types of lasers and optical systems and their use in various facets of everyday life as well as in scientific disciplines, medicine, and industry. This course will use the visual appeal of optics to introduce students to fundamental physical concepts like energy, momentum, waves, fields, and even quantum mechanics. This course will be taught for the first time in the fall semester of 1995 at Moscow State Pedagogical University in Russia as part of a Fulbright lectureship at that institution.

Other courses in the curriculum have benefited from the new laboratory. The geometrical optics course previously had no laboratory support, but now has demonstration equipment available for every student. The same is true for courses in physical optics and modern physics. A special advanced laboratory course now includes many topics which were previously omitted. As an introduction to spectroscopy, students use the scanning monochromator to record the emission spectrum of an unknown elemental gas. They identify the constituent in the cell by correlating spectral peaks with those tabulated in reference books. This leads to additional investigations in infrared spectroscopy of HC1 and the opportunity for saturated absorption laser spectroscopy using a tunable diode laser to probe the hyperfine splittings in the vapor of an alkali metal. In other experiments, the voltage-current relationships of light emitting diodes are recorded on the digital oscilloscope. This data, along with a measurement of the wavelength of the emitted light, allows for the determination of an experimental value for Planck's constant. The He-Ne lasers are used with Michelson and Fabry-Perot interferometers to study interference and diffraction effects and to determine the wavelength of the laser light. The laboratory includes a fully equipped photographic dark room, and several students have conducted independent study projects on laser holography. This has been complemented by similar projects in computer-generated holography where a student creates a transformed image computationally, makes a photographic slide of the transform, and reconstructs the object using laser illumination.

4. PUBLIC SCHOOLS/COMMUNITY OUTREACH

The laboratory has quickly gained recognition as the centerpiece for departmental outreach into the public schools and the community. Local elementary and middle school students visit the lab on field trips to the university. They are allowed (with supervision) to handle He-Ne and diode lasers and to create laser light shows. As optical fibers are passed among the group, a discussion of total internal reflection is demonstrated in an aquarium. Other interactive demonstrations are conducted illustrating polarization phenomena, index of refraction matching, behavior of lenses, optical activity, and optical communications techniques. All these demonstrations and discussions are conducted with supplies maintained in the lab and with readily available equipment such as flashlights and overhead projectors. Particularly noteworthy is the fact that a regional program which identifies talented but economically disadvantaged and minority students makes regular use of the laboratory to capture and increase those students' interest in science.

As part of the departmental recruiting effort, faculty transport laboratory equipment to regional high schools and conduct optics demonstration shows for physics or physical sciences classes or school-wide science clubs. These shows are always well-received and generate interest and enthusiasm for science (particularly optics) among the students. Many teachers use the demonstrations as a source of ideas for their classrooms, asking for information on how to purchase various items or how to construct a particular demonstration. Often this laboratory loans lasers and optics equipment to area teachers for short periods so that they may have a unit of study on light and optics. Students have borrowed equipment for use in science fair projects and classroom assignments. Clearly, the laboratory has served as a valuable resource for local teachers and increased our department's visibility in the community.

5. ACKNOWLEDGMENTS

We gratefully acknowledge the funding support of NSF via ILI grant USE- 9250289. We are also appreciative of funding made available through the Kentucky Space Grant Consortium which has made the acquisition of additional laboratory equipment possible. Murray State University College of Science has provided additional support in the form of in-kind matches for these grants, and we gratefully acknowledge this contribution.

6. REFERENCES

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