The Lasers and Optics Program at San Jose State University

Joseph F. Becker, Gareth T. Williams, H. Sarma Lakkaraju,
Ramen D. Bahuguna, and Osuk Y. Kwon

Institute for Modern Optics and Physics Department
San Jose State University
San Jose, California USA 95192-0106

ABSTRACT

Located in high-tech "Silicon Valley," California, San Jose State University is ideally suited to provide students with a high quality education in optics, and industry with a partner for optics related research and development projects. There are 130 undergraduate majors and 65 graduate (M.S.) students in the Physics Department. For the past five years the Department has offered a special program leading to the B.S. in Physics with a Concentration in Lasers and Optics. Students take the usual core undergraduate Physics courses plus upper division courses in Modern Optics, Lasers and Applications, Advanced Optics Lab, Advanced Lasers Lab, Advanced Instrumentation Lab, and either Individual Studies or a graduate course in Electro-optics, Graduate Optics, Optical Metrology, or Laser Spectroscopy. Graduates are well prepared to enter the lasers and optics industry or go on to graduate school. Recently, a 4000 square foot area in the Science Building has been renovated to house the new Institute for Modern Optics, an organized research unit in the College of Science. One of the major goals of the Institute is to facilitate collaborative research between the local optics industry and the faculty and students at SJSU. The Institute is well equipped with lasers, optical instrumentation, electronics/computers, and about 10 optical tables. A National Science Foundation Research Experience for Undergraduates Program grant provides research support in optics for about eight undergraduates at any time throughout the calendar year. The National Science Foundation also provides support for "Laser Applications in Science Education," a summer program that provides hands-on experience with lasers for high school science teachers.

1. B.S. IN PHYSICS WITH A CONCENTRATION IN LASERS AND OPTICS

During the past ten years, drastic changes have taken place at San Jose State University (SJSU), one of the largest of the 20 campuses of the California State University system. More than a decade ago faculty research was not at all encouraged, but that has now changed. San Jose State has evolved into a modern 30,000-student comprehensive university in which new faculty members are hired on the basis of their research interests and capabilities as well as their teaching ability, and are strongly urged to carry out research projects. During this period, the Department of Physics has also changed. Student enrollment is up to approximately 130 undergraduate majors and 60 graduate students (M.S. candidates), and the size of the faculty has more than doubled to 24 tenure-track and 4 non-tenure-track positions.

There now exists in the Department a formal program within the B.S. curriculum called the "Concentration in Lasers and Optics." Students enrolled in this Concentration are required to take, in addition to the usual core courses in Physics, a minimum of twelve units of lecture and laboratory courses from the following:

Modern Optics
Advanced Physics Laboratory: Optics
Lasers and Applications
Advanced Physics Laboratory: Lasers
Advanced Physics Laboratory: Instrumentation
Select one: Individual Study, Graduate Electro-optics, Graduate Optics,
Graduate Optical Metrology, or Laser Spectroscopy

Our undergraduate program in optics has received national recognition by the Optical Society of America; and, incidentally, our Physics Club has received national recognition and several awards from the American Physical Society.

0-8194-0732-1/92/$4.00

2. INSTITUTE FOR MODERN OPTICS

The new Institute for Modern Optics is an organized research unit in the College of Science at SJSU. The Institute is essentially housed in a 4000 square foot area recently renovated to accommodate a variety of lasers and optical instruments. One of the major goals of the Institute is to facilitate collaborative research between the local optics industry and the faculty and students at SJSU. Research and development projects of interest to and funded by local industry are continually being sought. Several of these projects have resulted in Masters Theses and career employment opportunities in the optics industry for students. There are approximately 14 full-time faculty members presently associated with the Institute, most of whom are physicists. In a typical semester there are approximately 20 undergraduates doing independent study research projects in optics, approximately 20 graduate (M.S.) students working on their Theses, and occasionally postdocs and visiting scientists. A wide variety of on-going research projects is carried out in the Institute using a full complement of lasers and optics related equipment. The major equipment in the Institute includes:

Argon lasers (Spectra-Physics, Coherent)
Nd:YAG laser (Quantel)
Helium-cadmium laser (Liconix)
Ruby laser (Korad)
UV-VIS-IR Spectrophotometers
Raman spectrometers
Nanosecond flash lamp
Thin film evaporation unit
Zeiss microscope
Genesee optical design software
Zygo interferometer
Thermo-plastic holographic recording system
Accessories: electronic signal conditioning equipment, computer
data acquisition and control equipment, optical tables, etc.

3. NSF-RESEARCH EXPERIENCE FOR UNDERGRADUATES SITE AT SJSU

In 1989 the National Science Foundation started funding a Research Experience for Undergraduates (REU) Site at SJSU, and the program has grown to be one of the largest NSF-REU Sites in the U.S. One of the major goals of the program is to provide research experience in optics for undergraduate students, especially under-represented minorities, who would not otherwise have had the opportunity.

Students at our NSF-REU Site begin with a very structured, well-supervised introduction to scientific research. Laboratory safety, where applicable, is emphasized. One-to-one faculty-student training in pertinent experimental methods and theoretical/computational techniques is performed in a "hands-on" setting until the student gains confidence by obtaining correct or expected results. The student gets progressively less direct faculty supervision as he or she gains the confidence to operate more independently. The more advanced students do similar experiments or computations, and they then compare and discuss their results, methods, etc. Our program includes a weekly seminar, the optics group meeting, which is attended by all faculty and students involved in all REU projects. Students teach each other about their project and its problems, successes, and failures. Thus this student-to-student communication (with faculty interaction) provides the students with an exposure to other problems and techniques relevant to the field of optics. Brief descriptions of the projects presently providing research experience for undergraduates are given below.

Project #1: Tunable Diode Laser Spectroscopy of $^{12}C/^{13}C$ Ratio in Carbon Dioxide (Principal Investigator Dr. Joseph F. Becker). [1-3] The overall objective of this on-going project is to develop a tunable IR semiconductor diode laser gas analysis technique to measure gas concentrations and isotope ratios of various gases in the laboratory. Tunable diode laser linewidths of approximately 0.0003 cm^{-1} allow detection of individual rotational lines, and at such high resolution problems of impurity gases interfering with the measurement can be eliminated. Much of the experimental work on this project is performed in a laboratory at the NASA Ames Research Center located near our campus.

Project #2: "Rare-Earth Spectroscopy". (Principal Investigator Dr. John B. Gruber). The overall objective of this on-going project is to measure the intensities, linewidths, lineshapes, and wavelengths of spectral lines of activator and sensitizer ions in laser host materials such as YAG, YSAG, GSGG. The active (absorbing) ions include rare earths such as Tm^{3+}, Ho^{3+}, and Dy^{3+} and transition metal ions such as Cr^{3+}, Ni^{2+}, Re^{4+}, and Os^{4+}. The data are originally measured at the Naval Weapons Center, China Lake, California. The analysis of data will be compared with theoretical calculations for the crystal field splitting of electronic states using the lattice-sum method to establish the crystal field parameters, B_{km}, and x-ray crystallography data to establish distances between ions in the lattice and the symmetry of the local environment.

Project #3: "A Theoretical Analysis of the Laser Backscatter from Suspended Frozen Nitric Acid Particulates" (Principal Investigator Dr. Patrick Hamill). [4] A theoretical study is being carried out using the methods of Mie scattering to evaluate the backscatter from polar stratospheric cloud (PSC) particles. The results will be compared with data obtained over Antarctica during the formation of the ozone hole. The results of the study, supported by NASA Ames Research Center, will be very useful to scientists attempting to understand the ozone hole.

Project #4: "Holographic Optical Elements and Microbial Growth" (Principal Investigator Dr. Gareth Williams). [5] Various applications of holographic optical elements (HOE) are being studied. Work has begun on the fabrication of holographic lenses and mirrors, and the effect of improving their efficiency using various development and bleaching techniques. The positive lens HOE will be fully characterized. An interesting "spin-off" of earlier work has been a scheme for detecting yeast and bacteria growth by studying light diffracted, rather than scattered, from colonies grown on specially prepared gelatin surfaces. This is associated with the production of HOE's using dichromated gelatin holograms.

Project #5: "Study of Microbial Growth by Holographic Interferometry" (Principal Investigator Dr. Ramen D. Bahuguna). [6-7] Conventional interferometry is mainly useful for making measurements on highly polished surfaces of relatively simple shape. Holographic interferometry extends the range to include three dimensional surfaces of arbitrary shape and surface condition. Recently, a hologram of a yeast sample was recorded. After recording, straight fringes were introduced by tilting the illuminating beam with the help of a mirror. As time progressed, the contrast of the fringes on the yeast gradually decreased within a few minutes. The decrease in the contrast is thought to be due to random changes in the scattered wavefronts which in turn are due to the random growth on the yeast surface.

Project #6: "Laser Induced Plasmas" (Principal Investigator Dr. H. Sarma Lakkaraju). [8-9] The overall objective of this project is to develop a complete experimental system to produce and analyze laser induced plasmas (LIP) in all three phases of matter. A Nd:YAG laser has been used to produce a LIP in a gas mixture reflecting the terrestrial and Titan atmospheres. This investigation was undertaken in order to understand the role of non-equilibrium processes in the formation of molecular species in simulated lightning and associated shock phenomena. Time resolved spectroscopic analysis of LIP in the Titan atmosphere and solar nebula gas mixtures is in progress. Work has also begun extending LIP to solid and liquid surfaces with a view toward understanding laser-matter interactions and production and control of clusters and free radicals. The LIP work is carried out at SJSU and has been supported by NASA Ames Research Center and by the Northern California Vacuum Society.

Project #7: "Electromagnetic Wave Propagation in Random Dielectric Media" (Principal Investigator Dr. Karamjeet Arya). [10] The propagation of electromagnetic (EM) waves in a random medium is usually studied in the diffusion approximation neglecting any coherence between scattered waves. However, the backscattered peak observed in recent experiments from polystyrene particles confirms earlier theoretical predictions that coherent interference between scattered waves propagating in time reversed path is very important. In fact, this is responsible for the well known phenomenon of the Anderson localization of EM waves in a random dielectric. Numerical calculations for the propagation of EM waves through a random dielectric medium including interference between scattered waves, which is responsible for the localization of the EM wave energy, are being carried out. By considering a reasonable number of dielectric layers in the calculations the effect of localization should be observable.

Project #8: "Structure and Optical Texture of a New Nematic Liquid Crystal Pattern" (Principal Investigator Dr. Lui Lam). [11-13] During the study of dielectric breakdown of nematic liquid crystals in a Hele-Shaw cell an interesting new pattern was discovered. The pattern was formed when air invades the nematic. The essentially two-dimensional pattern consists of constant width filaments of the nematic separated by air. The pattern looks very much like the electrohydrodynamic or Rayleigh-Bernard instability rolls of nematics except that in this case, it is a static equilibrium rather than a dynamic non-equilibrium structure. This new structure is being studied in detail. The exact conditions governing the formation of structures are being elucidated by varying the cell thickness, the type of nematics used, and the surface treatment of the glass plates of the cell. The optical structure under a polarized microscope is being studied and the molecuiar arrangement in the structure will be clarified.

4. NSF-LASER APPLICATIONS IN SCIENCE EDUCATION

In 1990 the National Science Foundation started funding the Laser Applications in Science Education Program at SJSU with Dr. Gareth T. Williams as the Program Director. The purpose of the program is to investigate the feasibility of using the laser as the main teaching tool in a high school level optics laboratory course. In the first part of the course the students are led through a series of prescribed exercises designed to reveal optical principles and applications. In the second part the students are encouraged to investigate "new" phenomena which ultimately lead to written articles in "LASE LOG", a newsletter published at SJSU. The introduction of "high-tech" ideas at a practical level using laser applications as the main theme is exciting. High school students like being seen using impressive looking equipment. The lasers, oscilloscopes, cameras, function generators, small motors, loudspeakers, liquid crystal displays, photodiodes, and optical elements are impressive when operated, and are highly visible to other students, parents, and high school officials. A major aspect of the program is the open-ended nature of the studies; a menu of projects extending from a basic investigation core is a vital feature. So many "what if ..." questions can be asked, and so many secondary effects can lead to whole new lines of investigation. The newsletter is a key feature of the on-going program since it demands refinement of experimental, observational, analytical, and communication skills, and the submission deadlines motivate students to complete their projects in a timely fashion. A large donation for new equipment for this feature of the program has been received from IBM Corporation. The program started during the summer of 1990 with a two-week workshop for seventeen high school teachers. The following summer forty additional high school and middle school teachers became involved. During the academic year monthly meetings and conferences, involving teachers and students, give the program continuity and afford further training for the teachers.

5. OTHER PHYSICS DEPARTMENT PROGRAMS AT SJSU

In addition to the B.S., the M.S. degree in Physics is offered at SJSU. The Masters program includes several courses (listed above) in optics related fields as well as the usual traditional core courses in Physics. We plan to establish an M.S. degree with a "Concentration in Optics" in the near future. Other programs in the Physics Department include the "Concentration in Computational Physics" at the graduate level and the "Concentration in Condensed Matter" at the undergraduate level.

6. SUMMARY

The optics program at San Jose State University is providing a quality educational experience for both undergraduate and graduate (M.S.) students. Located in a high-tech area of California, the University is able to attract and serve technologically mature students and to provide the local optics industry with a partner to carry out modest research projects. Support from local industry and the National Science Foundation supplements the regular State of California budget. Additional sources of funding for our program are constantly being sought.

7. ACKNOWLEDGMENTS

The National Science Foundation continues to support the Research Experiences for Undergraduates Site at SJSU (grant PHY-9100830) and the Laser Applications in Science Education Program at SJSU (grant TPE-9055440). Additional support has been provided by NASA, IBM, the Vacuum Society of America, and others.

8. REFERENCES

1. T.B.Sauke, J.F. Becker, T. Gutierrez, and V.V. Dinh, "Tunable Diode Laser Spectrometer for $^{12}C/^{13}C$ Measurements," SPIE / Northern California, Santa Clara, November 1990.

2. T.B. Sauke, J.F. Becker, T. Gutierrez, and V. V. Dinh, "Diode Laser Spectrometer for $^{12}C/^{13}C$ Measurements," Optical Society of Northern California Spring Meeting, Palo Alto, March 1991.

3. J.F. Becker, T.B. Sauke, and M. Loewenstein, "Stable Isotope Ratio Measurements Using Tunable Diode Laser Spectrometer," Applied Optics (accepted 1991).

4. R. Remling and P. Hamill, "Preliminary Studies in Mie Scattering Calculation for Modeling of Lidar Return," Optical Society of Northern California Spring Meeting, Palo Alto, March 1991.

5. G.T. Williams, R.D. Bahuguna, H. Arteaga, and E.N. LeJoie, "Study of Microbial Growth I: by Diffraction," SPIE Optical Testing and Metrology III Meeting, San Diego, July 1990.

6. R.D. Bahuguna, G.T. Williams, I.K. Pour, and R. Raman, "Study of Microbial Growth II: by Holographic Interferometry," SPIE Optical Testing and Metrology III Meeting, San Diego, July 1990.

7. R.D. Bahuguna and I.K. Pour, "Path Matching in Holography for Short Coherence-Length Lasers," Applied Optics (submitted 1991).

8. R. Youmans and H.S. Lakkaraju, "Laser Spectroscopy of Geological Samples," Optical Society of Northern California Spring Meeting, Palo Alto, March 1991.

9. D.S. Jebens and H.S. Lakkaraju, "Time Resolved Simulation of Lightning by Laser-Induced Plasmas," Optical Society of Northern California Spring Meeting, Palo Alto, March 1991.

10. K. Arya, "Calculated Threshold Current in Ga/Al GaAs Single Quantum Well Wire Laser," Bulletin of the American Physical Society, vol. 36, p. 814, 1991.

11. L. Lam, R.D. Friemuth, and H.S. Lakkaraju, "Fractal Patterns in Burned Hele-Shaw Cells of Liquid Crystals and Oils," Mol. Cryst. Liq. Cryst., vol. 199, pp. 249-255, 1991.

12. L. Lam, "Unsolved Nonlinear Problems in Liquid Crystals," in "Nonlinear and Chaotic Phenomena," Eds. W. Rozmus and J.A. Tuszynski World Scientific, Teaneck, 1991.

13. Y. Yung, L. Lam, Z. Ou-Yang, and M. Lax, "Frequency and Temperature Dependences of Refractive Indices of Liquid Crystals," (submitted for publication 1991).