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of the



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SPIE Volume 540

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Session THB—Symposium: Optics Along the Rio Grande Research Corridor, **K. Freese**, Los Alamos National Laboratory
Session FA —General, **A. Guenther**, Air Force Weapons Laboratory

SOUTHWEST CONFERENCE ON OPTICS

SPIE Volume 540

INTRODUCTION

In 1985 the Los Alamos Conference on Optics, which had been held previously in Los Alamos and Santa Fe, New Mexico, expanded its coverage and moved to Albuquerque as the Southwest Conference on Optics. This was made possible by a broad increase in the Conference sponsorship, which this year included research and educational institutions throughout New Mexico, Colorado, Arizona, Utah, Texas, and old Mexico, as well as SPIE, OSA, and LIA.

Proceedings of the three previous conferences have been published as SPIE Volumes 190 (1979), 288 (1981), and 380 (1993). Because of the increased size of the 1985 conference, the proceedings are being published this year in three volumes: the Proceedings proper; Critical Review of Technology: Radiation Effects in Optical Materials (SPIE 541); and Optical Fabrication and Testing Workshop: Large Optics (SPIE 542). In that portion of the Conference represented by the present volume, about 115 papers were presented, of which the majority were contributed papers given in poster sessions. The texts of most of these papers, both invited and contributed, are included here.

The organization of this volume generally follows that of the Conference, with the papers arranged by the various sessions: General Invited Papers; Optical Components, Materials, and Design; Lasers and Laser Systems; Spectroscopy and Spectroscopic Applications; Applications of Optics; and the Symposium on Optics Along the Rio Grande Research Corridor. There was some rearrangement to provide for a more logical sequence, and the postdeadline papers have been placed in their proper sessions.

It is a pleasure to thank the authors for providing camera-ready text of their contributions, for the most part on time and according to specifications. Each contributed paper has benefitted from two reviews, and thanks are due the reviewers (listed below) who gave generously of their time to help insure the quality of these Proceedings. The prompt and cooperative responses of all these people facilitated rapid publication. I also wish to thank Suzanne Stotlar, Conference Chairman, and the SPIE staff, particularly June Thompson and Kaye Pederson, for their assistance.

It is my hope, and that of every member of the Conference Organizing Committee, that these Proceedings will be useful in summarizing the state of optics research in the southwestern United States, as well as conveying some idea of the excitement felt by those of us fortunate enough to live and work in this region.

R. S. McDowell, Editor
Los Alamos National Laboratory

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viii/ SPIE Vol. 540 Southwest Conference on Optics (1985)

SOUTHWEST CONFERENCE ON OPTICS

SPIE Volume 540

OVERVIEW

The Southwest Conference on Optics was held March 4-8, 1985, at the Convention Center in Albuquerque, New Mexico. An outgrowth of the Los Alamos Conferences on Optics ('79, '81, and '83), this meeting brought together over 750 professionals, exhibitors, students, and guests to discuss recent developments in optics, optical technologies, and optical engineering. Enjoying a broad sponsorship from national societies and regional institutions, the contributions of the major laboratories and universities were highlighted. Attendees came from the United States and fifteen foreign countries. Over 150 papers were presented in the Optical Fabrication and Testing Workshop, the Critical Review of Radiation Damage in Optical Materials, and the regular program, 100 in poster format.

The conference also generated money to begin a scholarship fund to support optics-related study by regional students. This fund will be administered by the Albuquerque and Los Alamos sections of the Optical Society of America.

To the sponsors and committee of the conference go my thanks and congratulations. A meeting of this nature requires devotion to detail, endless hours, and great sacrifice, all voluntary. The sponsors, the organizing committee, and the members of the advisory committee are listed elsewhere in this volume. Without them, the Southwest Conference on Optics would not have been possible. Los Alamos National Laboratory and SPIE-- The International Society for Optical Engineering have sponsored the conference since its inception. Joe Yaver, Executive Director of SPIE, has provided his assistance unstintingly. Peter C. LaDelfe, Los Alamos, has served as treasurer since 1978 and taken on many other jobs. After serving on the editorial committee for several years, Robin S. McDowell has edited the '83 and '85 proceedings, no small task.

Having chaired both the Los Alamos and Southwest Conferences on Optics, one of the major rewards of this position has been the opportunity to work with some of the most talented and able members of our field. In technology, in resources, in environment, and in people, the Southwest is an exciting region with broad impact in optics. I hope that future meetings in this area will continue to benefit from the community support we have received.

Suzanne C. Stotlar, Chairman
Los Alamos National Laboratory

SCENES FROM THE SOUTHWEST CONFERENCE ON OPTICS



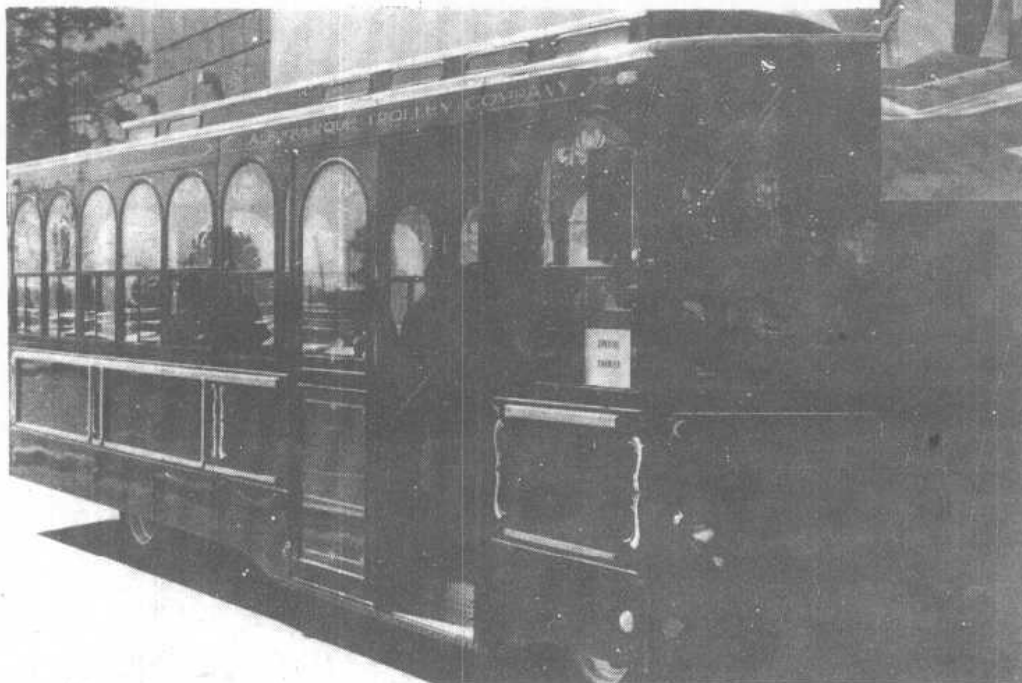
R. Shannon, OSA President



Air Force Weapons Laboratory Tour



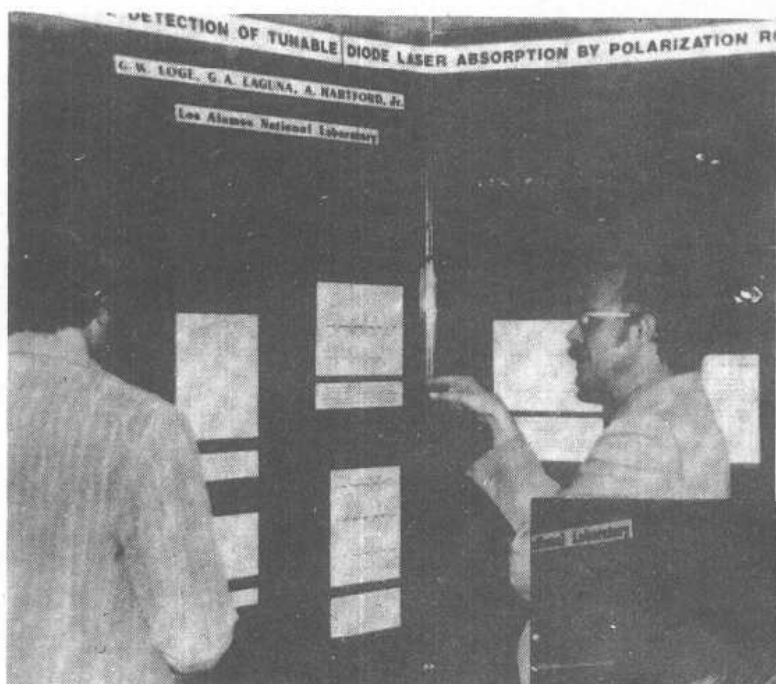
D. Malacara and son,
Centro de Investigaciones
en Optica



Molly Trolley
transported attendees



Exhibitor

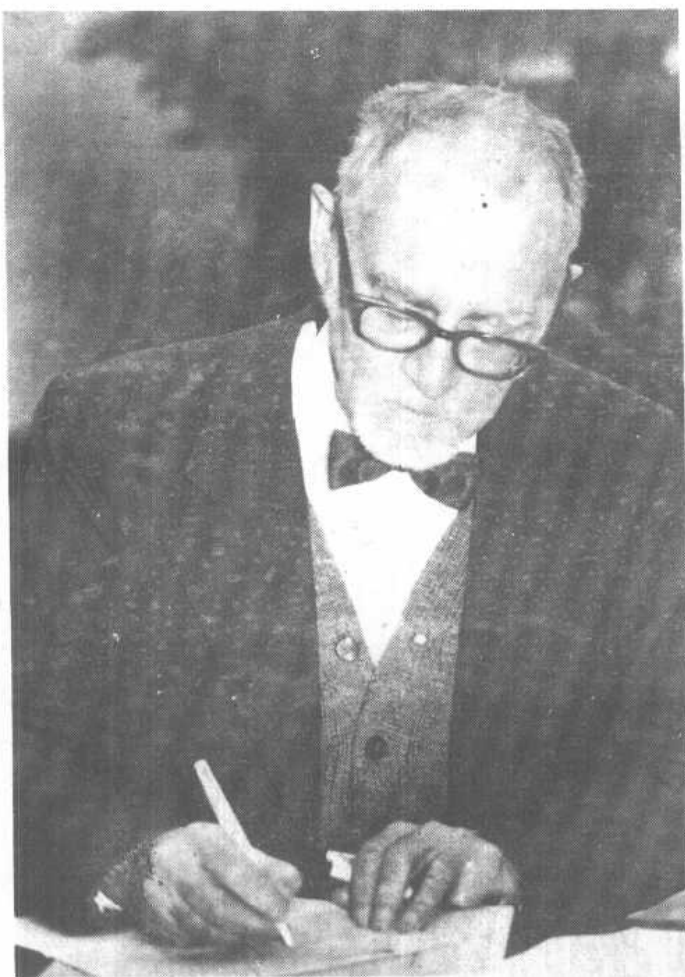


Poster presentations



Albuquerque Mayor Harry B. Kinney





John Howard, Editor of Applied Optics and Optics News and banquet speaker



(left to right) Joe Yaver, SPIE Executive Director; S. C. Stotlar, Conference Chairman; and P. C. LaDelfe, Treasurer



Exhibits





New Mexico Marimba Band



S. C. Stotlar,
Conference Chairman



Students visit the exhibits



Art Guenther, AFWL



Session



H. A. Macleod

SOUTHWEST CONFERENCE ON OPTICS

SPIE Volume 540

Contents

Committee Members	vii
Introduction	viii
Overview	ix
SESSION FA. GENERAL (Invited Papers)	1
Passive optical limiting, M. J. Soileau, S. Guha, E. W. Van Stryland, North Texas State Univ.	2
Characterization of CdZnS/CuInSe ₂ thin-film solar cells, R. K. Ahrenkiel, Solar Energy Research Institute	9
Technical and historical overview of the study at Lawrence Livermore National Laboratory of porous antireflection coatings, D. Milam, Lawrence Livermore National Lab.	19
Laser probes of general relativity, L. M. Pedrotti, W. Schleich, M. O. Scully, Univ. of New Mexico	28
ABSTRACTS OF INVITED PAPERS	32
Large optics: realities and possibilities, R. R. Shannon, Optical Sciences Ctr./Univ. of Arizona	
Applications of photoferroelectric properties of electrooptic ceramics, C. E. Land, Sandia National Labs.	
Metal vapor lasers: applications at last, R. E. Grove, Cooper LaserSonics, Inc.	33
SESSION TA. OPTICAL COMPONENTS, MATERIALS, AND DESIGN	33
Imaging of the wavefront under test in interferometry, D. Malacara, C. Menchaca, Centro de Investigaciones en Optica (Mexico) (Invited Paper)	34
Computer controlled optical surfacing with orbital tool motion, R. A. Jones, Itek Optical Systems	41
Simple technique for testing the figure of high order aspheric surfaces, T. Wise, Santa Barbara Research Ctr.	49
The effects of rigid body motion in interferometric tests of large-aperture, off-axis, aspheric optics, E. W. Young, Perkin-Elmer Corp.; G. C. Dente, W. J. Schafer Associates	59
Comparison of four methods of interferogram reduction and interpretation, G. Woodfin, M. Feind, Los Alamos National Lab.	69
Optical transfer function computer model for imaging systems, R. Kwong, Hughes Aircraft Co.	76
Wavefront analysis on a personal computer, W. Swantner, BSC Optics	85
Grazing incidence metal optics for the Berkeley Extreme Ultraviolet Explorer satellite: a progress report, D. Finley, R. F. Malina, S. Bowyer, Univ. of California/Berkeley	89
Grazing incidence beam expander, P. R. Akkapeddi, P. Glenn, A. Fuschetto, Perkin-Elmer Corp.; Q. Appert, V. K. Viswanathan, Los Alamos National Lab.	94
Achromatic N-prism beam expanders: optimal configurations II, R. Trebino, C. E. Barker, A. E. Siegman, Stanford Univ.	104
Optical performance of synthetic aperture telescope configurations, J. E. Harvey, P. R. Silverglate, A. B. Wissinger, Perkin-Elmer Corp.	110
Numerical study of a self-filtering unstable resonator, P. G. Gobbi, G. C. Reali, Univ. di Pavia (Italy)	119
Optical filters synthesis using Fourier series, S. A. Shakir, Univ. of New Mexico	124
Spectral filtering at a spatial filter: design principles for star simulators, G. C. Dente, W. J. Schafer Associates, Inc.	131
Study of possible solarization—related impurities in CaF ₂ and other fluorides, L. B. Edgett, S. C. Stotlar, Los Alamos National Lab.	134
Dynamic picosecond reflectivity studies of highly optically-excited crystalline silicon, T. F. Boggess, A. L. Smirl, K. Bohnert, K. Mansour, S. C. Moss, I. W. Boyd, North Texas State Univ.	140
Growth and applications of ferroelectric tungsten bronze family crystals, R. R. Neurgaonkar, W. K. Cory, J. R. Oliver, Rockwell International Science Ctr.	146
Thin-film microstructure modeling, L. Bangjun, H. A. Macleod, Optical Sciences Ctr./Univ. of Arizona	150
Multilayer coatings for astronomical telescope mirrors, D. Y. Song, H. A. Macleod, Optical Sciences Ctr./Univ. of Arizona	156
Strained-layer-superlattice optoelectronic devices, R. J. Chaffin, Sandia National Labs.	160

Summary of recent studies on AlGaAs/GaAs radiation hardened photodiodes , J. J. Wiczer, Sandia National Labs.	168
System characterization using a lateral shearing interferometer , M. K. Giles, J. L. Jernigan, D. P. Murphy, New Mexico State Univ.	171
Parallel-scan thermal imager with a thermoelectrically cooled multi-element detector , M. Nakamura, Y. Yoshida, H. Ishizaki, Fujitsu Labs. Ltd. (Japan); K. Murase, Fujitsu Ltd. (Japan)	179
SESSION TB. LASERS AND LASER SYSTEMS	187
Prospects for visible chemical lasers , S. J. Davis, U.S. Air Force Weapons Lab. (Invited Paper)	188
Laser excitation of atomic inner-shells by coherent processes with implications for x-ray lasers , K. Boyer, C. K. Rhodes, Univ. of Illinois/Chicago (Invited Paper)	196
Installation alignment of a multi-beam ICF target illumination system , W. Bauke, D. B. Stahl, Los Alamos National Lab.	205
Performance evaluation of the Antares reference telescope system , J. R. Parker, G. L. Woodfin, V. K. Viswanathan, Los Alamos National Lab.	212
Electron trajectories through a linear wiggler calculated with a three dimensional ray tracing program , K. M. Murray, KM Sciences	219
Resonator optical designs for free electron lasers , V. K. Viswanathan, A. Saxman, G. Woodfin, Los Alamos National Lab.	227
High-gain small-signal modes of the free-electron laser , G. T. Moore, Univ. of New Mexico	232
Long-base free electron laser resonant cavity , E. Miller, S. Bender, Q. Appert, A. Saxman, T. Swann, Los Alamos National Lab.	235
Quasi-analytical description of sideband formation in a free-electron laser (FEL) , C. J. Elliott, Los Alamos National Lab.	240
Onset of saturation in a high-gain free-electron laser , S. Prasad, Univ. of New Mexico	247
Gallium arsenide photocathode for the free electron laser , S. C. Stotlar, R. W. Springer, B. Sherwood, R. Cordi, Los Alamos National Lab.	251
A target plane imager for inertial confinement fusion , C. D. Swift, E. S. Bliss, W. A. Jones, L. G. Seppala, Lawrence Livermore National Lab.	261
Design and performance of a 125 Hz, 50 W alexandrite laser , R. C. Sam, R. W. Rapoport, M. L. Shand, Allied Military Laser Products	264
Spectral characterization of a tunable alexandrite laser by rubidium absorption at 780 nm , A. V. Nowak, B. J. Krohn, Los Alamos National Lab.	269
E-beam-induced fluorescence of excimers in cryogenic solutions , T. R. Loree, R. R. Showalter, T. M. Johnson, J. M. Telle, R. A. Fisher, W. M. Hughes, Los Alamos National Lab.	279
The Aurora project: optical design for a kilojoule class KrF laser , J. Hanlon, J. McLeod, J. E. Sollid, W. Horn III, R. Carmichael, B. Kortegaard, G. Woodfin, L. Rosocha, Los Alamos National Lab.	284
Mechanical coupling of an iodine laser pulse incident obliquely on aluminum , C. L. Bohn, M. D. Stephen, F. Eng, J. C. Souders, G. A. Brost, T. F. Deaton, U.S. Air Force Academy; B. W. Duvall, J. T. Tinsley, Kaman Sciences Corp. ...	290
Error sources in the "ring down" optical cavity decay time mirror reflectometer , T. M. Crawford, Litton Industries ..	295
Increasing the efficiency of stimulated scattering phase-conjugate mirrors , S. A. Shakir, Univ. of New Mexico	303
SESSION THA. SPECTROSCOPIC APPLICATIONS	307
Vibrational energy transfer in benzene-argon collisions , J. L. Lyman, G. Müller, P. L. Houston, M. Piltch, W. E. Schmid, K. L. Kompa, Max-Planck Institut für Quantenoptik (West Germany)	308
Production of gallium atoms by excimer laser photolysis of trimethylgallium , S. L. Baughcum, R. C. Oldenberg, K. R. Winn, D. E. Hof, Los Alamos National Lab.	314
Lifetime and quenching measurements of C₂H emission produced by vacuum ultraviolet photolysis of C₂H₂ , J. J. Tiee, R. K. Sander, C. R. Quick, Jr., R. J. Romero, Los Alamos National Lab.; R. Estler, Fort Lewis College	322
MPI spectroscopy of NH₃: application to rotational energy accommodation on surfaces , B. D. Kay, A. J. Grimley, T. D. Raymond, Sandia National Labs.	330
Photofragment fluorescence as a sensitive probe for gas-phase alkali compounds and their photochemistry , R. C. Oldenberg, S. L. Baughcum, D. E. Hof, K. R. Winn, Los Alamos National Lab.	339
Laser-induced fluorescence measurement of vapor concentration surrounding evaporating droplets , D. R. Neal, D. Baganoff, Stanford Univ.	347
Ionization detection of stimulated Raman spectra , P. Esherick, A. Owyong, Sandia National Labs.	356
Laser measurement techniques—laser spectroscopy in semiconductors , E. D. Jones, G. L. Wickstrom, Sandia National Labs.	362

Single-pulse Raman and photoacoustic spectroscopy studies of triaminotrinitrobenzene (TATB) and related compounds , W. M. Trott, A. M. Renlund, R. G. Jungst, Sandia National Labs.	368
Sensitive detection of tunable diode laser absorption by polarization rotation , G. W. Loge, G. A. Laguna, A. Hartford, Los Alamos National Lab.	376
Four-photon resonant third harmonic generation , A. V. Smith, Sandia National Labs.	381
Enhancement of the Stokes field by amplitude fluctuations , M. P. Sharma, A. Elci, Univ. of New Mexico	385
Multiband selection with linear array detectors , H. L. Richard, W. L. Barnes, NASA/Goddard Space Flight Ctr.	389
SESSION WA. APPLICATIONS OF OPTICS	397
Laser surgery: alternatives to CO₂ ablation , M. L. Wolbarsht, Duke Univ. (Invited Paper)	398
A lightwave digital test facility (LDTF) , F. P. Buchanan, GTE Communication Systems	405
Periodic coupling in semiconductor-clad optical waveguide devices , R. F. Carson, T. E. Batchman, M. L. McWright, Univ. of Virginia	413
Alteration of the transmission characteristics of fused silica optical fibers by pulsed ultraviolet radiation , E. A. Nevis, Coherent Medical Div.	421
Surface potential as a laser damage diagnostic , M. F. Becker, Univ. of Texas; J. A. Kardach, A. F. Stewart, A. H. Guenther, U.S. Air Force Weapons Lab.	427
Intervalence-band absorption saturation and optically induced damage of GaAs by pulsed CO₂ laser radiation , R. B. James, Sandia National Labs.; W. H. Christie, R. E. Eby, Oak Ridge National Lab.; L. S. Darken, Jr., Tennenec Corp.; B. E. Mills, Sandia National Labs.	435
Real time laser damage detection in bulk materials by Strehl intensities , B. W. Mullins, A. B. Romberger, U.S. Air Force Academy	445
Nuclear-radiation-induced absorption in optical materials , P. J. Brannon, R. W. Morris, J. B. Gerardo, Sandia National Labs.	451
Raman studies of laser damaged single- and multi-layer optical coatings , G. J. Exarhos, P. L. Morse, Battelle Pacific Northwest Lab.	460
Laser-induced photochemical dry etching of III-V compound semiconductors , C. I. H. Ashby, Sandia National Labs.	467
Ion beam reduction of optical scatter from coated metal surfaces , G. A. Al-Jumaily, J. J. McNally, K. C. Jungling, J. R. McNeil, Univ. of New Mexico	472
Ion beam assisted deposition of optical thin films—recent results , J. J. McNally, G. A. Al-Jumaily, S. R. Wilson, J. R. McNeil, Univ. of New Mexico	479
Simple, high sensitivity pencil beam light heterodyne interferometer , P. Drabarek, Central Lab. of Scientific Instruments and Science (Poland)	486
Application of laser speckle interferometry to fracture of concrete , F. Ansari, New Jersey Institute of Technology ...	492
Analytic expressions, calculational forms for scattering by a multilayered sphere , R. Bhandari, New Mexico State Univ.	500
Tests of the algorithm for the calculation of scattering by a multilayered sphere , R. Bhandari, New Mexico State Univ.	512
Far-infrared acousto-optical response of bubbly liquids , S. O. Sari, M. Kendig, D. Rogovin, Rockwell International Science Ctr.	520
Nonlinear refractive index of CS₂ at 10.6 μm , M. Mohebi, G. Reali, M. J. Soileau, E. W. Van Stryland, North Texas State Univ.	528
Measurement of n₂ in liquids at 1.06 μm and 0.53 μm , S. Guha, M. J. Soileau, E. W. Van Stryland, North Texas State Univ.	533
Direct solid metal analysis by laser ablation into the inductively coupled plasma , D. A. Cremers, F. L. Archuleta, Los Alamos National Lab.; H. C. Dilworth, ARMCO Inc.	542
Comparison of millimeter-wave scattering: a stellar dendrite vs. disk and spheroids , S. G. O'Brien, G. H. Goedecke, New Mexico State Univ.	547
Design, development, and testing of two prototype maritime laser aids to navigation , P. F. Jacobs, La Crescenta, California; T. S. Winslow, Coast Guard R&D Ctr.; J. D. Campbell, L. Reynolds, Loral Electro-Optical Systems.	555
LIDAR techniques for search and rescue , W. L. Cabral, Los Alamos National Lab.	560
Distributed computation in neural networks and their optical analogs , M. Cohen, New Mexico State Univ.	566
Small-scale and whole beam self-focusing of very intense laser beams in saturable absorbers , J. P. Babuel-Peyrissac, J. P. Marinier, CEA—Centre d'Etudes Nucléaires de Saclay (France); C. Bardin, Agence de Saclay (France); F. P. Mattar, New York Univ. and MIT; J. Teichmann, Y. Claude, Université de Montréal (Canada); B. R. Suydam, Los Alamos National Lab.	569

A finite Hankel algorithm for intense optical beam propagation in saturable medium, C. Bardin, Agence de Saclay (France); J. P. Babuel-Peyrissac, J. P. Marinier, CEA—Centre d'Etudes Nucléaires de Saclay (France); F. P. Mattar, City College of City Univ. of New York and New York Univ.	581
Propagation effects in strong pump-weak probe coherent interactions, F. P. Mattar, New York Univ. and MIT	588
SESSION THB. SYMPOSIUM: OPTICS ALONG THE RIO GRANDE RESEARCH CORRIDOR (Invited Papers)	605
Symposium: Optics along the Rio Grande research corridor, K. Freese, Los Alamos National Lab.	606
Strategic Defense Initiatives at Los Alamos National Laboratory, S. D. Rockwood, Los Alamos National Lab.	607
Recent advances in optical measurement methods in physics and chemistry, J. B. Gerardo, Sandia National Labs. ...	609
Optics at White Sands Missile Range, R. C. Fronczek, C. R. Hayslett, White Sands Missile Range	617
Center for High Technology Materials, W. Streifer, Univ. of New Mexico	621
Vision research at the NMSU Computing Research Laboratory, Y. Wilks, New Mexico State Univ.	630
The Plant Genetic Engineering Laboratory for Desert Adaptation, J. D. Kemp, G. C. Phillips, New Mexico State Univ.	634
SPECIAL PRESENTATIONS	641
TUTORIAL SHORT COURSE PROGRAMS	
Introduction to and applications of optical phase conjugation, R. A. Fisher, Los Alamos National Lab.	
Laser damage in thin films, J. M. McIver, A. F. Lange, Univ. of New Mexico; A. H. Guenther, A. F. Stewart, U.S. Air Force Weapons Lab.	
Surface analysis methods for optical materials and interfaces, G. J. Lapeyre, Montana State Univ.	642
Some sketches of Rayleigh, J. N. Howard, Newton Highlands, Massachusetts (Banquet Speech)	643
Author Index	647
Subject Index	650

SOUTHWEST CONFERENCE ON OPTICS

SPIE Volume 540

Session FA

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Air Force Weapons Laboratory

Passive optical limiting

M. J. Soileau, Shekhar Guha, and Eric W. Van Stryland

Center for Applied Quantum Electronics, Department of Physics,
North Texas State University, Denton, Texas 76203

Abstract

We describe a completely passive technique for limiting the power of light beams. The techniques we use are based on optical self-action (self-focusing or defocusing) and nonlinear absorption or a combination of both. These processes are passive and thus require no external mechanism to induce limiting other than the light beam itself.

Introduction

In this paper we report the results of our efforts to develop a nonlinear optical limiter that is completely passive. We present results using a technique by which self-focusing, nonlinear absorption and laser-induced breakdown are used to make the optical power limiter. The basic concept is to use irradiance dependent refraction (self-focusing) and irradiance-dependent absorption to make a passive optical device which has high transmission for low input power, but low transmission for high input power. Results for picosecond pulses and cw input are presented.

Passive optical limiting concept

In this study we used a "tight" focusing arrangement to demonstrate optical limiting. The beam is tightly focused into the nonlinear material and the propagation distance through the cell is large with respect to the Rayleigh range, i.e., the depth of focus is small relative to the sample thickness. Irradiance dependent refraction (self-focusing or self-defocusing) and/or irradiance dependent absorption limits the far field fluence. We have previously demonstrated a device based on this concept using nanosecond pulses at $1.06\text{ }\mu\text{m}$ ¹ and $10.6\text{ }\mu\text{m}$ ² and picosecond pulses at $1.06\text{ }\mu\text{m}$ and $0.53\text{ }\mu\text{m}$.^{3,4} The device, which we refer to as an optical power limiter (OPL), is described in detail in reference 3 and is similar to the arrangement used by Bjorkholm et al.⁵ to make a bistable device and by Teite et al.⁶ to make a power limiter for cw lasers.

In experiments where self-focusing is the dominant nonlinearity we observe catastrophic self-focusing which results in laser-induced breakdown. For materials with negative nonlinear refractive indices, we observe defocusing^{8,9,10} and subsequent beam breakup at high input powers.

The fact that the light is focused into the nonlinear material results in an enhancement of the nonlinear processes (self-refraction and/or nonlinear absorption). Many materials exhibit both nonlinear absorption and nonlinear refraction and this arrangement allows for the exploitation of both phenomena.⁸ The device response time is dependent on the response time of the nonlinear medium and therefore can be extremely fast, e.g., reorientational self-focusing in CS₂ has a 2 ps response time and materials for which the electronic Kerr effect is the dominant nonlinearity should result in limiting in 10^{-14} seconds. Finally, the device is completely passive.

Results and materials considerations

An example of the limiting behavior of the device described above is shown in Figure 1. For these data the nonlinear material is CS₂. In Figure 1 the device output (D_4) is plotted as a function of the input power for two pulsewidths. The laser wavelength is $0.53\text{ }\mu\text{m}$, the beam is linearly polarized, and the pulsewidths are 30 and 100 ps (FWHM). Each data point represents the average of five laser firings. Note that the response of the device is linear up to the cutoff power, P_c , of approximately 7 kW and is clamped for higher input powers. There is no apparent pulsewidth dependence shown in Figure 1. This is as expected since the response time for the dominant nonlinearity (the optical Kerr effect) is approximately 2 ps, which is much shorter than pulses used in this experiment. We have shown previously that $P_c = P_2$, the so called second critical power which is related to n_2 by the following relationship

$$P_2 = \frac{3.77 c \lambda^2}{32 \pi^2 n_2}$$

where n_2 is the nonlinear refractive index in esu, λ is the laser wavelength, and c is the speed of light in vacuum. Note that the limiting power scales as the wavelength squared for constant n_2 .

By choosing a material with the appropriate n_2 one can adjust the limiting power to the desired value. The fact that liquids having different values of n_2 may be mixed to adjust P_c is a distinct advantage of liquid based optical limiters.³ An additional advantage is that if optical breakdown of the material occurs, liquids are self-healing. In general it is a simple matter to adjust P_c to a value higher than that shown in Figure 1 since CS_2 has a relatively large n_2 and there are many solvents (e.g., CCl_4 and ethanol) which have very small n_2 's. It is quite difficult to decrease the limiting power below that achieved with CS_2 . While we and other workers have studied materials which exhibit larger nonlinearities than CS_2 for selected wavelengths and pulsewidths, to our knowledge no other material has the combined large n_2 , (1.3×10^{-11} esu) fast response time (2 ps), and broad band response observed in CS_2 . In fact CS_2 has a transmission window in the 10.6 μm region and we have recently demonstrated pulsed-power limiting and cw limiting at this wavelength. The pulsed limiting experiments are reported in detail elsewhere in these proceedings and cw results are shown in Figure 2.

The mechanism for the limiting shown in Figure 2 is thermal defocusing. The residual absorption in CS_2 at 10 μm is approximately 0.1 cm^{-1} . In this demonstration the beam was focused into a 1 cm thick cell with a 25 cm focal length lens used at $f/10$. A more optimum geometry, e.g., a tighter focus into the cell, should result in limiting at a lower input than the 0.1 W shown in Figure 2.

Another advantage of using liquids for limiter applications is that they can be used as solvents for other materials that can alter their optical properties.³ For example, chlorobenzene is a solvent which exhibits a relatively large, fast optical Kerr effect as shown in Figure 3. In Figure 3 the laser wavelength is 530 nm, the beam is circularly polarized, and the pulsewidths are 30 and 100 ps (FWHM). In this case limiting occurs at approximately 35 kW, which may be reasonable for some ps applications, but would be of little use for cw beams. However, a slight amount of mode-locking dye dissolved in the chlorobenzene results in a small amount of broad band absorption. This absorption, in turn, results in thermal defocusing and the resulting limiting is shown in Figure 4. In this case the laser source is a 545 nm, linearly polarized, cw Argon ion laser beam. Limiting is initiated at 3-5 mW and is maintained up to the 2 W maximum output of the laser source used in this experiment. No attempt was made to optimize the thermal defocusing which produced the limiting shown in Figure 4. For example, higher dye concentrations and a tighter beam focus could significantly reduce the limiting power.

Much of our effort is directed toward finding materials which exhibit large nonlinear absorption and/or nonlinear refraction. Three classes of materials which we are currently examining in detail are liquid organics, liquid crystals and intermediate band-gap semiconductors (such as the II-VI materials).^{8,9,10} Effective limiting has been demonstrated in the liquid crystal MEBBA, (4-methyl benzylidene 4'-n-butylaniline) for 0.53 μm , ps pulses.¹¹ The onset of nonlinear transmission in this material occurs at a considerably lower input power than observed for CS_2 for similar input parameters. The limiting observed in MEBBA and other liquid crystals at 0.53 μm does not have a sharp cutoff power as does CS_2 , rather there is a region of continuously changing transmission prior to limiting. This behavior is probably due to nonlinear absorption prior to the onset of catastrophic self-focusing. In fact a two-photon absorption coefficient of $0.6 \pm 0.2 \text{ cm/GW}$ has been measured for this material.¹¹

The mechanism for the observed nonlinearity in MEBBA is not yet understood. We are presently conducting more extensive studies of this material, other Schiff base liquid crystals, and liquid crystal esters. More refined characterization techniques are needed in order to more completely characterize the nonlinear properties of materials for which both nonlinear absorption and nonlinear refraction play an important role. Techniques presently used in our laboratories are described in greater detail elsewhere.^{8,9,12}

Summary

The growth of laser applications in a large number of areas, the emergence of optical information processing, and the prospect of optical computing have lead to a need for various types of optical limiters and switches. One such device, the OPL, is the optical equivalent of the Zener diode. We have demonstrated such devices with picosecond response times using various liquids and liquid crystals as the nonlinear optical medium. We have also done studies on optical limiting in solids.^{8,9,10} The continued development of materials, such as liquid crystals, with large, fast, broad band nonlinearities is needed to lower the threshold power at which such devices limit or switch off. This development, on the other hand, is paced by research efforts which are directed toward developing a more